Community-Based Land and Water Management Systems for Sustainable Upland Development in Asia: MSEC Phase 2 [1]

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Introduction

Degradation of the natural resource base in many of the countries in Asia is of increasing concern. As a result of increasing population, the pressure to exploit increasingly marginal resources is growing, particularly on the land and water resources of the upper watersheds where many of the region's poorest make their livelihoods.

The Management of Soil Erosion Consortium (MSEC) was established in 1997, as one of four consortia formed by the CGIAR under the Soil, Water and Nutrient Management Initiative, to bring together leading researchers and practitioners in Asia to find solutions to the pressing needs to manage upper watersheds more effectively. ADB supported the first phase of the MSEC project through RETA 5803 "Catchment Approach to Managing Soil Erosion in Asia" between September 1998 and December 2002. MSEC Phase I focused on the establishment of a network of NARES research partners in Indonesia, Laos, Nepal, Philippines, Thailand and Vietnam; and at advanced research institutes (ARI) including the Institute of Research for Development (IRD), France.

During MSEC Phase 1, the infrastructure for detailed soil erosion and runoff research was established in six selected basins in the partner countries and extensive human resources development undertaken[2] [3]. The project has developed and installed improvements to field equipment enabling the partners to acquire cutting-edge field studies and state-of-the-art knowledge on erosion and runoff processes.

The Phase 2 of MSEC continues to build on the results of Phase 1. It started in January 2003 with five countries, i.e., Indonesia, Lao PDR, Philippines, Thailand and Vietnam. Funding was provided by IWMI, IRD and the participating countries. Indonesia and Philippines have contributed cash resources for the implementation of the project in the countries.

This report captures and summarizes the highlights of the 2003 annual country reports which are also included in this volume. It presents the major activities in research, capacity building and information dissemination.

MSEC Phase 2 Goal, Purpose and Expected Output

Goal

MSEC Phase 2 aims to contribute to achieving the linked goals of alleviating poverty in the target communities and reducing degradation of natural resources in upland areas of watersheds in tropical areas of Southeast Asia. Appendix 1 shows the framework of the project indicating its goal, purpose, outputs, activities, and inputs.

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[1] Highlights of accomplishments of the project in 2003 in the five participating countries, namely, Indonesia, Laos, Philippines, Thailand, and Vietnam
[2] IWMI. 2003. Catchment approach to managing soil erosion in Asia. Technical Assistance (TA) Completion Report. submitted to the Asian Development Bank. April 2003
[3] IWMI, ADB. 2003. Catchment approach to managing soil erosion in Asia: Results and lessons learned.

Purpose

The purpose of MSEC 2 project is to provide solid foundations for the implementation of science-based land and water resources management to improve the livelihoods of the people in the upper catchments of five countries in Southeast Asia. These foundations will be attained through a combination of:

- Consolidation of the detailed bio-physical research on the processes of soil erosion and surface runoff on steep slopes established in Phase I;
- Implementation of research on the socio-economic and institutional landscape of the target environments;
- Formulation of practical guidelines for interventions leading to sustainable land and water management practices based on solid bio-physical and socio-economic research findings;
- Development of appropriate analytical tools and techniques for appraisal of management and farming systems options;
- Continued development of human and institutional capacity to do and interpret high quality research in regional NARES organizations;
- Development of dissemination materials and methods based on research outputs to influence policy makers, development workers, extension practitioners and farmer communities; and
- Development of policy and implementation guidelines used to improve the sustainable management of upper watersheds

Expected Outputs

The outputs of the project include the following:

a. Tools and methodologies for land and water management research and implementation at the catchment and community scales
    - Methodologies for identifying, evaluating and scaling-up the adoption of land and water management innovations at the community level
    - Multi-scale models to simulate and predict sediment budgets at catchment and community level under different climatic and land use change scenarios
    - Methodology for impact assessment, monitoring and evaluation
b. Research-based land and water management systems that are acceptable to farmers and the community
    - Socio-economic evaluation of the management systems
    - Acceptability and sustainability of the innovations
    - Socio-economic and environmental impact of the systems
c. Information materials and strategies for dissemination of research results
    - Synthesized reports of attendance to relevant conferences
    - Scientific papers and other publications resulting from the project
    - Annual meetings and periodic workshops to disseminate results
    - Policy briefings
    - Regularly updated web site
d. Field and laboratory-trained students who will contribute to the manpower pool of catchment research in the NARES or other organizations
e. Partners better trained in land and water management research, implementation and sustainability
    - Training of national teams and farmers conducted
    - Cross-site visits conducted
    - Competent national teams who can participate in implementing country projects involving soil erosion and catchment management

f. Specific action plans for catchment management research and implementation as well as generic policy guidelines for implementing sustainable land and water management programs in the region.

Methodology and Key Activities

Implementation Arrangements

The International Water Management Institute (IWMI) served as the executing agency (EA) for the project. Research implementation was the responsibility of the participating NARES from Indonesia, Laos, Philippines, Thailand, and Vietnam. The different benchmark catchments and the detailed methodology followed have been described in earlier reports of the project (Maglinao and Leslie, 2001; IWMI, 2003). The Institute of Research for Development (IRD) provided strong scientific support to the project in Laos, Thailand and Vietnam. The implementing NARES and contact persons and institutions are shown in Table 1.

Table 1. Implementing NARES institutions and contact scientists in the different countries

Country	Implementing NARES	Contact Person
Indonesia	Center for Soil and Agroclimate Research and Development (CSAR) Bogor, Indonesia	Dr. Fahmuddin Agus Head, Soil Research Institute Bogor, Indonesia
Laos	Soil Survey and Land Classification Center (SSLCC) Vientiane, Laos	Dr. Bounthong Bouahom Consortium Steering Committee Chair and Acting Director General, NAFRI Vientiane, Laos
Philippines	Philippine Council for Agriculture, Forestry and Natural Resources Research and Development (PCARRD) Los Banos, Laguna, Philippines	Engr. Raul Alamban Assistant Director ARMRD, PCARRD Los Banos, Laguna, Philippines
Thailand	National Park, Wildlife and Plant Conservation Department (NPWPCD) Bangkok, Thailand	Mr. Arthorn Boonsaner Researcher NPWPCD, Bangkok, Thailand
Vietnam	National Institute for Soils and Fertilizers (NISF) Hanoi, Vietnam	Mr. Tran Duc Toan Deputy Director, NISF Hanoi, Vietnam

Key Activities

The project continued to conduct research, build NARES capacity, disseminate information and promote the exchange of knowledge. Research was done in the established benchmark catchments in Indonesia, Lao PDR, Philippines, Thailand and Vietnam. The project continued the monitoring of on-going catchment experiments, the collection of biophysical and socioeconomic data through field measurements, GIS applications, surveys, and participatory appraisal methods. Simulation models were further validated. The project also conducted evaluation and validation of sustainable land and water management (SLWM) systems (i.e., hedgerow cropping, improved fallow, no-till system, mulching) at the catchment and community levels for wider promotion and adoption.

Capacity building of the NARES partners, students, and farmers on SLWM research and implementation is part of the research, through daily project work, networking and hands-on training. The NARES training include applications of impact assessment methodology, data management, and technology transfer and promotion. The project continues to actively support graduate students by providing access to the sites and available data, as well as counterpart financial support for their research that are relevant to MSEC objectives.

Knowledge sharing and information dissemination of the results of the project was done through meetings, attendance and presentation of papers at relevant workshops and conferences, through publications and on a regularly updated MSEC web page.

Results and Discussions

Catchment Hydrological Behavior

Rainfall and runoff

The hydrological behavior in terms of rainfall, runoff and soil loss showed variation among the catchments and sub-catchments in the different countries (Table 2). Laos, Thailand and Vietnam had almost similar rainfall amounts which are much lower than in Indonesia and the Philippines. Among the countries, the Philippines had the highest annual rainfall.

In Indonesia, the average rainfall during October 2002 to April 2003 was 2232 mm with the monthly maximum of 533 mm in January. The rainfall distribution showed slight variability within the catchment. It was higher in the northern part of the catchment than in the southern portion. It was observed that 10 mm of rain yielded runoff and soil loss in all microcatchments.

As in previous results, runoff was generated largely from the Tegalan microcatchment, and it was much higher than that from the Rambutan and Kalisidi microcatchments. Figure 1 shows that there are two peaks of discharge from the Tegalan microcatchment during the storm event on January 1, 2003, a typical characteristic for this catchment. The characteristics of the rainstorm and the corresponding runoff is presented in Table 3. The hydrograph shows a sharp increase after the start of the storm to reach the peak indicating the dominance of quick flow. The flow then rapidly declined. In the Kalisidi microcatchment, flow gradually increased but then decreased sharply during the falling limb. There was no clear shape of the hydrograph from the Rambutan microcatchment. In most cases, runoff was linearly correlated with rainfall as exemplified by Figure 2. The correlation cofficient between rainfall and runoff in the Tegalan microcatchment in 2003 is about 0.8.

Table 2. Rainfall, runoff and soil loss in the different catchments in 2003

Country/MC	Size (ha)	Rainfall (mm)	Runoff (%)	Soil Loss (t ha^{-1})
Indonesia		2232		
Tegalan	1.1	2232	2.25	2.27
Rambutan	0.9	2002	0.09	0.00
Kalisidi	13	2193	3.92	1.56
Babon	285			
Laos		1330		
S1	19.6		31.20	2.38
S2	32.8		25.90	1.59
S3	51.4		23.50	1.00
S4	60.2		28.30	1.55
S6	0.6		0.12	0.03
S7	0.6		0.39	0.05
S8	0.6		3.75	1.11
S9	0.7		4.39	0.07
Philippines		3169		
MC1	24.9			
MC2	17.9	3348	14.55	0.26
MC3	8			
MC4	0.9			
Mapawa	84.5	3169	0.61	0.42
Thailand		1109		
Huai Mee	11.8	1102	28.29	1.60
Huai Ma	9.6	1139	23.73	2.08
Huai Bong	3.2	1118	41.66	1.22
Huai Tong	7.1	1051	19.02	0.69
Huai Ma Nai	93.2	1109	17.68	0.47
Vietnam		1189		
W1	3.7	1578	2.01	0.39
W2	7.7		63.04	2.75
W3	10.8		28.82	0.51
W4	7.2		38.14	0.32
Whole	45.5		45.92	0.54

Table 3. Rainfall characteristics of the storm event in Babon catchment on January1, 2003

Rainstorm Characteristics	Value
Storm length (min)[a]	104
Total rainfall (mm)	62.8
Max intensity (mm.min^{-1})	12.4
Total runoff (mm.min^{-1})[b]	
• Tegalan	1.8
• Kalisidi	0.09
• Rambutan	-

a, b from 11:30 on August 21, 2001 (the storm started) to 15:30 on August 22, 2001 (the storm end) by excluding baseflow for the total runoff

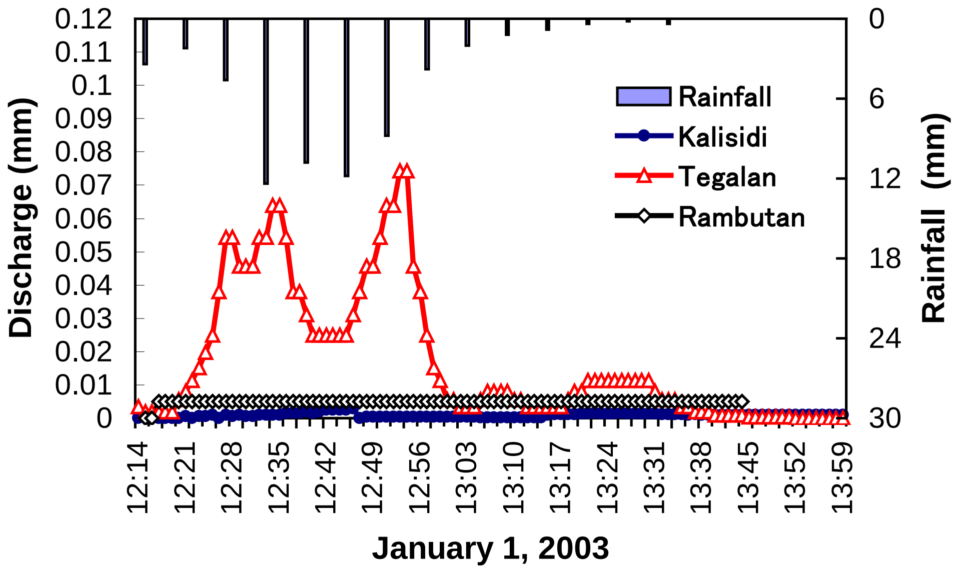

Figure 1. Hydrograph of the different micro-catchments in the Babon catchment in Indonesia during the storm event on January 1, 2003

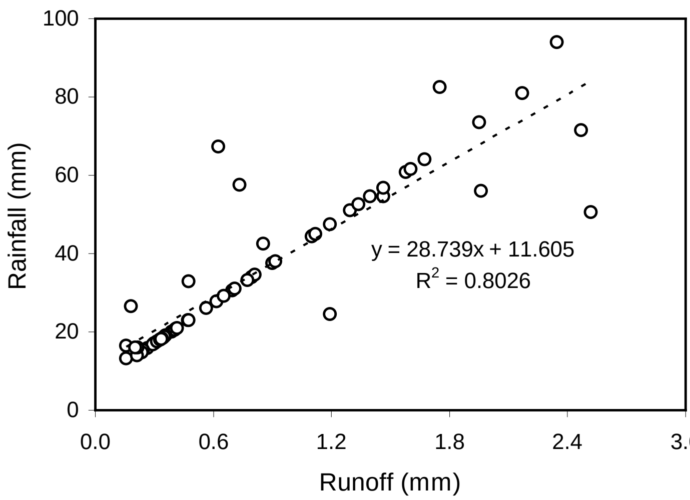

Figure 2. Relationship between rainfall and runoff in Tegalan microcatchment during wet season 2002/2003

In the Philippines, the rainfall in 2003 was higher than in the previous years and consequently higher than the average of four years of observation (Figure 3 and Table 4). However, there was no rain observed in the months of January and February which is similar to that observed in 2000.

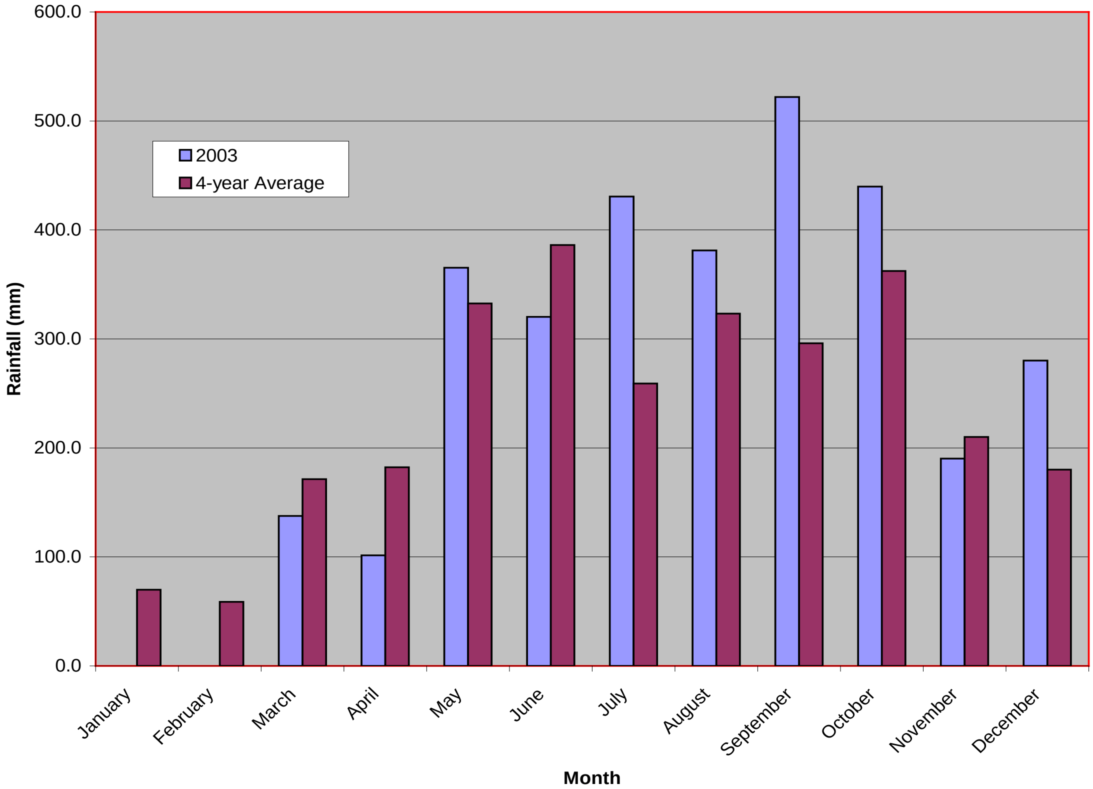

Figure 3. Monthly rainfall in Mapawa catchment in 2003 compared with the four-year average

Table 4. Monthly rainfall in the MSEC catchment from 2000 to 2003

Month	Year				
	2000	2001	2002	2003	Average
January	0.0	113.3	166.3	0.0	**69.9**
February	0.0	164.5	70.8	0.0	**58.8**
March	265.9	171.6	110.2	137.5	**171.3**
April	370.9	215.9	40.6	101.5	**182.2**
May	452.7	346.6	165.3	365.4	**332.5**
June	449.8	226.6	548.3	320.3	**386.3**
July	180.7	335.7	89.4	430.7	**259.1**
August	371.1	211.0	329.4	381.3	**323.2**
September	144.4	328.4	189.6	522.0	**296.1**
October	341.0	318.8	349.7	439.7	**362.3**
November	186.9	325.6	137.4	190.2	**210.0**
December	143.6	148.4	148.1	280.1	**180.1**
Total	**2907.0**	**2906.4**	**2345.1**	**3168.7**	**2831.8**

There were four (4) events that were recorded in the main weir and 10 events in MC2 in 2003. Table 5 shows the amount of rainfall, the flow and the runoff coefficients during these events. There were several events missed because of data logger problems. On the other hand, almost all events in MC2 were recorded. Table 6 shows the suspended sediment concentration and calculated soil loss measured during the four events observed in the main weir. During these events no bed load was observed in the weir.

Table 5. Rainfall, runoff and runoff coefficient of main weir (MW) and MC2 in 2003

N	Catchment	Date of Runoff	Rainfall (mm)	Flow (li)	R (%)
1	MW	9-Sep-03	33.5	4,177	0.01
2	MW	10-Sep-03	26.5	28,580	0.13
3	MW	11-Sep-03	35.5	277,080	0.92
4	MW	13-Sep-03	33.5	398,380	1.41
5	MC2	9-Aug-03	44.0	302,733	3.85
6	MC2	12-Aug-03	15.5	73,050	2.64
7	MC2	15-Aug-03	13.5	753,867	31.23
9	MC2	19-Aug-03	26.0	42,930	0.92
10	MC2	20-Aug-03	24.0	54,207	1.26
11	MC2	10-Oct-03	22.5	62,178	1.55
12	MC2	11-Oct-03	30.5	83,409	1.53
13	MC2	12-Oct-03	19.0	185,742	5.47
14	MC2	13-Oct-03	20.5	2,434,005	66.40
15	MC2	15-Oct-03	66.5	4,106,547	34.54

Table 6. Sediment concentration, runoff flux, soil loss and rainfall measured in the main weir during four events in the Philippine catchment

Time	Sediment Conc. (g li^{-1})	Flux (li sec^{-1})	Soil loss		Rainfall (mm)
			(g/12 sec)	**(g)**	
Sept. 9, 2003					
4:25:00	2.72	0.9	2.45	245	33.5
4:45:00	1.31	0.2	0.26	26	
5:05:00	0.21	0.1	0.02	2	
5:45:00	0.49	1.3	0.64	64	
6:05:00	0.00	0.6	0.00	0	
		Total		**337**	
Sept. 10, 2003					
4:05:00	4.50	1.7	7.65	765	35.5
4:25:00	2.82	0.9	2.54	254	
5:05:00	1.60	1.7	2.72	272	
5:25:00	4.24	4.3	18.23	1,823	
5:45:00	2.37	4.3	10.19	1,019	
6:05:00	0.16	3.5	0.56	56	
		Total		**4,189**	
Sept. 11, 2003					
3:00:00	6.46	36.6	236.44	23,644	26.5
3:20:00	1.37	28.4	38.91	3,891	
3:40:00	1.25	23.7	29.62	2,962	
4:00:00	0.97	17.5	17.00	170	
4:20:00	0.65	10.9	7.08	708	
		Total		**31,375**	
Sept. 13, 2003					
11:40	2.06	49.4	101.76	10,176	33.5
12:00	1.13	46.0	51.98	5,198	
12:20	2.13	46.0	97.98	9,798	
12:40	1.09	39.6	43.16	4,316	
1:00	0.10	31.0	3.10	310	
1:20	0.46	23.7	10.90	1,090	
		Total		**30,888**	

In 2003, the yearly rainfall in the catchment in Laos was much lower than the two previous years. Moreover, the rainfall in May, when the soils were bare, was very low compared to the three previous years. Except for April and September, the monthly rainfall was below the average calculated over the five-year period (Table 7 and Figure 4).

In contrast to what is usually observed, runoff percentage is much lower from small catchments (<1ha) than from larger catchments (<10 ha). This may result from 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.

Table 7. 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**

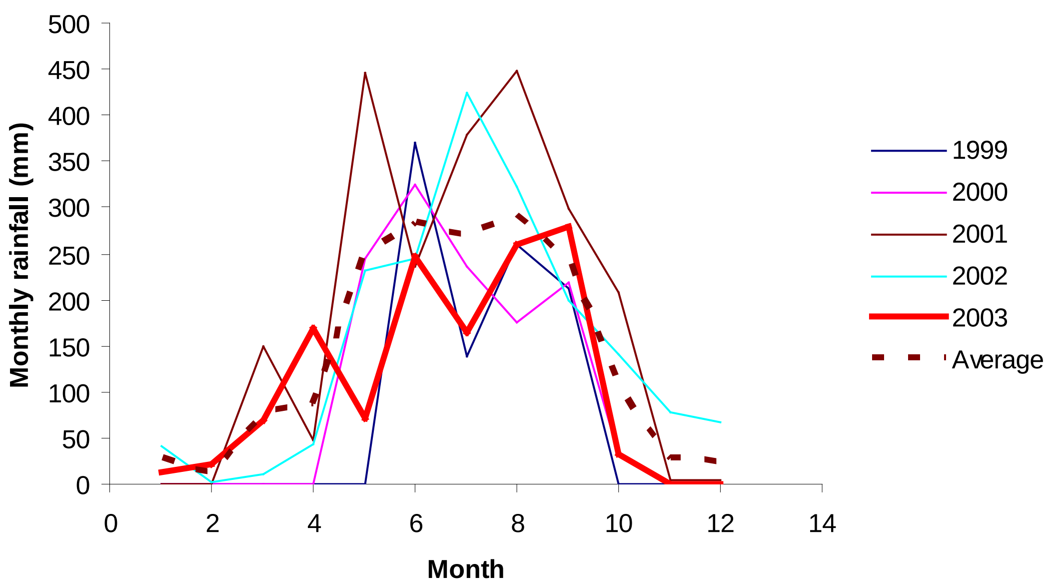

Figure 4. Monthly rainfall in Houay Pano catchment, 1999-2003

In Thailand, the annual rainfall in the Huai Ma Nai catchment from January to October 2003 was 1109 mm (Huai Ma Nai automatic climate station, Cimel 407). This represents an approximate volume of 1 million $m^3.yr^{-1}$. The rains in 2003, although less than those in 2001 and 2002, had comparable level of intensity, between 24 to 26 mm hr^{-1} (CV = <5%) (Table 8).

Table 8. Rainfall and runoff in the Huai Ma Nai catchment in 2001, 2002 and 2003.

Parameter	2001	2002	2003
Total rainfall (m^3)	486,500	306,300	192,500
Rainfall (mm) October – January	1159	1225	1016
Rainfall intensity (mm hr^{-1})	26.3	26.4	24.1
Coefficient of Runoff (%)	**45**	**30**	**18**

Total runoff from the Huai Ma Nai catchment is presented in Figure 5. Each peak corresponds to a runoff event. The sum of the runoff volumes over time gives the total volume of runoff exported by the catchment during the rainy season. The figure presents the data obtained during the 2003 rainy season (July 1st to September 30th, 2003). The comparatively high runoff values associated with the Huai Ma catchment are attributed to the fact that the Huai Ma catchment was cultivated primarily for cash crops with no forest cover remaining or soil protection measures adopted. The runoff coefficient for the catchment in 2003 was calculated at 20% (see Table 4).

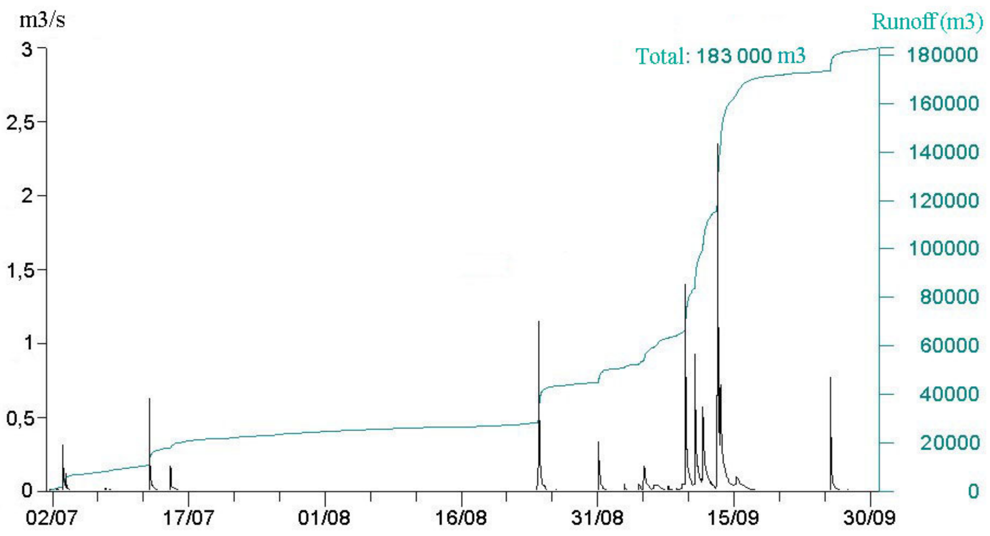

Figure 5. Runoff volumes from the Huai Ma Nai catchment, 2003

In Vietnam, the rainy season started at the beginning of April and ended in late October. There were fewer rainfall events that occurred in 2003 than in 2002, two times less in the month May (Figure 6 and Table 9). There were more events in the month of April although these were only small rains. The month of April was relatively wet in 2003 than in the same month in 2002. The rainfall during the month of May was similar in both years, but July was especially humid in 2003 (575 mm against 300 mm in an average year). It should be noted that between 21 and 25 July, two typhoons passed by northern Vietnam, bringing rains amounting to 420 mm. During this big storm event (typhoon Koni, Figure 7), the water level rose to over one meter, and the stream discharge carried more than 20 g/l of suspended matter measured at 0700 on July 23.

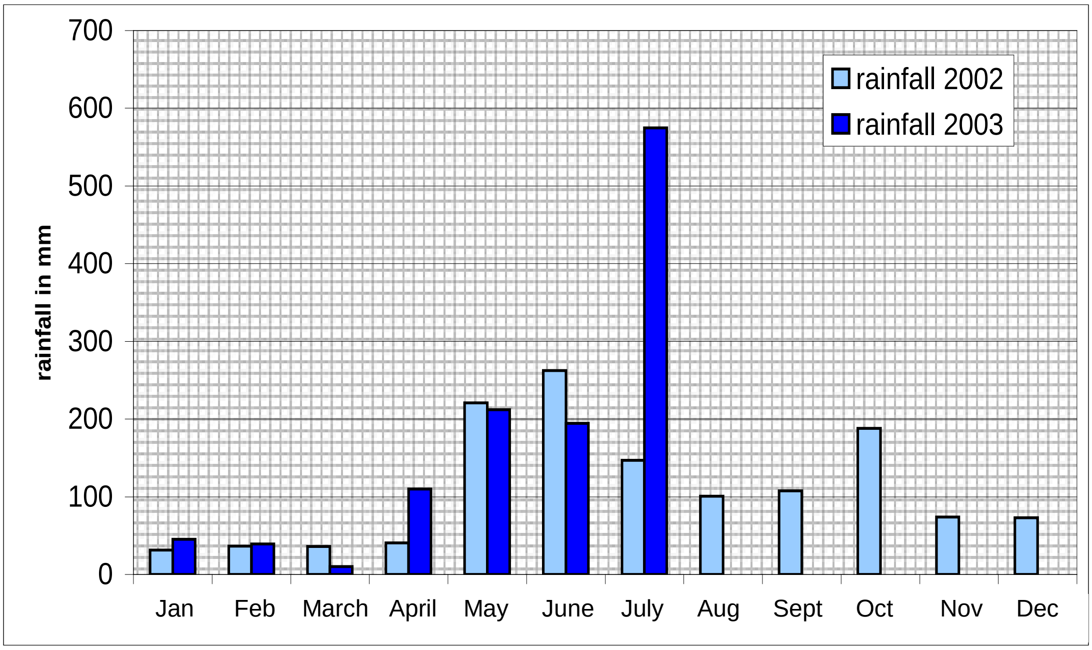

Figure 6. Monthly rainfall (in mm) in the Dong Cao catchment from January 2002 to July 2003.

Table 9. Rainfall monthly distribution, rainy season 2002 and 2003

Rainfall (mm)	April 2002	April 2003	May 2002	May 2003	June 2002	June 2003	July 2002	July 2003
0-10	6	14	5	2	8	5	10	3
10-20	2	0	7	1	2	1	3	1
20-30	0	1	2	1	2	1	1	1
30-40	0	0	0	2	3	0	0	3
40-50	0	0	1	2	0	3	1	0
50-60	0	0	0	0	1	0	0	1
60-70	0	1	0	0	0	0	0	1
>100	0	0	0	0	0	0	0	2
Total monthly amount (mm)	40.5	110	221	212	262.5	194.4	147	575
Number of event	8	16	15	8	16	10	15	12

Figure 7. Exceptional storm event (typhoon Koni) from 21 to 25 July 2003

There were fewer big floods (> 100 cm) in 2003 than in 2002. Runoff in Dong Cao catchment is low (10% for 2002). During the rainy season, the monthly runoff coefficients varied from 0 to 17% except during the typhoon in July 2003 when the soil becomes saturated and runoff coefficient reached as high as 88% (Table 10).

Table 10. Runoff coefficient in Dong Cao main outlet in 2002 and 2003

Year	Rain (mm)	Effective rainfall (with runoff) mm	Surface m^2	Effective rainfall volume m^3	Runoff volume m^3	runoff coefficient (%)
2002	592	532		242055	25183	10
2003						
Total end June	326	293	455000	133315	6683	5
Total end July	816	734	455000	333970	134424	40
flood 21-25 July	420	378	455000	173810	125843	72
flood 22-24 July	320	288	455000	131040	116207	88

Sediment yields

Total soil loss observed in the Indonesian catchment increased sharply at the beginning of the rainfall event. After some time, the increase became gradual, creating a log-normal relationship. The relationship between soil loss and rainfall in the Tegalan microcatchment is shown in Figure 8.

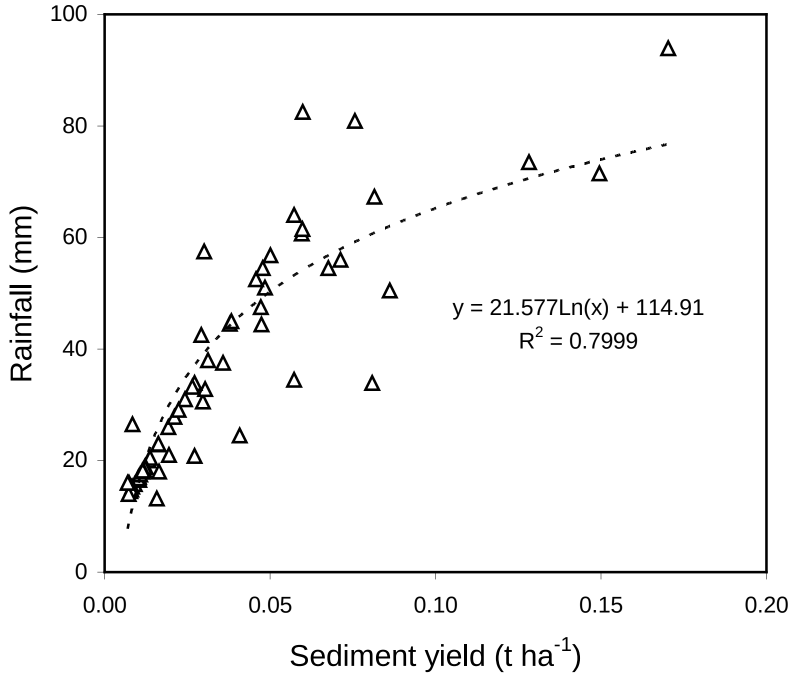

Figure 8. Relationship between rainfall and soil loss in the Tegalan microcatchment during wet season 2002/2003

Figure 9 shows the temporal variation of soil loss as bed load in the Mapawa catchment and the four micro-catchments from 2000 to 2003. Soil loss in the main weir increased from 2000 to 2002 but decreased in 2003. As shown in Table 1, the annual rainfall in 2002 was the lowest in four years but the observed bed load was the highest. This was probably because the main weir was reconstructed in January 2002 and the bed load capacity of the trap was doubled compared to the original capacity. A portion of the bed load had not been collected at the trap before the reconstruction. The bed load decreased in 2003, presumably due to the increased awareness about soil erosion as a result of the training the MSEC conducted earlier. Added to this was the cross site visit to Claveria, Misamis Oriental in the later part of 2002. It should be noted that there was an increase in the number of adopters of soil conservation measures in the MSEC catchment, particularly the establishment of the Natural Vegetative Strips as showcased by the ICRAF project. On the other hand, MC2 had the highest bed load yield in 2001 and the lowest in 2002.

In the Lak Sip catchment in Laos, water erosion was much lower in 2003 (Table 11) than in the previous years. In first analysis, this is due to the lower annual rainfall amount (see Table 7), 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 a higher amount of soil erosion. As for 2002, the treatments in S6 and S9 were effective to control soil erosion.

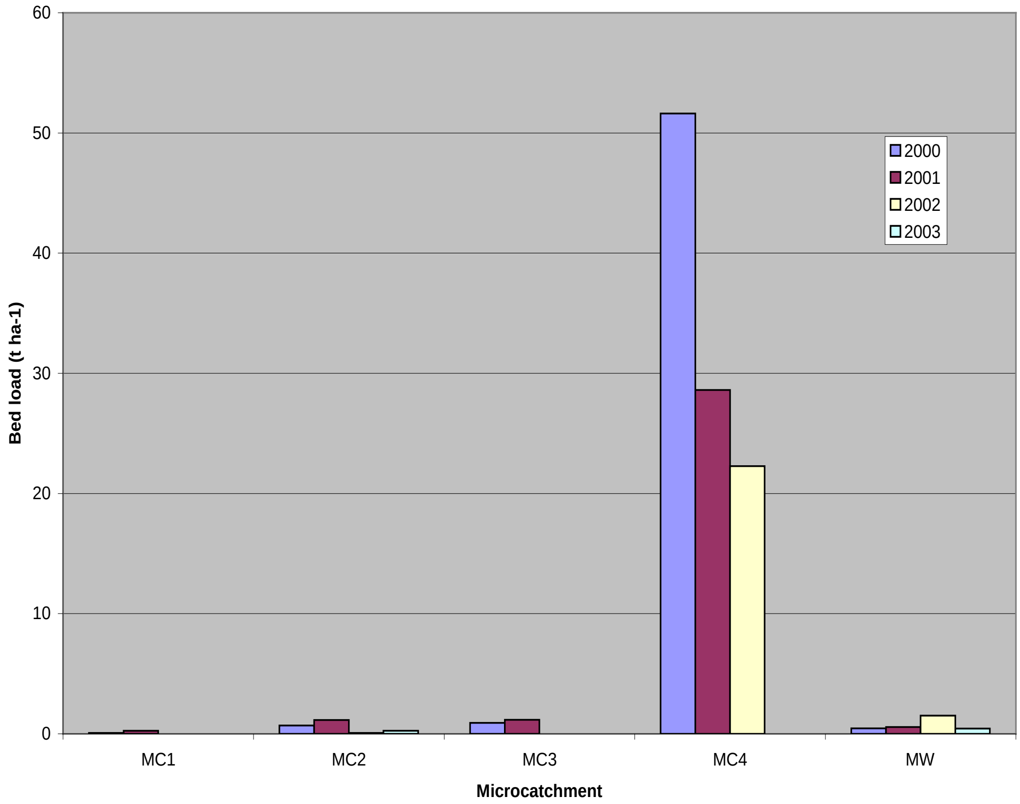

Figure 9. Yearly variation of soil loss in the different microcatchments in the Philippines, 2000-2003

Table 11. Runoff and soil loss (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 Till	0.727	0.00	0.07	0.07	4.39

The sediment exported (t.ha.yr^{-1}) by the Huai Ma Nai catchment in Thailand is shown in Table 12. The results indicate that the Huai Ma Nai catchment lost 44 t of soil during the 2003 rainy season. On a per unit area basis, this value corresponds to an average soil loss of approximately 0.47 t ha yr^{-1}.

Table 12. Runoff and soil loss in Huai Ma Nai catchment in 2003, rainy season.

	Huai Mee	Huai Ma	Huai Bong	Huai Tong	Huai Ma Nai
Surface (ha)	11.8	9.6	3.2	7.1	93.2
Rainfall (mm)	1102	1134	1118	1051	1109
Rain fall in volume (m^3)	130036	108864	35776	74621	1033588
Flow ($m^3.s^{-1}$)	36790	25831	14905	14196	182719
Run off coefficient (%)	**28.29**	**23.73**	**41.66**	**19.02**	**17.68**
Exported sediments (t)	15.11	7.59	0 *	1.586	44.24
Bedload (t)	3.78	12.368	3.912	3.279	0 *
Export by catchment (t)	18.89	19.958	3.912	4.865	44.24
Soil loss by catchment ($t.ha^{-1}$)	**1.60**	**2.08**	**1.22**	**0.69**	**0.47**

*: no measurements because of the installations which do not allow the analysis of these results.

In the Dong Cao catchment in Vietnam, the yearly bed load measured at the main weir was estimated at 0.5 t ha^{-1} $year^{-1}$ (Table 13, Figure 10). It was observed that the bed load was relatively lower in 2002. This observation can be explained by the lower rainfall and the denser grass cover in 2002. Because 2002 was a relatively dry year, the area that was cultivated was smaller than the previous years and the areas earlier cultivated had been left with wild grasses. The highest bed load was observed in W2 (2.7 t ha^{-1}) where cassava was planted. The other sub-catchments had bed loads of not more than 1 t ha^{-1}. It was also observed that there is no direct relation between the amount of rainfall and the production of sediments which is contrary to the observation in Indonesia.

Rill and gully erosion

In 2003, rill and gully erosion were studied in Laos and Thailand. At the onset of the rainy season, 29 rills were reported in Houay Pano catchment with a total length of 3,410 m. The total erosion rate by rill erosion in 2003 was 0.11 t ha^{-1} which is very low if compared with rill erosion in 2001 (2.4 t ha^{-1}) and 2002 (1.5 t ha^{-1}) (Table 14). Greater total rill erosion in 2003 mainly occurred within bigger microcatchments (1, 3 and 4) with the exception of microcatchment 2. Microcatchments 1 and 9 showed higher rates. It appeared that rill erosion was much lower than inter-rill erosion. This surprising result compared to 2001-2002 investigations may be explained by the higher soil surface cover when higher rainfall events occurred.

In Thailand, the development of the gullies and the factors affecting were studied. Its development was defined into different stages. The initial stage consists of the concentration of a significant volume of water on a determinate area. This concentration leads directly to the incision development, then to a maturation stage when there is loss of soil particles. Finally, at the stage of stabilization, vegetation can be established. These four stages are not independent of each other and occur successively. The development of gullies can thus be related to the position in the landscape, and soil characteristics such as porosity and slope.

Table 13. Sediments collected in the different weirs within the Dong Cao catchment during the rainy season of 2003.

Date	MW (kg)	W1 (kg)	W2 (kg)	W3 (kg)	W4 (kg)
6-Apr-03	632	0	28	185	74
3-May-03	253	0	3 745	210	74
5-May-03	162	0	0	0	0
15-May-03	401	0	129	0	0
22-May-03	125	0	422	389	39
28-May-03	621	0	3 440	230	0
29-May-03	0	0	4 087	0	0
6-Jun-03	1 135	0	201	69	42
18-Jun-03	857	0	1 427	261	75
24-Jun-03	632	0	1 480	0	0
2-Jul-03	944	0	439	428	0
11-Jul-03	1 398	0	1 455		0
19-Jul-03	814	0	530	252	124
24-Jul-03	6 263	1 450	0	0	0
25-Jul-03	0	0	2 776	2 409	1 501
27-Jul-03	2 974	0	0	0	0
13-Aug-03	1 071	0	278	508	156
28-Aug-03	731	0	124	220	69
19-Sep-03	5 599	0			
20-Sep-03		0	580	314	121
Year total	**24,612**	**1,450**	**21,142**	**5,475**	**2,274**
Area (ha)	49.7	2.64	7.71	9.92	8.36
In 2003	**0.54**	**0.39**	**2.75**	**0.51**	**0.32**
In 2002	0.46	1.30	1.90	0.79	0.60

More than 6 t of sediments was collected at the main weir after the exceptional heavy rains of July 24/25

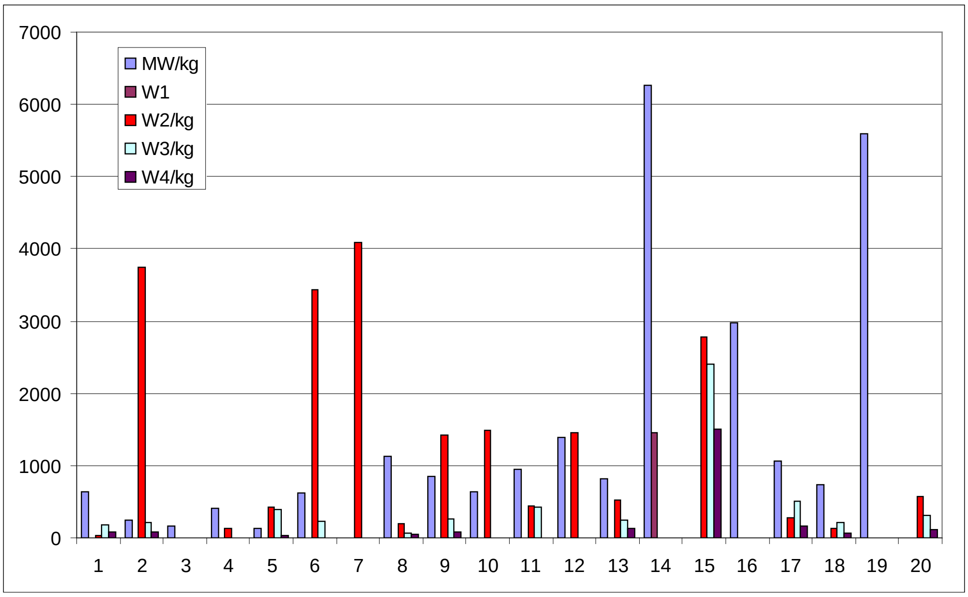

Figure 10. Bed load yields for each rainfall event in Dong Cao watershed, 2003

Table 14. Rill erosion in Houay Pano sub-catchments (1 to 9) from 2001 to 2003.

		2001		2002		2003	
Sub catch ment	**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**

Soil Erosion and Land Use Practices

In all countries, runoff and erosion occurred differently under different land use systems. As earlier mentioned, in Indonesia, runoff was generated largely from the Tegalan microcatchment, and it was much higher than that from the Rambutan and Kalisidi microcatchments. Consequently, total soil loss was also higher in the Tegalan microcatchment. It should be noted that the Tegalan microcatchment has a land use of annual upland crops that are more intensively cultivated.

In December 2001, conservation technology was introduced in the Tegalan microcatchment by planting Benggala grass (*Panicum maximum*) along the contour and some cultivated areas. The system reduced soil loss by up to 50% in a period of only one year. There was a reduction of as much as 90% in the second year (Figure 11). The reduction in soil loss was mainly in the reduction in the amount of bed load. Although not as high as in Tegalan microcatchment, soil loss also tended to decrease in Rambutan catchment. Soil loss in the Kalisidi microcatchment did not show any trend but varied from year to year. Moreover, suspended load was higher than the bed load.

The cropped area of the Mapawa catchment in the Philippines increased to 21% of the whole area in 2003 from 16% in 2000 (Figure 12). Microcatchment 1 (MC1) increased from 5% to 18%, while MC2, MC3 and MC4 had very little changes in land use. New areas were opened for potato plantation and a good number of farmers started adopting the NVS technology in the area.

Crop rotation was practiced in a larger percentage of the entire catchment in about 12.4 ha or 15% of the whole catchment. Only 3% of the area is planted to corn monocrop. A comparison among cropping systems showed that all of the farmers in MC1, MC2 and MC4 plant high value vegetables rotated with corn. On the other hand, the cultivated area in MC3 is used for monocrop. A certain portion of the cultivated area has been left fallow for a number of years already.

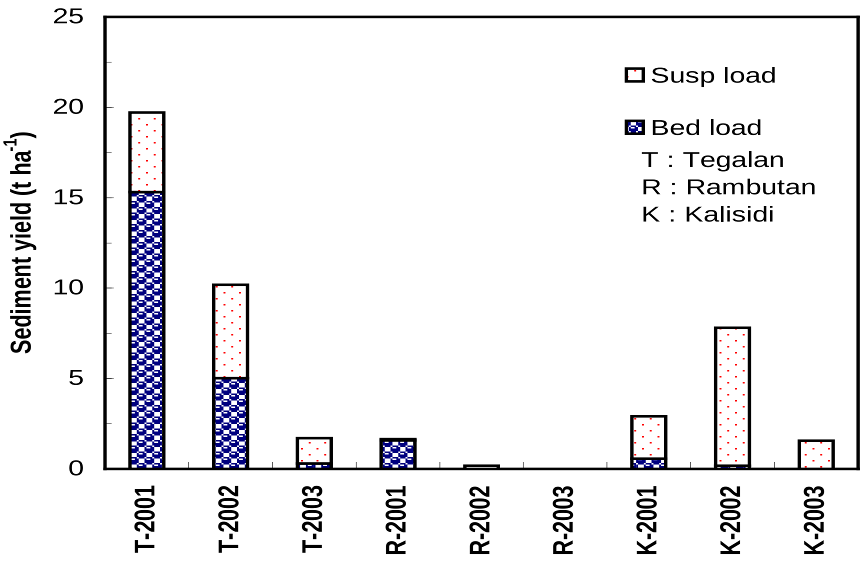

Figure 11. Temporal variation of total soil loss under different land use system

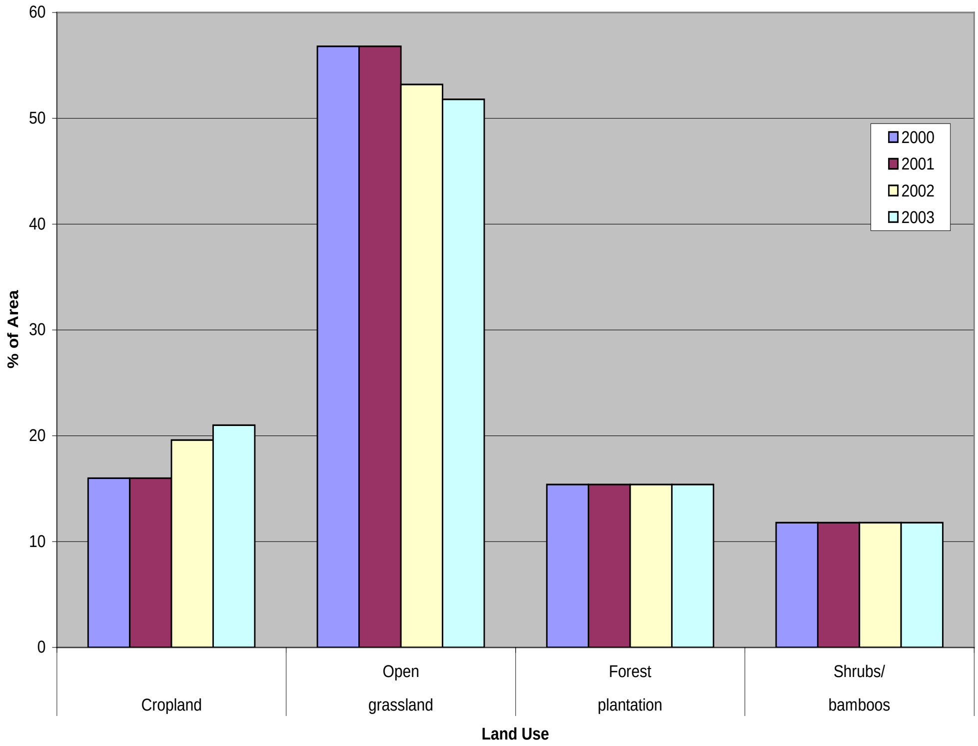

Figure 12. Change in land use of the Mapawa catchment from 2000 to 2003

As shown earlier, soil loss in the main weir increased from 2000 to 2002 but decreased in 2003. The decrease in bed load in 2003 could partly be attributed to the improved land use as there was an increase in the number of adopters of soil conservation measures in the catchment, particularly the establishment of the Natural Vegetative Strips.

In Laos, fallows on steep slopes are more frequently turned into cultivation because of land shortage. As a result, tillage erosion has increased substantially over time in the last 15 years (Figure 13). 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. The analysis of data had also 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.

Slope: 90%

Slope: 60%

Slope: 30%

Figure 13. Tillage erosion as affected by slope

In Thailand, there were significant changes in land use from 2001 to 2003 (Figure 14). In 2001, the majority of the cultivated area was used for mungbean. In 2002, soybean occupied more than 90% of cultivated area. In 2003, there was a marked increase in the area cultivated to maize, the original cash crop of the catchment, with 58% of the cultivated land used for the crop. Soybean was cultivated on 34% of the agricultural area. Land use patterns for 2003 are presented in Figure 15 which allows the visualization and characterization of different small catchments of Huai Ma Nai.

In contrast to soybean which is associated with low vegetative cover; fruit orchards provide a very good protection to soil. The soybean root system does not provide efficient resistance against the flow. In terms of cash crops, maize is a better soil conservation crop due to a comparatively higher Manning's coefficient and percentage of vegetative cover due to inherent plant physiology. Good vegetative cover in the Huai Ma Nai catchment during the 2003 rainy season as a result of favorable climatic conditions resulted in minimal soil losses.

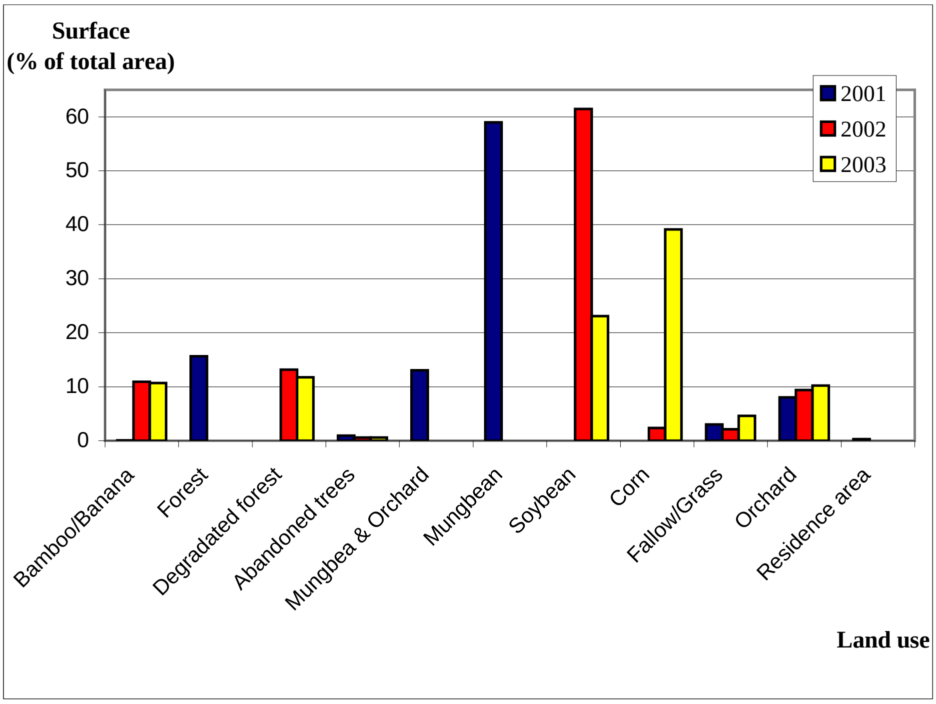

Figure 14. Changes in land use in the Huai Ma Nai catchment since 2001

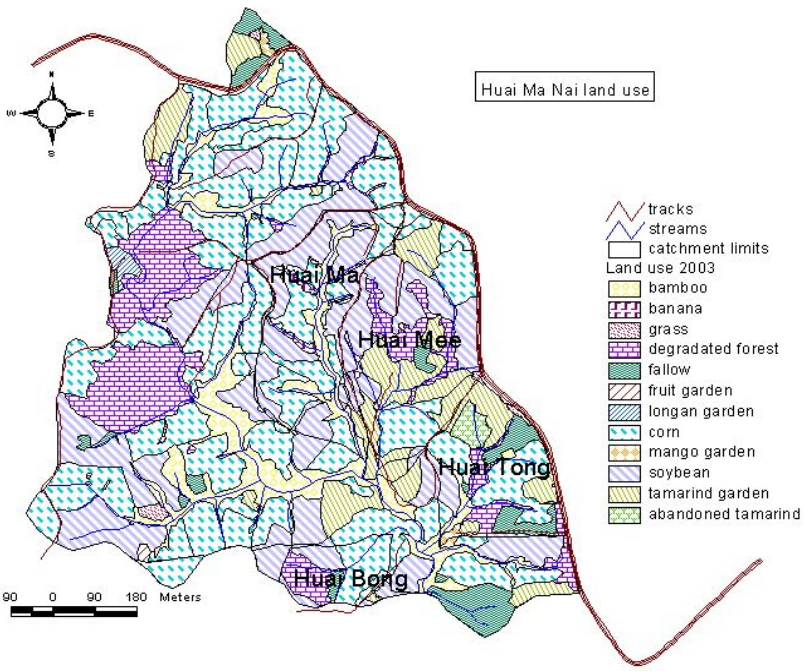

Figure 15. Land use of the Huai Ma Nai catchment in 2003 (Chatwatcharakul, 2003).

In the Vietnam catchment, the areas of *Acacia mangium*, secondary forest and *Venicia montana* in 2003 remained the same as in 2002 (Table 15 and Figure 16). The fallow area decreased by 4%, while the area of cassava decreased by 65%. The arrow root was completely stopped and 55% of the Eucalyptus was cut down. A small area was planted to bamboo and *Tephrosia candida.*

Table 15. Area (ha) per kind of crop in 2002 and 2003

CROP	2002	2003
Acacia mangium	7.4	7.4
Arrow root	0.5	0
Bamboo	0	0.3
Bracharia ruziziensis	0	4.3
Canarium trandenus	0	4.1
Cassava	4.4	1.5
Chukrasia tabularis	0	**13.8**
Eucalyptus	6.4	2.9
Fallow	**24.9**	**24.0**
Secondary forest	9.4	9.4
Stylosanthes guyanensis	0	1.1
Styrax	0	**22.0**
Tephrosia candida	0	0.8
Venicia Montana	0.8	0.8

(Source : Koïkas J. Renaud J. & al. Dong Cao GIS Arcview project, with former inquiry, 2003)

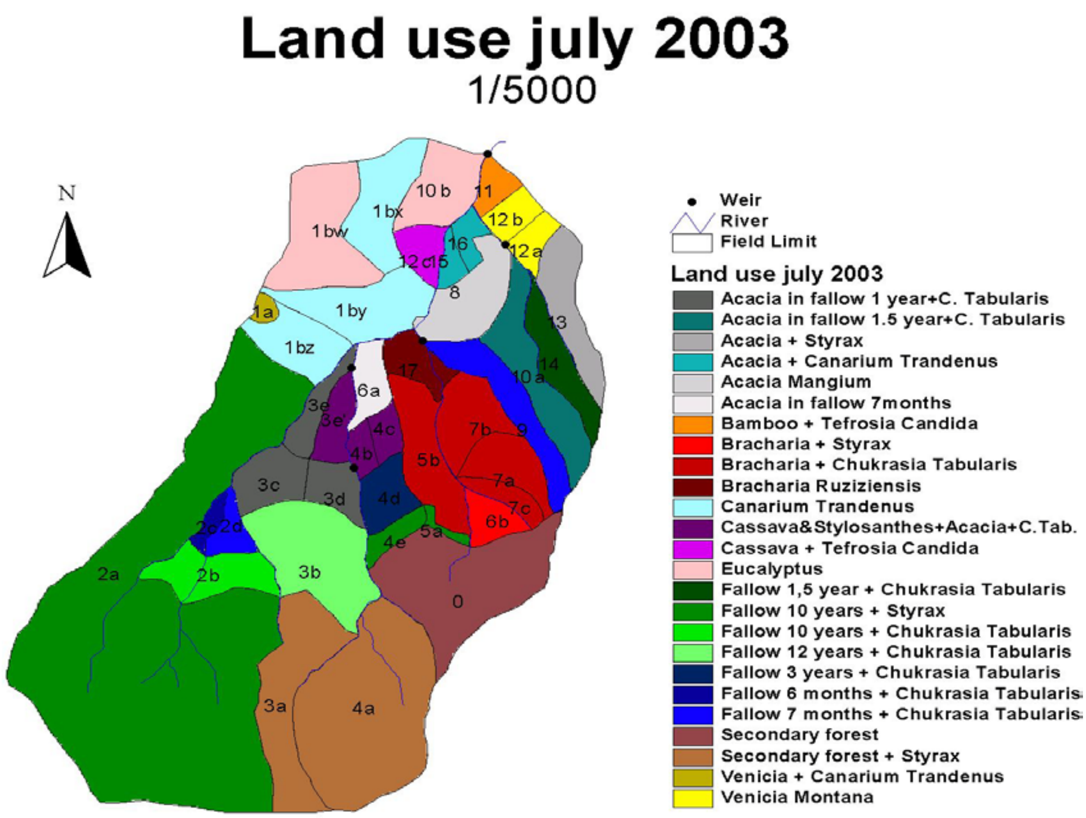

Figure 16. Land use map of the catchment in 2003 showing the plots

The main changes in the watershed were the cultivation of fodder crops, and the planting of trees (by one farmer of Dong Cao, Mr Bôn). Thus, 4.3 ha was planted to *Bracharia ruziziensis*, a fodder grass, and 1.1 ha to *Stylosanthes guyanensis*, a leguminous fodder, in association with cassava. In the lower part of the watershed, 4.1 ha was planted to *Canarium trandenus*, 13.8 ha to *Chukrasia tabularis*, mainly in the middle part of the watershed, and 22 ha to Styrax, mainly in the upper part of the watershed. These trees were planted on areas already covered by other crops, or in fallow areas, on almost all the watershed. At the end of 2003, 80% of the watershed was thus planted to these trees.

Nutrient Loss and Productivity Decline

The on-site effect of soil erosion is generally reflected in the decline in the productivity of the soil by impairing its chemical, physical and biological fertility. Erosion reduces the soil depth, decreases its water holding capacity and reduces its chemical fertility through nutrient and organic matter loss.

As a consequence of the shortening of fallow period and the lengthening of cropping period, the yields of upland rice in Luang Prabang in Laos showed a clear decline since 1990. The yield decrease reflects weed invasion, soil erosion and soil fertility depletion. The comparison of yields measured in 'normal' soils and soils affected by erosion (rills and shallow landslide) show a clear impact, especially for shallow landslides (Figure 17). In the case of shallow landslide, the impact is more pronounced for Job's tear than for rice.

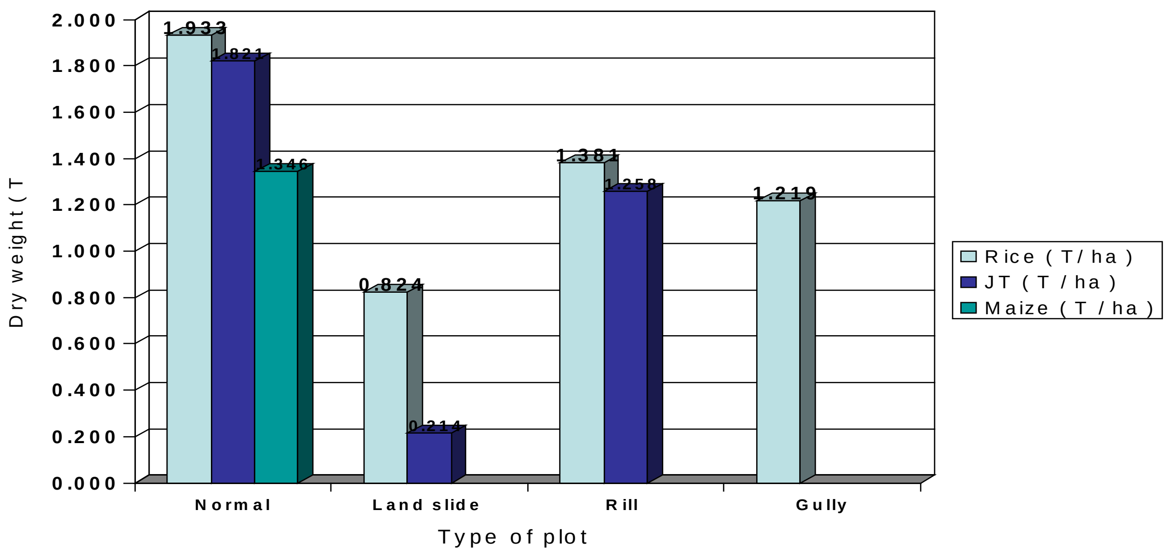

Figure 17. Yields of crops under normal soil and that affected by erosion

Observations in the Philippines showed that the loss of nutrients and the cost of replacing them were high for N compared to P and K (Table 16). This was probably because the P and K contents in the soil were relatively lower than N. Furthermore, there was a significant decline in organic matter as shown in the monitoring of the changes in chemical properties of the soil. The P and K content were more or less maintained after three years.

The cost to replace N in the four year data generally differs, with 2002 having the highest recorded cost. The information presented in the tables were only those derived from the measured bed load. For sure, the cost would be much higher if the nutrients carried in the suspended sediment were considered. Nevertheless, this simple estimate clearly showed the need to reduce erosion in order to maintain the soil fertility in the sloping uplands.

Table 16. Nutrient loss and replacement cost of erosion in MC2 and the whole Mapawa catchment, 2000-2003

Year	Soil loss ($t\ ha^{-1}$)	Nutrient loss (kg)			Replacement cost (PHP)		
		N	P	K	N	P	K
MC2							
2000	0.45	112.67	0.07	12.57	1715.42	1.99	183.63
2001	0.57	88.4	0.11	14.5	1422.4	3.13	222.9
2002	1.52	134.6	0.08	16.65	2166.15	2.22	256.7
2003	0.43	63.72	0.02	6.79	1745.93	0.51	141.66
Mapawa							
2000	0.69	38.04	0.03	2.11	579.17	0.85	30.84
2001	1.15	44	0.05	7.17	708.41	1.52	110.25
2002	0.08	3.8	0	0.57	60.4	0.08	8.82
2003	0.26	9.82	0.01	1	268.99	0.26	20.68

The study on nutrient balance in the paddy field at the lower portion of the catchment in Indonesia showed that during land preparation, the incoming sediment was lower than that flowing out. About 106 to 118 kg of sediment per hectare was eroded from the field while only 8 to 24 kg ha^{-1} came in from the irrigation water, respectively. It was observed that the amounts of sediment deposited per day depended on the activities upstream, stream bank erosion, and other biophysical conditions upstream. These data suggests that terraced paddy field system plays an important role in controlling erosion at catchment scale and can minimize the negative impact downstream.

The outgoing nutrients via runoff sediment were higher than the incoming nutrients from irrigation water, as the outgoing sediment was also higher. In the case of nitrogen, contribution of incoming sediment was higher than losses through outgoing sediment (erosion). This is because nitrogen may not be bound in the fine materials (eroded soil) as P and K. In addition, contribution of rainfall, decomposed organic matter and leaching of nitrate from upstream may enrich the irrigation water. The net gain of nitrogen from the incoming sediment during land preparation was 0.13 N g ha^{-1}, which was very small.

A week before and after the first fertilizer application, the incoming nutrients were higher than outflowing nutrients, meaning that during these periods the soil was enriched by nutrients from deposited sediment. The total nutrient inputs from irrigation water a week before and after fertilization activities were 17.8 N, 2.4 PO4, and 3.1 K g ha^{-1}. These values were small and may not potentially contribute to soil fertility improvement.

Off-site Effect of Erosion

In the project site in Thailand, off-site effect of erosion was conducted by evaluating the sedimentation rate in the Mae Thang reservoir. In 2003, preliminary monitoring of the water quality in the lake in terms of dissolved oxygen concentration, turbidity, temperature, electrical conductivity (EC), chlorophyll-a concentration, redox (Eh), pH, and light backscatter in the lake was started.

Soil erosion calculated by determining the sedimentation rate in the reservoir showed a soil loss from the watershed of 51 t ha^{-1} $year^{-1}$ (Janeau *et al*, 2003) This rate of sediment discharge is significantly higher than the design estimate of 1.45 t ha^{-1} $year^{-1}$ and a reservoir life span of over 100 years. Notwithstanding this, the estimated sediment discharged into the reservoir is similar to that estimated by Inthasothi *et al.* (2000) using the Universal Soil Loss Equation (USLE).

Figure 18 shows the changes of the different parameters of water quality with depth as measured in the water column near the lake outlet. Except for the electrical conductivity all other properties measured decreased at a depth of 5 m. Depletion of dissolved oxygen in natural and artificial water reservoirs is a major environmental problem because of their importance to human settlement, in particular for irrigation, flood control, fishing and energy production. Critical conditions may arise when the dissolved oxygen concentration available to decompose organic matter falls below a minimum level of < 1 $mg.l^{-1}$. The depletion can be caused by a high organic matter supply generated by soil erosion and runoff.

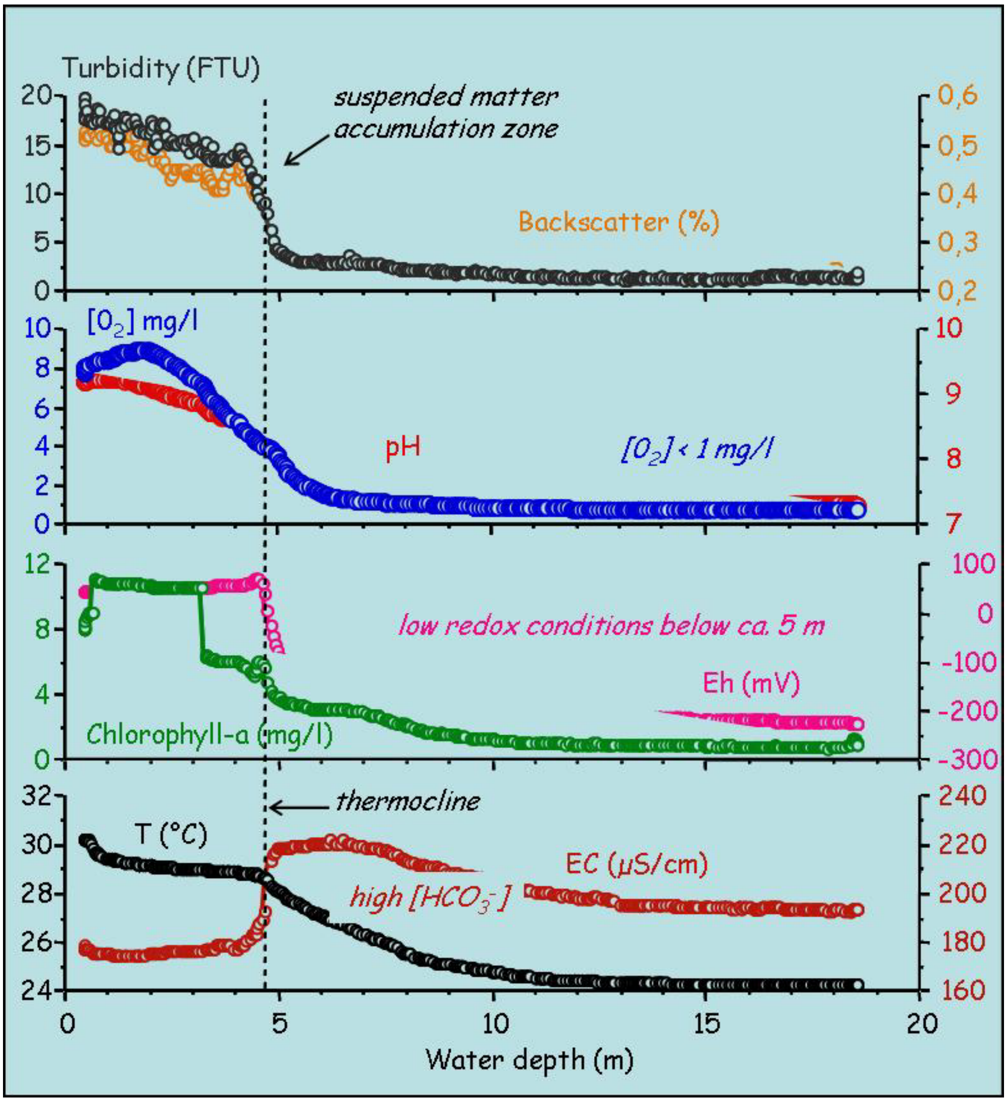

Figure 18. Data obtained with multi parameter probe in September 2003.

Catchment Management Interventions

During the late rainy season of 2001, the integration of fodder grass planting and cattle fattening was introduced as an alternative option to the conventional intensive annual crop cultivation in the Tegalan microcatchment in Indonesia. Planting grass for soil conservation in sloping uplands is known widely and almost every farming system technology package introduced in the uplands of Java has fodder grass and livestock components (Hermawan and Prasetyo, 1991; Prawiradiputra *et al,* 2000). The grasses reduce runoff and serve as filters of eroded soil. Integrating livestock into the system provides additional source of income for the farmers.

Benggala grass (*Panicum maximum*) introduced and planted in some of the bench terrace risers and in the small portions of the microcachment has decreased soil erosion. After the second year of implementation (2002) erosion decreased by almost 50% and by more than 90% in the third year (see Figure 11 above). The sharp reduction in soil loss was mainly caused by the decrease in bed load rather than in suspended load.

On the average, the farmers earned an income of US$ 9.52/month in 2002, but only US$ 3.57/month in 2003. The lower benefit in2003 was primarily because of the lower price of the animal in 2003. In 2002, the cattle were sold during the Idul Qurban (Sacrifice Moslem Celebration) time when the demand was high. However, this lower income did not dampen the enthusiasm of the farmers. They still wanted to continue this cattle fattening activity and tried other mechanism to have higher returns.

The alley cropping technology using natural vegetative strips (NVS) as hedgerow was the first option identified for introduction in the Mapawa catchment in the Philippines. Even before the project, some of the farmers in the area had been practicing some conservation practices in their farms. There were seven existing NVS adaptors cultivating an area of 3.5 ha and 1.4 ha practicing agroforestry with eucalyptus. After the training and the cross site visit conducted in 2002, the number of adaptors of NVS in the MSEC catchment increased. Seven farmers with a total farm area of 3.2 ha adopted the technology. As stated earlier, this was one possible reason why there was a lower sediment yield in 2003.

The farmers whose farms are near the creek were also encouraged to plant bamboos near stream banks to reduce soil erosion. Erosion in the stream bank is considered a major cause of soil loss in the catchment and has contributed much in the amount of sediment yield measured after a storm event. A total of 13 farmers participated in this option.

To motivate more farmers to adopt soil conservation measures, the project introduced livestock dispersal. Four heads of cattle were given to four beneficiaries who have already established a conservation practice, particularly with the NVS technology. The animals were distributed in the last quarter of 2002. The Local Government of Lantapan supports this activity through its Livestock Dispersal Project.

In Laos, soil erosion, crop productivity, labor 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 conventional system of slash and burn include reduced fallow periods ranging from 1 to 3 years. The other three systems were: 1) improved fallow as recommended by the Integrated Upland Agricultural Research Project (IUARP), 2) improved fallow with contour planting as recommended by the ASIALAND project, and 3) mulch planting without tillage as recommended by CIRAD.

The systems of improved fallow and mulch planting without tillage required less labor than the traditional system which required about 220 days ha^{-1} of labor. The contour planting system required about 116 days ha^{-1} of labor.

The yields in the traditional system were extremely low, reflecting the exhaustion of the soils and the weed invasion. As a result, soil erosion was low. The highest yields of Job's tear were observed on the contour planting system. This can be ascribed to an efficient weed control which limited competition between weeds and Job's tear. However, this favored soil erosion.

Impact Assessment

A simple questionnaire was prepared and used in the evaluation of the impact of the project in Indonesia, Laos, Philippines, Thailand and Vietnam. The impact was evaluated based on the responses by the researchers to the change indicators related to five project outputs and by the farmers to two project outputs (Outputs 2 and 3) (Table 17). In the case of the farmers, the analysis was done for Indonesia, Laos, Philippines and Vietnam.

The Likert scale was used to analyze the data. This is classified as a summated rating scale of a set of attitude items to which subjects respond with degrees of agreement or disagreement (intensity). The scores of the items of such a scale are summed and average to yield an individual's attitude score (Maglinao *et al*, 2003). On the final scale, the subject marks each statement in one of the categories of: 1.00 – 1.50 (strongly disagree), 1.51 – 2.50 (disagree), 2.51 – 3.50 (undecided), 3.51 – 4.50 (agree), and 4.51 – 5.00 (strongly agree). The individual's final score is obtained by summing the item scores.

In general, based on the level of agreement of their responses to the change indicators, the outputs of the project have had positive impact on the researchers and the farmers in all countries except Thailand (Figures 19 and 20). The perception of both respondent groups showed the tendency to agree or strongly agree to a positive change that the project has made. Figure 21 shows that at least 60% of the researchers agreed or strongly agreed to the change indicators for all outputs, while Figure 22 shows that more than 86% of the farmer respondents agreed or strongly agreed with the change indicators for technology options and information dissemination.

The highest positive response was in the effect of improved information dissemination strategies. This implies that the conduct of regular meetings with the farmers has resulted in very positive effects. For both researchers and farmers, the effect of the introduced intervention has not yet been strongly felt. While it may be too early to assess the impact in terms of productivity improvement, the responses by farmers clearly indicated their positive anticipation. The usefulness of the tools and guidelines and program management outputs has also not yet been fully realized by researchers. In all identified outputs, it appears that there has been no positive change by the project in Thailand.

While the study has provided some indications of the impact of the MSEC project, further evaluation of the methodology and analysis of the data are needed to complete the requirement of the framework. It should consider particularly the biophysical and economic impact of the project.

Table 17. Change indicators evaluated in the assessment of project impact

Project Outputs	Change Indicators
1. Tools, guidelines, methodologies	1. improvement in research implementation 2. reduction in degree of research supervision 3. improvement in data collection, analysis and interpretation 4. enhanced decision making 5. enhanced innovativeness/resourcefulness 6. increased appreciation of the project
2. Alternative technologies and land management options	1. recognition of severity of erosion problem in the area 2. recognition that problem can be addressed by appropriate technology 3. data and observations in the field change thinking about the problem 4. better appreciation about the project 5. ways by which the options are introduced acceptable 6. willing to continue to practice the management options introduced 7. income will increase with new option 8. any change in erosion rate because of the technology 9. better production, quality of water
3. Improved information and communication strategies	1. enhanced collaboration and adoption 2. increased appreciation of meetings 3. usefulness of the meetings 4. enhanced capacity
4. Enhanced NARES capacity	1. enhanced capacity 2. assigned higher responsibility 3. increased participation in scientific meetings and conferences 4. increased chance of better job 5. improved confidence to serve as trainer in catchment management 6. improved confidence in dealing with colleagues 7. enhanced opportunity to write scientific articles 8. increased involvement in policy and decision making 9. increased interest and motivation to do work on catchment management 10. improved interactions with others
5. Improved management, monitoring and evaluation	1. improved ability to share resources with other institutions/projects 2. increased collaboration base 3. optimized the use of scarce research resources 4. improved evaluation of project results 5. improved resource generation 6. improved relevance of institute's policy 7. reduced cost of research and extension

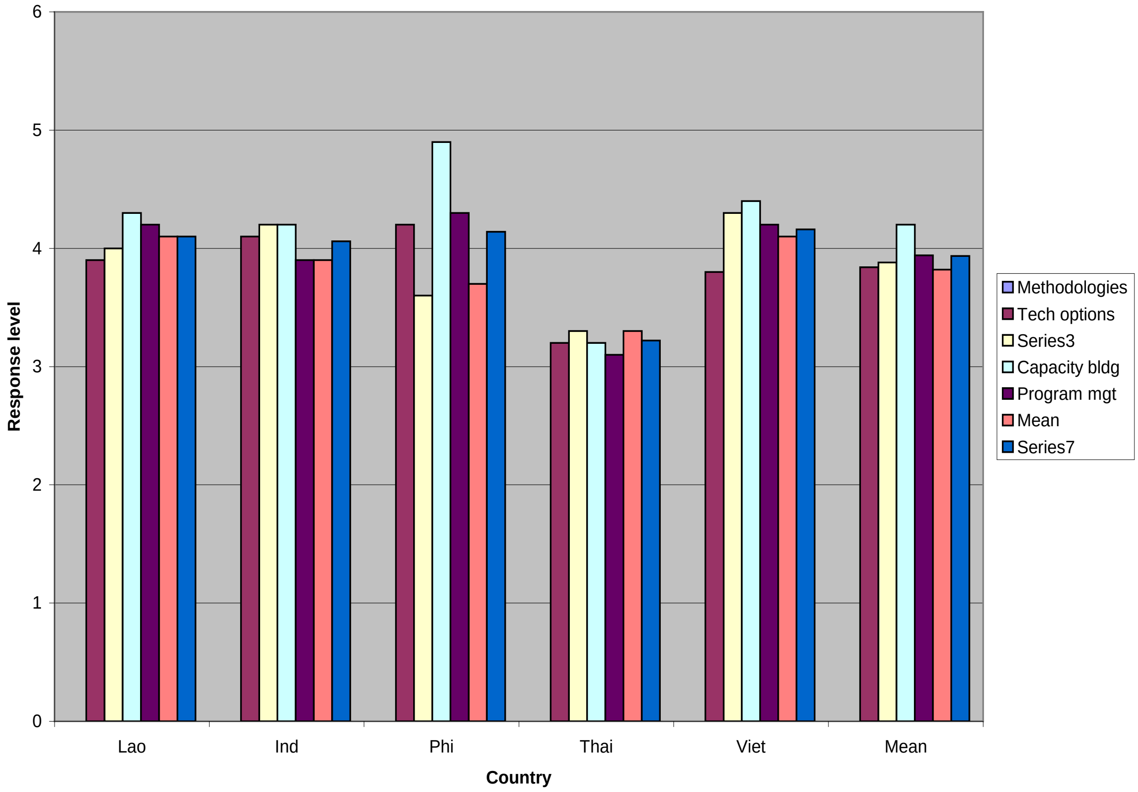

Figure 19. Response level of researchers to change indicators by country and expected outputs

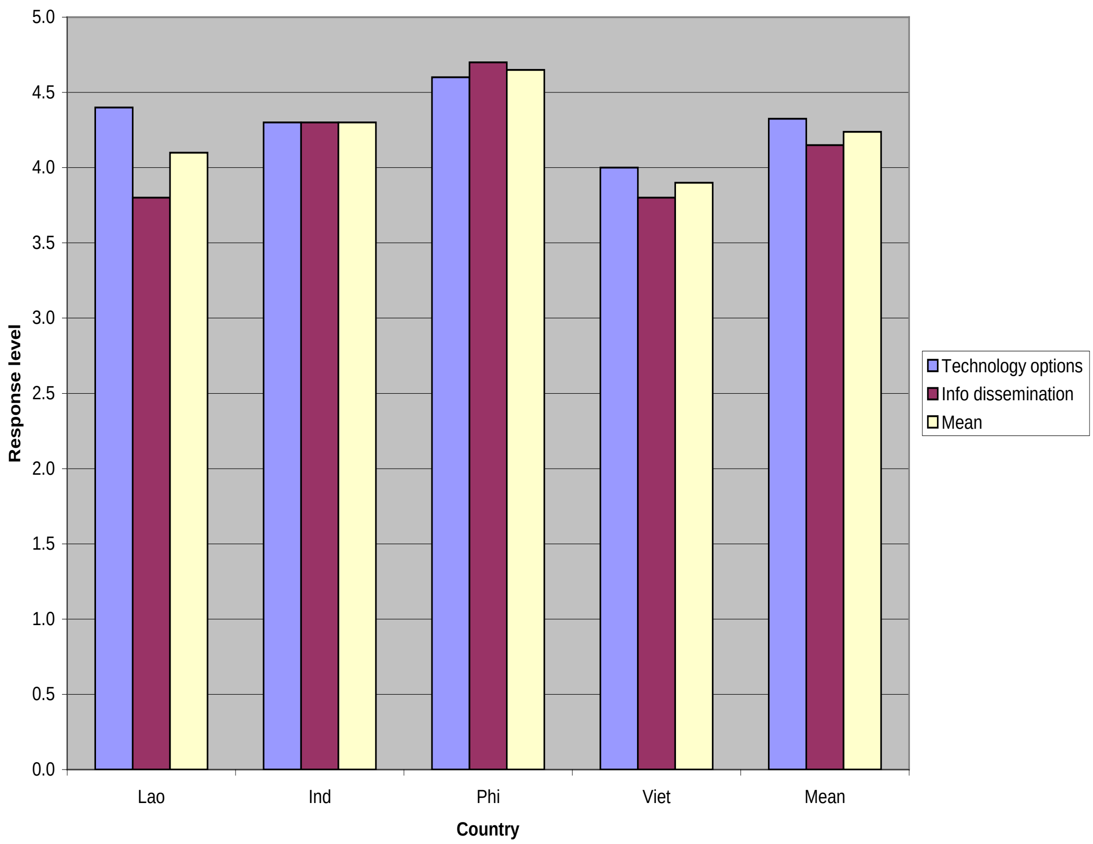

Figure 20. Response level of farmers to change indicators by country and expected outputs

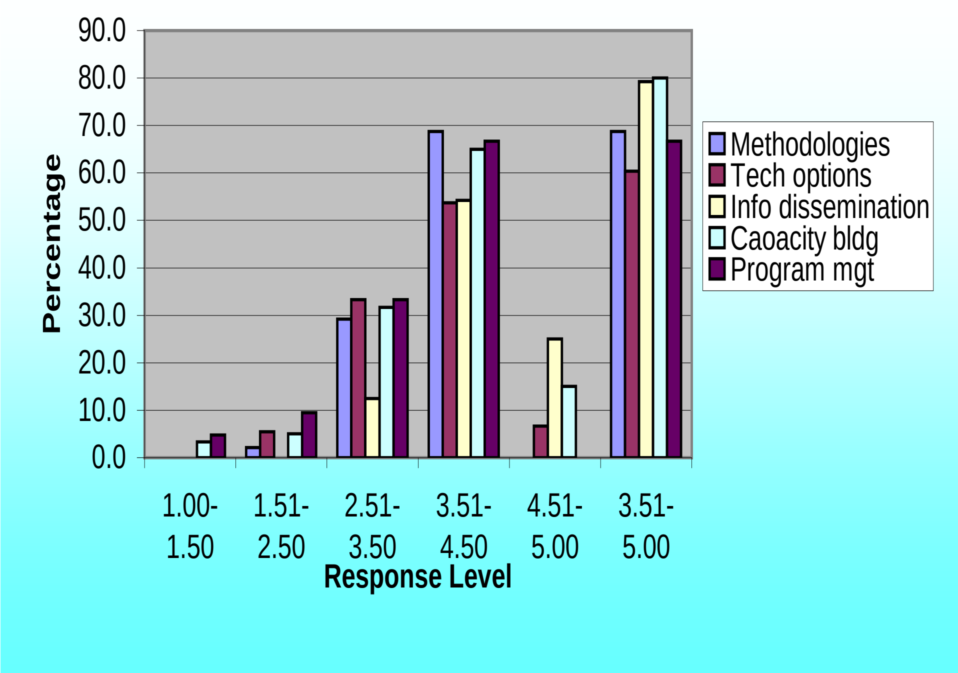

Figure 21. Proportion of the levels of agreement by researchers with the change indicators for the different outputs

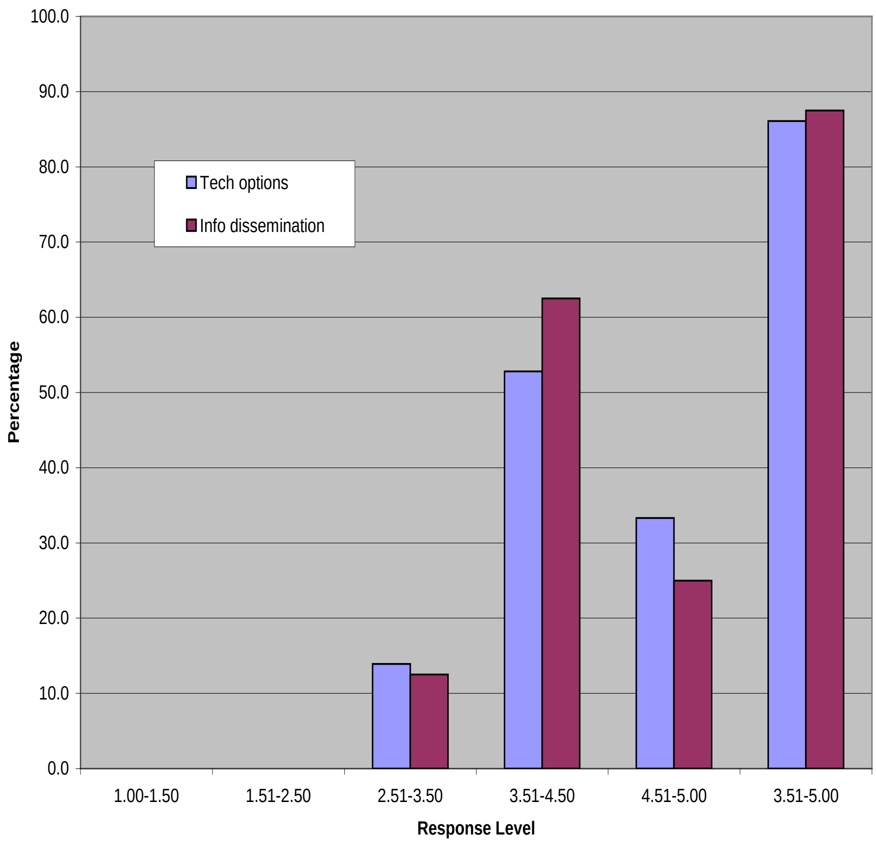

Figure 22 Proportion of the levels of agreement by farmers with the change indicators for the different outputs

Summary and Conclusion

In 2003, the International Water Management Institute (IWMI) continued to support the operation of the Management of Soil Erosion Consortium (MSEC) and the implementation of its research project in Indonesia, Laos, Philippines, Thailand and Vietnam. The evaluation of catchment behavior in relation to environmental factors and land use changes was intensified and farming systems options to minimize soil erosion and improve farmers' income were further investigated.

Rainfall, runoff and sediment yields varied from country to country and among catchments and microcatchments. During the year, Indonesia and Philippines had higher rainfall than Laos, Thailand and Vietnam. The erosion rate calculated at the catchment level was not alarming, as the highest observed was only a little over 2 t ha^{-1} yr^{-1}. This value is very much lower than those resulting from plot scale measurement because of the balancing effect of sediment transport and deposition within a bigger area.

Runoff and soil erosion at the catchment scale are also strongly influenced by the land use practices employed in the given area. Observations in 2003 still support the earlier findings that higher erosion occurs in catchments that are more intensively cultivated to annual crops, particularly under clean culture. It is therefore suggested that on steep slopes, more permanent cover (agroforestry, mulch) should be chosen over annual crops wherever possible. Diversification of production should be encouraged and improved farming systems, including reduced tillage, need to be applied. In essence, these concerns are being addressed by the options that have been evaluated. In Indonesia, Philippines and Vietnam, the integration of livestock in the farming system could provide additional source of income to the farmers at the same time being able to practice conservation.

The study on tillage erosion likewise showed that it can be higher than water erosion on steep slope. This research has helped establish a clear relationship between: Reduced fallow period==>Increased density and population of noxious weeds==>Increased number of tillage operations ===> Increased tillage erosion.

The effect of erosion off-site particularly in reservoirs could be serious in terms of reduced life span because of sedimentation and reduced quality of water for other uses. Preliminary assessment of the water quality in the Mae Thang reservoir in Thailand showed a reduction of dissolved oxygen concentration, pH, redox potential and temperature at the 5-meter depth of water.

The innovative approach employed by the project has had positive effect on the researchers and the participating farmers. The outputs that have been generated by the project have positively changed their knowledge, skills and attitude concerning soil loss and erosion management. It is hoped that further analysis will be done to more completely evaluate impact as the project is a long term undertaking.

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Information Dissemination and Exchange

Workshops and Scientific Meetings Conducted and/or Attended

1. Scientific Seminar on “Water quality and treatment in Hanoi”, NCSTV-CNRS, Hanoi, February 2003
2. “National workshop for pro-poor project”, VIWRR-IWMI, Hanoi, May 2003
3. Seminar on “Information technology and communication for natural disaster warning and mitigation”, ISTED-MARD, Hanoi, November 2003
4. Workshop on “Land and water management research in the uplands of South-East Asia” held in NAFRI, 30 September 2003, with participants from Lao PDR, Thailand, Vietnam and France. A CD-ROM including all the presentations was prepared and distributed.
5. Presentation of project results at the Brown Bag Seminar at ADB, Manila. 6 May 2003.

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CD-ROM

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Capacity Building

Training Workshops Organized and Conducted

1. International Training on Impact Assessment and Process Documentation. 20-30 July 2003. Los Banos, Laguna, Philippines

    The training aimed to provide basic understanding of the various methods and approaches for conducting impact assessment and process documentation for the MSEC and ASIALAND network partners, and to formulate a common framework for conducting the same in the network countries. Twenty-nine (29) participants from China, Indonesia, Laos, Malaysia, Philippines, Thailand and Vietnam attended the training. An interdisciplinary team of ten scientists from PCARRD, UPLB and IWMI served as lecturers and resource persons.

    Classroom lectures, discussions and exercises focused on establishing a common understanding of impact evaluation, the biophysical/environmental, economic, and social dimensions of impact assessment, sampling techniques and statistical tools for impact assessment, and the elements and techniques of process documentation. A field visit to the MSEC-ASIALAND site in Ma. Paz, Tanauan, Batangas was conducted on the fifth day and the techniques of how to conduct a Focus Group Discussion (FGD), Key Informant Interview (KII), and Process Documentation (ProDoc) were practiced.

    Both the MSEC and ASIALAND groups came up with a proposal to conduct impact evaluation using the lessons learned in the lectures and field exercises. The participants and the resource persons focused on improving the general methodology. Impact assessment should be done by outside teams which should be multi-disciplinary with at least an economist and a sociologist as members. Change can be measured by either the *before/after* or *with/without* approach. The use of the *target vs. accomplishment* approach is commonly used in making a project performance review. Data to be collected must be consistent with the objectives of the impact assessment and data collection techniques and data analysis depend on the type of data collected.

2. Training Workshop on Data Management and Interpretation. 6-10 October 2003. Bangkok, Thailand

Twenty-five participants from the MSEC countries participated in the training-workshop. The objectives were 1) improve data management; 2) improve the use of hydrological tools; 3) establish water and sediment balance, with focus on minimum data set; and 4) integrate socio economic components. The different resource persons gave a deep comprehension of the database system, how hard it is to build a proper database, and how important it is to know the units we express results. All participants were enthusiastic about the training. An evaluation was conducted at the end of the week to estimate the impact of those training.

3. Training-workshop on Topography: From Field Survey to DEM Generation. 17-21 February, NAFRI, Vientiane, Laos.

4. Training on Selection of Optimal Interpolation Techniques at Different Scales. 3-14 November, NAFRI, Vientiane, Laos.

5. Country training on Hydras 3 and Minimum Data Set for Indonesia. 1-3 November 2003. Bogor Indonesia. This was conducted by J.P. Bricquet and attended by T. Vadari and K. Subagyono of the Indonesian team.

Students Involved in the Project in 2003

Country	Name of Student	Degree	Academic Institution
Indonesia			
	Mr. Tagus Vadari	MSc	Bogor Agricultural University, Indonesia
	Mr. Sukristiyonubowo	PhD	University of Ghent, Belgium
	Mrs. Rohlini	PhD	Asian Institute of Technology, Thailand
	Mr. Yusrial	MSc	Gajah Mada University, Indonesia
Laos			
	Mr. Thanong Kham Vanthongkham	BSc	NUOL, Faculty of Agriculture
	Mr. Phengher Xaychou	BSc	NUOL, Faculty of Agriculture
	Mr. Sengheo Rasaket	BSc	NUOL, Faculty of Agriculture
	Mr. Kongmany Thammavongxay	BSc	NUOL, Faculty of Agriculture
	Mr. Korrakanh Chanthavonsa	BSc	NUOL, Faculty of Agriculture
	Mr. Brice Dupin	MSc	ENGREF (Faculty of Rural Engineering and Forestry, Montpellier)
	Ms. Charlotte Dumas de Rauly	MSc	ENSAM (Faculty of Agronomy, Montpellier)
	Ms. Marie Alexis	MSc	University of Paris
	Mr. Amen Arous	MSc	University of Paris
Thailand			
	Ms. Warinya Thothong	MSc	Asian Institute of Technology, Thailand
	Mr. Jean Philippe Luc	MSc	
	Ms. Caroline Boulais	MSc	
Vietnam			

	Pham Ha Hai	MSc	University of Hanoi
	Ngo Van Viet	MSc	University of Hanoi
	Nguyen Kim Ngoc	BSc	University of Hanoi
	Luu Thi Nguyet Minh	BSc	University of Hanoi
	Agnes Bayer	DESS	University of Grenoble
	Julien Renaud	BSc	University of Chamberry

Monitoring and Field Visits

Mission of IWMI staff in 2003

Date of Mission	Name of Staff	Place
3-4 April	C.Valentin	Bangkok, Thailand
28-29 April	C.Valentin	Bangkok, Thailand
5-8 May	C.Valentin	Bangkok, Manila
29-30 May	C.Valentin	Bangkok, Thailand
12-17 May	J.P Thiebaux	Hanoi, Vietnam
25 June to 7 July	G. Lestrelin	Phrae, Thailand
2-5 July	N. Silvera	Hanoi, Vietnam
2-5 July	J. P. Thiebaux	Hanoi, Vietnam
27 July to 2 August	V. Chaplot	Coimbatore, India
17 July to 11 August	A. Maglinao	Manila, Philippines
26-28 August	C. Valentin	Bangkok, Thailand
29 August to 8 September	G. Lestrelin	Phrae, Thailand
25-26 September	C.Valentin	Bangkok, Thailand
6-15 October	J. P. Thiebaux	Hanoi, Vietnam
10-16 October	G. Lestrelin	Phrae, Thailand
19-October	G. Lestrelin	Hanoi, Vietnam
6-17 October	N. Silvera	Vietnam, Thailand
16-21 November	C.Valentin	Thailand, Vietnam
7-11 December	N. Silvera	Bangkok, Thailand
5-11 December	J. P. Thiebaux	Bangkok, Thailand
15-17 December	G. Lestrelin	Bangkok, Thailand
17-12 December	V. Chaplot	Bangkok, Thailand

Land Management for Controlling Soil Erosion at Microcatchment Scale in Indonesia

K. Subagyono, T. Vadari, Sukristiyonubowo, R.L. Watung, and F. Agus

Introduction

Background and Statement of the Problem

Erosion is widely considered as the major cause of soil degradation. In the past, most erosion studies have been conducted at plot scale. These provide valuable data to compare erosion rates between different land management systems and soil types, but the measurement can not be directly extrapolated to catchment scale. Most of the plots have 22 m length and 9% slope, which is similar to the traditional plots used in the formulation of the Universal Soil Loss Equation (USLE). Errors in the estimation of erosion rates may occur if this approach is implemented at the catchment scale because: (a) artificial border in the plot scale blocks run-in soil particles and aggregates from the upper slope, and (b) there is no single slope in nature (catchment scale) and hardly uniform. Many of the studies have proven that this approach tends to overestimate rates of soil loss if the measurement is extrapolated to catchment scale.

Profitable land management techniques need to be introduced to increase quality and quantity of crop yields and the income of farmers and sustain the land resource base. Innovative technologies need to be implemented to have sustainable agricultural systems. Research on the micro catchment scale (Craswell *et al*, 1998) can help develop such technologies, which are able to reduce environmental damage and bring benefits to farmers (Garrity and Agus, 1999).

In the recent decades, many effective land management strategies have been developed to reduce erosion, but their adoption has been considerably limited. This was mainly because of the limited consideration of the farmers' socio-economic condition and the dynamics of on-going social changes. For this reason, the Indonesian Center for Soil and Agroclimate Research and Development (CSARD) collaborated with the International Water Management Institute (IWMI) to conduct soil erosion research under the Management of Soil Erosion Consortium (MSEC).

The first phase of this project showed erosion rates of 20 t $ha^{-1}yr^{-1}$ under multiple cropping system of food crops, 1.9 t ha^{-1} yr^{-1} under rambutan crops, and 1.7 t ha^{-1} yr^{-1} under the combination of rambutan and shrub, respectively (Agus *et al*, 2002). From their study at plot scale under similar climatic condition and soil types, Haryati *et al* (1995) reported a value of soil loss which was three times higher. This indicates that the measurement of soil loss at the plot scale cannot simply be extrapolated to catchment scale.

Results of the first phase of the project showed that the soil loss through erosion under Tegalan based cropping system exceeded the tolerable soil loss of 2 to 11 ton $ha^{-1}yr^{-1}$ for agricultural lands (El-Swaify, 1989). Under this condition, conservation measures have to be introduced for agricultural sustainability. Improving soil fertility is a great concern for the local farmers who apply fertilizers, lime and soil amendment like organic matter, even if the amount and kind are not those recommended. In contrast, most of the local farmers are not enthusiastic in applying conservation technologies to reduce erosion and increase land productivity. The reason is that the introduced conservation measures are considerably expensive and have not given real benefit to farmers.

As soil is lost through erosion, the contained nutrients are also lost. The analysis showed that 21.53 kg N, 5.82 kg P, and 9.02 kg K were lost per hectare per year from the

Tegalan microcatchment. From the Rambutan and the mixed rambutan and shrub microcatchemnts, 9.24 kg N, 0.21 kg P, and 5.97 kg K and 0.89 kg N, 0.89 kg P, and 1.11kg K were lost per hectare per year, respectively. These nutrients lost can reduce income of farmers from Rp 14,600 to Rp 205,400 ha^{-1} yr^{-1} (Agus and Sukristiyonubowo, 2001).

After more than two rainy seasons of observation, it has been shown that land management system determines the amount of erosion. Paddy field system had the lowest erosion and it can even deposit sediment coming from the upper area. Perennial tree system is very effective as long as there is good litter cover on the ground. When the tree floor is intensively cultivated, erosion increases. Intensive annual crop system had the highest erosion compared to tree and paddy rice systems. Modification of the intensive annual crop farming in the steep slope land with fodder grass has been observed to reduce erosion significantly even a few months after planting the grass. This could be attributed to the combined effect of the no tillage system and improved filtration of sediment by the grass.

The promising observations described above need to be further validated and therefore the project has continued to monitor the dynamics of land management to gain insights on the effects of various land uses and its changes on runoff and erosion processes and nutrient balances. A model would be useful to predict erosion rate at the micro catchment scale.

Immediate Objectives

1. To study the effects of land management systems on water and sediment yields at micro catchment scale;
2. To study nutrient balance under different land use systems;
3. To validate the GUEST model for predicting runoff and erosion.

Long Term Objectives

1. To improve land management systems for icreased productivity and conservation of natural resources;
2. To validate prediction model of erosion and runoff suitable for typical Indonesian catchments.

Scope of Work

The research in 2003 was focused on three major activities. These are related to: 1) land management systems, runoff and erosion, 2) nutrient balance in paddy fields, and 3) validation of soil erosion prediction model.

The *first activity* on the dynamics of land management systems and its effects on erosion and runoff at micro catchment scale is aimed to study the effects of various land use systems, changes in land management practices and the size of micro catchment on surface runoff and erosion. In the first phase of the project and in the current study, much attention has been paid to the surface hydrological response and behavior of solute balance with less attention to solute transport by flow. So far, the 2002 results show that fodder grass planting, in combination with cattle fattening of only one head of cattle per family, contributed to an increase in farm income by 60% for the Ungaran (Central Java) upland farmers where farming is a part time job. With population density of about 1000 persons per km^2, there is not much room for the farmers to expand their animal production, but for many farmers, there is potential to raise two to three heads of cattle per family and this promises a significant increase in their income. While capital is problematic for most farmers in the area, they prefer profit sharing more than availing of credit.

The *second activity* was focused on the nutrient balance under various land use systems and land management practices aimed at monitoring the nutrient dynamics as affected by the land management system. In the first phase of the project and the current year of 2003, the study was focused on the N, P and K balance under the rice–based cropping systems. Nutrient inputs were accounted from the fertilizer application, irrigation and recycled rice straw. Nutrient losses were related to erosion and crop removal at harvest. The change of nutrient in the soil and transported sediment by water has not yet been considered.

The 2002 results show that the main nutrient output from paddy field system is through harvest with N and P mainly in the rice grain and K in the rice straw. Therefore, recycling of rice straw can significantly alleviate the need for K fertilizer. Nutrient loss through erosion from paddy field is negligible.

The *third activity* was focused on the validation of the GUEST model for runoff and erosion prediction. The 2002 activity was mainly focused on data collection. Rainfall, runoff and erosion and factors such as soil physical and chemical properties, land use and soil cover data have been gathered. Rainfall and runoff event data such as time to peak, sediment yield (both suspended and bed load) have also been gathered. However, to run and validate the model, more comprehensive data are still required. This validated model is used to support policy makers in their planning and development programs.

Materials and Methods

Study Site

This long-term (intended for 10 years) watershed scale research was started in late 1999 at the upper Babon Catchment (about 285 ha area; 07^{o}20'S 110^{o}E), within the Kali Garang Watershed (220 km^2) in Central Java Province. Babon catchment is located about 3 km west of Ungaran, the capital of Semarang district, and about 20 km south of Semarang, the capital of the province. The study has been set up involving three micro catchments (MC): Tegalan (1.1 ha), Kalisidi (13 ha), and Rambutan (0.9 ha). The Tegalan MC is planted to upland annual crops with cassava as the main crop. Rambutan MC has wild grasses and rambutan as the main vegetation, while Kalisidi MC has Rambutan as the main crop. Characteristics of these MCs are described in Table 1 (Agus *et al*, 2002).

Data Collection and Analysis

The initial hydrological data were recorded in January 2000 after the complete identification and characterization of the catchment (mostly literature study) and the micro catchments, installation of V-notch weirs and sediment traps, automatic water level recorders (AWLR), and automatic weather station and manual rain gauges. Data on hydrology and nutrient concentration in soil, plant and water have been continuously collected until 2003. These were analyzed to evaluate the effects of land use and land management practices on runoff and erosion processes at micro catchment scale.

The activities undertaken were built on the past activities and include:

a. The dynamics of land management systems and its effects on erosion and runoff at micro catchment scale;
b. Nutrient balance under different land use systems;
c. Validation of soil erosion and runoff prediction model using GUEST (*Griffith University Erosion System Template*).

Table 1. Characteristics of catchment used in the study

Catchment	Area (ha)	Runoff coeff. (%) [1)]	Soils	Land use/Farming system	Dominant slope (%)
Tegalan	1.1	5	Andic Eutropepts	Cassava, maize, some trees in 2000 and 2001 and fodder grass covering about 60% area starting in December 2001	45 – 47(46)
Rambutan	0.9	1	Andic Dystropepts	95% Rambutan, 5% Shrub	22 – 55(40)
Kalisidi	13.0	14	Andic Dystropepts	100% Rambutan, lower catchment encroached for annual crops	22 – 55(37)
Babon	285.0		Typic Tropaquepts	All above + Rice field of about 17 ha	0 – 55(30)

1) Based on March 2000 to February 2001measurement

Effect of land management systems on erosion and runoff

The research was initiated with the construction of gauging station with sediment trap at each microcatchment to observe soil loss (bed load and suspended load), construction of small station at canals to monitor water level and suspended load, and biophysical and socioeconomic characterization of the site. To monitor discharge, each MC was equipped with V-notch gauging weir with both Automatic Water Level Recorder (AWLR, Orphimedes) and staff gauge for manual observation. The AWLR was set to record water level at one- or five- minute interval. The reading of the staff gauges was conducted three times daily at 08:00, 12:00 and 16:00.

Total soil loss or sediment yield is defined as sum of bed load and suspended load which are both measured every rainfall event. After taking sample for nutrient analysis, bed load from each trap was calculated separately. Sediment yield was estimated on a weight basis.

As rainfall-runoff relationship is very important in predicting soil loss at the catchment scale, rainfall was measured using the network of rain gauges within the catchment. Theoretically, the number of gauges required depends on the expected variability of precipitation over the catchment (WMO, 1994). In this research, seven manual rain gauges and one automatic climatic station were installed to observe daily rainfall over the catchment. The Thiessen Polygon Method was used to calculate the average precipitation over a specific area. In this procedure, lines are drawn between adjacent stations on a map. The perpendicular bisectors of these lines form a pattern of polygon with one station in each polygon.

The Tegalan and Kalisidi microcatchments are undergoing changes in land management systems. In the Tegalan microcatchment, 12 farmers introduced (with facilitation by researchers and extension workers) improved management system in the form of fodder grass planting and cattle fattening. The grass serves as catchment filter for sediments and as animal feed. This grass species has been tried in earlier conservation projects but monitoring the effects on erosion and runoff is limited. The participatory approach was employed with the farmers involved in the planning and implementation of the research. The empowerment of the group to be a dynamic and productive entity has been enhanced through field visits and group discussion. Monthly meetings were conducted to address problems met and become more familiar with the introduced technology.

Nutrient balance in paddy fields

To assess nutrient balance within each microcatchment (Tegalan, Rambutan and Kalisidi) and under the terraced paddy field, nutrient gains and losses or nutrient inputs and outputs were monitored. The study has been limited to assess the NPK balance only. NPK inputs include those contributed from fertilizers, irrigation water, sediment inflow, rainfall, and crop residues. The outputs include NPK concentration in sediment outflow, harvested rice grains and straw. The basic approach to evaluate nutrient balance is described in Figure 1 and Tables 2 and 3. Also in the year of 2002/2003, contribution from rainfall was taken into account. Rainfall was sampled once per month from all rain gauges.

The study on nutrient balance and land management was conducted in the terraced paddy fields. The terraced paddy fields for lowland rice production cover about 17 ha in the valley of the Babon catchment. In general, farmers cultivate rice twice a year. The first cropping season starts in October-November and ends in February-March; the second season starts in March-April and ends in June-July. IR-64 is the common variety planted at a spacing of 25 cm x 25 cm.

The study was started during the dry season of 2001. During this time, rice yields (rice grains and rice straw production) were measured from a 1 x 1 m plot in the farmers' fields, repeated three times for each terrace. Beginning the rainy season of 2001/2002, a simple treatment was introduced. The farmers' practice where only 50 kg ha^{-1} of Urea is applied was compared with the 'improved technology' where as high as100 kg ha^{-1} $season^{-1}$ each of Urea, TSP, and KCl as recommended by the Food Crop Institute at District Level is used. The fertilizers were spread on the soil surface during the application.

The rainy season cropping in 2001/2002 started in October to November and ended the following February to March. The second cropping started in March/April until June/July 2002. High yielding rice variety of IR-64 was planted with spacing of about 25 cm x 25 cm. Six farmers were involved in this study with three of them representing each treatment.

The number of participating farmers increased to 10 in the rainy season 2002/2003 and to 12 in the 2003 dry season. Rice was planted in late December 2002 until January 2003. It was about two months delay compared with that in 2001/2002. The results in the rainy season 2002/2003 were discussed with the farmers coming up with the idea to modify the treatment for the dry season 2003. The treatments in the rainy season 2002/2003 included the recycling of 67% of the rice straw. This time, four treatments were done: (1) pure farmers' practice as control; (2) farmers' practice + recycled rice straw; (3) improved technology; and (4) improved technology + recycled rice straw.

Soil erosion was monitored from land preparation (plowing, harrowing, and puddling) to rice harvest. The measurement of suspended sediments was taken from the main outlet (the last terrace before the runoff goes out to the river) and the main inlet. The discharge at the main outlet was determined using tipping bucket method. An 11-liter bucket was used to measure discharge and to collect sediment samples. The relationship between the water level and discharge at the inlet (where the water from the canal enters the first terrace) was determined as the product of water velocity (measured using the float method) and the cross sectional area of the flowing water at the gauge.

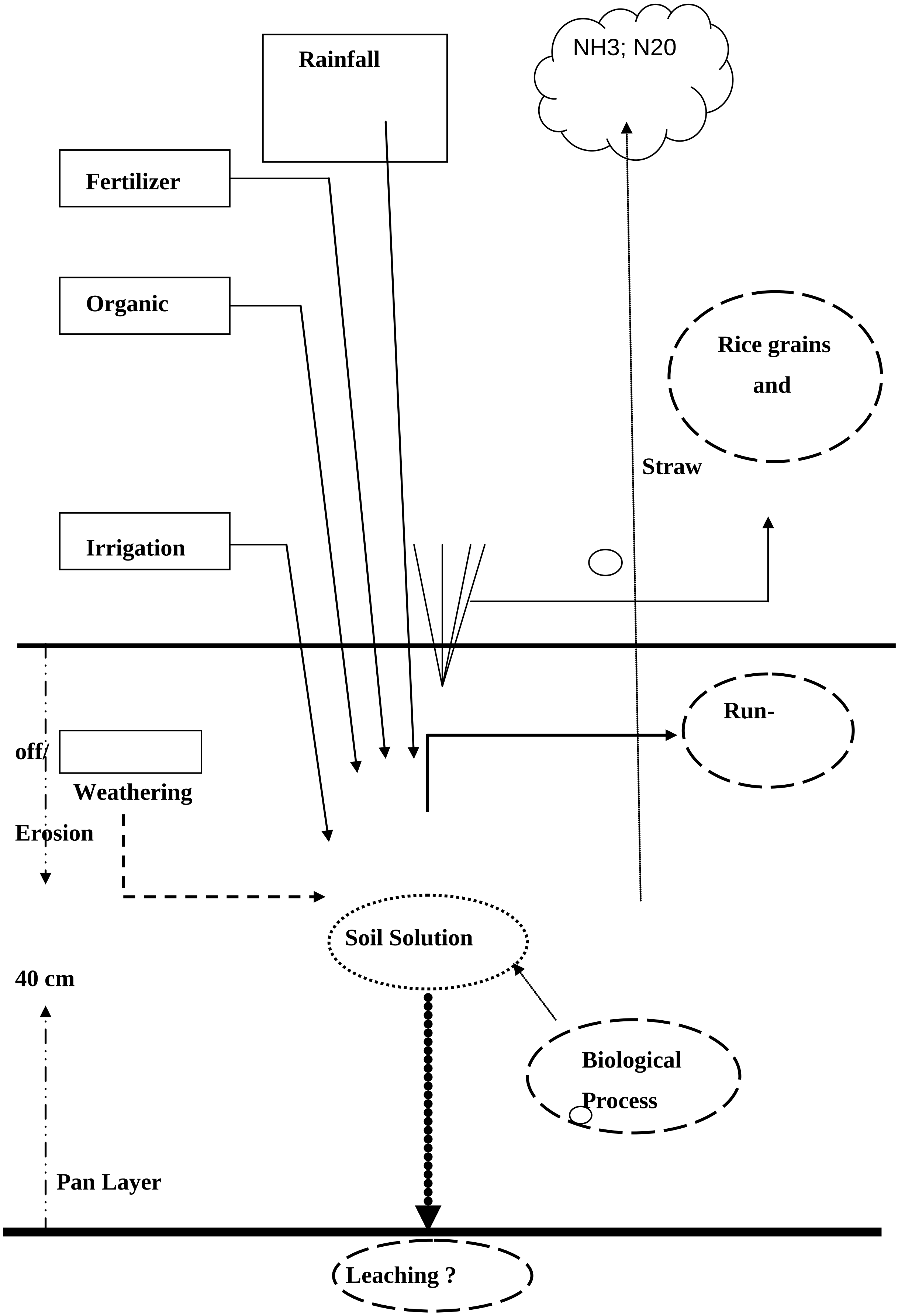


Figure 1. Basic approach for assessing nutrient balances in terraced paddy field

Table 2. Data collected and methods for the INPUTS unit in the assessment of N, P, and K balances at terraced paddy field system

Input data	Code and Nutrients	Data required/collected	Method of quantification
Mineral Fertilizers	IN-1: N, P, and K	• Type of fertilizer applied • Amount of fertilizer Applied • Nutrient content in fertilizer	• Field measurement • Field measurement • Laboratory analysis
Organic Fertilizer	IN-2: N, P, and K	• Amount of rice straw remain in the field • Amount of rice straw recycled • Nutrient content in rice straw that remain in the field • Nutrient content in recycled rice straw	• Field measurement • Field measurement • Laboratory analysis • Laboratory analysis
Irrigation	IN-3: N, P, and K	• Water level • Discharge • Nutrient concentration in water	• Field measurement • Field measurement • Laboratory analysis
Rainfall	IN-4: N, P, and K	• Daily, monthly and annual rainfall • Nutrient content in rainfall • N, P, and K deposition in rainfall	• Field measurement / record • Laboratory analysis • Study literature (for checking)
B N F	IN-5: N Only		• Secondary data/Study literature

During land preparation, suspended samples were collected every 10 minutes, starting from the first runoff at the V-notch of the main outlet to the stage when the color of suspension became nearly the same as the incoming water through inlet. These samples were taken to determine sediment concentration. To determine nutrient content in the run off water during land preparation, samples and discharge measurement were taken every 30 minutes. The incoming nutrients from the canal were sampled and monitored three times a day at 08:00, 12:00 and 16:00 o'clock.

For the first and the second fertilizer application, inflowing and outgoing sediments were sampled three times a day at 08.00, 12.00, and 16.00 o'clock a week before and after the fertilizers were applied. During these periods, the farmers open both inlet and outlet. When the fertilizers were added, both were closed for two days.

In the initial study, nutrient balance at teraced paddy field was calculated as the difference between inputs and outputs. The changes of nutrient in the soil were not taken into consideration. Nutrient inputs were accounted from the fertilizer addition, irrigation, and recycled rice straw, while nutrient losses were calculated from erosion and crop removal. In 2003, contribution from rainfall was included in the system.

Table 3. Data collected and method for OUTPUT unit in the assessment of N, P, and K balances at terraced paddy field system

Output data	Code and Nutrients	Data required/collected	Method of quantification
Harvested Product	OUT-1: N, P, and K	• Rice grain yield • Nutrient content in rice grain	• Field measurement • Laboratory analysis
Crop residues	OUT-2: N, P, and K	• Rice straw production • Amount of recycled rice straw • Amount of rice straw for feeding • Nutrient content in rice straw	• Field measurement • Field measurement • Field measurement • Laboratory analysis
Erosion	OUT-3: N, P, and K	• Water level • Discharge of outlet • Nutrient concentration in suspended sediment • Sediment concentration • Soil and nutrient losses	• Field measurement • Field measurement • Laboratory analysis • Laboratory analysis • Estimation based on field measurement : • Soil loss = q x sediment concentration • Nutrient loss = soil loss x nutrient concentration in sediment
Denitrification	Out-4: N only	• Annual rainfall • N in applied fertilizer • N recycled rice straw • Denitrification	• Field measurement • Laboratory analysis • Laboratory analysis • Estimation/transfer function
Leaching	OUT-5: N and K		• Secondary data/ Study literature. It may be neglected since there is pan layer that water can not pass through
Volatilization	OUT-6: N only		• Secondary data/Study literature.

Validation of runoff and soil erosion prediction model

The GUEST (Griffith University Erosion System Template) model of erosion prediction has been validated since the first phase of the project. Further refinement is still done in the current study. SIG software to run the model is PCRaster version 2.0, which is able to operate mathematical analysis based on the spatial and temporal variation of the data used. It can also be used to run dynamic and cartographic models.

Spatial, tabular, and time series data were used as inputs. Spatial data consist of digital elevation model (DEM), soil maps, land use maps, rainfall station distribution maps, and site of monitoring station maps. Slope range (class), cropping pattern, infiltration capacity (based on the soil types, land use, cropping pattern and slope ranges), Manning's coefficient (based on land use) and land cover (based on land use and slope ranges) are included in tabular data. Time series data includes rainfall intensity at 5-sec interval (Paningbatan, 2001).

Model validation was done through a comparison between the predicted and measured erosion. Parameters that were compared are discharge and total sediment. Paired data (discharge and runoff for the same point in time) was tested by t-test. Measured and calculated values are significantly different if t-calculated is higher than t-table at $\alpha = 0.05$. The model was also tested by plotting the predicted (Y) and measured (X) values and comparing it with the 1:1 line to evaluate the distribution of the data. Predicted is different from measured value if data plotted are far from the 1:1 line.

Results and Discussions

Land Management Systems, Runoff and Erosion

Rainfall – runoff – erosion relationship

The relationships between rainfall, runoff and erosion were analyzed for the different microcatchments to assess any effect of land management systems. The relationship was discussed using not only the 2003 data, but also the data from previous years (2001 – 2002) to evaluate the temporal variability particularly the effect of the introduced soil conservation measure using grass on runoff and erosion.

The rainfall distribution showed variability within the catchment. It was higher in the northern part of the catchment than in the southern portion although the difference was not significant (Figure 2). The average rainfall during October 2002 to April 2003 was 3020 mm

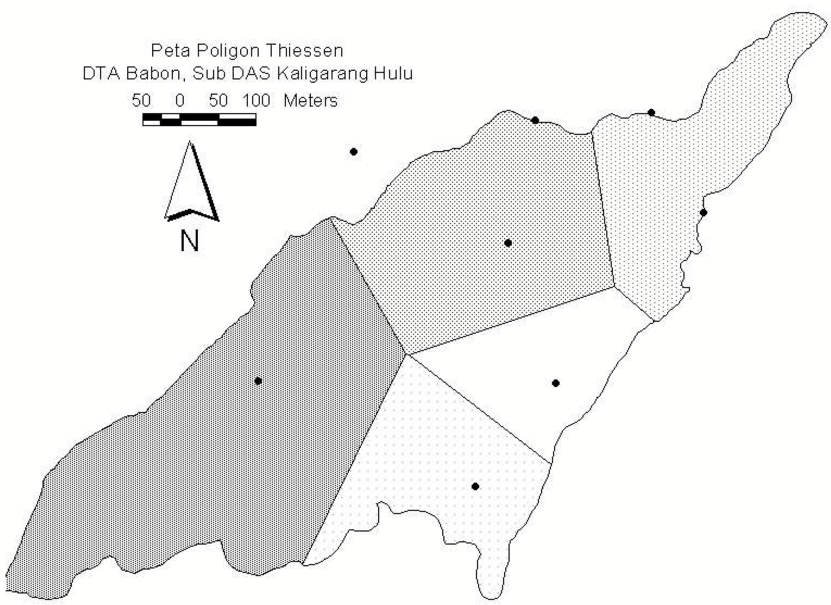


Figure 2. Polygon of Thiessen in Babon catchment, upper Kaligarang sub catchment

with the maximum of 151.2 mm in an event that occurred in January. It was observed that 10 mm of rain yielded runoff and soil loss in all microcatchments. With a measured rainfall of 35.4 mm, the Tegalan microcatchment produced 0.83 mm of runoff and 0.036 t ha^{-1} of soil loss. The maximum runoff of 2.52 mm occurred during an event with 93.9 mm of rainfall producing a total soil loss of 0.17 t ha^{-1}. The relationships between rainfall, runoff and erosion under Tegalan cropping system are shown in Figures 3, 4, and 5.

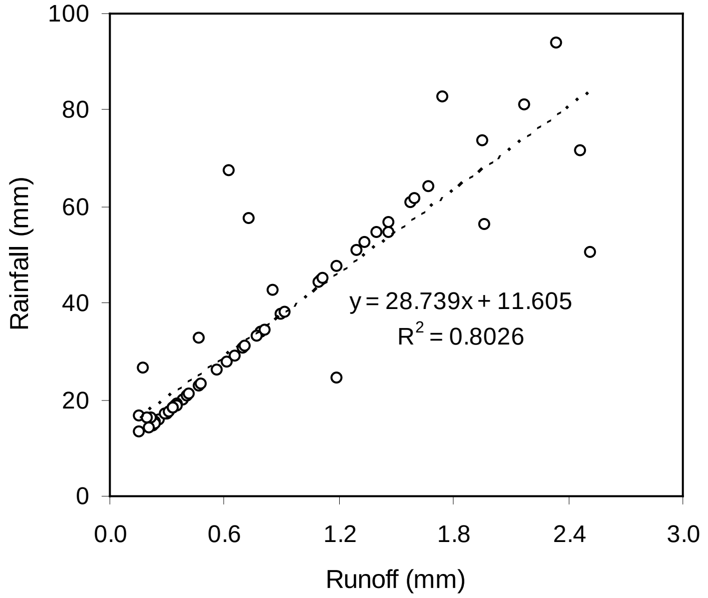


Figure 3. Relationship between rainfall and runoff in Tegalan microcatchment during wet season 2002/2003

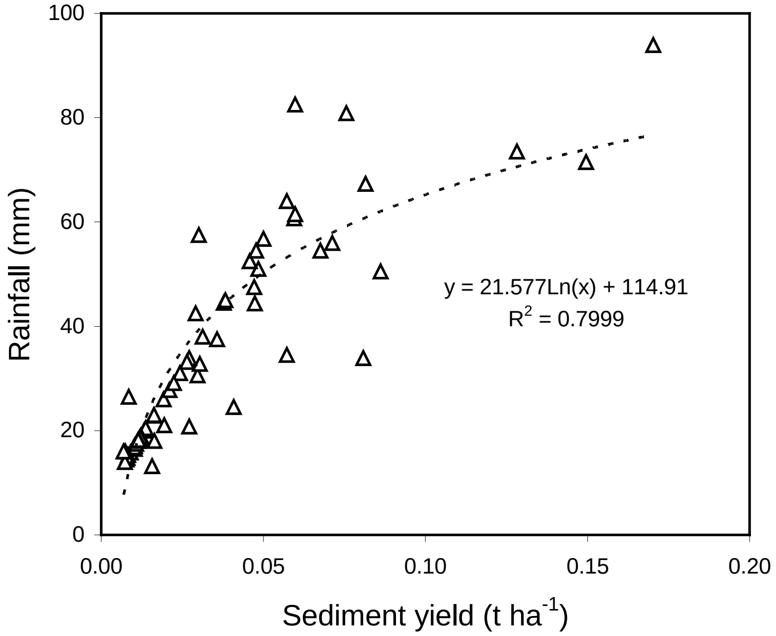


Figure 4. Relationship between rainfall and erosion in Tegalan microcatchment during wet season 2002/2003

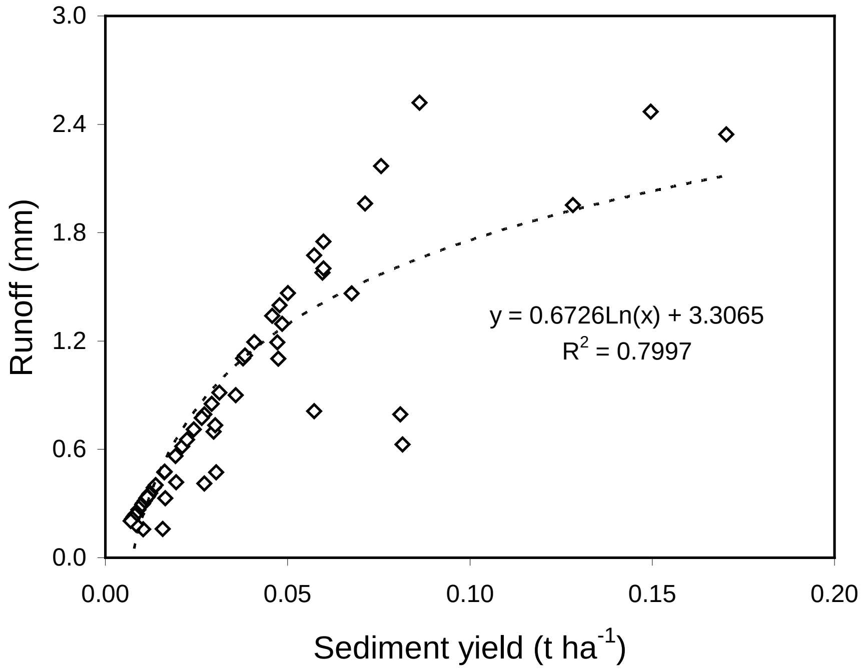


Figure 5. Relationship between runoff and erosion in Tegalan microcatchment during wet season 2002/2003

Under the Rambutan based cropping system, runoff and erosion were lower compared with those under Tegalan system (seasonal based cropping system). With 44.5 mm of rainfall, a runoff of 0.04 mm was produced with a soil loss of 0.00006 t ha^{-1}. The maximum rainfall of 104.8 mm yielded 0.17 mm of runoff and soil loss of 0.00026 t ha^{-1}. The relationships between rainfall, runoff and erosion under Rambutan cropping system are depicted in Figures 6, 7, and 8.

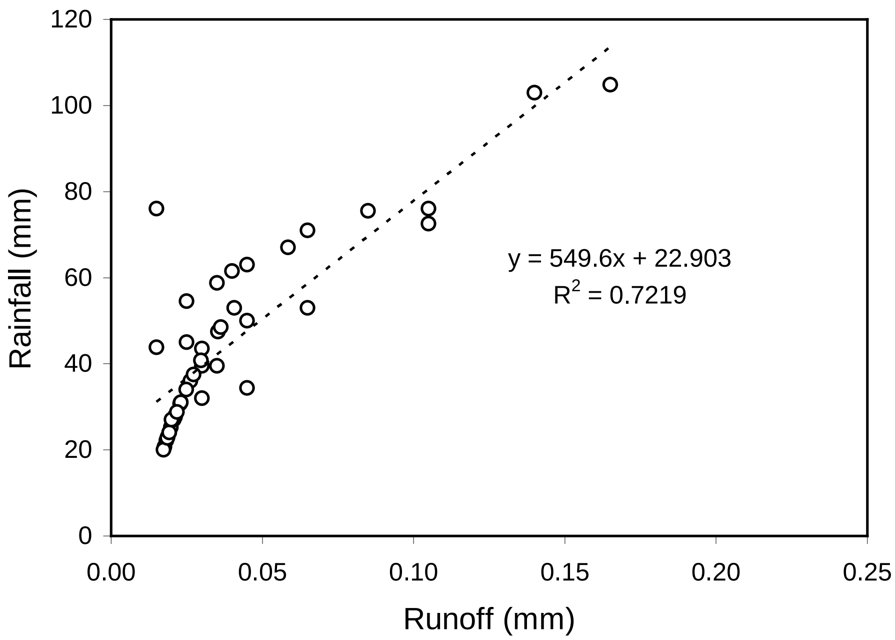


Figure 6. Relationship between rainfall and runoff in Rambutan microcatchment during wet season 2002/2003

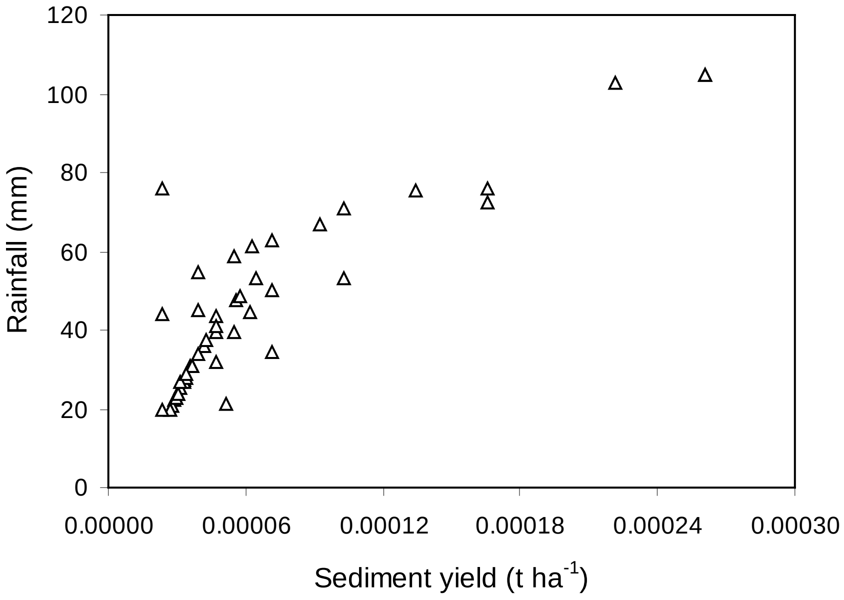


Figure 7. Relationship between rainfall and erosion in Rambutan microcatchment during wet season 2002/2003

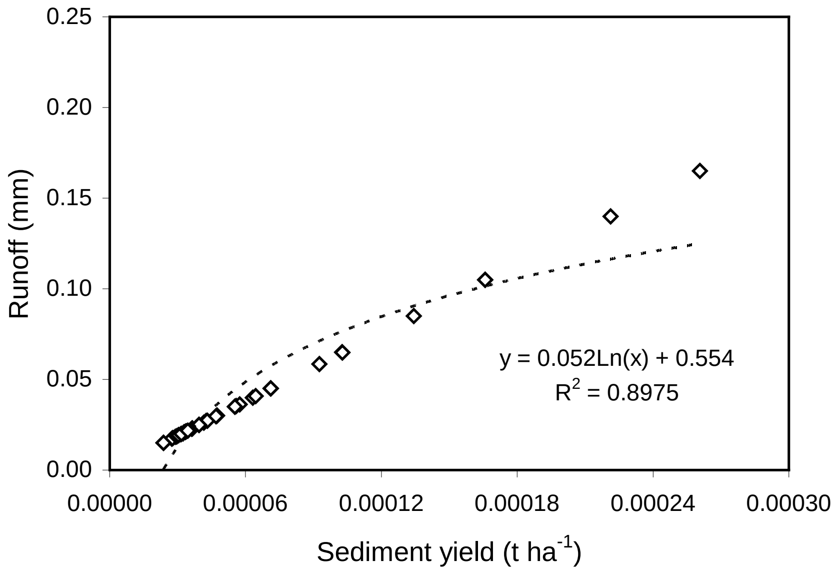


Figure 8. Relationship between runoff and erosion in Rambutan microcatchment during wet season 2002/2003

In the Kalisidi microcatchment, the rainfall of 42.2 mm generated a runoff 1.6 mm and total soil loss of 0.029 t ha^{-1}. This is almost similar to those observed in the Tegalan microcatchment. The maximum rainfall of 110.5 mm generated runoff of 51.0 mm and erosion of 0.93 t ha^{-1}. This supports the earlier findings of Agus *et al* (2002) that catchment size showed some effect on the measured runoff and erosion. The relationships between rainfall, runoff and erosion in Kalisidi micro catchment are depicted in Figures 9, 10, and 11.

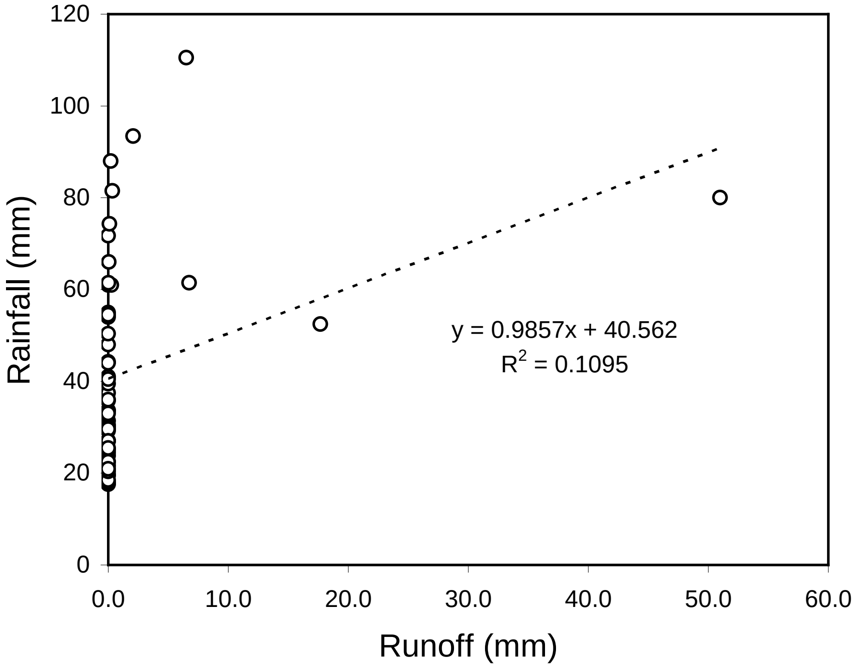


Figure 9. Relationship between rainfall and runoff in Kalisidi microcatchment during wet season 2002/2003

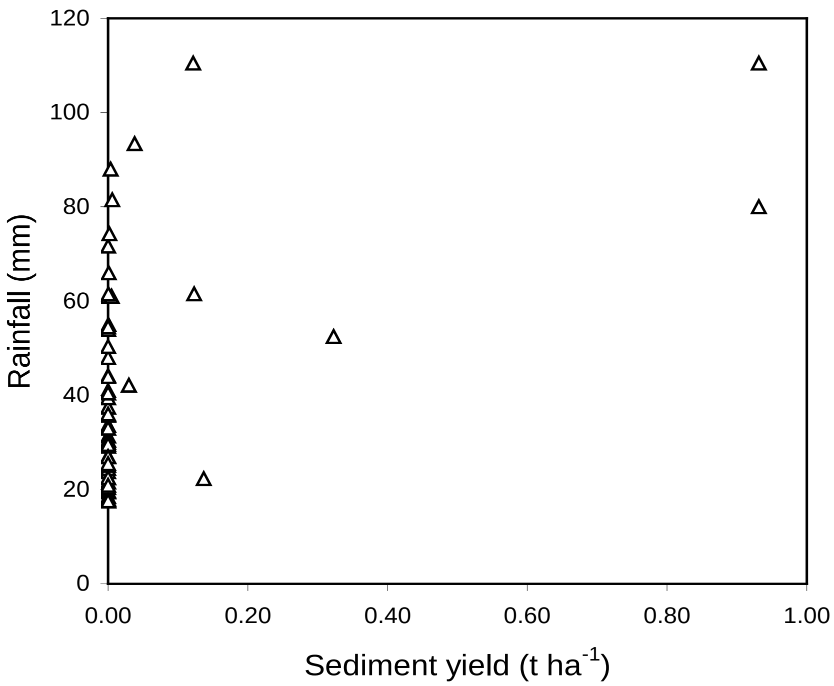


Figure 10. Relationship between rainfall and erosion in Kalisidi microcatchment during wet season 2002/2003

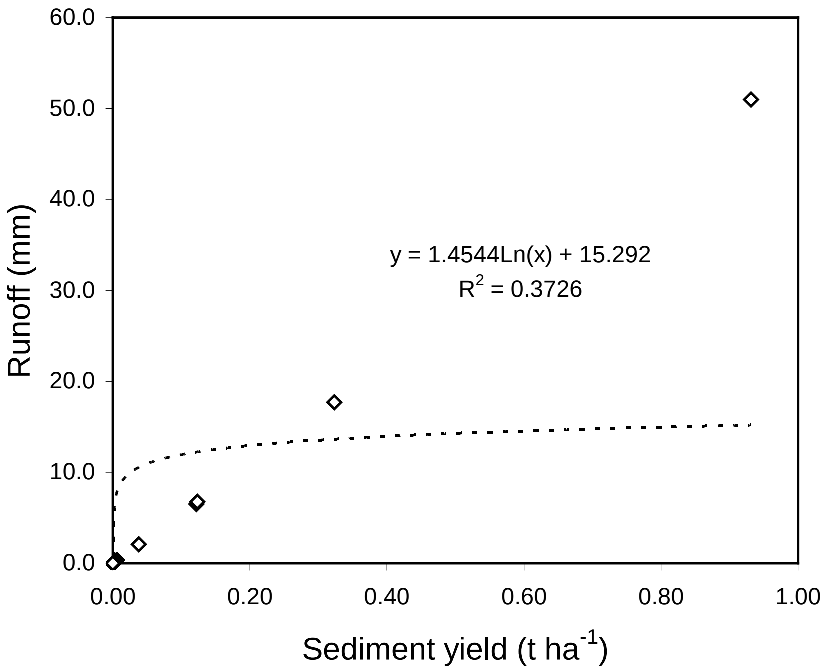


Figure 11. Relationship between runoff and erosion in Kalisidi microcatchment during wet season 2002/2003

The above results indicated that runoff and erosion occurred differently under different land use systems. This finding is similar to that observed by Agus *et al* (2002) and Vadari *et al* (2003). As the interception of rainfall is less, areas under seasonal crops show higher runoff than those under the tree based cropping system. Consequently, total soil loss was also be higher. In most cases, runoff was linearly correlated with rainfall. Total soil loss increased sharply at the beginning of the rainfall event, then increased gradually after some time creating a log-normal relationship.

As in previous results, runoff was generated largely from the Tegalan microcatchment, and it is much higher than that from the Rambutan and Kalisidi microcatchments. Figure 12 shows that there are two peaks of discharge from the Tegalan microcatchment during the storm event on January 1, 2003, a typical characteristic for this catchment. The hydrograph shows a sharp increase after the start of the storm to reach the peak indicating the dominance of quick flow. The flow then rapidly declined. In the Kalisidi microcatchment, flow gradually increased but then decreased sharply during the falling limb. There was no clear shape of the hydrograph from the Rambutan microcatchment. Characteristic of the rainstorm and corresponding runoff is presented in Table 4.

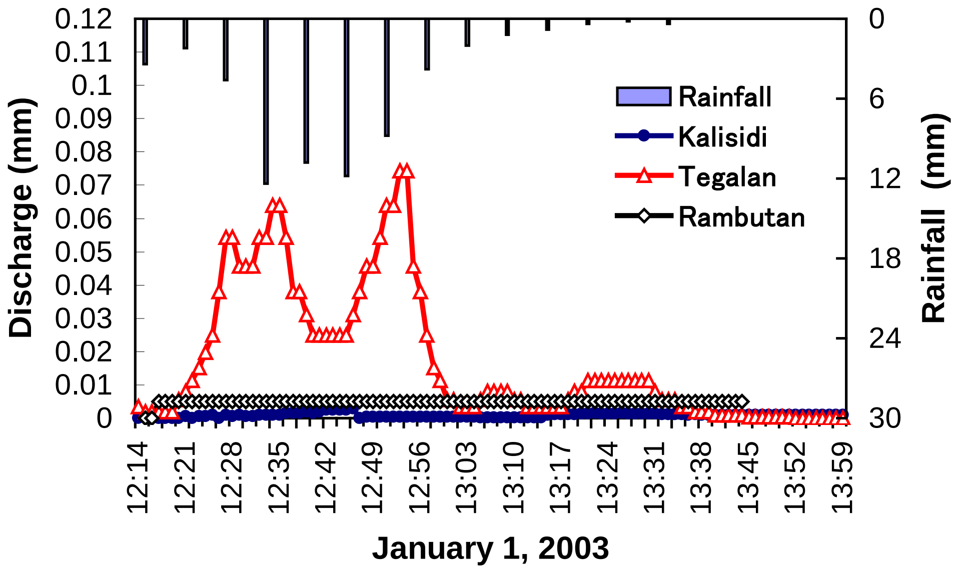


Figure 12. Effect of land use on hydrograph during the January 1, 2003 strom event

Table 4. Rainfall characteristics of the storm event on January1, 2003 with corresponding runoff

Rainstorm Characteristics	Value
Storm length (min)[a]	104
Total rainfall (mm)	62.8
Max intensity (mm.min^{-1})	12.4
Total runoff (mm.min^{-1})[b]	
• Tegalan	1.8
• Kalisidi	0.09
• Rambutan	-

a, b from 11:30 on August 21, 2001 (the storm started) to 15:30 on August 22, 2001 (the storm end) by excluding baseflow for the total runoff

In December 2001, conservation technology was introduced in the Tegalan microcatchment by planting Benggala grass (*Panicum maximum*) along the contour and some cultivated areas. The system reduced soil loss by up to 50% in a period of only one year. There was a reduction of as much as 90% in the second year (Figure 13). The reduction in soil loss was mainly in the reduction in the amount of bed load. Although not as high as in Tegalan microcatchment, soil loss also tended to decrease in Rambutan catchment. Soil loss in the Kalisidi microcatchment did not show any trend but varied from year to year. Moreover, suspended load was higher than the bed load.

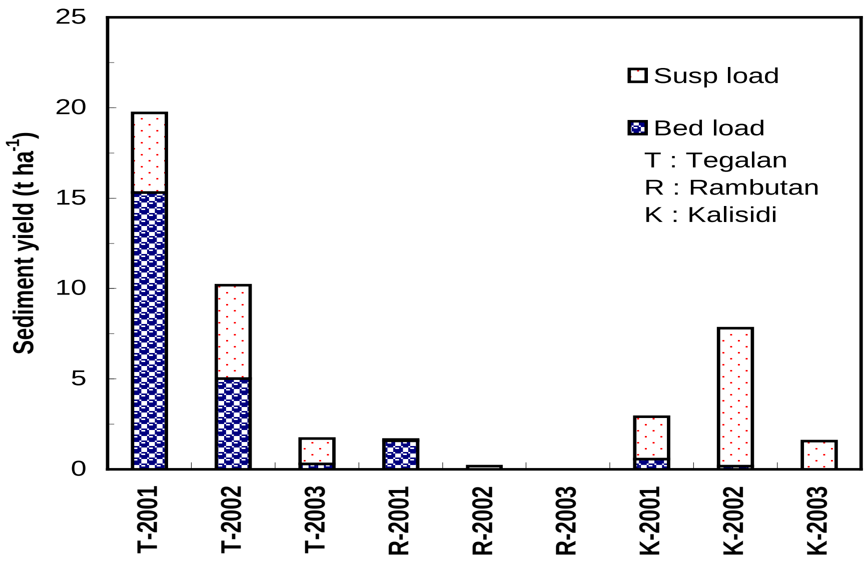


Figure 13. Temporal variation of total soil loss under different land use system

Alternative management system

There have been many technologies that have been introduced in soil conservation projects but adoption by farmers does not sustain because most of the introduced measures can not generate intrinsic rewards to farmers while external rewards or incentives are normally temporary at best. Mechanical and vegetative conservation measures are widely known but the implementation of those technologies is relatively limited. Bench terracing and planting grass as soil conservation measures are widely known to reduce erosion (Abujamin *et al*, 1983; Haryati *et al*, 1993). However, the adoption of such techniques may prove unsuccessful if farmers are not fully involved.

The participatory approach considers both the biophysical condition of the area and the socio-economic aspects of the farmers in the management of upland. Participatory research for development includes empowering farmers in (1) diagnosing the biophysical as well as socio-economic problems, (2) development of plans by blending farmer's solution with research based alternatives, (3) implementation, and (4) monitoring and evaluation. The farmers in general take the initiative while extension workers and researchers facilitate the process.

Planting grass for soil conservation in sloping uplands is known widely and almost every farming system technology package introduced in the uplands of Java has fodder grass and livestock components (Hermawan and Prasetyo, 1991; Prawiradiputra *et al*, 2000). The grasses reduce runoff and serve as filters of eroded soil, while the cattle component serves as an income source.

During the late rainy season of 2001, the integration of fodder grass planting and cattle fattening was introduced as an alternative option to the conventional intensive annual crop cultivation in the Tegalan microcatchment. The selection of the best bet option was based on lessons learned from elsewhere in Indonesia, that farmers' adoption of alternative technologies is determined by the economic contribution of the measure to the household economy. Farmers are attracted to a practice only if the practice promises direct economic benefits and this consideration must be put forward in the participatory technology selection.

Benggala grass (*Panicum maximum*) introduced and planted in some of the bench terrace risers and in the small portions of the microcachments has decreased soil erosion. After the second year of implementation (2002) erosion decreased by almost 50% and by more than 90% in the third year (Figure 12). The sharp reduction in soil loss was mainly caused by the decrease in bed load rather than in suspended load.

The scarcity of the fodder this year did not affect the farmers. During this dry season, only two out of 12 farmers went outside the village to source out the rice straw. In the previous year, during the peak of the dry season in July - August 2002, the farmers had to travel as far as 25 km out of Keji village to get 240 kg rice straw.

Fodder given to the cattle was mostly natural grass and the approximate daily fodder requirement for 13 cattle raised by 12 farmers was 300 to 450 kg. The grass was collected from their upland farms and paddy fields and from the estate land or common land. The introduced grass yielded only 570 kg and this was good for only two days. The rice straw as fodder given to the cattle accounted to 15% (100 kg), 5% of introduced grass, and the rest from common grass or other forages.

The income of the farmers who raised cattle this year was less than last year. On the average, the farmers earned an income of US$ 9.52/month in 2002, but only US$ 3.57/month in 2003. The lower benefit was primarily because of the lower price of the animal in 2003. In 2002, the cattle were sold during the Idul Qurban (Sacrifice Moslem Celebration) time when the demand was high. This lower income did not dampen the enthusiasm of the farmers. They still want to continue this cattle fattening activity. In one meeting, one solution proposed was to sell meat instead of live animal.

Based on the study, at least four heads of cattle for each farmer would be needed for increased income, but this alternative might not be suitable due to shortage of fodder or farmers' lack of capital. Figure 14 shows a scenario of the fodder required for raising one and two heads of cattle. The analysis was based on the assumption that the initial weight of the cattle is 200 kg, daily weight gain is 0.4 kg, and daily fodder requirement is 20 kg (20% of cattle weight). This also assumed that the fodder will be supplied from natural grass, introduced grass and rice straw. The introduced grass has an average yield of 570 kg/month based on production in 2003 harvested twice a month from 1000 m^2 upland. The rice straw is assumed at 240 kg collected twice a year in March and August after paddy field harvest. The natural grass collected daily, usually by women, from the surrounding areas (common land, estate crops land, and paddy field ricers) is 30 kg.

Raising one cattle will cause no problem for the farmers as the required fodder can be obtained by just collecting natural grass for up to 11 months of raising the cattle. At that time, the animal will have reached the weight of 332 kg (weight gain of 132 kg). Also, he would have earned a gross profit of about US$ 232 in 11 months or a monthly income of US$ 21 (carcass weight is 45 % of total weight, carcass price is US$ 1.55/kg, 1 US$=Rp 8,400). This figure agrees with the earlier report of US$ 15.44 – 21.13 additional expected income based on four heads of cattle (Project Completion Report of Phase I, 2003).

For two heads of cattle, the farmers would require minimum effort to find grass in five months and after seven months the effort increases over time to find more grass or collecting rice straw from his village or outside Keji village. After five months the expected gross income will be US $ 362.70, but thereafter, the effort increases but the profit decreases. To manage the increasing demand for fodder, expanding the area of the grass or the use of rice straw may be further studied

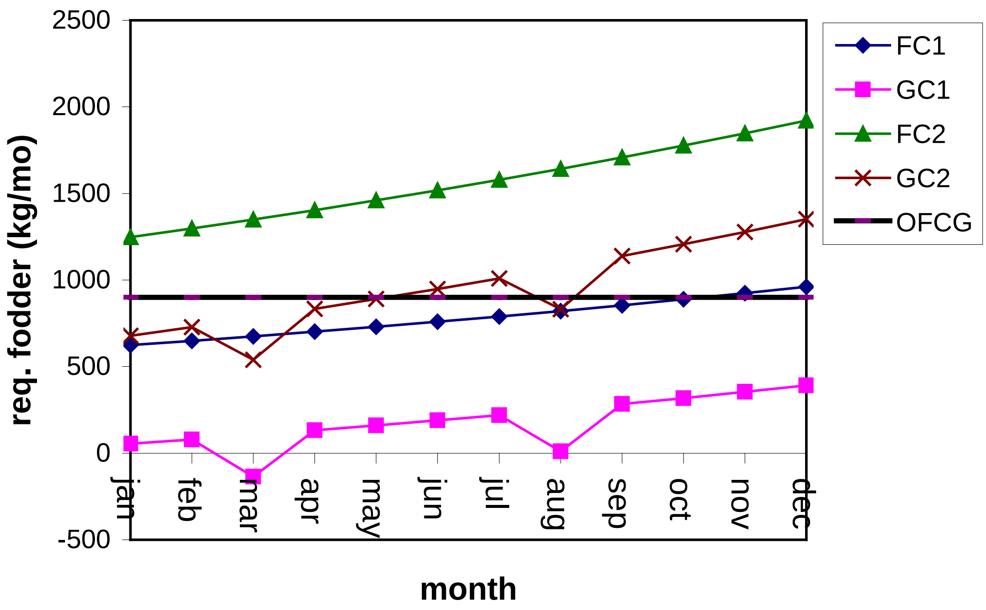


Figure 14. Fodder and grass required for raising one and two heads of cattle (FC1= monthly weight of fodder required for one head; GC1=monthly weight of field grass required for head; FC2=monthly weight of fodder required for two heads; GC2=monthly weight of field grass required for two heads; OFCG=optimal monthly weight of field grass collected by farmers)

Observations on the reaction of the participating farmers on the new management system revealed that their cooperation has been gradually established. This is further enhanced through regular meetings and visits to other cooperatives established by non-government organizations such as Trukajaya and Uswatun Khasanah. The meetings were conducted monthly and almost all of the participant farmers attended the 11 meetings in 2002.

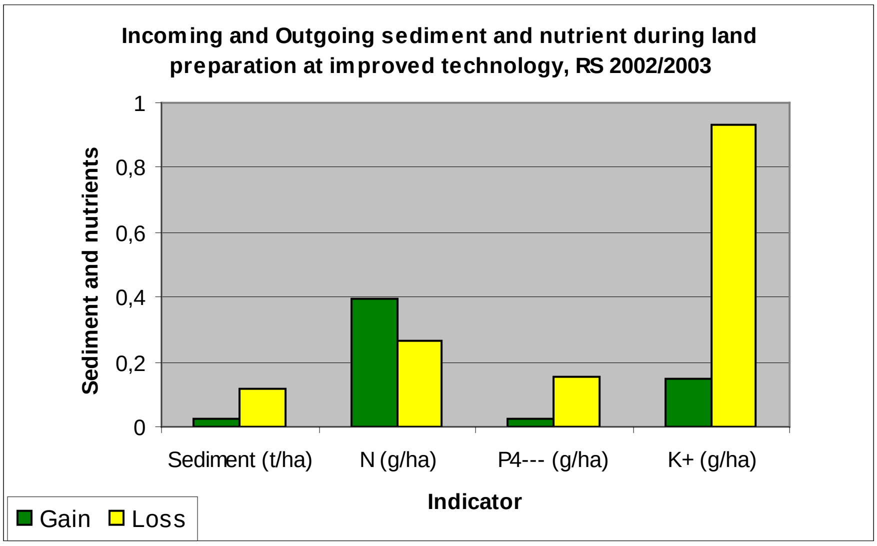
Sediment and Nutrient Balance in Paddy Fields

Sediment balance

Soil or sediments going in and out of the paddy fields were determined during land preparation and fertilizater application when the soil is greatly disturbed and the inlet and outlet are opened allowing entry and exit of sediments. Weeding, by hand or rotary weeder, was not done since the farmers did land preparation very well and kept the water at the desired level (about 5-7cm) resulting in less weeds during the rice growing period (personal communication with all farmers involved in this study, 2003). Similar result was also reported by Kukal and Aggarwal (2003), Sharma and De Datta (1996), and Adachi (1990) which showed that puddling reduces percolation loss of irrigation water, controls weeds and makes easy transplanting.

During land preparation, in both the farmers' practice and improved technology, the incoming sediment was lower than that flowing out. About 106 to 118 kg of sediment per hectare was eroded from the field while only 8 to 24 kg ha^{-1} came in from the irrigation water, respectively (Figure 15a and b). This finding is similar to that found by Tarigan and Sinukaban (2001) in Way Besay Watershed Lampung. They concluded that the sediment loss under terrace paddy field mainly occurred during land preparation. Meanwhile during fertilization period, the data indicated that a week before and after the first fertilization, inflowing sediment was higher than outgoing sediment (Figure 16a and b). It means that incoming sediment through irrigation water was deposited in the field. Total sediment deposited varied from about 76 to 281 and 4 to 147 kg day^{-1} ha^{-1}

(a)



(b)

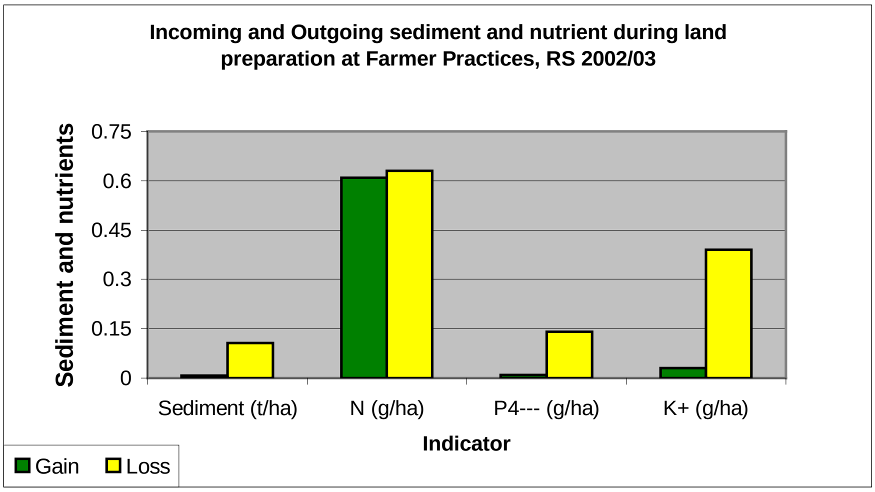
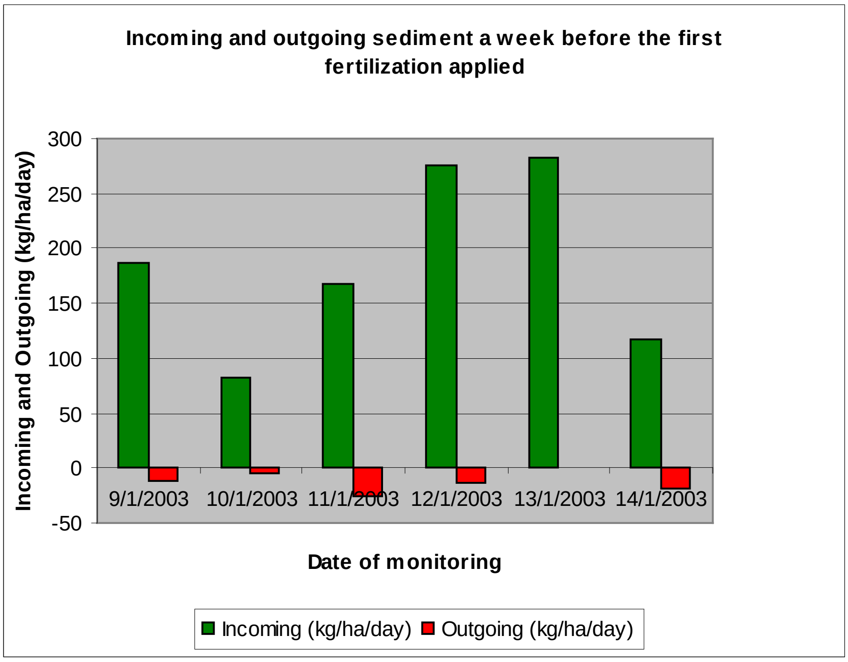


Figure 15. Incoming and outgoing sediment during land preparation under improved technology (a) and farmers practices (b)

observed a week before and after fertilizer application, respectively. These amounts of sediment deposited per day depended on the activities upstream, stream bank erosion, and other biophysical conditions upstream. Many scientists reported that nutrient movement in agricultural fields is influenced by climate, soil, topography, land use, and management practices (Agus *et al*, 2003; Lal, 1998; Powlson, 1998). These data suggests that terraced paddy field system plays an important role in controlling erosion at catchment scale and can minimize the negative impact downstream. From both activities, it can be concluded that during rainy season 2002/2003, about 1385 kg ha^{-1} season^{-1} sediment were deposited and distributed along the terraces. Therefore, it is also interesting to study the deposition rate of sediment in each terrace.

(a)



(b)

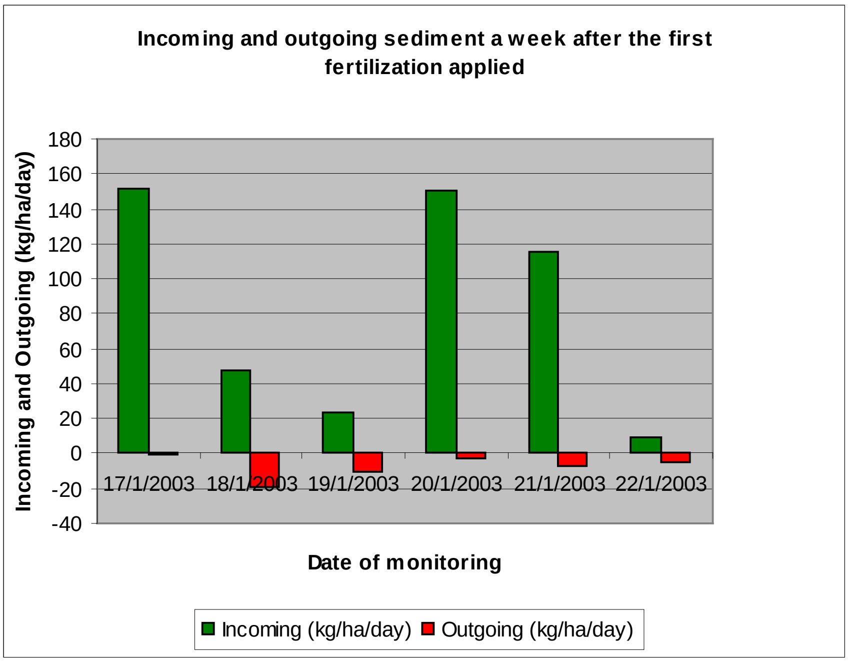


Figure 16. Incoming and outgoing sediment a week (a) before and (b) after the first fertilizer application

Nutrient balance

The measured discharge at the canal and at the gate (inlet, outlet) during land preparation is presented in Table 5. In general, the discharge at the gate was higher in the morning than in the afternoon. It varied among farmers depending on the soil condition (wetness), slope position, puddling depth, the number of terraces, the size of each terrace, and the discharge at the canal. The average discharge at the inlet was 3.06, 3.44, and 2.05 l sec^{-1} measured in the morning, mid-day, and afternoon, respectively. The corresponding values at the outlet were 0.84, 1.29, and 0.92 l sec^{-1} The discharge at the inlet was significantly different from the discharge at the outlet during land preparation and fertilizer application. During land preparation, more water was required to saturate the soil for easy puddling and transplanting. On the other hand, a week before and after fertilization, water was mainly used to maintain a certain level of about 5-7 cm for normal rice growth and weed control.

Table 5. Mean discharge of canals and inlet and outlet during land preparation and fertilizer application in the rainy season of 2002/2003 in terraced paddy filed, Babon catchment

	Discharge (l sec^{-1})			Range		
Location	08:00	12:00	16:00	08:00	12:00	16:00
Canal - SS 1	351.7	373.1	395.3			
Canal - SJ 1	357.1	406.6	481.2			
Canal - SK 1	607.5	767.1	733.2			
INLET (Land Prep)	3.06	3.44	2.05	1.40 - 3.71	1.47 - 4.83	0.86 - 3.42
OUTLET (Land Prep)	0.87	1.29	0.92	0.65 - 0.98	0.68 - 2.31	0.49 - 1.66
INLET (wbf)*	4.52		4.57			
OUTLET (wbf)**	0.29		0.29			
INLET (waf)	3.28		2.80			
OUTLET (waf)	0.40		0.40			

WBF: Week Before Fertilization; WAF: Week After Fertilization; SS1: *Saluran Sawah* 1; SJ1: *Saluran nJaru* 1; SK1: *Saluran Kemloso* 1

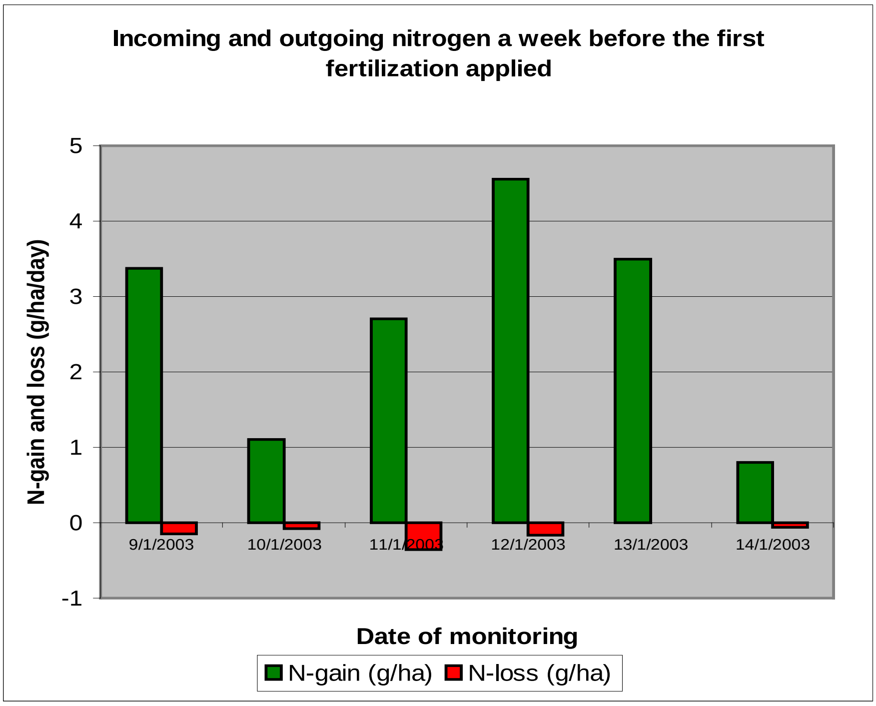
The contribution of irrigation water to the nutrient input was mainly during land preparation and fertilizater application when incoming and outgoing nutrients through water and sediment were greatly dynamic even if both the inlet and outlet are closed during fertilizer application. Less water passes through the inlet and outlet during other stages of the rice growth meaning that less nutrient movement also takes place.

The data showed that the outgoing nutrients via runoff sediment were higher than the incoming nutrients from irrigation water, as the outgoing sediment was also higher (Figure 15). It is interesting to note that the K loss was higher in the improved technology treatment than in the farmer practices. During these activities, 0.36 and 0.79 K^+ g ha^{-1} was lost from the field. For phosphate the loss was almost the same, about 0.13 $P0_4^{3-}$. In the case of nitrogen, contribution of incoming sediment was higher than losses through outgoing sediment (erosion). This is because nitrogen may not be bound in the fine materials (eroded soil) as P and K. In addition, contribution of rainfall, decomposed organic matter and leaching of nitrate from upstream may enrich the irrigation water. The net gain of nitrogen from the incoming sediment during land preparation was 0.13 N g ha^{-1}, which was very small. The study on N and P transport by surface runoff reported by Ng Kee Kwong *et al* (2002) showed insignificant level of N and P moving from the plot and subcatchments during runoff event. Less than 1 kg total P was lost and about 2 to7 kg N ha^{-1} was transported by surface runoff. These values were agronomically not important. Douglas *et al* (1998), Albert *et al* (1978), and Kissel *et al* (1976) reported similar results.

A week before and after the first fertilizer application, the incoming nutrients were higher than outflowing nutrients, meaning that during these periods the soil was enriched by nutrients from deposited sediment (Figures 17, 18, and 19). The total nutrient inputs from irrigation water a week before and after fertilization activities were 17.8 N, 2.4

PO4, and 3.1 K g ha^{-1}. These values were small and may not potentially contribute to soil fertility improvement.

(a)



(b)

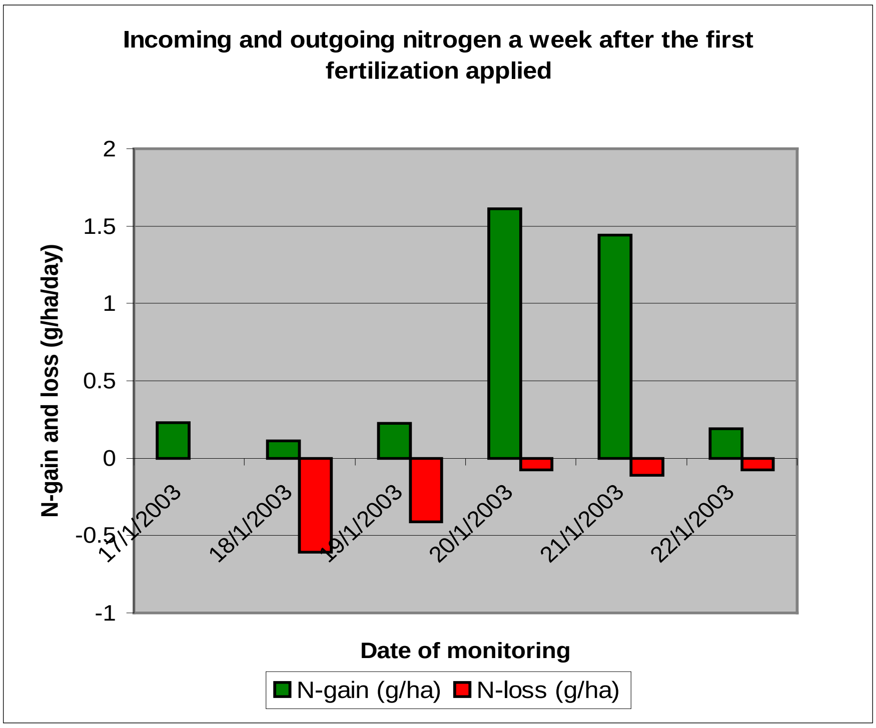
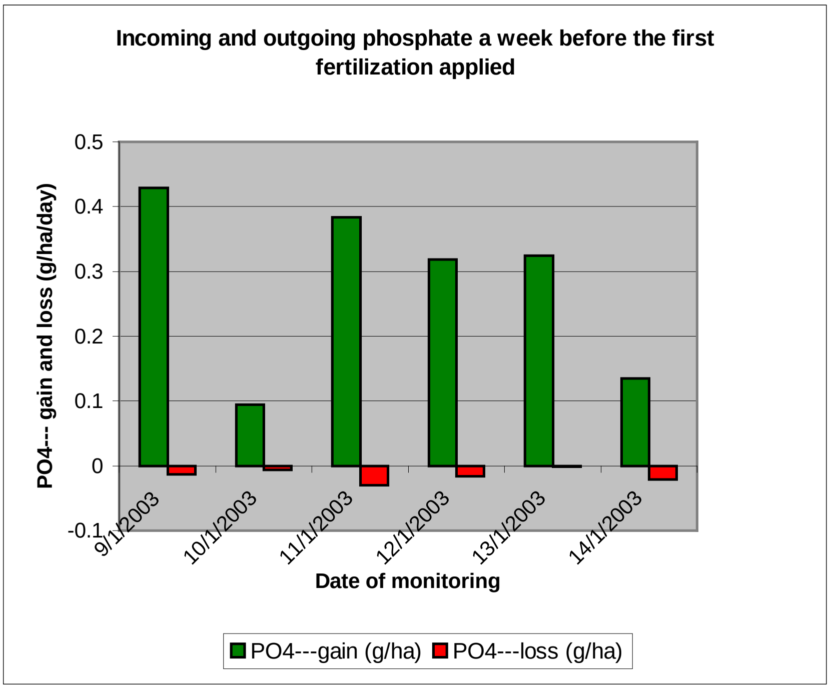


Figure 17. Incoming and outgoing nitrogen a week (a) before and (b) after the first fertilization applied in Babon catchment (terraced paddy field)

(a)



(b)

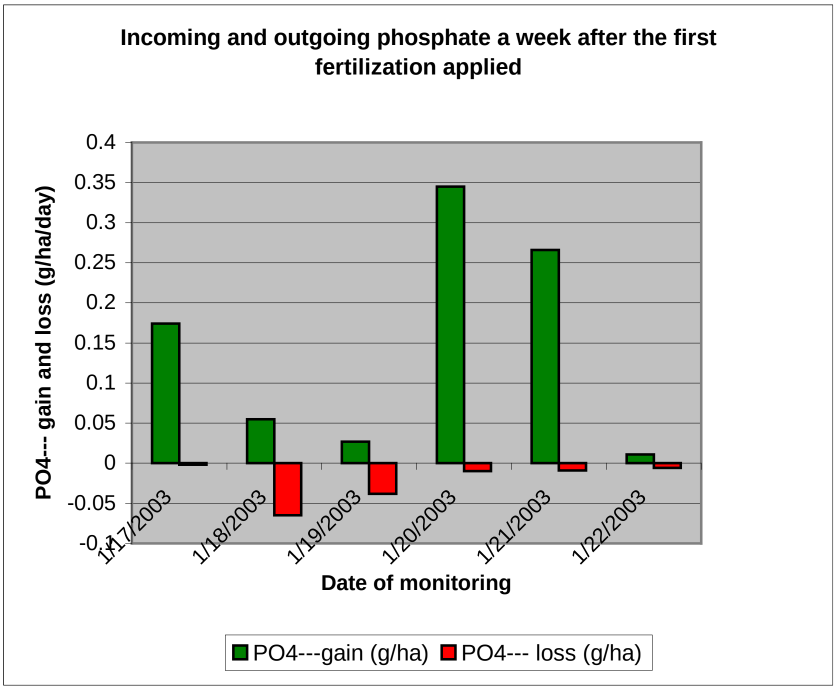


Figure 18. Incoming and outgoing P a week before (a) and after (b) the first fertilizers were applied in Babon catchment (terraced paddy field)

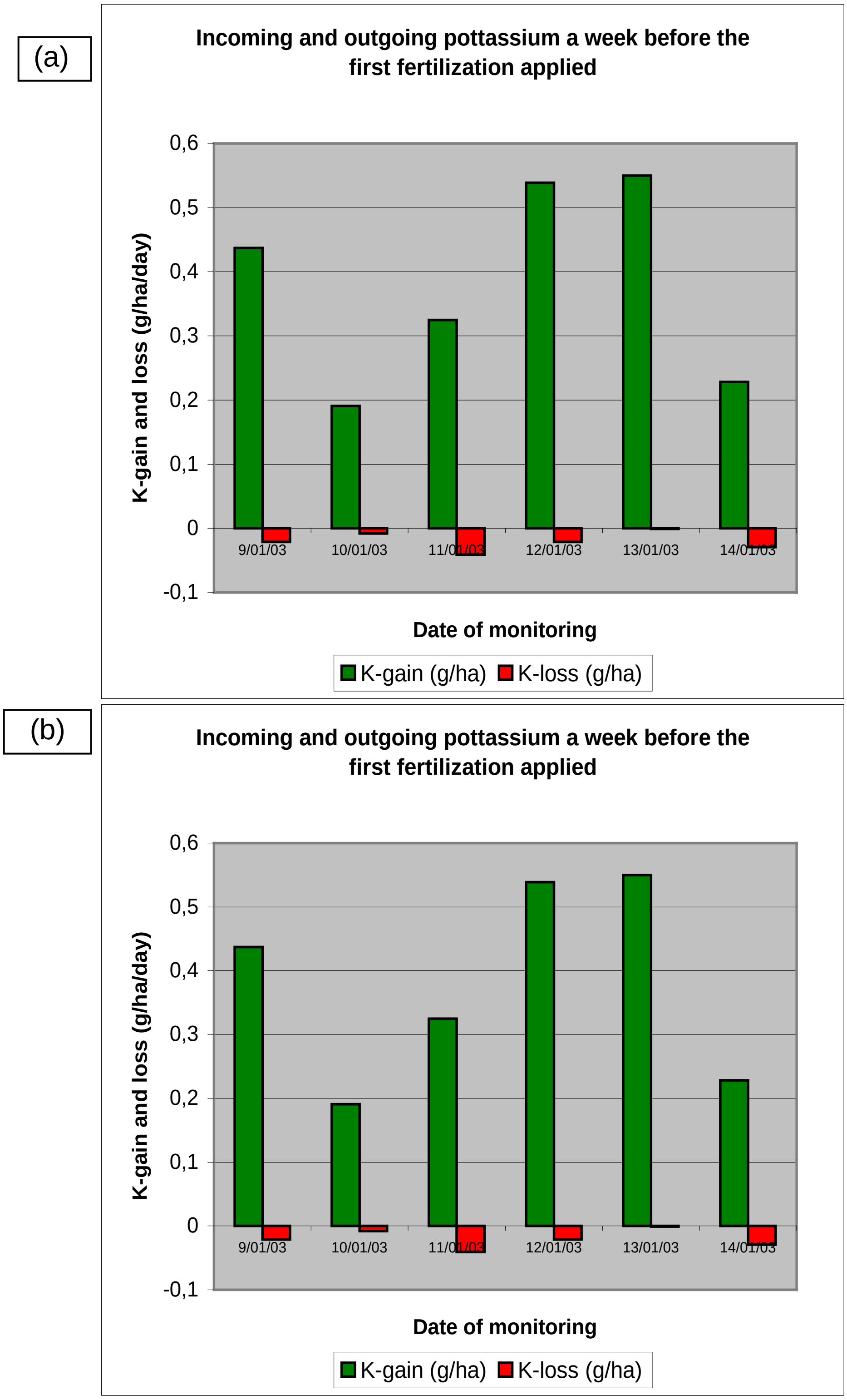


Figure 19. Incoming and outgoing K a week before (a) and after (b) the first fertilizers were applied in Babon catchment (terraced paddy field)

Rainy season 2002/2003 occurred from end of October 2002 to April 2003 (Figure 20). The annual rainfall was 2231 mm with monthly maximum of 533.1 mm occurring in January 2003. This rainfall amount was lower by 905 mm from the rainfall in 2001/2002. Total nutrient gain from the rainfall was about 8.53 N, 1.09 P, and 3.65 K kg ha^{-1} yr^{-1}. These values were considered low. Poss and Saragoni (1992) obtained the same result from samples collected in Togo, getting values of 4.4 $N0_3$, 1.1 $P0_4$, and 4.1 K kg ha^{-1} yr^{-1}. Schuman and Burwell (1974) recorded a value of 7.26 kg N ha^{-1} yr^{-1} from an average precipitation of 926 mm. These are lower compared to the nitrogen content measured in Belgium of about 25 kg N yr^{-1} (Demyttenaere, 1991). Lefroy and Konboon (1999) also measured low nutrient content in rainfall.

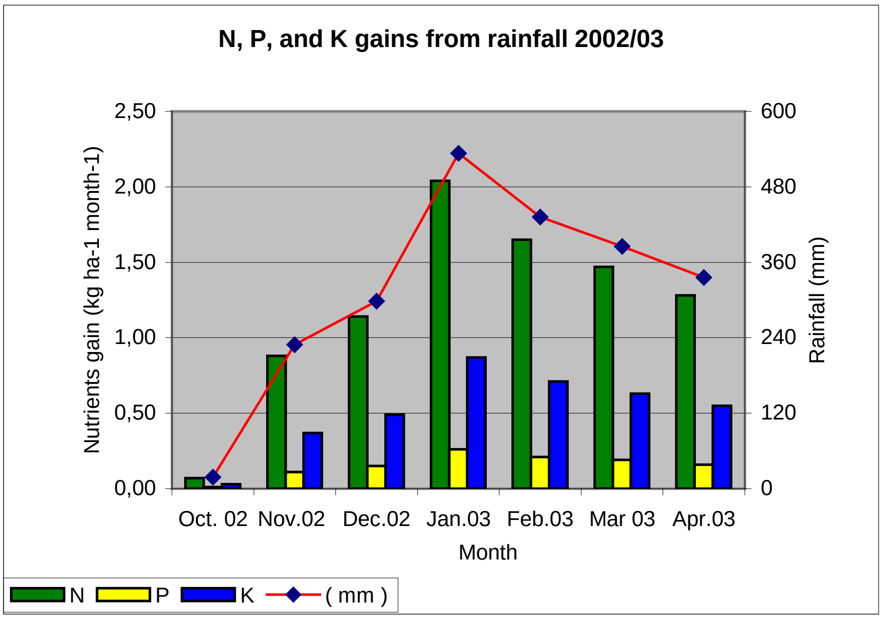


Figure 20. Monthly rainfall and its contribution to nutrient inputs

Rice was harvested by cutting the straw at 10 to 15 cm above the ground. The stem and roots remained in the field, and therefore considered an input. The total rice residues and their contribution to input are presented in Table 6. The data indicated that rice residues are rich in N and K and these have potential to increase soil fertility, although they are low in P.

Table 6. Rice residues and their contribution to N, P, K input in rainy season 2002/2003

Treatment	Rice residues (t ha^{-1})	INPUT (kg ha^{-1} season^{-1})		
		N	P	K
Farmer Practices	5.26	137.3	3.9	106.3
Improved Technology	8.51	222.1	6.4	171.9

The total nutrient gains from rice residues were 137, 4, and 106 kg ha^{-1} season^{-1} of N, P, and K respectively under the farmers' practice, and 222, 6, and 172 kg ha^{-1} season^{-1} of N, P, and K respectively under the improved technology. Rice residues and nutrients were higher in the improved technology than in the farmers' practice. This can be attributed to higher fertilizer rates in the improved technology. This finding is similar to that reported by many authors (De Datta, 1981; De Datta *et al*, 1991; Yoshida, 1981; Sukristiyonubowo *et al*, 2003).

Loss of nutrient by crop removal through harvest was high especially for N and K, which are mainly contained in the rice straw. Among the nutrients studied, nitrogen loss was highest and contained in the rice grain. Loss of nutrient under the improved technology was considerably higher than that under the farmers' practice (Table 7). Similar results were obtained in the first year study as reported by Sukristiyonubowo *et al* (2003). The result suggests that rice straw can be a potential nutrient source for improving soil fertility. Recycling of rice straw either for organic fertilizer source or fodder source for cattle will be tested in Suruhan Village.

Table 7. Nutrients losses through harvest in terraced paddy field during rainy season 2002/2003

Loss (kg ha^{-1}season^{-1})			Rice straw		Rice grain	Loss (kg ha^{-1}season^{-1})		
K	P	N	(t ha^{-1})	Treatment	(t ha^{-1})	N	P	K
204.9	8.4	281.7	9.85	Farm Prac	4.79	127.9	11.7	14.8
233.0	14.9	333.0	10.80	Imp Tech	5.85	168.1	15.6	19.7

It is interesting to note that the yield of rice under the farmers' practice showed a declining trend while it was increasing under the improved technology (Figure 21). From simple correlation analysis, an increase of 0.20 t ha^{-1} in the yield of rice is expected every cropping while a decrease of 0.25 t ha^{-1} is expected every cropping in the farmers' practice. This correlation is represented in the equation, Y= 0.5074 Ln (x) + 5.2109, for improved technology, and Y=0.6134Ln(x) - 5.1163 for the farmers' practice.

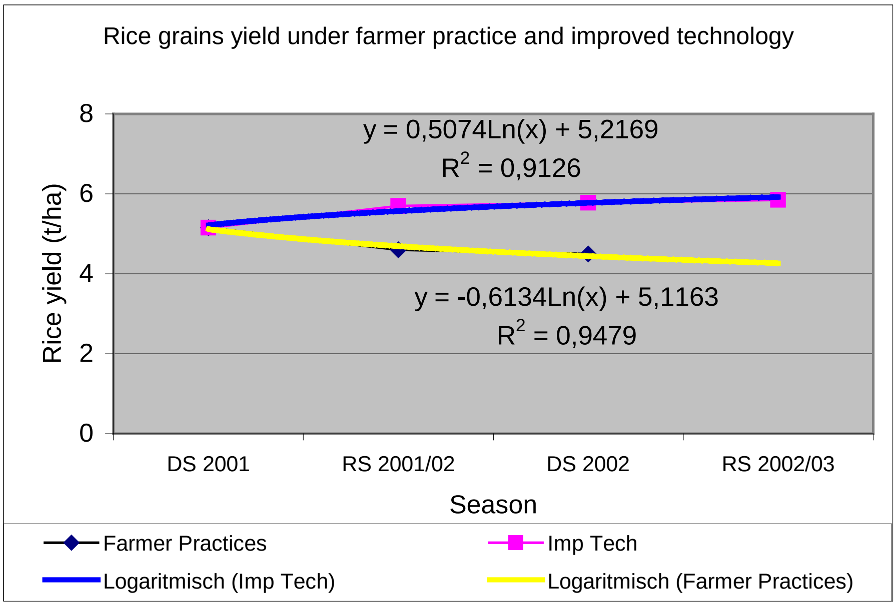


Figure 21. Rice grains yield under farmer practices and improved technology in terraced paddy field

The N, P, and K balances during the rainy season cropping 2002/2003 are presented in Table 8. The results showed that crop residues under both the farmers' practice and the improved technology provided the biggest contribution to the input.

Under the farmers' practice, 78-98% of the nutrient gain was contributed by the crop residues. Under the improved technology, crop residues contributed 23-85% of the nutrient gain.

Crop removal is also the major cause of nutrient loss in the paddy fields. Nutrient loss through erosion is almost nil. Recycling rice straw can therefore be a good management practice. It will be beneficial to leave more rice straw in the field, say, by cutting the rice straw higher from the ground during harvest.

Table 8 also shows a negative balance for all nutrients under both the farmers' practice and the improved technology indicating the urgent need to improve management to address further nutrient depletion. This observation is similar to that from the first year data. Nitrogen showed the highest negative balance of -241 and -219 N kg $ha^{-1}season^{-1}$ under the farmers' practice and the improved technology, respectively. For P, a negative balance of -15 and -3 kg ha^{-1} $season^{-1}$ under the farmers' practice and the improved technology, respectively, was observed. The corresponding balance for K was -56 and -32 kg ha^{-1} $season^{-1}$.

Table 8. N, P, and K balances at terraced paddy field system for rainy season 2002/2003

Parameter	Nutrient Balance (kg ha^{-1} $season^{-1}$)					
	Farmer Practices			Improved Technology		
	N	P	K	N	P	K
Gains:						
1. Fertilizer	22.50	-	-	45.00	20.00	25.72
	*(14%)**			*(15%)*	*(73%)*	*(13%)*
2. Irrigation	0.02	0.002	0.003	0.02	0.002	0.003
3. Rainfall	8.53	1.09	3.65	8.53	1.09	3.65
4. Crop Residues	137.30	3.90	160.30	228.10	6.40	189.80
	(81%)	*(78%)*	*(98%)*	*(81%)*	*(23%)*	*(85%)*
Total Gains	168.35	4.99	163.95	279.65	27.49	220.17
Losses:						
1. Removal by harvest						
• Rice grains	127.90	11.70	14.80	168.10	15.60	19.70
	(31%)	*(58%)*	*(6.7%)*	*(33.9%)*	*(51%)*	*(7.8%)*
• Rice straws	281.70	8.40	204.90	330.10	14.90	233.00
	(69%)	*(42%)*	*(93%)*	*(66%)*	*(49%)*	*(92%)*
2. Soil Loss						
• Run off sediment	0.00	0.00	0.00	0.00	0.00	0.00
• Bed load	-	-	-	-	-	-
Total Losses	409.60	20.10	219.70	498.20	30.50	252.70
Balance	-241.25	-15.11	-55.75	-218.55	-3.01	-32.53

*Values in bracket are the percentage of the total nutrient gain or loss

Scenarios to support higher production

The high negative balance of all three major nutrients, especially under the farmers' practice, points to the need to immediately address the problem of nutrient depletion. Integrated nutrient management, with due consideration of managing inputs and outputs of nutsrients must be looked at. The results taken from two years of study indicated that rice grain and straw represent about 66-74% of total rice biomass and contain an equivalent amount of 69-75% N, 83-84%P and 58-60% K. Rice straw alone therefore contains about 46-52% N, 35-40% P, and 54-55% K. Rice straw management like recycling it back to the rice paddies appears to be a potential strategy to look at.

Recycling about 67% of the total harvested straw provides about 94, 2.8, and 68.3 kg ha^{-1} season^{-1} of N, P, and K, respectively, under the farmers' practice, and 110, 4.9, and 77.6 kg ha^{-1} season^{-1} under the improved technology. This would result in the nutrient balance of -133, -10, and +80 kg ha^{-1} season^{-1} of N, P, and K, respecticvely, in the farmers' practice. The corresponding balance in the improved technology is -4, +7, and +104 kg ha^{-1} season^{-1} of N, P, and K, respectively (Table 9).

Table 9. Expected nutrient balance for lowland rice with 67% of rice straw produced per year recycled

Treatment	Nutrient balance (kg ha^{-1} season$^{-1)}$		
	N	P	K
1. Rice straw is used for feeding:			
▪ Farmer Practices	- 241	- 15	- 56
▪ Improved Technology	- 219	- 3	- 32
2. 33% of rice straw recycled:			
▪ Farmer Practices	- 133	- 9	+ 81
▪ Improved Technology	- 4	+ 7	+ 104

Validation of Soil Erosion Prediction Model

Digital elevation model (DEM) was developed based on the topographic map by converting the vector format into raster using grid tools analysis. The vector format was converted into triangulated irregular network (TIN) using 3D and spatial analysis from the Arc View 3.1. The result was exported into ASCII format, which was used as the spatial data input for PCRaster. Before converting into raster format, *clone.map* was created from the available spatial data. The overall procedure is shown in Figure 22.

DEM maps of Tegalan, Rambutan and Kalisidi are presented in Figures 23, 24, and 25 respectively. These maps were used to create the slope map and the local drain direction (LDD) map, which is the flowpath of the surface runoff. Using these maps, the sediment that is transported from one raster to the other raster was calculated, while the flow path was used to calculate runoff and sediment within the raster. LDD map was created using operational commands of PCRaster as follow:

PCRCalc LDD.map = lddcreate(DEM.map,1,1e35,1e35,1e35)

In Tegalan microcatchment, slopes ranged from 40 to 60 percent with some parts about 90 percent. The Rambutan microcatchment has gentle slope near the ridge with dominant slope of 40 to 60 percent at the middle and lower slope. The Kalisidi microcatchment has steeper slopes of 50 to 70 percent, especially near the natural creecks. The LDD map of Tegalan, Rambutan and Kalisidi microcatchments showed that the flow to the outlet was as the original.

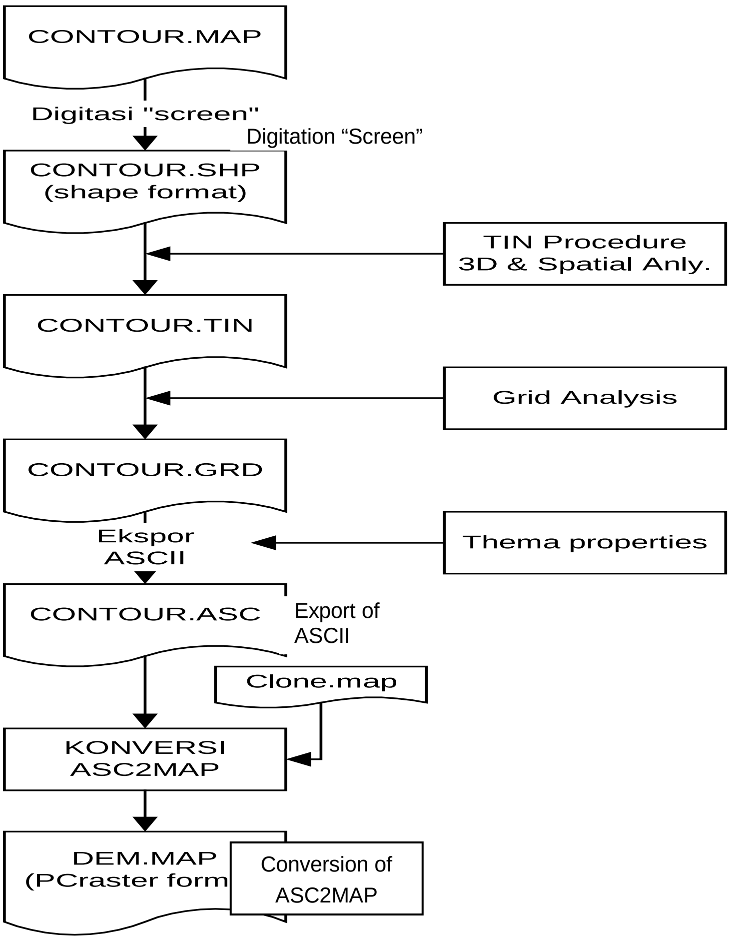


Figure 22. Flowchart explaining the process of data conversion of the contour in the digital elevation model in the model of MSEC-1 (Paningbatan, 2001; ICRAF, 2001; Eiumnoh, 2002).

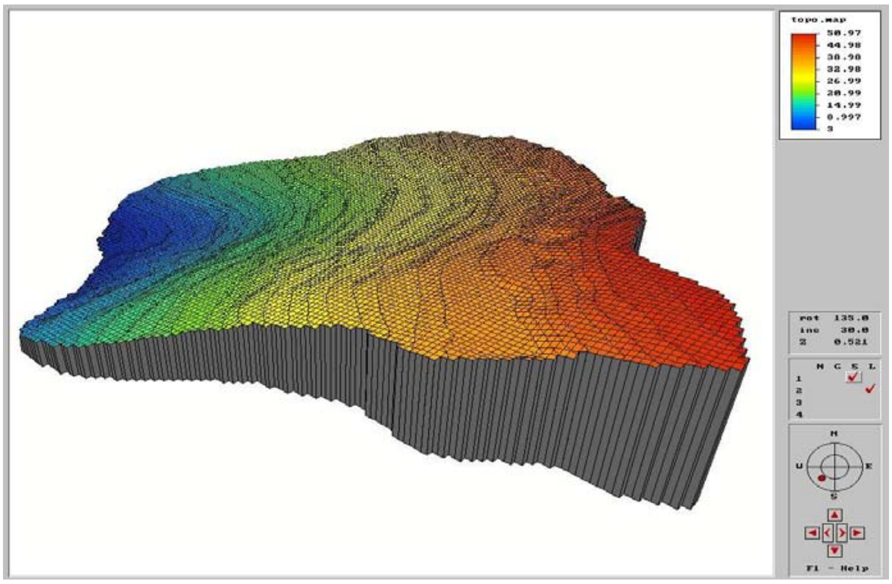


Figure 23. DEM map of Tegalan micro catchment with the raster size of 1 x 1 m (not in the scale)

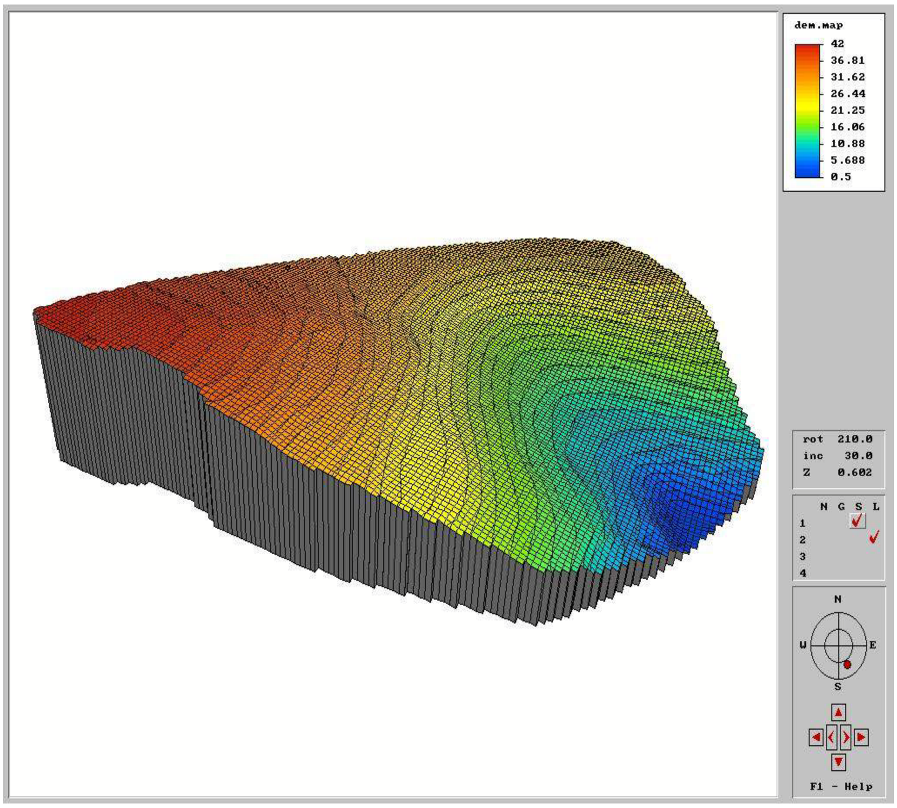


Figure 24. DEM map of Rambutan micro catchment with the raster size of 1 x 1 m (not in the scale)

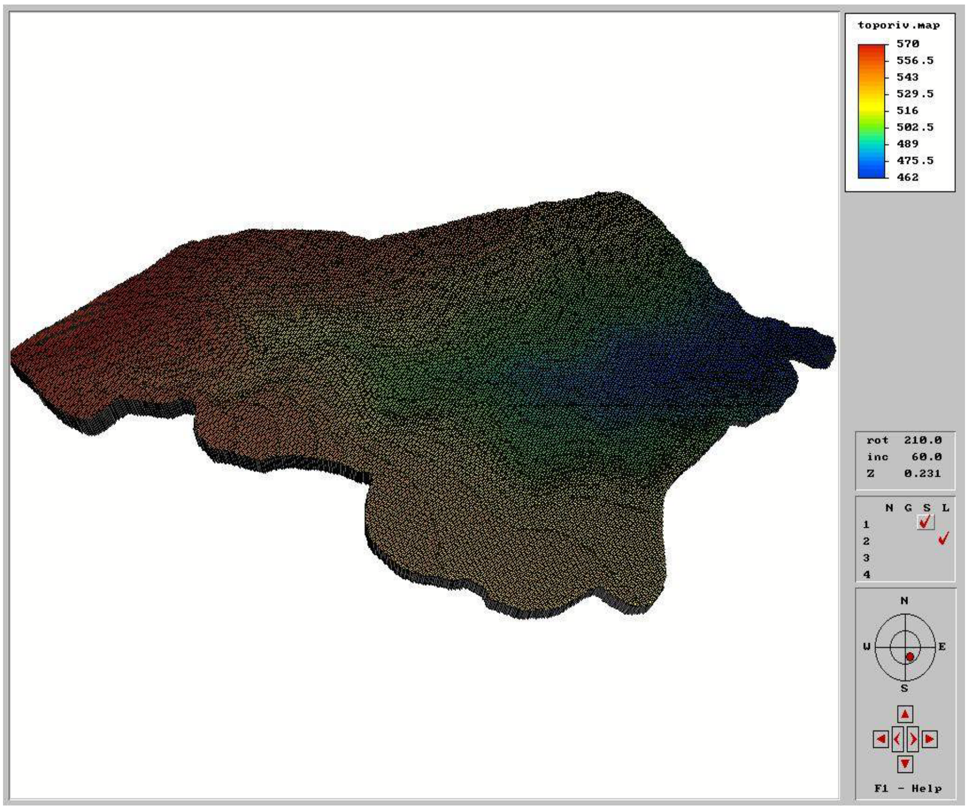


Figure 25. DEM map of Kalisidi micro catchment with the raster size of 1 x 1 m (not in the scale)

Soil maps were created by converting analog soil map into digital (raster) format using extention facility of grid tools analysis from the ArcView 3.1 without TIN procedure. The result was exported as the ASCII format, and used for spatial data entry from PCRaster using clone.map created from previous spatial data. The overall procedure to create soil map is depicted in Figure 26.

The created soil maps of Tegalan, Rambutan, and Kalisidi are presented in Figure 27, 28, and 29. These maps were used to create Sed-den and Sed-vel maps, which present the density of the sediment particle and the flow velocity of the soil particle, respectively. These two parameters are affected by soil types. The soils of Rambutan and Kalisidi are dominated by Andic Dystropepts, while Andic Eutropepts dominate in Tegalan. These maps were used for further calculation, where the entry of spatial data is done using a command of LookUp from PCRaster as follow:

PCRCalc Sedden.map = lookupscalar(Density.tbl,Soil.map)
PCRCalc Sedvel.map = lookupscalar(Velocity.tbl, Soil.map)

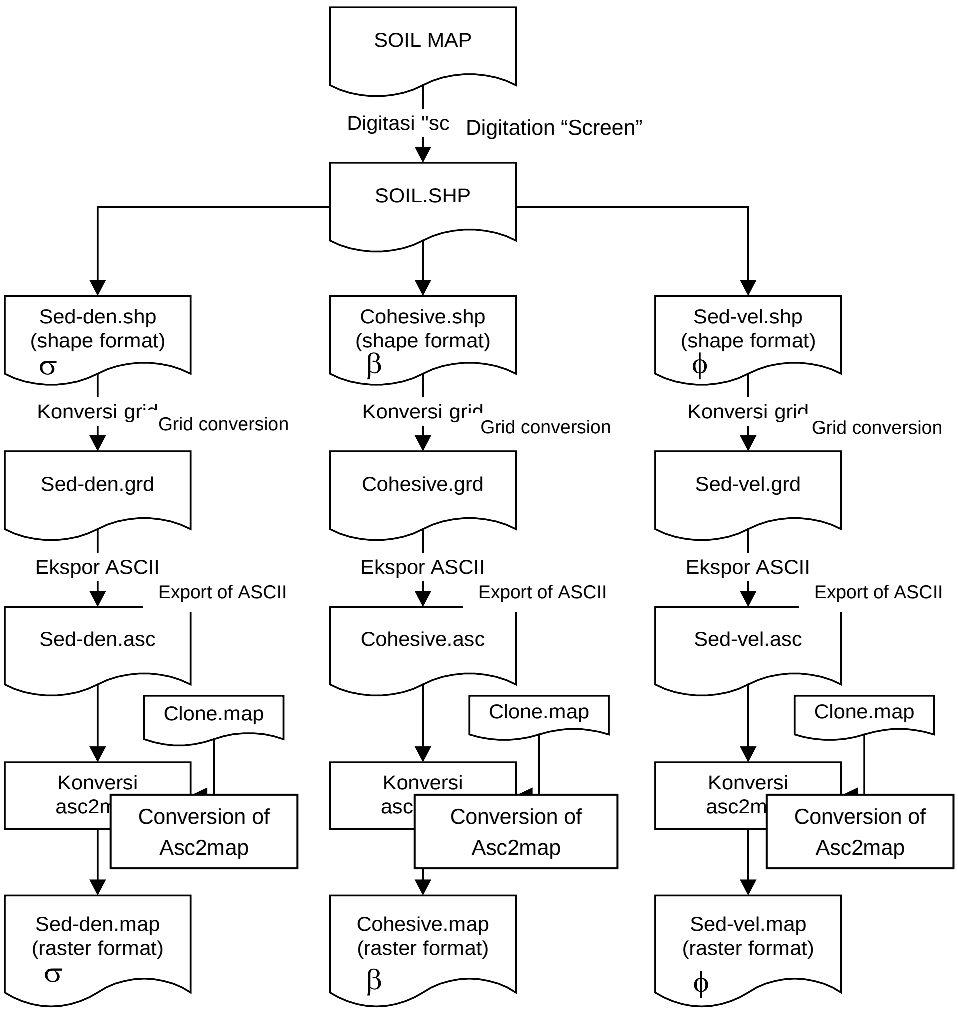


Figure 26. Flowchart explaining procedure to convert analog soil data into digital soil data (ICRAF, 2001; Eiumnoh, 2002)

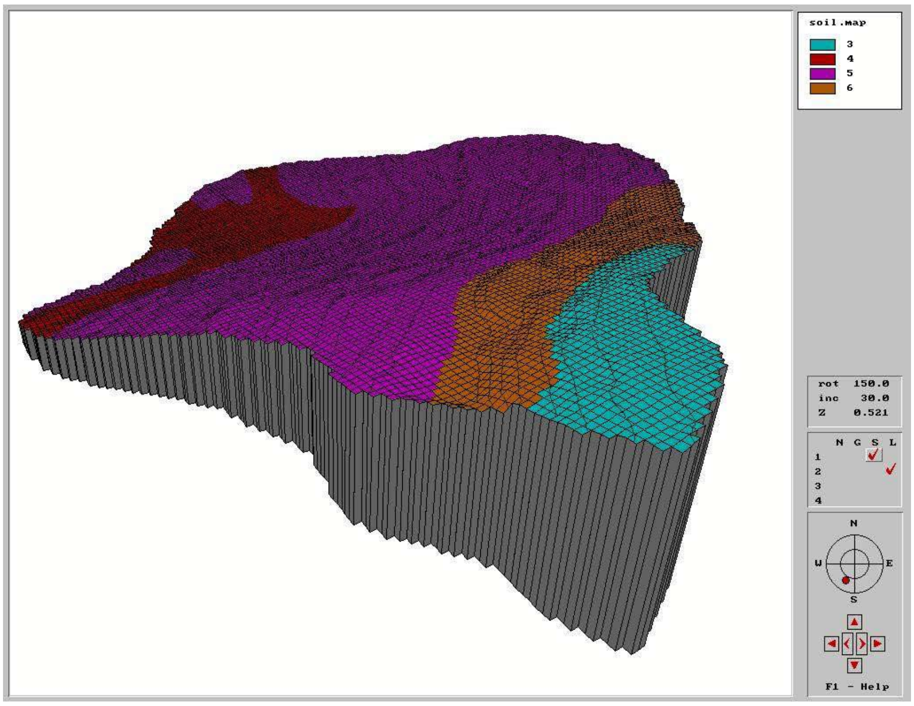


Figure 27. Soil map of Tegalan micro catchment with the raster size of 1 x 1 m (not in the scale)

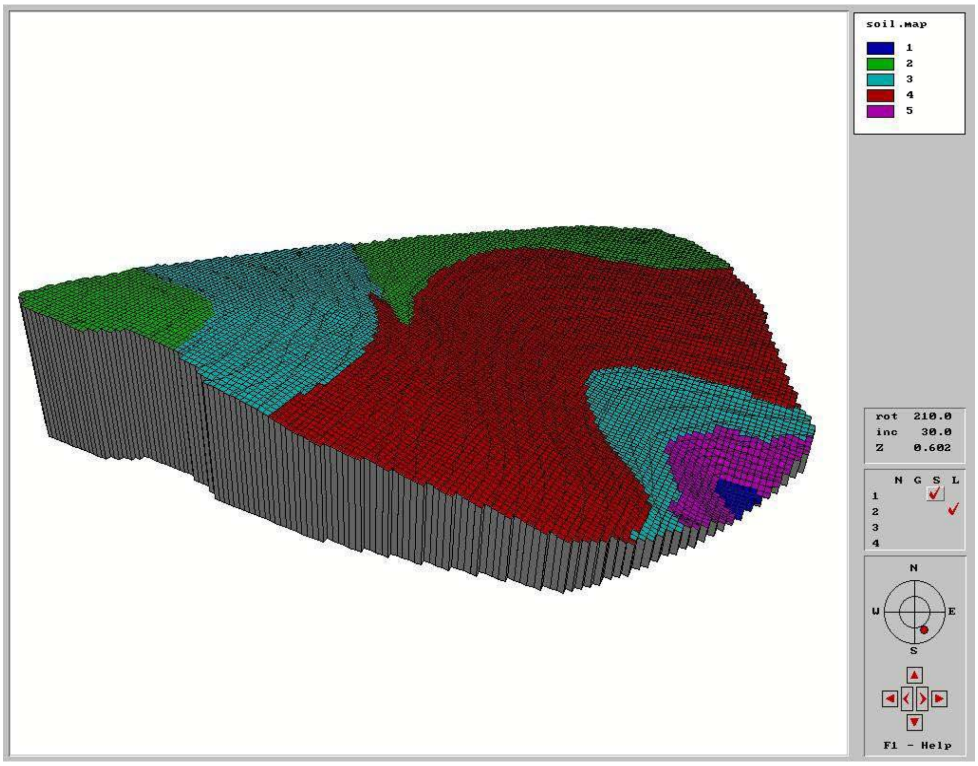


Figure 28. Soil map of Rambutan micro catchment with the raster size of 1 x 1 m (not in the scale)

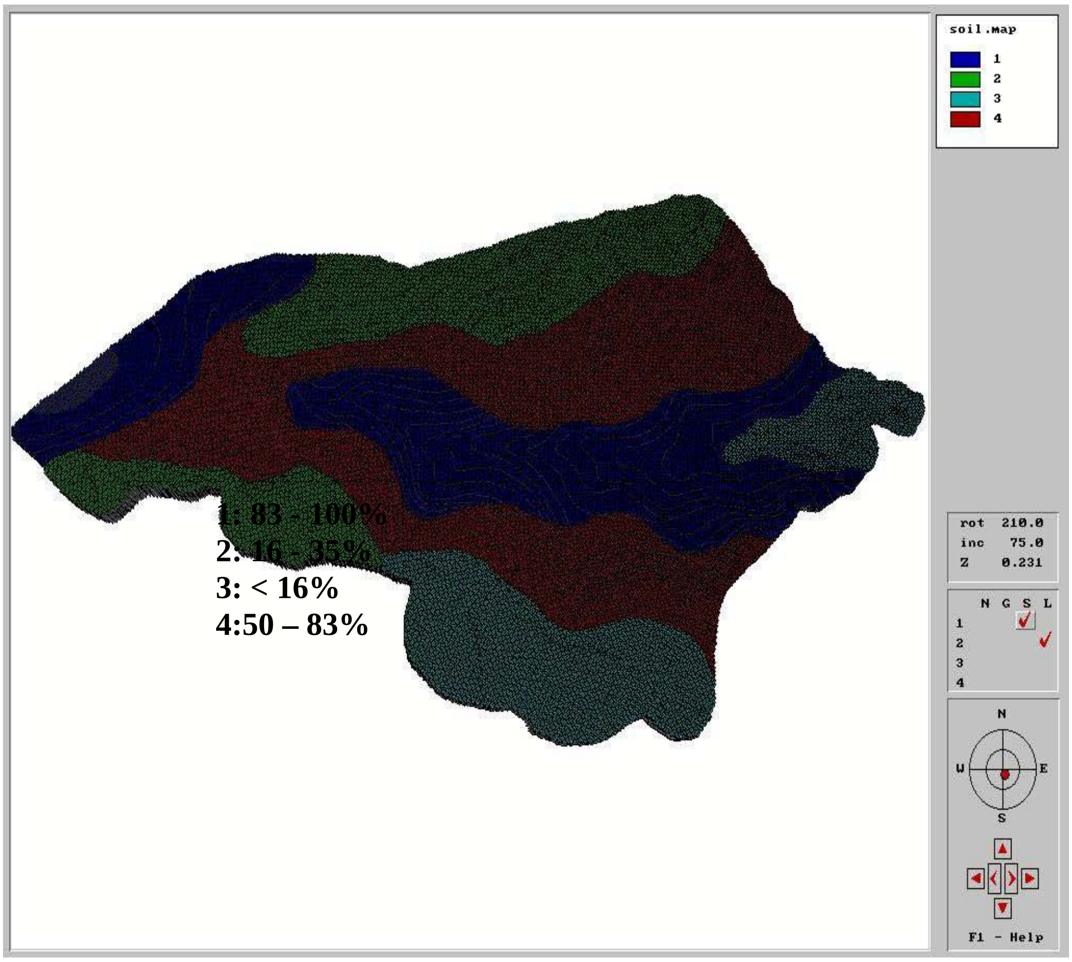


Figure 29. Soil map of Kalisidi micro catchment with the raster size of 1 x 1 m (not in the scale)

Both density and flow velocity of the particle are based on the soil texture *i.e* clay loam and the particle size (2680). Since there was no study on these parameters in Indonesia, the values were adopted from ACIAR project. The produced soil maps were also used to create erodibility map. Like the Sed-den and Sed-vel maps, which are interconnected spatial data, they were used for further calculation. The next step was to create a Beta map, which was done according to the following command:

PCRCalc Beta.map = lookupscalar(Cohesive.tbl,Soil.map)

ACIARs' parameter of cohesiveness was also adopted to create tabular data, which were used in the model. The value of 0.50 was used for parameter of particle size. The tabular data was formatted into ASCII structure named sedden.tbl, sedvel.tbl, dan cohesive.tbl (Rose *et al*, 1997; Eiumnoh *et al*, 2001).

Similar procedure was done to create land use maps. The overall procedure is presented in Figure 30. The land use map of Tegalan, Rambutan and Kalisidi microcatchments are presented in Figures 31, 32, and 33.

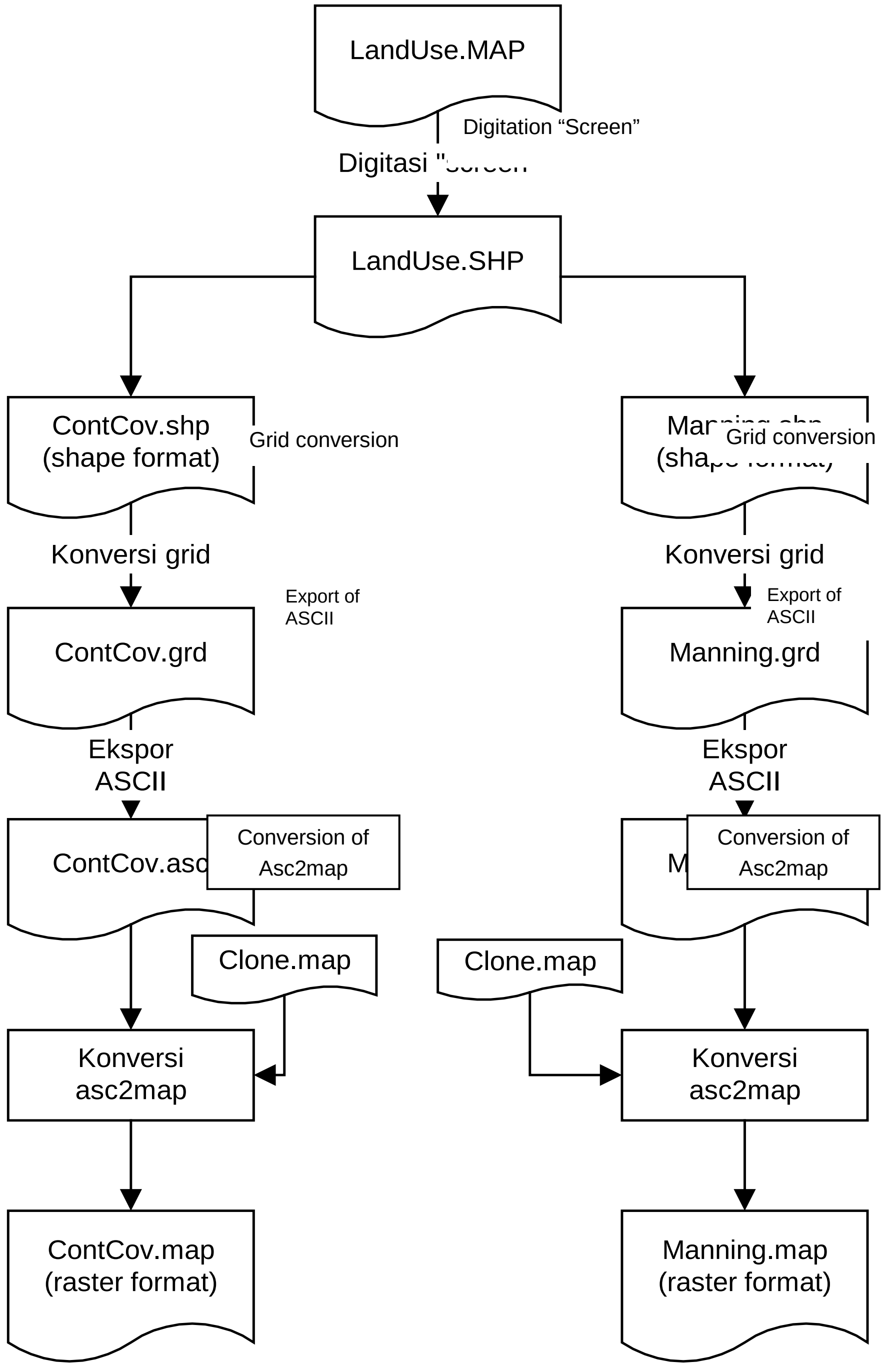


Figure 30. Flowchart explaining the procedure to covert analog land use data into digital land use data (Paningbatan, 2001; ICRAF, 2001; Eiumnoh 2002)

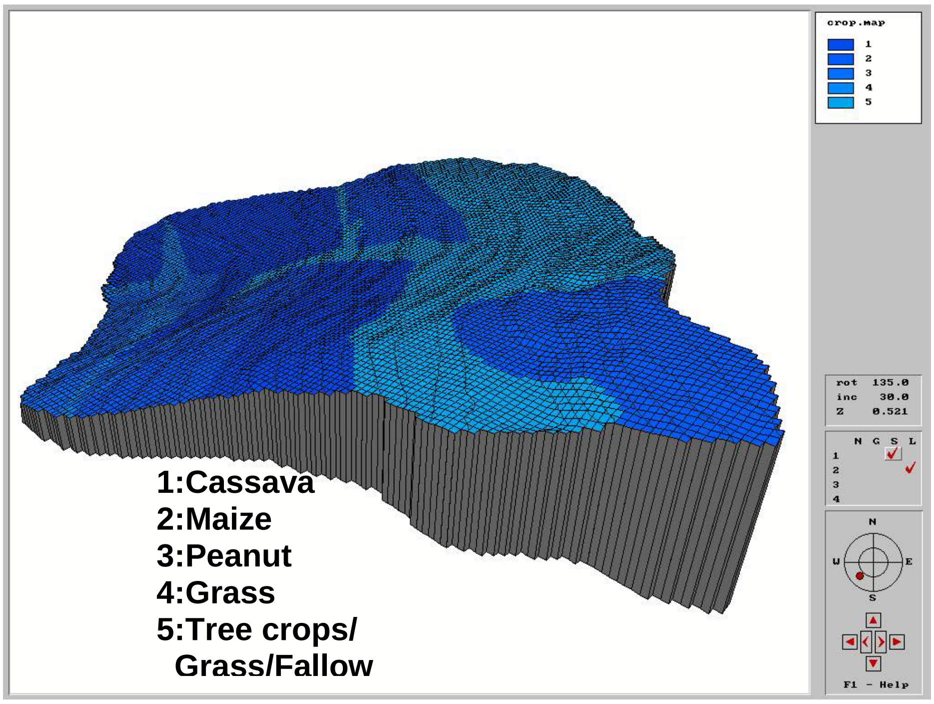


Figure 31. Land use of Tegalan micro catchment with the raster size of 1 x 1 m (not in the scale)

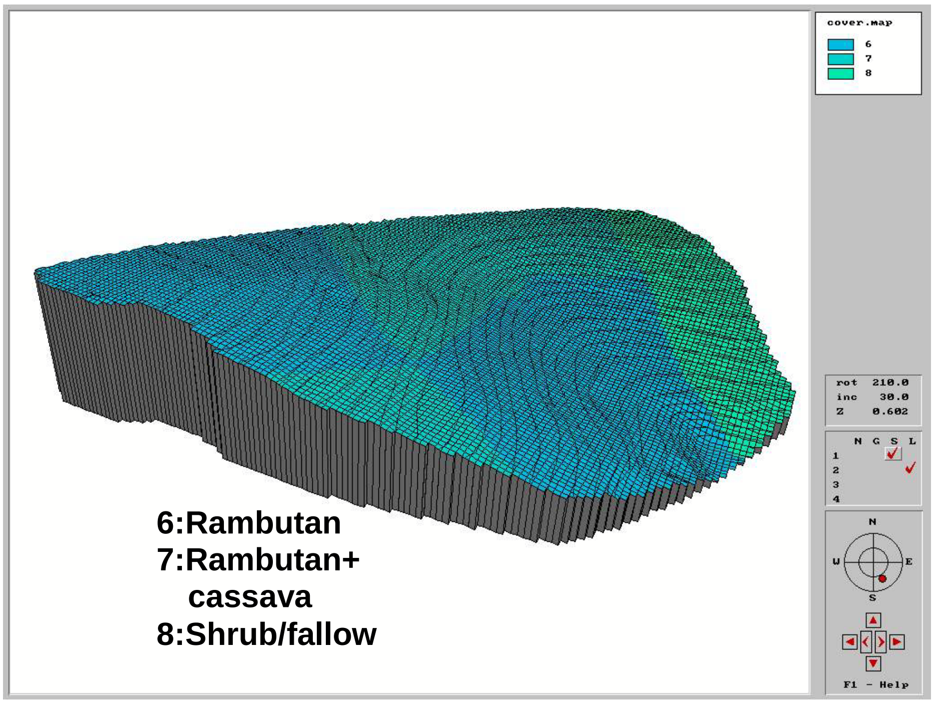


Figure 32. Land use of Rambutan micro catchment with the raster size of 1 x 1 m (not in the scale)

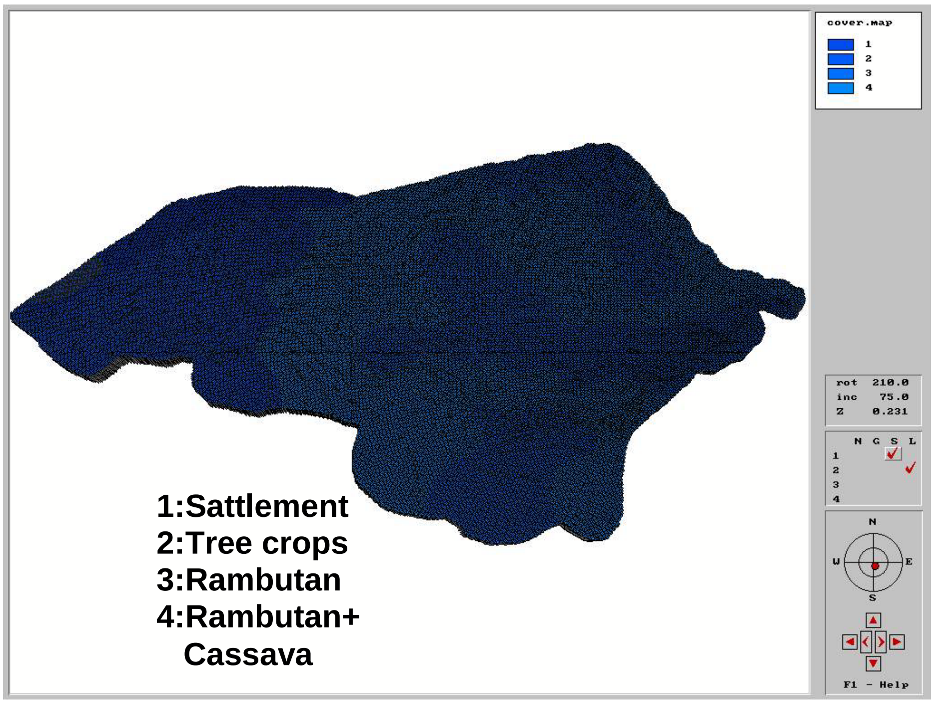


Figure 33. Land use of Kalisidi micro catchment with the raster size of 1 x 1 m (not in the scale)

In Tegalan microcatchment, cassava, corn, and peanut were dominant, with a few tree crops like coffee, rambutan and durian. The surface of the ground was covered by grass and shrub. In both Rambutan and Kalisidi microcatchments, rambutan was the main vegetation. About 25 – 30 % of the Rambutan microcatchment was fallow. Beside rambutan, part of the Kalisidi microcatchment was covered with cassava and used for traditional estate and settlement.

The Mannings'roughness constant and the contact cover maps are created using the land cover map. These maps were used for further calculation on which the spatial values have been entered using a command of LookUp from PCRaster as follow:

PCRCalc Manning.map = lookupscalar(Manning.tbl,Crop.map)
PCRCalc Contcov.map = lookupscalar(Contcov.tbl, Crop.map)

The Manning Table and Contact Cover values were related to the existing crops when rainstorm and erosion occurred. These values were published by the ACIAR project and used in this study. Theses values were derived from the studies done in Malaysia, Thailand, Philippines, Northern Australia. Values for Indonesia were based on ICRAF project in Lampung under coffee based cropping system (ICRAF 2001, Rose, *et.al.*, 1985, dan Rose, *et.al.*, 1997; Eiumnoh, *et.al*, 2001). These maps were, then, used to define runoff and transport capacity of sediment and deposition through the flowpath.

Rainfall was recorded in six minute interval using automatic weather station and converted into hour data to define intensity in mm per hour. The first step was to save the data in Raind.tss file, then the Raind.tss file was freated by coding 1 or 0 every rainfall event. The third step was to create the dune.tss file after converting the unit of time from minute to second (6 x 60 = 360) (Paningbatan, 2001; and Eiumnoh, 2002). Those files were made in ASCII format like what was done for tabular data required in the PCRaster to run the model. The model is valid for a single rainfall event.

This model was run using the command of Model.mod. The model deals with the dynamic process that corresponds to the timestep. The number of timestep was the same as the rainfall data input. Automatic calculation used batch file (1run.bat), which consisted of command of PCRCalc –f Model.mod.

As mentioned in the previous discussion, two peaks of discharge were also predicted for the Tegalan microcatchment (Figure 34). The rising limb of the hydrograph was almost similar to the falling limb, indicating the dominance of quick flows. The predicted flow during the rising limb increased sharply, while the measured one increased gently suggesting that the flow response to rainfall occurred later than the predicted response. This provides insight that Hortonian overland flow seems to occur in the field suggesting that the infiltration parameter need to be incorporated in the model as done in the MSEC 2 or PCARES models.

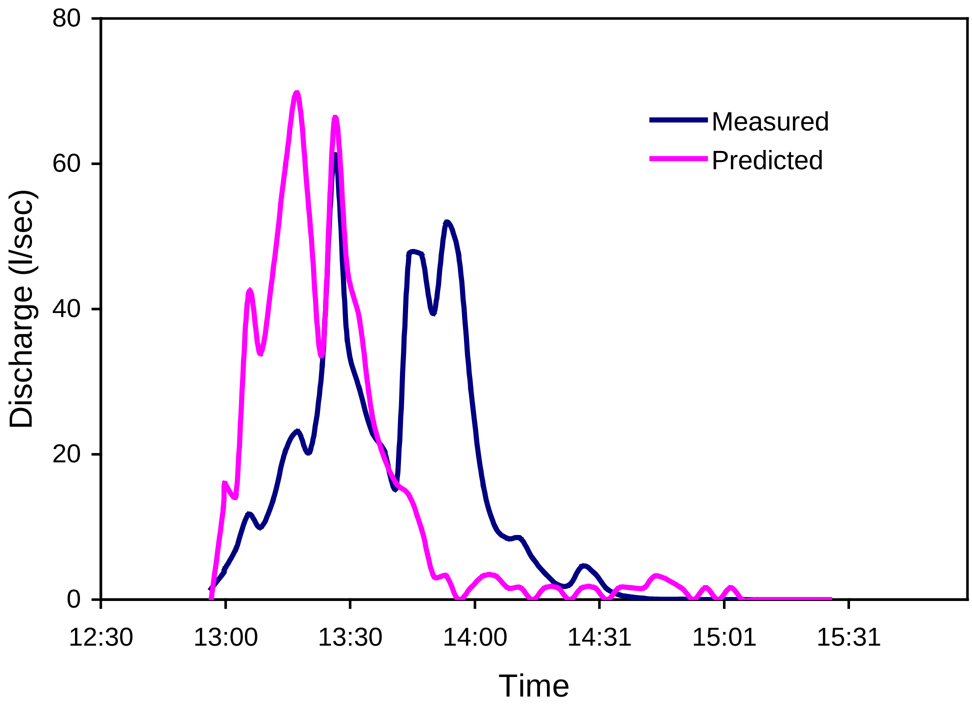


Figure 34. Comparison between predicted and measured runoff for Tegalan microcatchment on January 15, 2003 event

There was a close relationship between predicted and measured runoff with a coefficient of determination (R^2) of 0.72 (Figure 35). This means that about 30 percent of the predicted value still needs to be accounted for. Hydrologically, the model has not yet correctly predicted the time to peak, but able to predict volume of runoff as a response to rainfall.

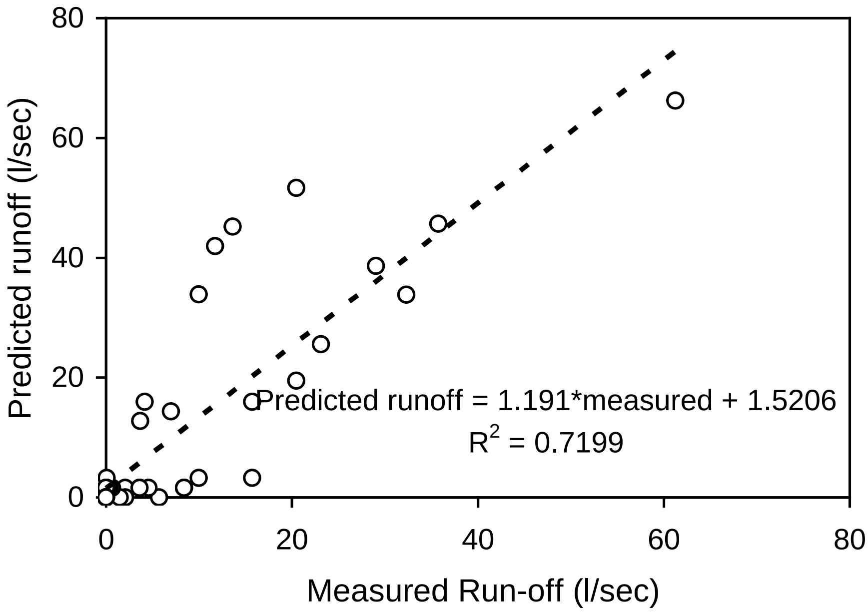


Figure 35. Relationship between predicted and measured of runoff for Tegalan microcatchment

Compared with Tegalan microcatchment, the predicted runoff in Rambutan microcatchment occurred much earlier than the measured one, although the hydrographs were similar (Figure 36). This shows that the lag time was longer meaning that much rainfall infiltrated and time to peak was longer. The predicted runoff occurred just at the same time as the rainfall. The regression analysis showed a lower correlation of 0.40 (Figure 37). During the rainfall event, the ground floor of the Rambutan microcatchment was covered by about 30% of grass and shrub, which facilitated infiltration and reduced the surface runoff.

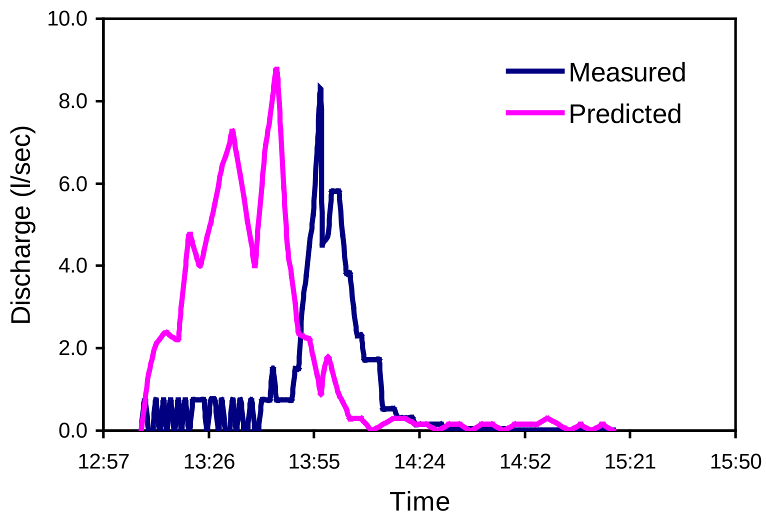


Figure 36. Comparison between predicted and measured runoff for Rambutan microcatchment on January 15, 2003 event

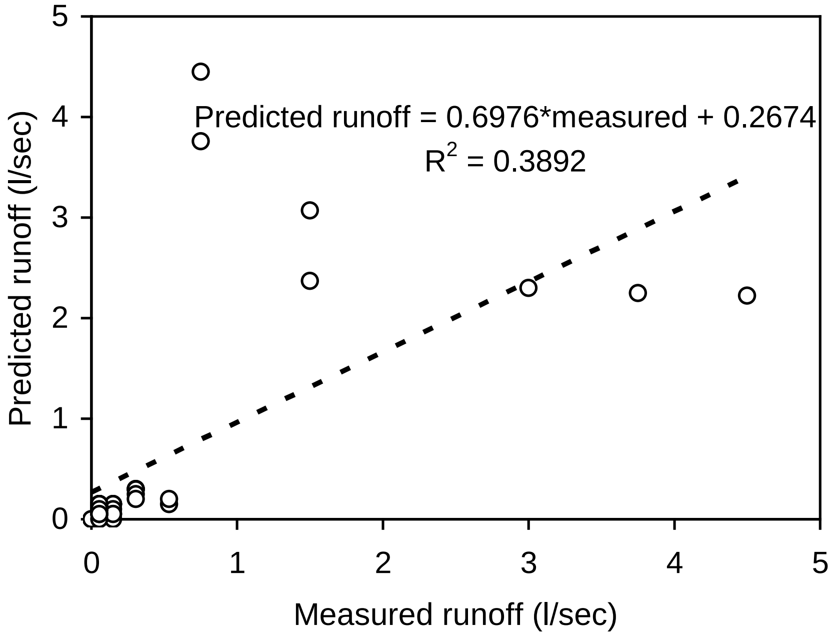


Figure 37. Relationship between predicted and measured of runoff for Rambutan microcatchment

Although it has similar land use as the Rambutan microcatchment, the Kalisidi microcatchment showed better prediction of runoff with a correlation value of 0.72 (Figures 38 and 39). Similar to the Tegalan and Rambutan microcatchments, the predicted flow occurred earlier than the measured one although the lag time was shorter. There was lag time between rainfall event and generated runoff and the pattern of hydrograph indicated that the flow increased sharper than the predicted one. The different in the surface roughness is one of the key factors influencing the surface runoff.

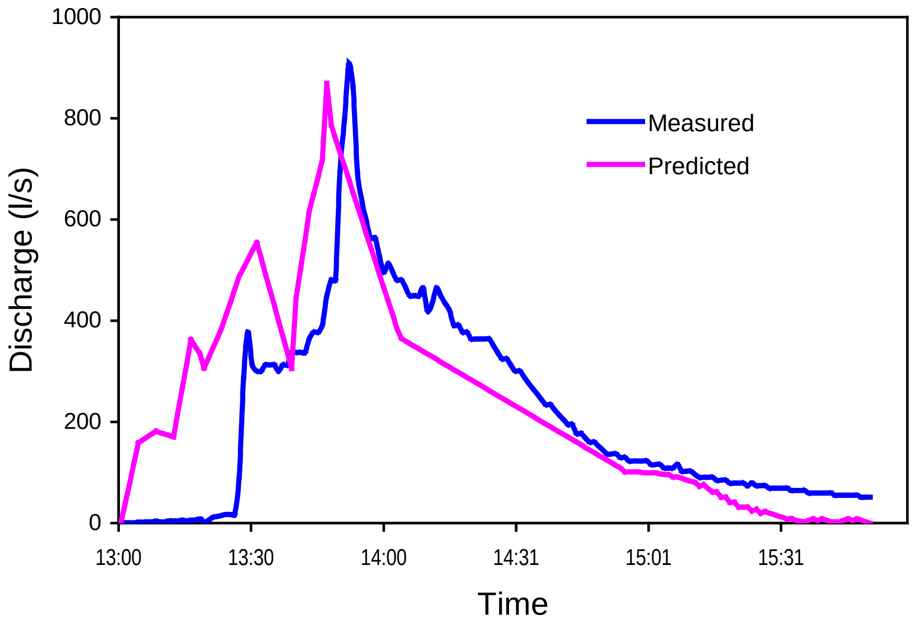


Figure 38. Comparison between predicted and measured runoff for Kalisidi microcatchment on January 15, 2003 event

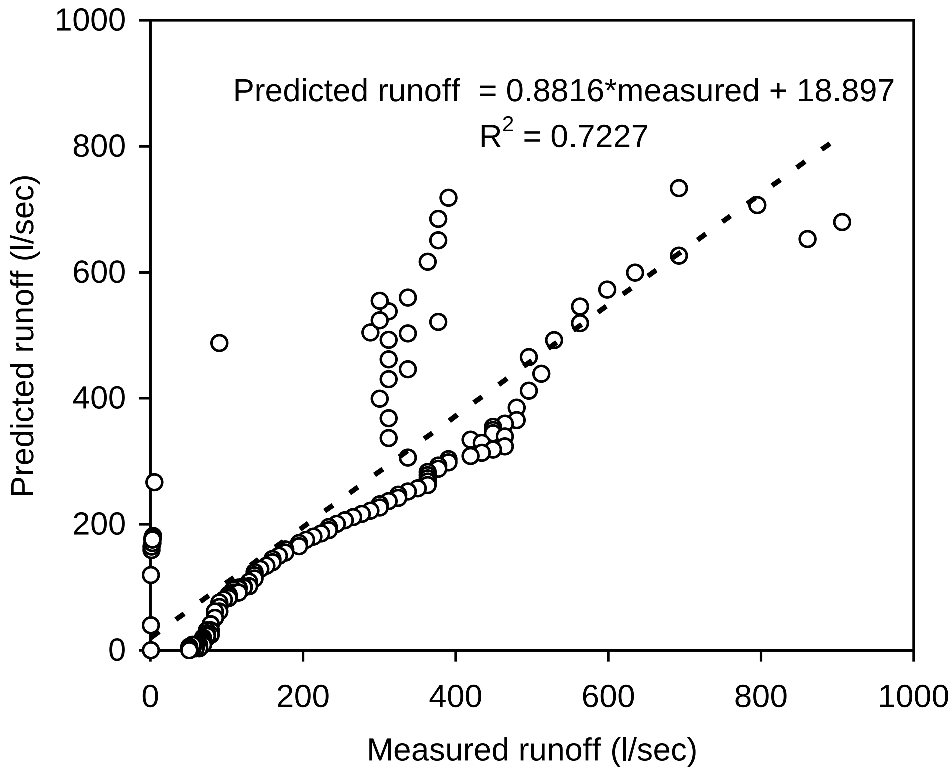


Figure 39. Relationship between predicted and measured runoff for Kalisidi microcatchment

Conclusions and Recommendations

Conclusions

1. The upland soil is more susceptible to surface runoff and erosion when it is used for seasonal crops compared to perennial crops. As far as controlling surface runoff and soil loss is concerned, tree crop provides significant contribution. If the cultivation of seasonal crops is selected to be an alternative, conservation measures have to be introduced to avoid land degradation. The use of Benggala grass (*Panicum maximum*) for erosion control resulted in 50% lower sediment yields in the first year and almost 90% in the second year. Integrated grass planting and cattle fattening promises sustainable conservation farming system that reduces soil erosion and increases farmer's income.
2. Loss of N, P and K through runoff, sediment transport and crop harvest has been noticed to be high. Most of N and K losses are concentrated in the transported sediment, while that of P was in the surface runoff.
3. Under the terraced paddy field, the lost of sediment and nutrient was high during land preparation. It is recommended to recycle rice straw as much as 67% of the total straw produced during the year.
4. The farmers' practice in which only 50 kg urea ha^{-1} cropping $season^{-1}$ was applied, needs to be improved. Application of 100 kg each of Urea, TSP and KCl ha^{-1} cropping $season^{-1}$ has been tested and gave no response to crop yield. Perhaps, the additional fertilizer or readjustement of the composition of the three fertilizers is required and it needs further study to test the effects.
5. Validation model of GUEST on the surface runoff has come up with the results, which showed different coefficient of determination (R^2) among the land use systems. The

R^2 values of Tegalan, Rambutan and Kalisidi were 0.72; 0.39; and 0.72, respectively. In all land use systems, predicted values showed typical pattern where the flow occurred earlier than the measured one. This suggests that, for application in Indonesia, GUEST model need to be refined by including a parameter of infiltration rate. The processes have explained that Hortonian overland flow occurred in the catchment studied.

Recommendation

So far, the study has been focused on the surface runoff and erosion with respect to the rainfall event. Stream flow is hydrologically not only the result of surface flow but also subsurface flow. Understanding the dynamic behavior of the rainfall – runoff relationship will be more comprehensive if it deals with subsurface flow. The dynamic change in nutrient status in the soil has not been much considered in the present study concerning the nutrient balance.

The future study may cover some topics as follow:

- Linking hydrology and biogeochemical processes
- Hydrologic pathways and erosion processes
- Community-led of soil and water conservation measures

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Institution and Capacity Building

The MSEC project in Indonesia has not only contributed to scientific research, but also given opportunities to the team members to interact with the regional scientific community and learn more about advanced research methodologies through the training, workshops and others. The list of students involved in Indonesian MSEC project is also given below.

Training, Workshops, and Seminars on 2003

Place/Date	Name	Activity/Seminar attended/Paper presented
Los banos, Philippines, July 20-30, 2003	Kasdi Subagyono	International Training-Workshop on Impact Assessment and Process Documentation
Bangkok, Thailand, October 6-10, 2003	Kasdi Subagyono Tagus Vadari	Training-Workshop on Data Management and Interpretation
Bogor, Indonesia, November 1-3, 2003	J.P. Bricquet Tagus Vadari Kasdi Subagyono	Hydras 3/Minimum Data Set of Indonesia

Students doing research in MSEC project site on 2003

I	a. Name of Student	Mr. Tagus Vadari
	b. Degree sought	MS
	c. University Affiliation	Bogor Agricultural University, Indonesia
	d. University Supervisor	Dr. Hidayat Pawitan
	e. Thesis Research Title	Micro-catchment scale Erosion Modeling (tentative)
	f. Duration of Program	Jan. 2002-October 2004
	g. Source of funding support	Personal
II	a. Name of Student	Mr. Sukristiyonubowo
	b. Degree sought	PhD
	c. University Affiliation	University of Ghent, Belgium
	d. University Supervisor	Prof. Dr. Ir. M. Verloo
	e. Thesis Research Title	Nutrient Balance under Different Land Use Systems at Babon Meso Catchment
	f. Duration of Program	2002 - 2005
	g. Source of funding support	Government of Indonesia
III	a. Name of Student	Mrs. Rohlini
	b. Degree sought	PhD
	c. University Affiliation	AIT - Bangkok
	d. University Supervisor	Prof. Dr. Apisit Eiumnoh
	e. Thesis Research Title	USLE Aided Development of Improved Land management Systems
	f. Duration of Program	2002 – 2004?
	g. Source of funding support	Government of Indonesia
IV	a. Name of Student	Mr. Yusrial
	b. Degree sought	MS
	c. University Affiliation	Gajahmada University, Yogyakarta, Indonesia
	d. University Supervisor	
	e. Thesis Research Title	Spatial and temporal variation in infiltration capacity of Babon catchment, Central Java
	f. Duration of Program	Jan. 2002-April 2003
	g. Source of funding support	Government of Indonesia

Financial Status

In the Fiscal Year 2003, research fund was provided by two sources: The Participatory Development of Agricultural Technology Project (PAATP), and International Water Management Institute (IWMI). PAATP provided a budget of 157.500.000 IDR, while IWMI provided a total of US$ 11,000. These funds were used to cover expenses for scientific support and research assistance, travel, supplies and information exchange.

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

C. Valentin, A. Chantavongsa, A. de Rouw, V. Chaplot, J.P. Thiébaux N. Silvera , and G. Lestrelin

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.

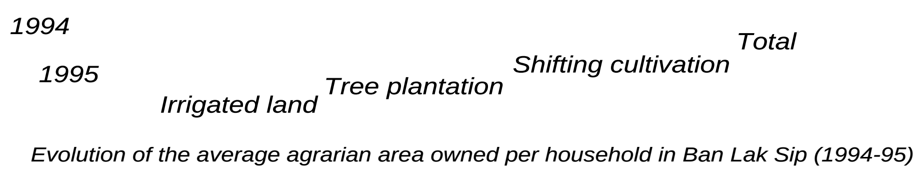

Figure 2. Land allocation for each household in Ban Lak Sip, 1994-1995

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.

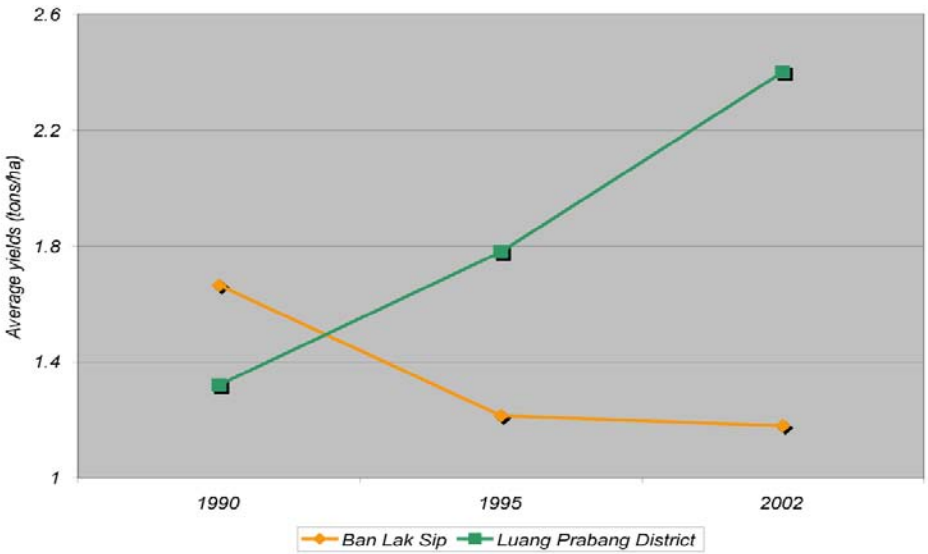

Figure 5. Compared evolution of the upland rice yields in Ban Lak Sip and the Luang Prabang District

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**

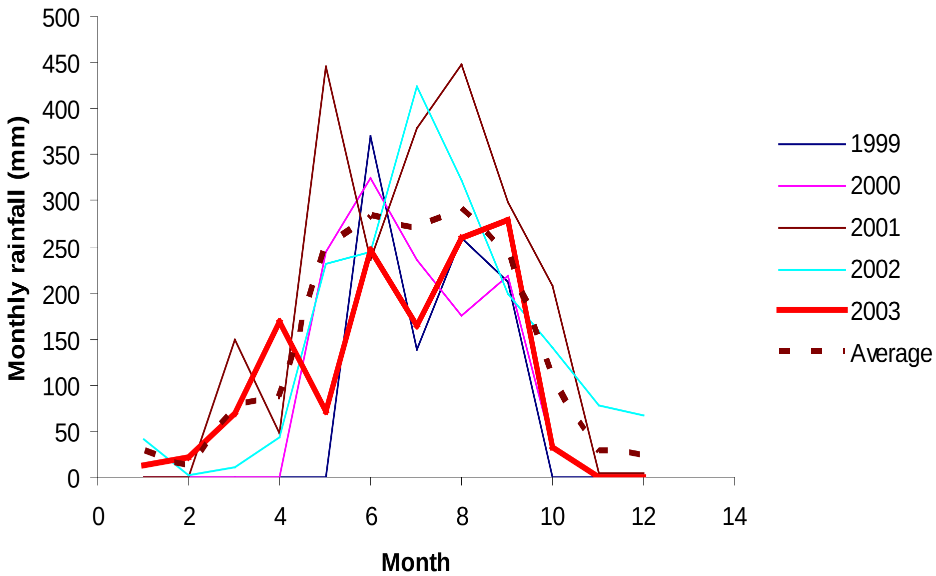

Figure 6. Monthly rainfall in Houay Pano catchment, 1999-2003

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.

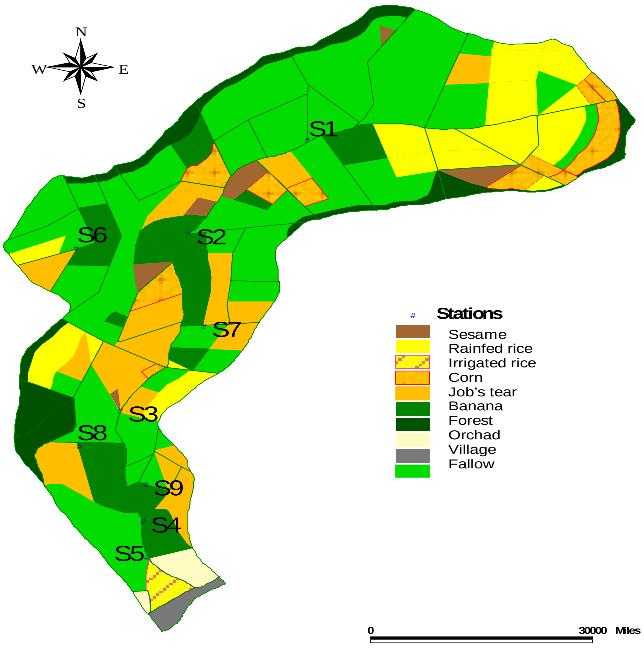

Figure 7. Land use map of Houay Pano catchment, 2003

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**

Slope: 90%

Slope: 60%

Slope: 30%

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

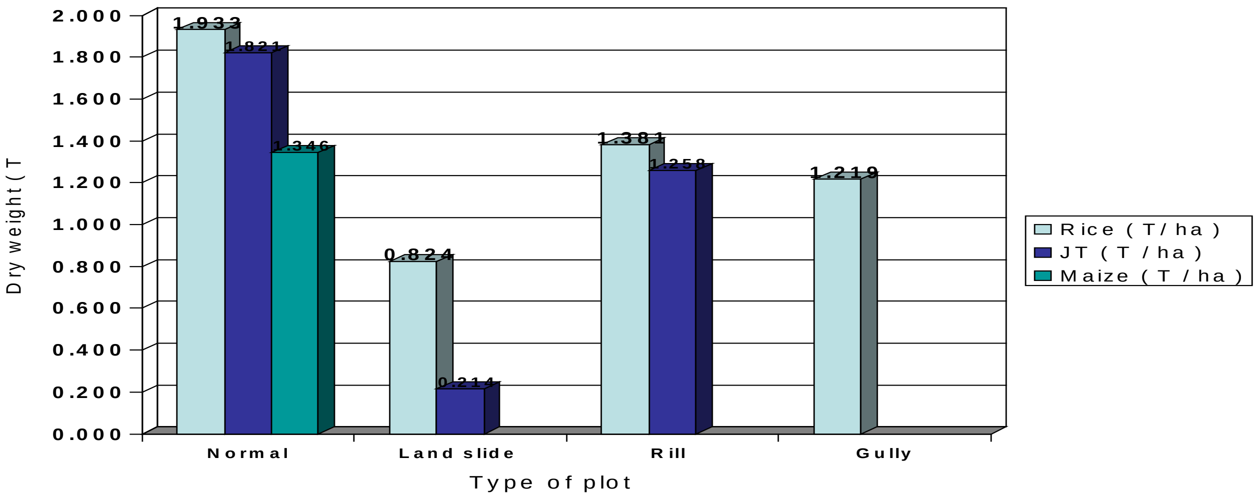

Figure 10. Yields of crops under normal soil and that affected by erosion

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.

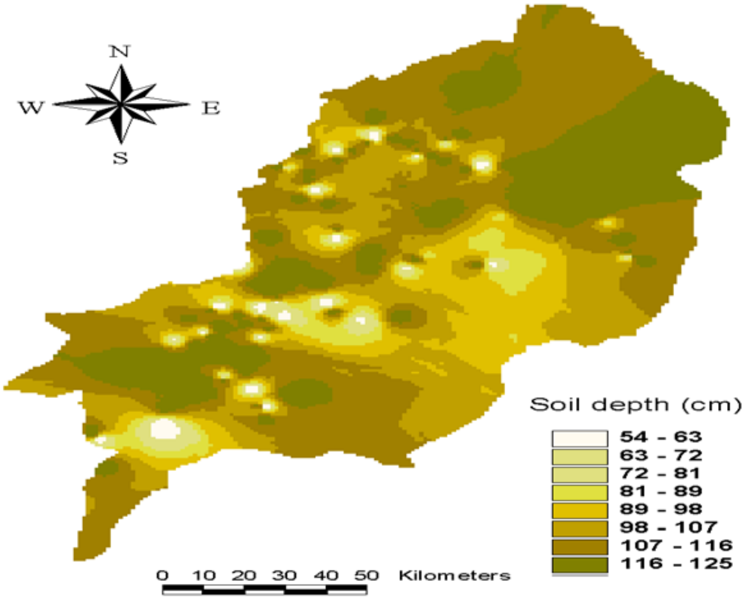

Figure 11. Soil depth map of the Luang Prabang province interpolated using 140 available data points by using inverse distance weighting (IDW) with 12 neighbors. Grid with a 1000-m mesh. Location of streams.

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.

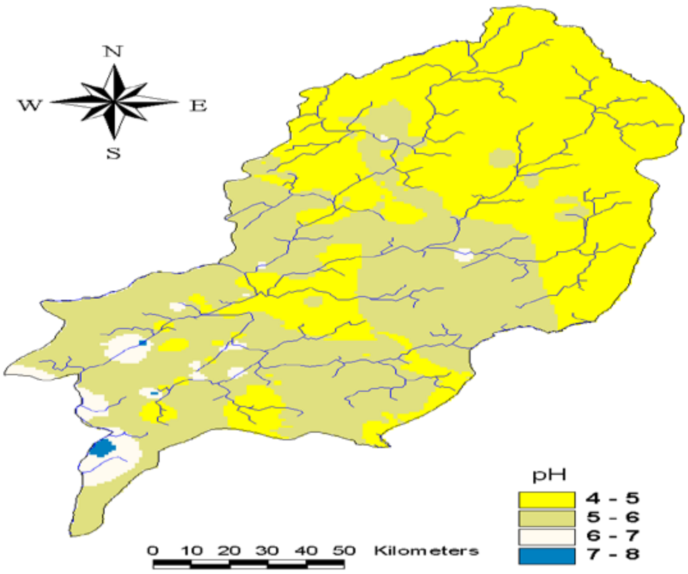

Figure 12. pH map of the Luang Prabang province interpolated using 140 available data points for surface A horizons by using inverse distance weighting (IDW) with 12 neighbors. Grid with a 1000-m mesh. Location of streams

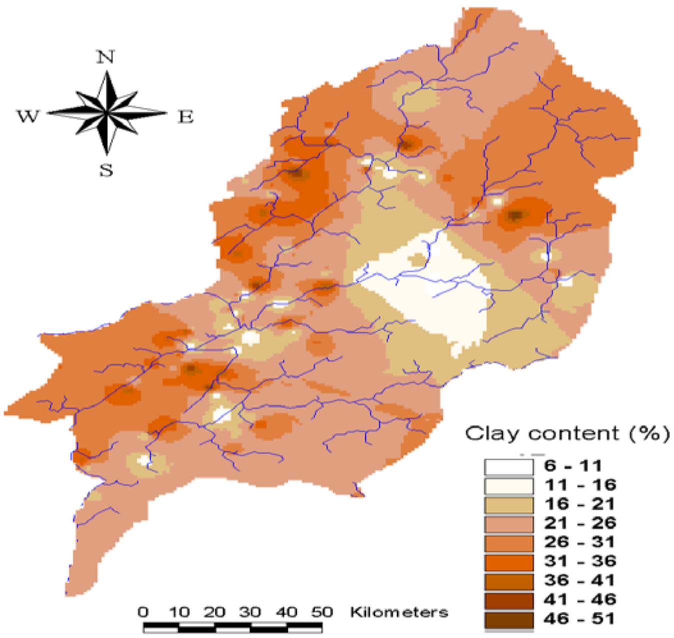

Figure 13. Clay content map of the Luang Prabang province interpolated using 140 available data points for surface A horizons by using inverse distance weighting (IDW) with 12 neighbors. Grid with a 1000-m mesh. Location of streams.

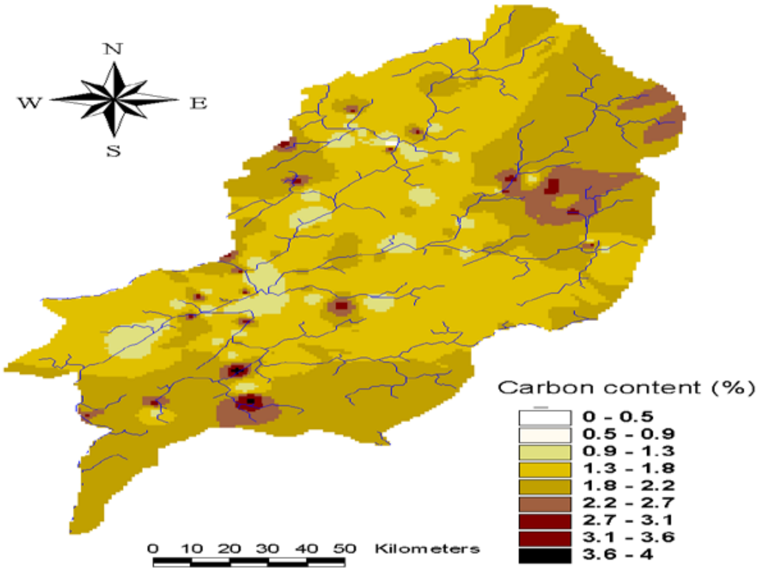

Figure 14. Carbon content map of the Luang Prabang province interpolated using 140 available data points for surface A horizons by using inverse distance weighting (IDW) with 12 neighbors. Grid with a 1000-m mesh. Location of streams.

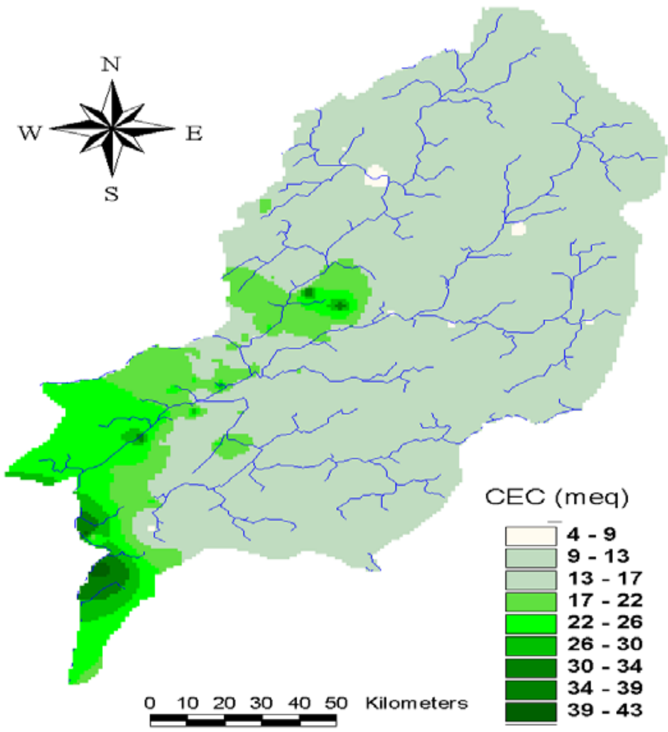

Figure 15. Total CEC map of the Luang Prabang province interpolated using 140 available data points for surface A horizons by using inverse distance weighting (IDW) with 3 neighbors. Grid with a 1000-m mesh. Location of streams.

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

Management of Soil Erosion Consortium (MSEC): An Innovative Approach to Sustainable Land Management in the Philippines

R.B. Cagmat, R.B. Alamban, R.C. Quita, M.T.L. de Guzman,
L.E. Tiongco, N.V. Carpina, and B.G. Santos

Introduction

There have been several erosion studies conducted around the world to address the alarming concern on the loss of soil and natural resources degradation. However, most of those researches are conducted in a plot scale, while only a few addressed the problem on a catchment scale. This has led the then International Board for Soil Research and Management (IBSRAM) to establish the Management of Soil Erosion Consortium (MSEC) as one program under the Soil, Water and Nutrient Management (SWNM) initiative of the Consultative Group on International Agricultural Research (CGIAR). The MSEC methodology is anchored on the innovative research paradigm based on a participatory and interdisciplinary catchment scale approach. In late 1998, the consortium started the project "Catchment Approach to Managing Soil Erosion in Asia". It was implemented in six Asian countries, including the Philippines, with support from the Asian Development Bank (ADB). This phase was completed in December 2002.

The International Water Management Institute (IWMI) continued to support the project in 2003 in partnership with local R&D coordinating agencies in Indonesia, Laos, Philippines, Thailand, and Vietnam. In the Philippines, the project focused on the following objectives:

1. To enhance data management to facilitate exchange and sharing of information among MSEC member countries and other interested users;
2. To continue to:
    a. Quantify and evaluate the biophysical and environmental factors affecting soil erosion.
    b. Generate reliable information and scientifically-based guidelines for the improvement of catchment management for soil erosion control.
3. To conduct more in-depth analysis, assessment and synthesis of data collected during Phase I and have a better understanding of the biophysical and socioeconomic processes and their interactions at the catchment level;
4. To enhance the complementation between the ASIALAND sloping lands and MSEC projects for a more integrated and comprehensive approach to minimizing/controlling soil erosion and increasing land productivity.

This report presents the highlights of the 2003 activities and outputs of the project in relation to research, information dissemination, capacity building, linkages and other related activities.

Activities and Methodology

In relation to these objectives, the activities in 2003 were concentrated on the following:

1. Analysis and assessment of rainfall, runoff and soil loss

2. Evaluation of on-site effects of erosion
3. Monitoring and analysis of land use and socioeconomic changes.
4. Development, dissemination and advocacy of information, education and communication materials on MSEC.
5. Institutionalization and linkages with other agencies and institutions.
6. Formulation and advocacy of relevant policies at the municipal level.
7. Monitoring and assessment of catchment management intervention
8. Enhancement of MSEC Philippines project information database

The methodology for data collection and analysis followed the same procedure employed in the previous years (Ilao *et al*, 2002). However, because of some problems in instrumentation, data collection and monitoring was not done in all microcatchments and for all parameters. Monitoring and analysis of land use changes and socio-economic data were done twice in 2003, in March and December. A ground survey was conducted to gather the changes in land use in the Mapawa catchment.

Likewise, in 2003, MSEC Philippines implemented a complementation scheme proposed in 2002 with the IWMI-ASL Project. This was done by adopting a common site, the Bgy. Maria Paz, Tanauan City, and implementing joint complementary activities.

Results and Discussion

Maintenance of Project Site

In 2003, repair and rehabilitation/improvement of the main weir (Figure 1) and the AMS were undertaken to improve data collection and interpretation. Also, strengthening of the structure is needed as some defects/leakages were detected in the main weir. With regard to the AMS, the Project Team was able to coordinate and solicit support from the Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA) to repair and improve the operation of the said instrumentation. Thus, data collection for the temperature and relative humidity was put to order including the recalibration of the different sensors installed in the AMS.

Figure 1. Repair and rehabilitation of the main weir

Rainfall and Runoff

Rainfall occurs all throughout the year in the MSEC catchment of Mapawa. It increases in the months of April and May and declines in October or November (Table 1 and Figure 2). The driest month monitored during the last four years is April of 2002, with rainfall of only 41 mm, and the wettest is in the month of June of the same year with 548 mm of rain.

The rainfall in 2003 was higher than in the previous years and consequently higher than the average for four years of observation (Figure 3). However, there was no rain observed in the months of January and February which is similar to that observed in 2000.

Table 1. Monthly rainfall in the MSEC catchment from 2000 to 2003

Month	Year				
	2000	**2001**	**2002**	**2003**	**Average**
January	0.0	113.3	166.3	0.0	**69.9**
February	0.0	164.5	70.8	0.0	**58.8**
March	265.9	171.6	110.2	137.5	**171.3**
April	370.9	215.9	40.6	101.5	**182.2**
May	452.7	346.6	165.3	365.4	**332.5**
June	449.8	226.6	548.3	320.3	**386.3**
July	180.7	335.7	89.4	430.7	**259.1**
August	371.1	211.0	329.4	381.3	**323.2**
September	144.4	328.4	189.6	522.0	**296.1**
October	341.0	318.8	349.7	439.7	**362.3**
November	186.9	325.6	137.4	190.2	**210.0**
December	143.6	148.4	148.1	280.1	**180.1**
Total	**2907.0**	**2906.4**	**2345.1**	**3168.7**	**2831.8**

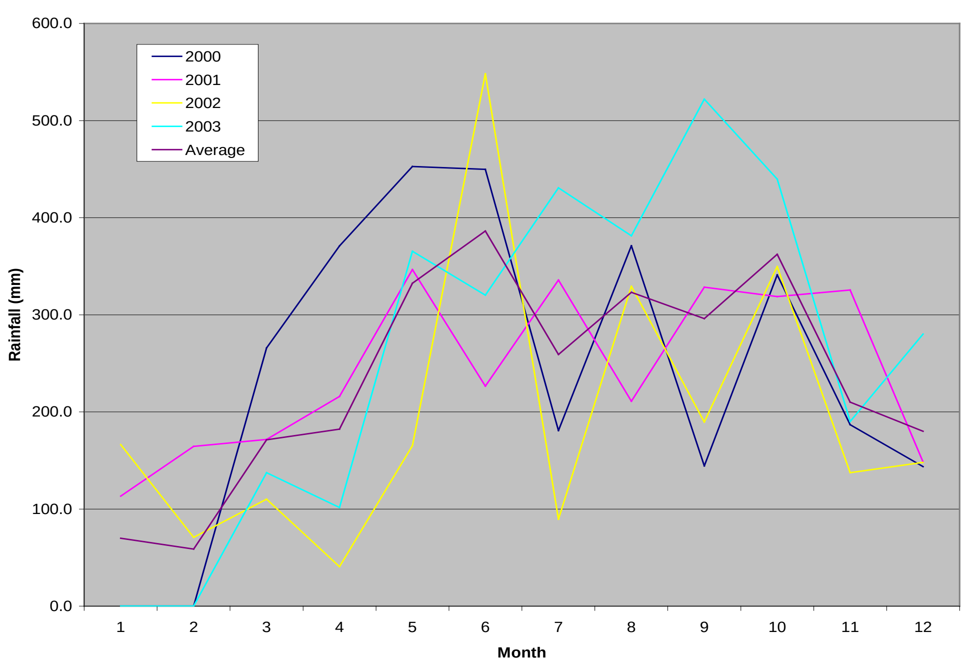

Figure 2. Temporal variation of monthly rainfall in Mapawa catchment, 2000-2003

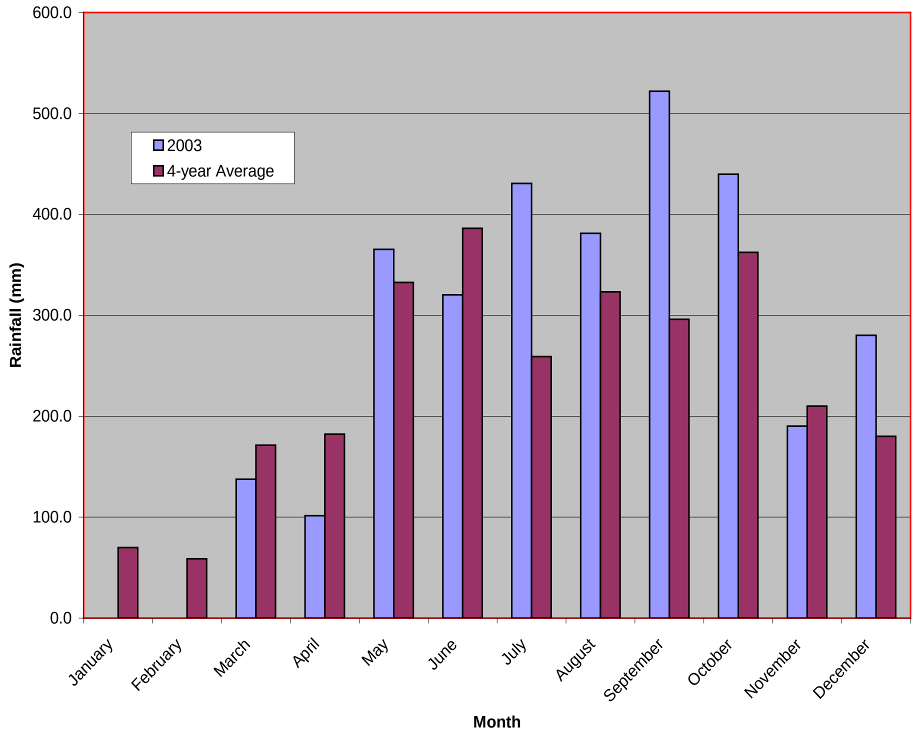

Figure 3. Monthly rainfall in Mapawa catchment in 2003 compared with the four-year average

There were four (4) events that were recorded in the main weir and 10 events in MC2 in 2003. Table 2 shows the amount of rainfall, the flow and the runoff coefficients during these events. There were several events missed because of data logger problems. On the other hand, almost all events in MC2 were recorded. Table 3 shows the suspended sediment concentration and calculated soil loss measured during the four events observed in the main weir. During these events no bed load was observed in the weir.

Table 2. Rainfall, runoff and runoff coefficient of main weir (MW) and MC2 in 2003

N	Catchment	Date of Runoff	Rainfall (mm)	Flow (li)	R (%)
1	MW	9-Sep-03	33.5	4,177	0.01
2	MW	10-Sep-03	26.5	28,580	0.13
3	MW	11-Sep-03	35.5	277,080	0.92
4	MW	13-Sep-03	33.5	398,380	1.41
5	MC2	9-Aug-03	44.0	302,733	3.85
6	MC2	12-Aug-03	15.5	73,050	2.64
7	MC2	15-Aug-03	13.5	753,867	31.23
9	MC2	19-Aug-03	26.0	42,930	0.92
10	MC2	20-Aug-03	24.0	54,207	1.26
11	MC2	10-Oct-03	22.5	62,178	1.55
12	MC2	11-Oct-03	30.5	83,409	1.53
13	MC2	12-Oct-03	19.0	185,742	5.47
14	MC2	13-Oct-03	20.5	2,434,005	66.40
15	MC2	15-Oct-03	66.5	4,106,547	34.54

Sediment Yield

Figure 4 shows the temporal variation of soil loss as bed load in the Mapawa catchment and the four micro-catchments from 2000 to 2003. Soil loss in the main weir increased from 2000 to 2002 but decreased in 2003. As shown in Table 1, the annual rainfall in 2002 was the lowest in four years but the observed bed load was the highest. This was probably because the main weir was reconstructed in January 2002 and the bed load capacity of the trap was doubled compared to the original capacity. A portion of the bed load had not been collected at the trap before the reconstruction. The bed load decreased in 2003, presumably due to the increased awareness about soil erosion as a result of the training the MSEC conducted earlier. Added to this was the cross site visit to Claveria, Misamis Oriental in the later part of 2002. It should be noted that there was an increase in the number of adopters of soil conservation measures in the MSEC catchment, particularly the establishment of the Natural Vegetative Strips as showcased by the ICRAF project. On the other hand, MC2 had the highest bed load yield in 2001 and the lowest in 2002.

Table 3. Sediment concentration, runoff flux, soil loss and rainfall measured in the main weir during four events

Time	**Sediment Concentration ($g\ li^{-1}$)**	**Flux ($li\ sec^{-1}$)**	**Soil loss**		**Rainfall (mm)**
			($g\ 12\ sec^{-1}$)	**(g)**	
Sept. 9, 2003					
4:25:00	2.72	0.9	2.45	245	33.5
4:45:00	1.31	0.2	0.26	26	
5:05:00	0.21	0.1	0.02	2	
5:45:00	0.49	1.3	0.64	64	
6:05:00	0.00	0.6	0.00	0	
		Total		**337**	
Sept. 10, 2003					
4:05:00	4.50	1.7	7.65	765	35.5
4:25:00	2.82	0.9	2.54	254	
5:05:00	1.60	1.7	2.72	272	
5:25:00	4.24	4.3	18.23	1,823	
5:45:00	2.37	4.3	10.19	1,019	
6:05:00	0.16	3.5	0.56	56	
		Total		**4,189**	
Sept. 11, 2003					
3:00:00	6.46	36.6	236.44	23,644	26.5
3:20:00	1.37	28.4	38.91	3,891	
3:40:00	1.25	23.7	29.62	2,962	
4:00:00	0.97	17.5	17.00	170	
4:20:00	0.65	10.9	7.08	708	
		Total		**31,375**	
Sept. 13, 2003					
11:40	2.06	49.4	101.76	10,176	33.5
12:00	1.13	46.0	51.98	5,198	
12:20	2.13	46.0	97.98	9,798	
12:40	1.09	39.6	43.16	4,316	
1:00	0.10	31.0	3.10	310	
1:20	0.46	23.7	10.90	1,090	
		Total		**30,888**	

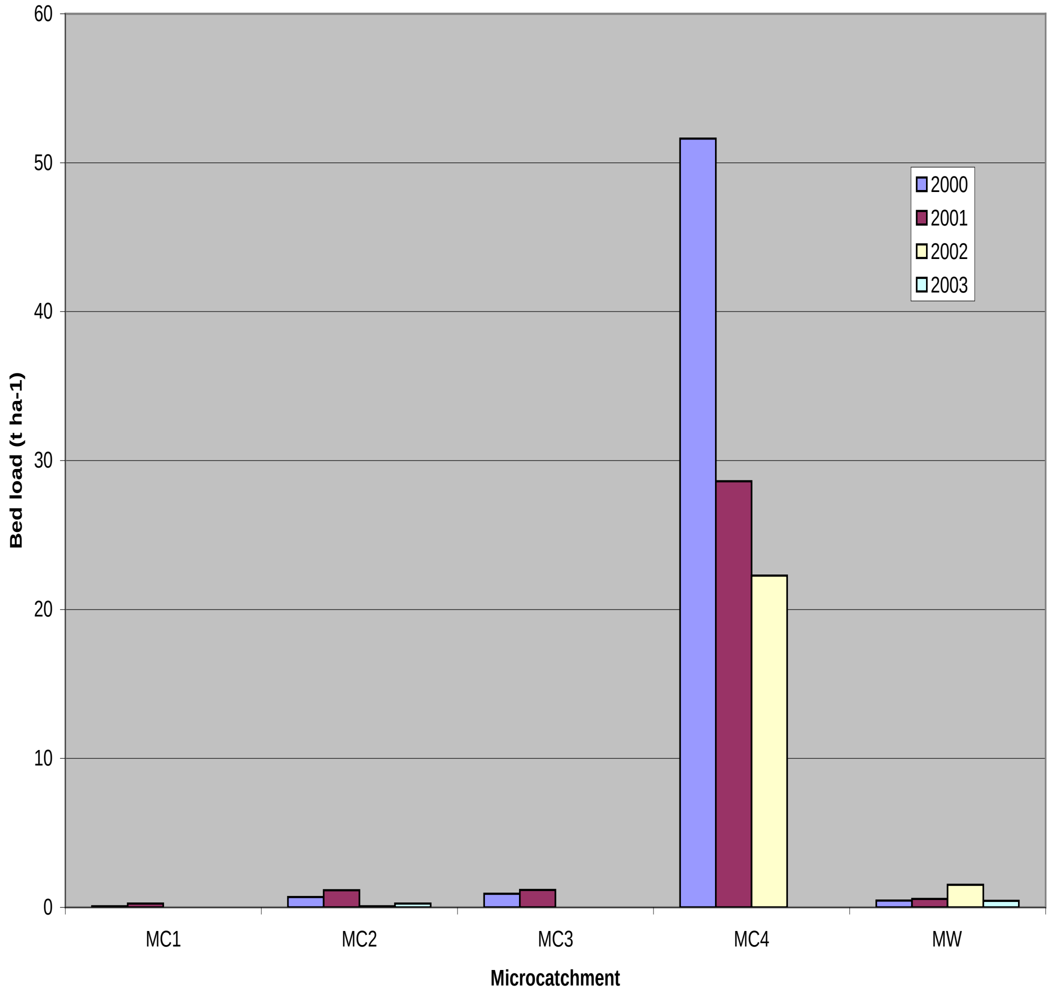

Figure 4. Yearly variation of soil loss in the different microcatchments in the Philippines, 2000-2003.

Nutrient Loss and Replacement Cost

Table 4 shows the nutrient loss and the cost of soil erosion using the replacement cost analysis on a yearly basis from 2000 to 2003. The cost to replace the nutrient N in all microcatchments was very high compared to P and K. This was probably because the P and K contents in the soil were relatively lower than N. Furthermore, there was a significant decline in organic matter as shown in the monitoring of the changes in chemical properties of the soil. The P and K content was more or less sustained after three years.

The cost to replace N in the four year data generally differs, with 2002 having the highest recorded cost. The information presented in the various tables were only those derived from the measured bed load. For sure, the cost would be much higher if the nutrients carried in the suspended sediment were considered. Nevertheless, this simple estimate clearly showed the need to reduce erosion in order to maintain the soil fertility in the sloping uplands.

Table 4. Nutrient loss and replacement cost of erosion in MC2 and the whole Mapawa catchment, 2000-2003.

Year	Soil loss	Nutrient loss (kg)			Replacement cost (PHP)		
	(t ha-1)	N	P	K	N	P	K
MC1							
2000	0.45	112.67	0.07	12.57	1715.42	1.99	183.63
2001	0.57	88.4	0.11	14.5	1422.4	3.13	222.9
2002	1.52	134.6	0.08	16.65	2166.15	2.22	256.7
2003	0.43	63.72	0.02	6.79	1745.93	0.51	141.66
Mapawa							
2000	0.69	38.04	0.03	2.11	579.17	0.85	30.84
2001	1.15	44	0.05	7.17	708.41	1.52	110.25
2002	0.08	3.8	0	0.57	60.4	0.08	8.82
2003	0.26	9.82	0.01	1	268.99	0.26	20.68

Land Use

Table 5 shows the changes in land use in the catchment from 2000 to 2003. The cropped area of microcatchment 1 (MC1) increased from 5% in 2000 to 18% in 2003, while the increase was from 16% to 21% for the whole catchment (Figure 5). New areas were opened for potato plantation and a good number of farmers started adopting the NVS technology in the area. Micro-catchments 2, 3, and 4 had very little changes in land use.

Presented in Table 6 are the proportion of the catchment and microcatchments planted to corn monocrop, area under crop rotation and under fallow in 2003. Aside from corn (*Zea mays*) which is the staple crop, other high value crops are also grown. These include vegetables such as wongbok (*Brassica rapa* L.), cabbage (*Brassica olaiacea*) and tomato (*Lycopersicum esculentum*). The farmers usually plant corn as a monocrop. However, crop rotation is practiced in a larger percentage of the entire catchment in about 12.4 ha or 15% of the whole catchment. Only 3% of the area is planted to corn monocrop. A comparison among cropping systems showed that all of the farmers in MC1, MC2 and MC4 plant high value vegetables rotated with corn. On the other hand, the cultivated area in MC3 is used for monocrop.

Table 5. Land use change in the MSEC catchment from 2000 to 2003.

Catchment	Area (ha)	Land Use			
		2000	2001	2002	2003
MC1	24.9	74.6% open grassland, 16% forest plantation, 4% shrubs/ bamboo and 5.4% cropland	74.6% open grassland, 16% forest plantation, 4% shrubs/bamboo and 5.4% cropland	60% open grass land, 16% forest, 4% shrubs and 18% cropland	60% open grassland, 18% cropland, 16% forest plantation , 4 % shrubs/ bamboo
MC2	17.9	65% open grassland, 20% cropland, 11% forest plantation , 4% shrubs/ bamboo	65% open grassland, 20% cropland, 11 % forest plantation, 4% shrubs/bamboo	65% open grassland, 20% cropland, 11% forest plantation, 4% shrubs/bamboo	65% open grassland, 20% cropland, 11% forest plantation, 4% shrubs/bamboo
MC3	8	80% open grassland, 13% forest plantation, 6% cropland, 1% shrubs/ bamboo	80% open grassland, 13 forest plantation, 6% cropland, 1% shrubs/bamboo	80% open grassland, 13% forest plantation, 6% cropland, 1% shrubs/ bamboo	80% open grassland, 13% forest plantation, 6% cropland, 1% shrubs/bamboo
MC4	0.9	42% cultivated, the rest are G-melina and open grassland	42% cultivated, the rest are G-melina and open grassland	42% cultivated, the rest are G-melina and open grassland	42% cultivated, the rest are G-melina and open grassland
Mapawa	84.5	15.4% forest, 11.8% shrubs/ bamboo, 16% cropland, 56.8% open grassland	15.4% forest, 11.8% shrubs/ bamboo, 16% cropland, 56.8% open grassland	15.4% forest plantation, 11.8 % shrubs/bamboo, 19.6% cropland, 53.2% open grassland	51.8% open grassland, 15.4% forest plantation, 21% cropland, 11.8% shrubs/ bamboos

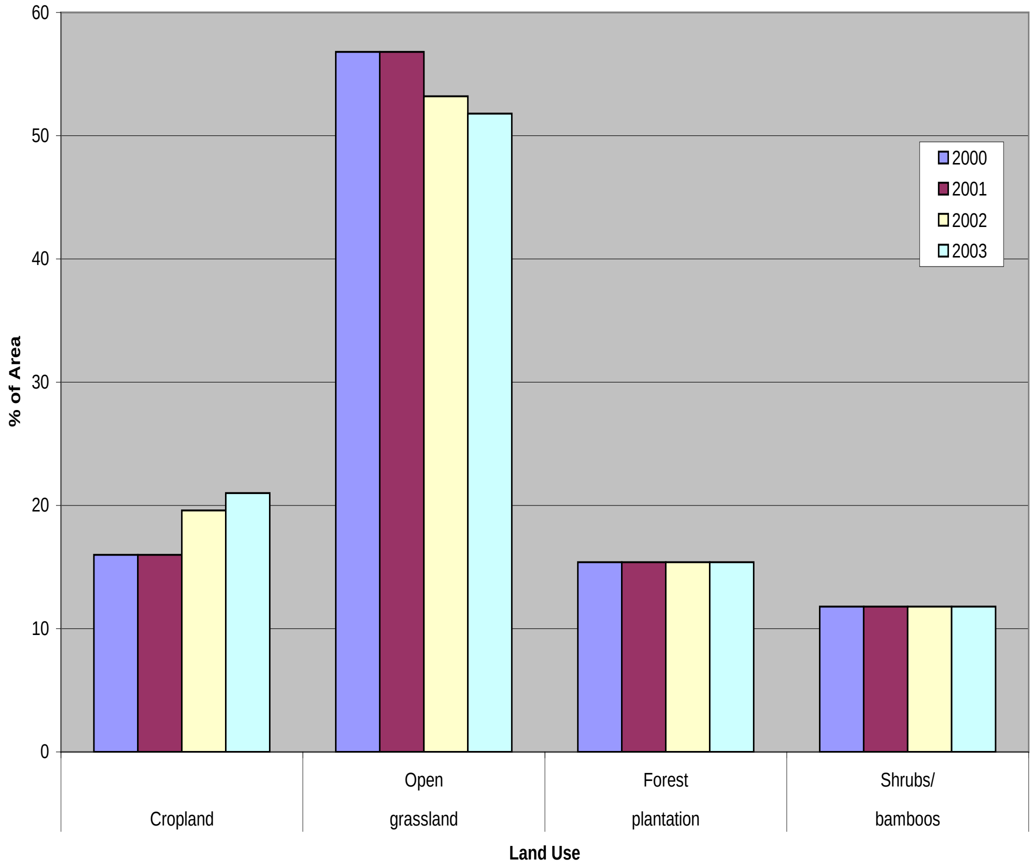

Figure 5. Change in land use of the Mapawa catchment from 2000 to 2003.

Table 6. Area planted to corn monocrop, under crop rotation and under fallow in 2003.

Catchment	Area (ha)	Corn Monocrop		Crop Rotation		Fallow	
		Area (ha)	% of Area	Area (ha)	% of Area	Area (ha)	% of Area
MW	84.5	2.66	3.14	12.4	14.64	2.69	3.17
MC1	24.93	0	0	3.55	14.24	0.94	3.77
MC2	17.88	0	0	2.32	12.78	0.77	4.31
MC3	7.96	0.5	6.28	0	0		
MC4	0.94	0	0	0.24	28.72		

A certain portion of the cultivated area has been left fallow for a number of years already (Table 7). Leaving the land fallow for a certain period is practiced as a pest management strategy to prevent potato bacterial wilt. The planting calendar followed by the farmers is shown in Table 8. A comparison of the income derived from farming employing crop rotation and cultivation of corn monocrop is shown in Table 9.

Table 7. Area under fallow of one to three years as of 2003

Catchment	Area (ha)	One Year Fallow		Two Years Fallow		Three Years Fallow	
		Area (ha)	Area (%)	Area (ha)	Area (%)	Area (ha)	Area (%)
MW	84.5	0	0	0.86	3.45	1.29	1.52
MC1	24.93	0.77	4.31	0	0	1.32	1.56
MC2	17.88		0	0	0.32	0.08	0.09

Table 8. Planting calendar from May 2000 to December 2003 of farmers in the catchment

Name of Farmer	May 2000	Sep 2000	May 2001	Sep 2001	Mar 2002	Aug 2002	Mar 2003	Dec 2003
Ernesto Timay	Potato			Wongbok				Potato
Vicente Quilaton		Corn	Corn		Corn	Beans		Potato
Julius Quilaton	Corn	Wongbok		Corn		Corn	Corn	
Ernesto Tamola							Cabbage	Wongbok
Domingo Conge			Potato					
Danilo Longjas							Potato	Tomato
Roger Tanosan		Corn		Tomato	Tomato		Corn	Wongbok
Carlito Dalaut				Corn			Potato	Wongbok
Ignacio Longjas	Potato							
Jessie Dawat	Cabbage		Corn			Corn		
Billy Layahon			Corn	Tomato		Tomato		
Ernesto Timay	Wongbok	Potato						
Rudy Lunga								Potato
Ener Ayocan							Carrots	Potato
Leonardo Galap					Potato			Corn
Dencio Dique					Cabbage			
Adelina Sihagan								Cabbage
Ruben Layahon								Tomato

Table 9. **Comparison of net income (Phil. Peso) from crop rotation and monocrop cultivation**

	May 2000	Sep 2000	May 2001	Sep 2001	Mar 2002	Aug 2002	Mar 2003	Dec 2003
				Crop Rotation				
Cost of Input	15478	699	6887	3533	8730	4964	11865	18154
Gross Income	63258	2712	42382	48150	21953	17221	24966	66491
Net Income	47779	3798	54388	73741	31517	29734	21473	42138
				Monocrop				
Cost of Input	2,000	1,426	2,487	2,779	1,240		2,740	2,428
Gross Income	8,000	3,924	3,633	6,678	1,854		8,074	12,624
Net Income	6,000	2,964	2,128	3,899	614		5,334	10,196

Soil Chemical Properties

Presented in Table 10 are the soil chemical properties in MC2 under different cropping systems. There were twelve (12) parcels being cultivated in the microcatchment, with 11 parcels employing crop rotation and one parcel planted to corn as a monocrop. The crops grown were during the time the area was surveyed. On the average, there was no change in the soil pH and extractable P and a slight decrease in exchangeable K in the farms of eleven farmers practicing crop rotation.

Only one farmer planted a monocrop of corn with NVS since 1999 adopting the technology from ICRAF. There was an increase in the pH from 4.9 to 5.3 after two years although no lime was applied. However, the organic matter content decreased from 9 to 7% in the two-year period. There was also a slight increase in phosphorus and a decrease in potassium. The farmer applies inorganic fertilizer.

The only farmer practicing rotation and with NVS is Roger Tanosan. He established his NVS in 1997. From 2000 to 2002, the soil extractable P, exchangeable K, and organic matter decreased from 15.4 to 7.04 ppm, from 333 to 213 ppm and organic matter from 11.4 to 4.80%, respectively. However, the pH has been maintained within the period of two years.

Table 10. Soil chemical properties in MC2 under different cropping systems.

Parcel Owner	2000					2002				
	Crop	pH	O.M (%)	Extr. P	Exch K	Crop	pH	O.M. (%)	Extr. P	Exch. K
Crop Rotation										
Roger Tanosan	Corn	4.9	10.42	3.1	213	agroforestry/ tomato	4.4	5.63	8.8	183
Jessie Dawat	Cabbage	4.6	12.11	9.6	405	Corn	5.0	9.38	1.7	141
Roger Tanosan	Potato	4.9	11.41	15.4	333	corn	4.8	7.04	4.8	213
Densio Dique	Corn	4.7	2.82	9.9	162	cabbage	5.2	8.21	9.8	309
Dencio Dique	Corn	4.8	6.1	9.3	204	corn/sweet potato	5.0	5.16	3.1	270
Dencio Dique	Corn	5.3	10.7	1.9	159	fallow	5.2	7.27	2.3	114
Ronilo Compas	Corn	4.9	9.43	2.9	261	corn	4.9	7.27	0.7	99
Victor Compas	Corn	4.9	9.43	2.9	261	corn	5.3	6.68	3.5	210
Gilbert Ceballos	Fallow	5.1	9.72	3	243	vegetables	5.1	5.63	0.9	381
Average		4.9	9.13	6.4	249		5.0	6.92	3.96	213
With NVS and on crop rotation										
Roger Tanosan	Potato	4.9	11.41	15.4	333	corn	4.8	7.04	4.8	213
Farmer monocrop to corn and with NVS										
Victor Compas		4.9	9.43	2.9	261	corn	5.3	6.68	3.54	210

Catchment Management Intervention

Alley cropping using natural vegetative strips

Even before the project, some of the farmers in the area had been practicing some conservation practices in their farms. There were seven existing NVS adaptors cultivating an area of 3.5 ha and 1.4 ha practicing agroforestry with eucalyptus. After the cross site visit conducted in September 2002, the number of adaptors of NVS in the MSEC catchment increased. Seven farmers with a total farm area of 3.2 ha adopted the technology (Table 11).

Table 11. Farmers who adopted NVS, 2002-2003.

Name	Year established	Estimated area (ha)
1. Vicente Quilaton	2002	0.51
2. Eddie Montesa	2003	0.24
3. Dominador Balansag	2002	0.25
4. Carlito Dalaut	2003	0.64
5. Ernesto Tamola	2002	0.57
6. Ener Ayocan	2003	0.23
7. Benedicto Devilleries Jr.	2002	(1) 0.24
		(2) 2.68

Stream bank stabilization

The project conducted training on Laak bamboo (*Bambusa sp.*} propagation and provided bamboo propagules to interested farmers. Farmers whose areas are near the creek were encouraged to plant bamboo near stream banks to reduce soil erosion. Erosion in the stream bank is considered a major cause of soil loss in the catchment and has contributed much in the amount of sediment yield measured after a storm event.

A total of 300 propagules have been distributed to 13 farmers, almost 35% of these propagules (130 pcs) was given to Mr. Benedicto Devilleries Sr. whose farm lies along a creek and is intensively grown to corn throughout the year.

Livestock fattening

The project introduced livestock dispersal to motivate farmers in adapting conservation measures in their farm. Four heads of cattle were given to four beneficiaries who have already established a conservation practice, particularly with the NVS technology. The animals were distributed in the last quarter of 2002. Two of the animals were provided by the Local Government of Lantapan under their Livestock Dispersal Program.

Impact Assessment

In 2003, no follow-up activities were done on assessing the impacts of the project. However, two stakeholder surveys were undertaken to collect relevant information and data that could be used later for impact assessment of the project. In fact, PCARRD is requiring all its coordinated projects to undertake regular assessment of impacts of these projects.

Collaboration with ASIALAND Project

To strengthen the collaboration with another IWMI project, the ASIALAND sloping lands project, a monitoring station was established in Bgy. Maria Paz, Tanauan City, Batangas (Figure 6).

Figure 6. Weir at the Maria Paz site

However, the weir being constructed was damaged when a very heavy downpour occurred in August, 2003. It was repaired immediately with the technical and financial help of the Local Government Unit (LGU)-Tanauan City, contributing US$ 1,500 for the repair and improvement of the weir and the necessary support structure. IWMI-ASL Project and the Bureau of Soils and Water Management (BSWM) contributed also in terms of financial and technical support by complementing the structure with the establishment of a Water Impounding structure at the downside of the weir to collect and impound water mostly coming from the weir and use it for irrigation of nearby fields. Corn and vegetables are the most common crops planted in these farms.

Figure 7 shows the rainfall pattern in the area from 1989 to 1999. The rainfall belongs to the Type I climate classification in the Philippines as contrasted to the Type IV climate in Lantapan Bukidnon. Wet months are from July to November and very dry months are usually from January to March. This is only altered during El Niño and La Niña occurrences.

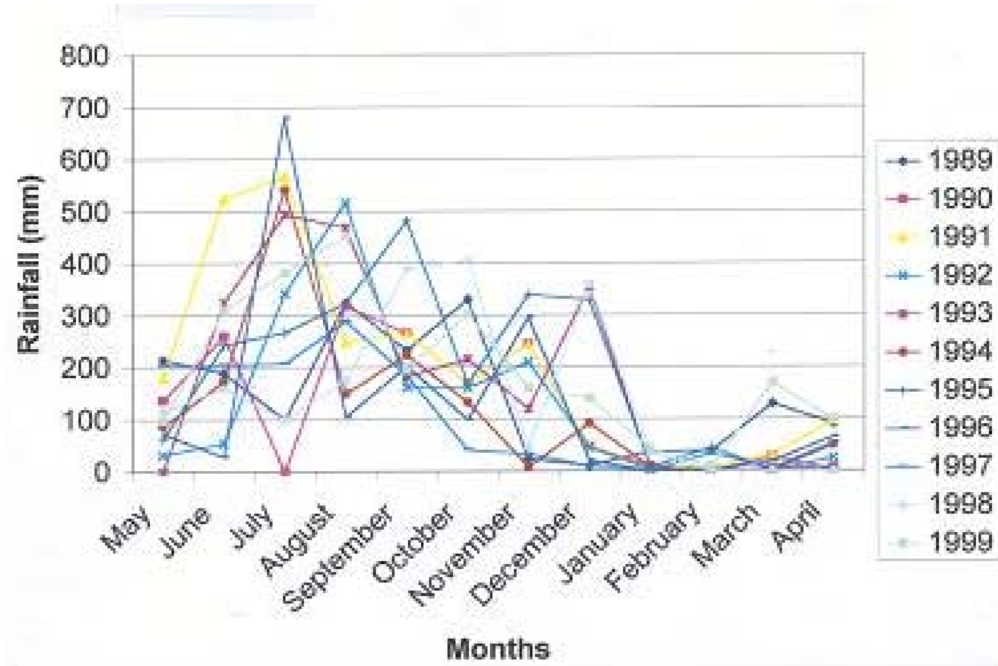

Figure 7. Rainfall pattern in Maria Paz from 1989-1999, PAGASA

Summary and Conclusion

Land use management in relation to soil erosion management is primarily influenced by ethnic background/culture, farming experiences accumulated through the years, environmental resources available in the locality, and trading/marketing forces prevalent in the area and the surrounding environs. These considerations can be viewed from the current farming community dynamics in Lantapan and Maria Paz sites. However, the degree and manner of interplay of these influences varied in these two sites.

Most of the farmers in these two sites derived substantial portion of their income from economic activities outside of the catchments. Off-farm income of farmers from Maria Paz Farmers are relatively higher than their counterparts in the Lantapan site because of more opportunities abound in nearby areas such as the industrial parks and related industries than those found in Bukidnon and nearby provinces.

The study of soil erosion management at catchment level have brought together the various stakeholders in an area, deepened the understanding of interaction among biophysical and social, economic and institutional aspects. The holistic and interdisciplinary manner of bringing together all the stakeholders can be described as difficult and requires more resources, but holds promise of being more sustainable, especially in institutionalizing the approach among these stakeholders.

The participatory approach to the research design and implementation remains as the best effective means of sustaining the cooperation of land users especially in the selection of land management options that will be most beneficial to them. However, it is necessary that participatory rural appraisal, focused group discussions and key informant interviews should be done regularly to solicit feedbacks and information critical in the assessment of the impacts of the approach and interventions introduced by the project to the stakeholders.

The project has generated and compiled data and information that will have to be sustained and utilized. For further analysis of these information should be done and should be shared and exchanged with other country partners and stakeholders. Further analysis and interpretation will bring out more meaningful information leading to more firmed up conclusions vital in the modeling the results for strategic planning and management of our natural resources and environment.

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Capacity Building

At the regional and country levels, IWMI identified the needs of the country partners and NARES on skills and capabilities to achieve the objectives of the consortium. The conduct of soil erosion research on catchment is relatively new. With the reorganization and addition of the Ma. Paz site to the project, the project team and various stakeholders need to be continuously equipped with tools and concepts to better understand and enhance their capabilities on the various interactions among the biophysical, social, economic and institutional factors at the catchment level with regard to soil erosion management.

In 2003, there were 4 training-workshops sponsored by IWMI and MSEC-Philippines attended by the members of the project team and the various stakeholders. These trainings provided the MSEC researchers and stakeholders, especially in Ma. Paz site, the necessary skills and knowledge on how to collect and process data gathered by the project. For the Lantapan site, the farmers and the Lantapan LGU were updated on the developments of the project implementation and given some guidance on the organization and management of their association/cooperative. A Technology Needs Workshop was also done to identify and formulate recommendations to address these needs.

Capacity building activities of the researchers and coordinator are not limited to the informal and formal trainings. Attendance to agency in-house reviews, field visits and committee meetings organized by the other country partners were actively participated by the MSEC-Philippines. Exchange of information with other scientists contributed much to increase in understanding of biophysical, social and economic phenomena covered by the project. Field exposure greatly enhanced technical skills in the use of devices, experimental designs and structure needed by the project.

Trainings conducted/attended by the IWMI/MSEC Philippines Project Team.

Title/Subject Of Training	Date	Venue	Participants
1. Stakeholders Training -Workshop on Cooperative Development and Technology Needs		Bgy. Songco, Lantapan, Bukidnon, Philippines	Dr. Rebecca Cagmat Engr. Raul Alamban Engr. Ruby Quita Ms. Lydia Tiongco LGU-Lantapan LGU-Songco ICRAF researchers CMU student interns Mapawa farmers
2. Impact assessment and process documentation	July 20-30, 2003	PCARRD, Philippines	Engr. Raul Alamban Dr. Rebecca Cagmat Engr. Ruby Quita Ms. Ma. Teresa de Guzman MSEC partners from Thailand, Laos, Vietnam, and Indonesia
3. Data management and interpretation	October 6-10, 2003	Bangkok, Thailand	Engr. Raul Alamban Ms. Ma. Teresa de Guzman
4. Project orientation and participatory approaches for catchment research, biophysical processes instrumentation and data collection		Bgy. Ma. Paz, Tanauan City, Philippines	Engr. Ruby Quita Engr. Raul Alamban LGU-Tanauan City LGU-Ma. Paz Ma. Paz farmer-volunteers

Four (4) development communication undergraduate student interns worked with the project as part of their internship training. They were tapped in the documentation of meetings, workshops and trainings conducted by the project.

Workshop with stakeholders to assess technology needs

Information Dissemination

Information about the project and its activities and related information have been presented at the regional, national and municipal/catchment levels. At the regional level, the conduct of the International Training-Workshop on Impact Assessment and Process Documentation at PCARRD, Los Baños, Laguna, Philippines in July, 2003 facilitated exchange of information and experiences of the Project. At the local level (national, regional, municipal), information about the project and its status were presented during the meetings of LPHC and NOMCARRD-coordinated meetings and agency in-house reviews held regularly. The MSEC Database is being shared with the LPHC and other interested stakeholders of the project.

At the national level, information on the MSEC Philippines Project was presented during the meeting of the PCARRD Directors' Council Meeting on February 19, 2003 at PCARRD, Los Baños, Laguna. Other venues where the information about the project were presented were the Annual In-house Reviews of the Central Mindanao University, the Regional Symposium on R&D Highlights being conducted by the NOMCARRD, and local exhibits held in Lantapan and Cagayan de Oro City. Further, the Project is actively supporting the establishment of a Farmers' Information and Technology Services (FITS) Center in Lantapan to showcase the various information of the project. FITS is one of the components of the PCARRD-coordinated "National Techno Gabay Program".

At the municipal/catchment level, the information and results generated by the project were presented during the Lantapan Project Holders' meetings and during consultation meetings with the farmers/stakeholders.

Institutional Linkages and Policy Advocacy

One of the principal mandates of the Philippine Council for Agriculture, Forestry and Natural Resources Research and Development (PCARRD) is strengthening and improving continuously the capability of the National Agriculture and Resources Research and Development System (NARRDS) to organize, manage and conduct R & D activities. PCARRD strategically operates as a network, coordinating the R & D activities of government departments and state colleges and universities in various regions through its established regional R & D consortia.

MSEC's site in the Philippines is in Lantapan, a municipality in the province of Bukidnon. Bukidnon is one of the three provinces comprising Region 10 in the northern island of Mindanao. The consortium in this region is the Northern Mindanao Consortium for Agriculture and Resources Research and Development or NOMCARRD. Its base agency is the Central Mindanao University while its member agencies include the following:

1. Department of Agriculture - Region10
2. Department of Science and Technology - Region 10
3. National Economic Development Agency - Region 10
4. Department of Environment and Natural Development - Region 10
5. Central Mindanao University
6. Misamis Oriental State College of Agriculture and Technology
7. Mindanao State University - Institute of Fishery and Development
8. Xavier University
9. National Irrigation Administration - Region 10
10. Mindanao Polytechnic State College

MSEC Philippines Project is linked to the NARRDS at the national and municipal levels. NOMCARRD reviews, monitors and evaluates MSEC Philippines Project through the mechanisms of agency in-house reviews (AIHRs) and conduct of Regional Symposium (RS) just like any other R & D projects implemented in Region 10.

At the municipal level, PCARRD established the Lantapan Project Holders' Committee (LPHC) composed of a Steering Committee (SC) and the Technical Working Group (TWG). It is being coordinated and led by the PCARRD-coordinated Sustainable Agriculture and Natural Resources Management (SANREM) Project. The SC is composed of representatives from national and international agencies with projects at Lantapan such as PCARRD, SEARCA, ACIAR and ICRAF. NOMCARRD, CMU, Lantapan Local Government Unit (LGU), Province of Bukidnon as well as the regional offices of the Department of Agriculture and the Department of Environment and Natural Resources are also represented in the SC. The TWG is composed of the coordinators/project leaders of the various R & D projects being implemented in Lantapan municipality including the MSEC-Philippines. Also included are non-government organizations (NGOs) and various private entities located in Lantapan.

The LPHC is the integrating mechanism at the municipal level while the NARRDS (with PCARRD as the Secretariat) integrates MSEC R & D activities at the national level.

Policy Advocacy

To follow-up what has been undertaken in 2002, the Project organized a Dialogue and Consultation Workshop with the officials of the LGU-Lantapan Municipal Council and the representative of the Department of Interior and Local Government (DILG) in the province of Bukidnon to discuss the progress of activities started in 2002 on policy advocacy on soil and water resources management for various stakeholders, especially the farmers in the Mapawa catchment. The general intent is to formulate policy instruments at the municipal level for natural land resource management. The discussion is focused on the drafting of the Implementing Rules and Regulation (IRR) for relevant ordinances and resolutions passed by the Municipal Council.

As a result of the dialogue/consultation, the Council requested the Office of the Mayor to initiate the drafting of the IRR through the Office of the Municipal Agricultural Officer (MAO). The Mayor is agreeable to the request provided that this effort will be in line and in support of the draft Lantapan Municipal Watershed Development Plan and Program. He requested the Council to act and pass the said Plan and Program soonest to be able to implement it in tandem with related ordinances and resolutions. The Project offered to extend the necessary technical support to the activities to be undertaken by the LGU-Lantapan.

Institutionalization of the Project

In 2003, the Project Team initiated discussions and arrangements with the LGU-Lantapan and the Bureau of Soils and Water Management (BSWM) for the institutionalization of the project under their respective mandates and functions. The LGU-Lantapan had seriously considered the absorption of the project under the Office of the MAO by 2005. Recently, the LGU-Lantapan had created the Municipal Environment and Natural Resources Office (MENRO) administratively under the MAO.

Further, the BSWM through its Director, Dr. Rogelio Concepcion, had agreed in principle to officially consider the MSEC sites in Lantapan and Maria Paz as part of the BSWM Outreach Station Network. Hence, these sites will be visited regularly by the BSWM researchers to conduct regular activities related to soil erosion management. It will also extend technical assistance to the concerned LGUs in the operation and management of the sites and their facilities.

Likewise, PAGASA will consider the AMS in the Lantapan site as part of its Meteorological Station Network in the Philippines. With this consideration, technical assistance on the regular check-up, repair and maintenance of the said equipment will be provided by PAGASA. Drafts of the MOA on the various collaborations of the Project with these institutions are now being reviewed by the concerned stakeholders and the Project Team.

Catchment Approach to Combating Soil Erosion in Thailand

J.P. Bricquet, J.L. Janeau, A. Boonsaner, J.P. Luc, S. Huon, C. Boulais, G. Lestrelin and M. Kurian

Introduction

Erosion is a major cause of soil degradation in the world. It is a natural phenomena but inappropriate land use can significantly accelerate the impacts of erosion processes. It decreases arable surface, reduce soil fertility, cause harmful effects like soil and water pollution, the silting of reservoirs and irrigated fields. Subject to threshold, erosion varies considerably from one farming system to another. Water erosion (sheet and gully erosion), tillage and wind erosion are the main types of erosion (Valentin, 2001). In the humid and semi-humid tropics, rain and tillage erosion are the most important, causing decreases in crop yields and the loss of valuable arable land. In Southeast Asia, erosion rates range from 2 to 54 t ha^{-1} yr^{-1} according to land use and farming practices.

Understanding and modelling rainfall and tillage erosion is very important in all developing countries. This is due to the need to ensure the sustainability of the agricultural system. Rainfall induced soil erosion has several impacts. These include sheet erosion, linear cutting, mass movement and chemical degradation (Zante *et al*, 2003). Linear cutting is often presented as the most significant source of erosion.

In Thailand, MSEC has analysed the emergence and impacts of rainfall erosion in a small catchment. The main objective is to develop land management systems to better control erosion and increase income of farmers by evaluating both the biophysical and socioeconomic dynamics in the study catchment. Two forms of soil erosion, namely, rainfall and tillage erosion are investigated. Further, the study demonstrated how rainfall and tillage erosion results in the emergence and development of gullies. Investigations into the typology and the functioning of gullies can provide solutions that allow the adaptation of agricultural techniques.

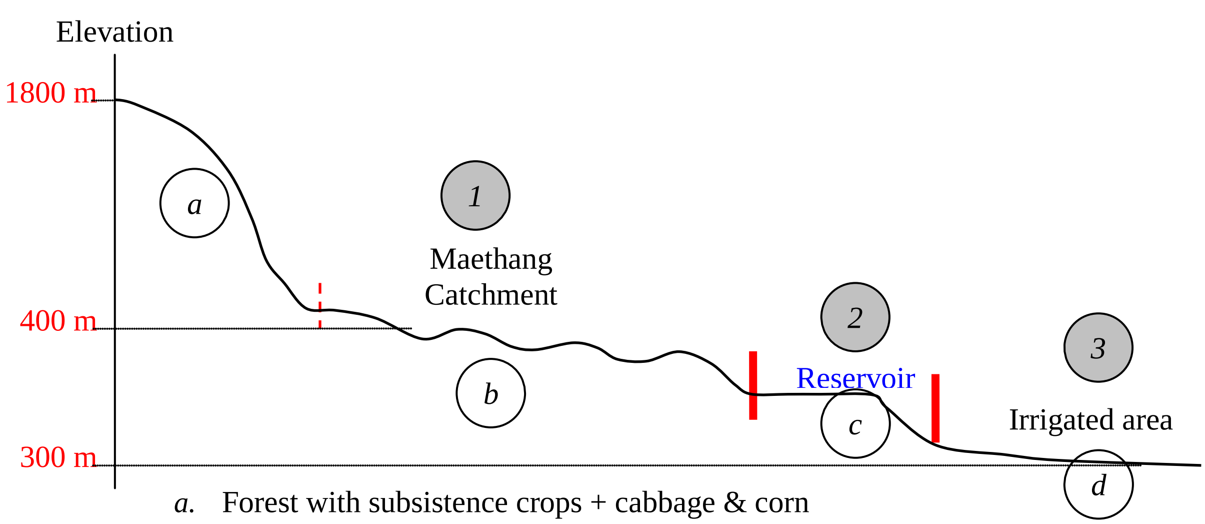
This report presents the accomplishments in 2003 and related results of the previous years.

Materials and Methods

Study Site

The study catchment is located in the province of Phrae in the north of Thailand, about 550 km. from Bangkok (Figure 1). It is not only the large plains of the province that are used for agricultural activity, but also the mountains (altitudes go from 250 to 1630 m), which are cleared and then used for agriculture. This is perfectly illustrated by the agricultural communities within the Mae Thang subwatershed, which can be sub-divided into three distinct zones (Figure 2).

Figure 1. Location of Mae Thang catchment (100km^2) and Huai Ma Nai catchment (93ha) in Northern Thailand



a. Forest with subsistence crops + cabbage & corn
b. Cash crop: corn, soybean and mungbean
c. Fish farming and recreation area
d. Rice during rainy season, mungbean in dry season

Figure 2. Principal areas of the large catchment of Mae Thang.

Zone 1, an upstream area called Mae Thang catchment occupies a surface area of 100 km^2 and can be separated into two sections. Section 1 is the mountainous upstream area. It is populated by recently established ethnic groups known as the Hmong and Malbri, who are increasingly subjected to Thai government influences. Traditionally, the Hmong and Malbri had until now a very small impact on the catchment. However, this is now changing. Actually there is village policy of large scale deforestation combined with the systematic use of inputs such as pesticides and manure. This is however, beyond the scope of the research activities presented in this report. Section 2 consists of the downstream area and is utilized by Thai Farmers (as opposed to Hmong and Malbri ethnic groups) for cash crops. Section 2 was completely deforested for crops including corn, soybean and mungbean. The use of manure and pesticides is systematic. Land management has a very strong impact on soil loss (rotations, tillage, crop managements).

Zone 2, consists of the Maethang reservoir which collects the entire flow of Mae Thang catchment. Runoff entering the reservoir contains a very high suspended load during the rainy season and pesticides and other residues from manures applied as soil amendments. The reservoir was constructed to contain water to be used for the irrigated agriculture downstream. However, it is also used for fish farming and recreation.

Zone 3, comprises the irrigated area downstream of the reservoir. The main crop is subsistence rice during the rainy season and mungbean during the dry season. Mungbean has beneficial impacts on the soil, allowing good nitrogen and phosphorus fixing (El-Hafiez Abl *et. al.*, 2002).

Due to the complex and interrelated characteristics of the Mae Thang catchment, the Management of Soil Erosion Consortium (MSEC) undertakes a project in this area to undertake research on soil erosion.

During 2003, the studies were done on three main areas:

1. Erosion in small catchment (93 ha) – Hydrological survey and soil losses.
2. Socio economic survey at larger watershed in irrigated area (Mae Thang Catchment 100km^2)
3. Water quality and bathymetric survey in the reservoir.

Erosion in Small Catchment

The Huai Ma Nai catchment within the Mae Thang subwatershed has an area of 93 ha. Mae Thang sub-watershed used to be covered by mixed deciduous forest but a major portion is now degraded and used to grow many crops. Field crops such as soybean and mungbean are commonly grown with fruit trees planted in patches. In the lowland, the cropping sequence is mungbean/paddy rice/ soybean or corn. Farmers usually apply chemical fertilizer. The more detailed socioeconomic and biophysical characterization of the catchment has been described in earlier reports (Inthasothi *et al*, 2002).

Rainfall and runoff

The impact of rainfall erosion in the Huai Ma Nai catchment is very important with each rainy season resulting in significant soil loss. A comprehensive detailed

assessment of rainfall patterns within Huai Ma Nai catchment permits an evaluation of the multiple direct and indirect consequences of processes resulting in soil degradation.

Several methods are used to generate the average depth of rainfall over a given area. The method adopted in the study due to its simplicity, easily obtainable information requirements and positive results is the Thiessen Polygon method (Thiessen, 1911).

During a flood, sediments are transported by runoff. The size of these sediments are more or less large and are classified as suspended particles in water and as bed load which are transported to and settled at runoff measurement stations. By using a specific device to collect sediments during rising of water, results on soil losses Huai Ma Nai catchment are obtained.

The Huai Ma Nai catchment covers an area of 100ha. Initially, turbidity of the runoff was measured and used to calculate the proportion of the soil loss from the Huai Ma Nai catchment. This was combined by measuring the bed load transported during each runoff event. The resultant research output can be extrapolated to predict soil erosion losses from the Mae Thang catchment.

Runoff from the Huai Ma Nai catchment is as described earlier, monitored by five measurement stations. The main important station is the flume located at the outlet from the Huai Ma Nai catchment. The Huai Ma Nai catchment is divided into several sub-catchments each of which is monitored and controlled by a weir at which runoff is measured. The sub-catchment specific stations are called W1 for the Huai Mee catchment, W2 for the Huai Ma catchment, W3 for the Huai Bong catchment and W4 for the Huai Tong catchment.

It is always necessary to collect samples during the period to peak discharge as this period is associated with high turbidity. Subsequently, samples must be collected during the period of peak discharge (plateau) and again as discharge decreases to normal levels. Around twenty-five to thirty samples were preserved for analysis.

For each significant runoff event, it is also necessary to collect the bed load in each station. By combining the suspended and bed load sample weights, an estimate of soil loss can be made. The runoff measurement stations and flume provide information concerning the volume of runoff exported from the Huai Ma Nai catchment and total sediment losses. Climate information obtained from in-field rain gauges provides exact rainfall data at a sub-catchment level. By combining the above information, the portion of the rainfall lost as runoff and that infiltrating in the soil as well as soil losses ($t.ha.yr^{-1}$) can be determined.

Land use

Rainfall erosion is a direct result of raindrops impacting an exposed soil surface. Therefore, vegetative cover is a critical factor. Consequently, to undertake a detailed interpretation of runoff from each stream within the Huai Ma Nai catchment, it is necessary to have a detailed understanding of the land use.

Since 2001, a detailed analysis of land use within the Huai Ma Nai catchment has been done. This is essential to understand catchments dynamics. By analysing this information over several years the impact of vegetative cover as a means of soil protection can be identified. Initial results indicate that deforestation at Weir 3 (W3) and a change in crop type at Weir 2 (W2) from soybean to maize are very significant causes of increased soil loss.

Once complete, this work will allow the development of appropriate land use planning in terms of soil protection and cash cropping objectives. This provides a sustainable farming system.
A downstream impact of rainfall and tillage erosion is the significant sedimentation of Mae

Thang reservoir. It is estimated that 10% of the storage capacity of the reservoir has been lost in 8 years. In addition, sedimentation has resulted in a significant decline in water quality for downstream use.

Gully erosion

The main type of erosion in Mae Thang catchment is gully erosion which is a direct result of the deforestation process. Gullies dramatically alter the landscape and farmers must adapt their cultivation methods. What are the mechanisms of gully formation and what are the main causes of gully development? To answer the first question a detailed understanding of the typology of gullies is essential. As a result of this typology causes of gully development can be identified. One of the main problems associated with gullies is to understand their mains impacts. Once understood, various solutions for limiting gully formation and improving land management can be developed.

Gullies are formed due to the negative impacts of intensive agriculture on runoff dynamics in previously forested upland systems (Peersman and Ohler, 1999). Some studies have been undertaken to further understand and model gully formation (Sidorchuk, 1999). These studies have focused on predicting gully formation according to a dynamic model or through the use of a static model based on the final morphology of the gully. In addition, several papers have investigated the global impact of gullies on soil erosion (Peter *et al*, 1997). In general, gully would have impacts on the sediment losses for the soils, and deposits downstream in the reservoir.

However, a simple gully typology based on slope characteristics and zoning within a micro-catchment has not yet been fully developed. Determining the functions and typology of gullies is important to understand gully development and its erosive function.

The gully selected for analysis at the beginning of the 2003 rainy season is located at the Huai Ma sub-catchment associated with W2 (Figure 3). Rain gauge No. 6 provides exact rainfall data for the Huai Ma sub-catchment. The gully is in the form of a Y with a tree structure at the end of the two branches. In the 2003 rainy season, soybean was cultivated on the upstream part and maize on the downstream part. During October 2002 to October 2003, 1,391 mm of rainfall was recorded. The gully selected had several advantages including

1 The gully is representative of the gullies observed within the catchment and occurs on an old deforested field (30 years old) associated with a double cropping rotation and both manual and mechanized tillage
2 The gully is active with discharge observed after each major rainfall event,
3 The gully is associated with little vegetation establishment at outlet zone,

4 The size of the gully allows the installation of the material,
5 The gully is easily accessible.

Figure 3. Gully monitored during the 2003 rainy season in Huai Ma Nai catchment.

Socioeconomic Survey

The study is based on the production system which describes the combination of different production components or sub-systems, the production activities' diversity and purposes, and the production activities' management (special and temporal distribution, workload allocated) (Figure 4). The production system is defined both at human scale, the village community, and at land scale, the village land. The household is used as basic unit of assessment of the production activities and distribution within the village community (Lestrelin, 2003). The purpose is to characterize the production activities with diverse variables:

- How they are organized between them;
- Where they are located;
- Workload allocated;
- How many people they mobilize;
- How much money they get, if it is a cash activity;
- What amount of money allocated for this activity;
- Tools used.

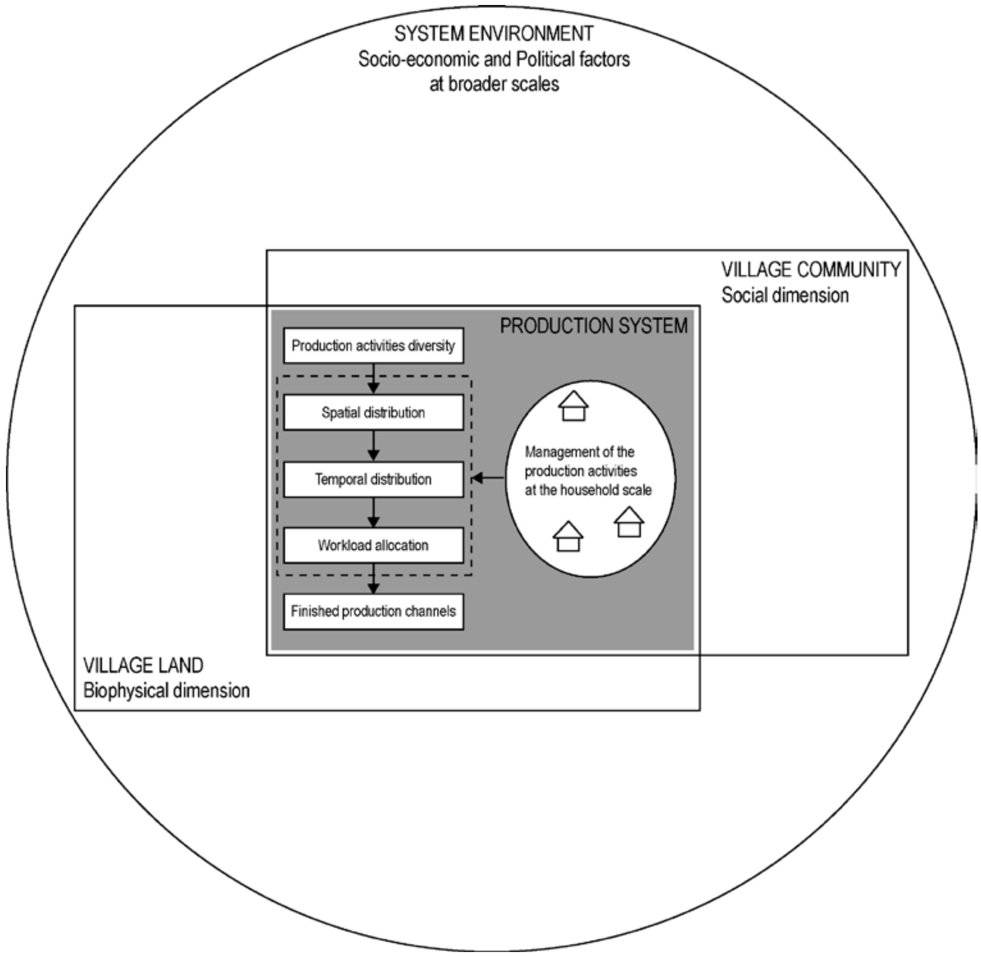


Figure 4. The production system showing the different levels interacting in the differentiation of the production systems (Lestrelin, 2003)

Most of these variables interact with each other. It will be important to know how these interactions happen and the consequent effects at the local level and extrapolated to the global level. If similar modifications emerge with the time in the production system, the reasons of these modifications are interesting to know and characterize. This change to new systems can have several influences on erosion and how to address it.

Scale of analysis

The study is based on a scale of analysis that goes from the global level to the local one. This allows the collection of different kinds of information as the same data would not be gathered from a national organization or at the village community. These information are useful to also cover the extent of the problems based on the influence of the global factors on the local scale.

Selection of the villages

Because a village is a production system in itself, several of them were selected. As the major concern is erosion and land management, the villages have to be linked hydrologically, representing the upstream-downstream continuum. This representation can describe the interaction between the activities in the upland which can cause erosion and affect the activities downstream.

Three villages were selected for the study. Ban Pong, with most of the residents cultivating in the small catchment of Huai Ma Nai represents the upper catchment. Representing the downstream area is the Ban Waieng village with 11 households producing fish in the Mae Thang reservoir. The discharge system of the watershed area of Huai Ma Nai runs to the Mae Thang reservoir. The village of Ban Huai Hung was the third village chosen because its residents do not have any activity in the upland and in the reservoir.

Development of the questionnaire

As mentioned earlier, the investigation is organized around the productive systems of the village community. To collect information on this subject, the questionnaire was based on the activities constituting the production system. Thus, the questionnaire was divided into six gropus of questions as follow:

1) General Information, which made it possible to characterize and differentiate the villages, identify the respondents and the focus of the survey.
2) Activity of production, which gives information on the type of activity carried out, when is the activity done, and the final product. The type of activity could be seasonal crop production, livestock raising, rice production, plantation crops, vegetable production, etc.
3) What is used to conduct the activity and obtain the final product. It is interesting to collect information on the way the product is obtained, chemicals used, etc. The answers can change with time because of global factor.
4) Distribution of this activity to get information about the field use for the activity, the site of the activity, area and number of plots used. The site could be in upper slope, lower slope, reservoir, etc.
5) Economic of production to know the inputs used, the products sold and the marketing channel.
6) Calendar of activities to know the organization of the productive activities and why they are organized as such.

Sampling and interview

Population samples were determined by the method of stratified sampling which consists of the subdivision of a heterogeneous population in sub-populations more homogeneous (mutually exclusive and collectively exhaustive). The households were primarily subdivided in groups, according to their land size. For the village with fields in the upland and the lowland, a second classification of the location of the field was done. It was planned to have 45 sample respondents from Ban Pong, 26 from Ban Waieng, and 27 from Ban Huai Hung. However, the final number was 20 from Ban Pong, 6 from Ban Waieng, and 15 from Ban Huai Hung. The number of samples from Ban Pong and Ban Huai Hung is sufficient, but the little information taken from Ban Waieng makes it difficult to make comparison with the two other villages.

Both direct interviews using the structured questionnaire and semi-direct interviews with open-ended questions were used. The questions were asked to get information relative to a time scale as follows:

- 2003 because is the year of realization of the investigation, to obtain recent information on the activities of the villagers.

- 2000 because it had appeared certain changes since the watershed area is studied by IWMI;
- 1990 to know the activities existing in the area before the realization of the reservoir.
- 1950 collect information on the past and high light dates of appearance of certain production activity because at this time normally, people don’y go yet in up land.

Construction of the data base and analysis

The tool used to build the data base was Microsoft Access because of its utility. MS Access is a basic relational format which allows a simple and fast treatment of the data under various formats (text, date, numerical...). Them text format for example can be treated in term of a number of occurrence (by carrying out a cross analysis of the attributes " type of activity " / " product use ", " cash " will be able to take value 35 because it appeared 35 times for the attribute " type of activity ", which is not possible with Excel.

Monitoring Dissolved Oxygen Depletion

Dissolved oxygen depletion in natural and artificial water reservoirs is a major environmental problem because of their importance to human settlement, in particular for irrigation, flood control, fishing and energy production. Critical conditions may arise when the dissolved oxygen concentration available to decompose organic matter falls below a minimum level ($[O_2] < 1$ mg.l^{-1}). Bacterially-mediated processes lead to the degradation of water quality through a cascade of redox reactions that involve NH_4^+ production, SO_4^{2-} / H_2S conversion or dissolved metal release from fine suspended matter. Several processes may account for oxygen depletion in freshwaters:

1. enhanced biological productivity resulting from high input of nutrients (eutrophication),
2. high organic matter supply generated by soil erosion and runoff in the drainage area
3. low water turnover

In-situ monitoring was performed using probes equipped with sensors that allow high resolution and low response time (<1 second) (Figure 5).

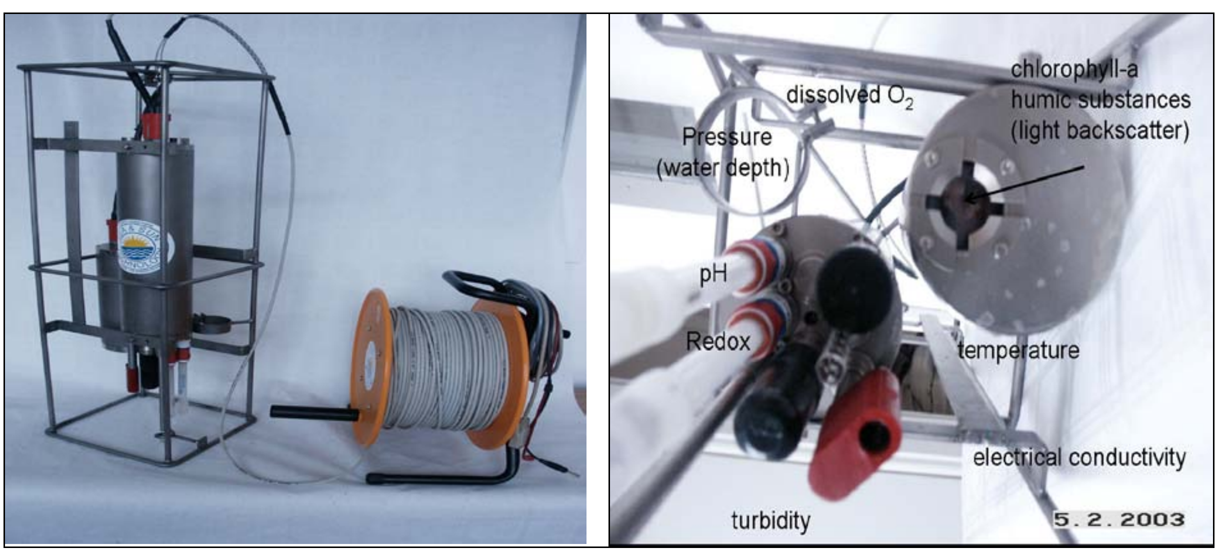


Figure 5. Multi-parameter probe used in Mae Thang reservoir.

Results and Discussion

Rainfall, Runoff and Erosion

Table 1 shows the rainfall over the catchment and subcatchments in the Thailand site in 2003 generated by the Thiessen polygon method. The annual rainfall in the catchment was 1107 mm from January to October (Huai Ma Nai automatic climate station, Cimel 407). This represents an approximate volume of 1 million $m^3.yr^{-1}$. A proportion of this volume was lost as runoff via the natural drainage network of the Huai Ma Nai. The rains in 2003, although less than those in 2001 and 2002 had comparable level of intensity (CV = <5%).

Table 1. Distribution of rainfall in the Huai Ma Nai catchment (Thiessen Polygon Method)

Rain Gauges	1	2	3	4	5	6	7	8	9	10	11	Climatic station		Surf (ha)	Rain fall volume (m3)
Rainfall (mm)	1124	1109	1129	1087	1134	1145	1101	1142	1145	1073	1100	994			
Huai Ma Nai	45	78	56	87	125	160	110	69	137	86	77	80	1109	93	**1033856**
Huai Mee	0	0	0	0	0	34	0	503	217	0	99	249	1102	12	**130036**
Huai Ma	0	0	0	0	0	527	0	0	355	0	253	0	1134	10	**108904**
Huai Bong	135	0	722	261	0	0	0	0	0	0	0	0	1118	3	**35781**
Huai Tong	34	499	0	0	0	0	0	11	0	0	0	507	1051	7	**74627**

The accurate determination of water level measured at each station provides a complete assessment of the runoff volumes for each sub-catchment. Total runoff from the Huai Ma Nai catchment is presented in Figure 6. Each peak corresponds to a runoff event. The sum of the runoff volumes over time gives the total volume of runoff exported by the catchment during the rainy season. This measurement is the second component (the first being rainfall) of the determination of the coefficient of run off*. This measures correlated with the measurement of turbidity provide information regarding the quantity of sediment ($t.ha.yr^{-1}$) exported by the catchment (Figure 7). The dynamics of the rain fall and runoff in the Huai Ma Nai catchment is presented in Table 2.

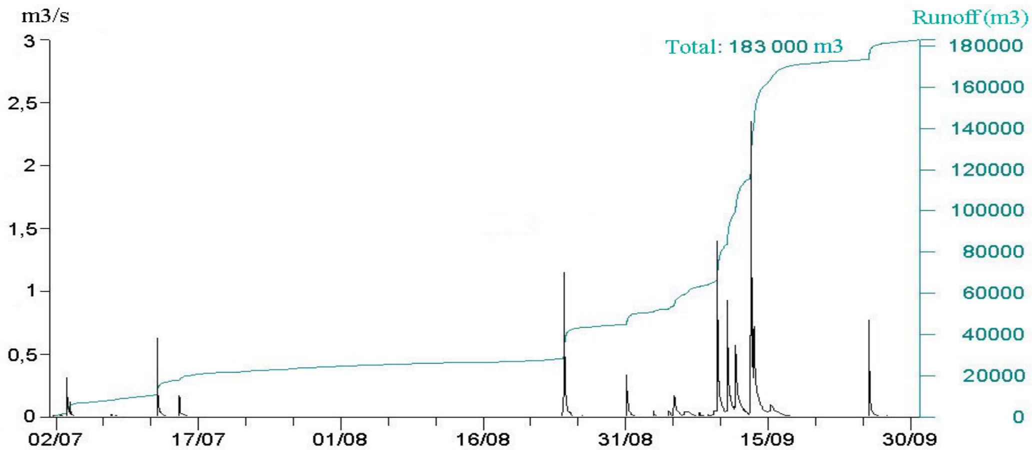


Figure 6. Assessment of runoff volumes from the Huai Ma Nai catchment (2003).

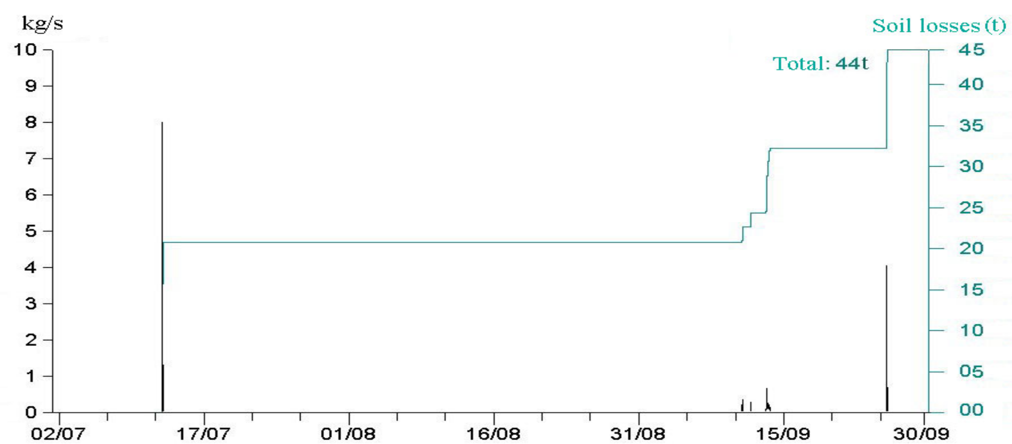


Figure 7. Assessment of sediment exported by the Huai Ma Nai catchment (2003).

Table 2. Dynamics of rainfall and runoff in the Huai Ma Nai catchment from 2001 to 2003.

	2001	*2002*	*2003*
Total rainfall (m^3)	486,500	306,300	192,500
Rainfall (mm) October – January	1159	1225	1016
intensity of rain (mm hr^{-1})	26.3	26.4	24.1
Coefficient of runoff	**45%**	**30%**	**20%**

The results indicate that the Huai Ma Nai catchment lost 44 t of soil during the 2003 rainy season. The Huai Ma Nai catchment occupies an area of 93 ha. Consequently, the average loss of soil from the Huai Ma Nai catchment is approximately 0.47 t ha yr^{-1}.

The analysis of the catchment can be more precise. As stated, the Huai Ma Nai catchment is sub-divided into four sub-catchments. The experimental set up allows the combined runoff volume from the sub-catchments to be cross-referenced with the runoff volume determined by the flume at the catchment outlet. Table 3 represents the data obtained during the 2003, rainy season (July 1st to September 30th, 2003). The comparatively high runoff values associated with the Huai Ma catchment are a result of the fact that the Huai Ma catchment was cultivated primarily for cash crops with no forest cover remaining or soil protection measures adopted.

Table 3. Rate of run off and soil loss in Huai Ma Nai catchment for 2003, rainy season.

	Huai Mee	**Huai Ma**	**Huai Bong**	**Huai Tong**	**Huai Ma Nai**
Surface (ha)	11.8	9.6	3.2	7.1	93.2
Rainfall (mm)	1102	1134	1118	1051	1109
Rain fall in volume (m^3)	130036	108864	35776	74621	1033588
Flow ($m^3.s^{-1}$)	36790	25831	14905	14196	182719
Run off coefficient (%)	**28.29**	**23.73**	**41.66**	**19.02**	**17.68**
Exported sediments (t)	15.11	7.59	0 *	1.586	44.24
Bedload (t)	3.78	12.368	3.912	3.279	0 *
Export by catchment (t)	18.89	19.958	3.912	4.865	44.24
Soil loss by catchment ($t.ha^{-1}$)	**1.60**	**2.08**	**1.22**	**0.69**	**0.47**

*: no measurements because of the installations which do not allow the analysis of these results.

Land Use and Dynamics of Runoff

The land use practices are a determinant of the degree of soil protection and thus soil erosion. By comparing land use with the coefficients of runoff, the impact of climate can be evaluated. Changes in land use since 2001 are presented in Figure 8. In 2001, the majority of the cultivated area was used for mungbean. In 2002, soybean occupied more than 90% of cultivated area. In 2003, there was a marked increase in the area cultivated to maize, the original cash crop of the catchment, with 58% of the cultivated land used for the crop. Soybean was cultivated on 34% of the agricultural area. Land use patterns for 2003 are presented in Figure 9 which allows the visualization and characterization of different small catchments of Huai Ma Nai.

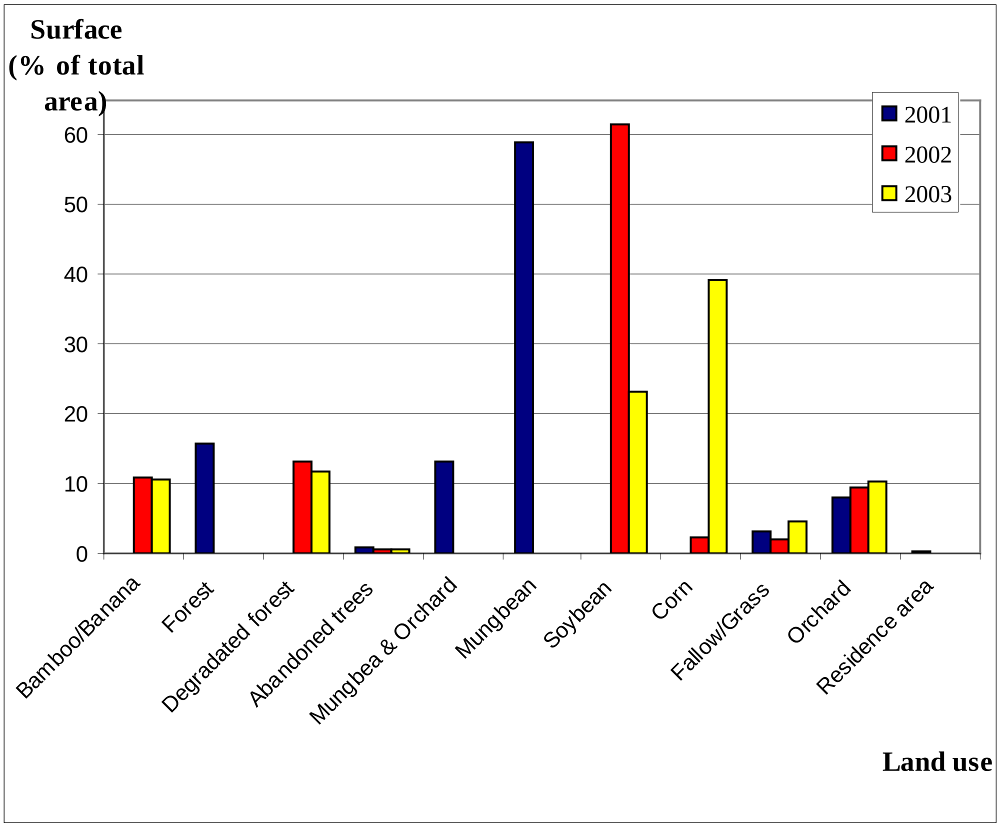


Figure 8. Changes in land use in the Huai Ma Nai catchment since 2001

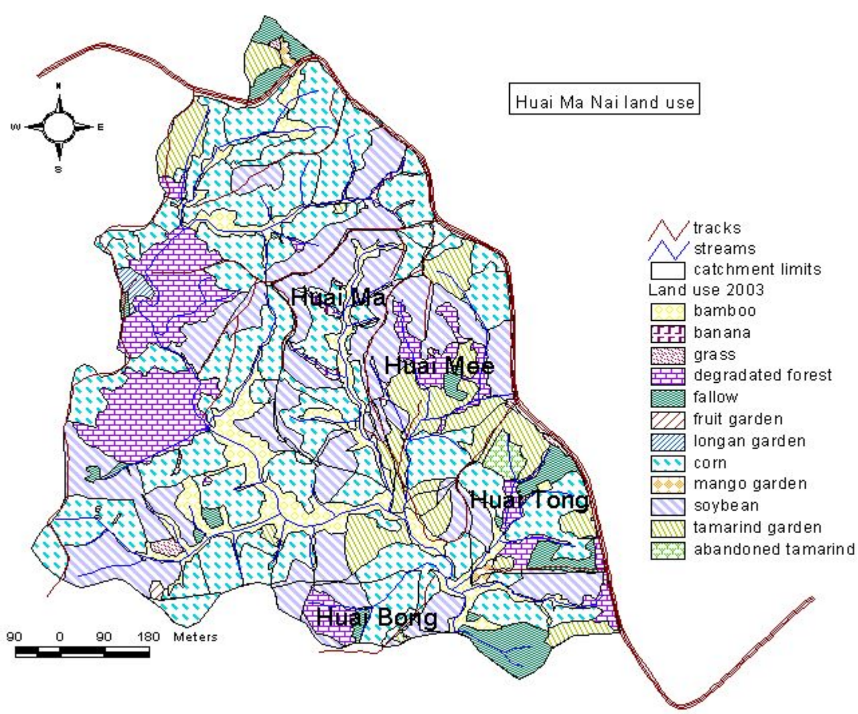


Figure 9. Land use of the Huai Ma Nai catchment in 2003 (Chatwatcharakul, 2003).

The rains in 2003 although weaker than those of 2001-2002 have a comparable level of intensity (CV = < 5 %). In addition, good vegetative growth and therefore surface cover resulted in high soil infiltration capacities. In this respect, the results indicate that maize is more effective than soybean cover and even more than the mungbean. The Manning coefficient and the coefficient of vegetative cover (expressed as a percentage of the soil surface) are good indicators of soil protection. The higher the coefficients are, the more resistant the system is against erosion (Table 4).

Table 4. Manning coefficients and vegetative cover as related to land use.

	Coefficient of Manning	**Vegetative cover**
Drill	0.20	70 %
Orchard	0.70	60 %
Fallows	0.04	50 %
Maize	0.09	35 %
Soybean	0.01	20 %

In contrast to soybean which is associated with low vegetative cover; fruit orchards provide a very good protection to soil. The soybean root system does not provide efficient resistance against the flow.

In terms of cash crops, maize is a better soil conservation crop due to a comparatively higher Manning's coefficient and percentage of vegetative cover due to inherent plant physiology. Good vegetative cover in the Huai Ma Nai catchment during the 2003 rainy season as a result of favourable climatic conditions resulted in minimal soil losses.

Best Bet Option

In terms of reducing soil losses, the current experimental system of tamarind in association with other cash crops appears to be promising. In addition, in certain fields, the cultivation methods adopted between the maize-mungbean rotations appear effective in reducing soil losses. Specifically, several farmers currently pull up the maize during harvest, use disc cultivator for tillage and then sow mungbean. Consequently, during the period of mungbean vegetative growth, the maize residue protects the soil surface from raindrop impacts, prevents surface sealing and maintains high infiltration rates. Upon decomposition and humification, the maize residue improves aggregate stability. In addition, the off field exportation of organic matter and associated nutrients is limited.

In comparison, the currently adopted soybean cultivation practices are conducive to accelerated soil losses. Prior to harvest, the soybean plant is allowed to die down resulting in vegetative cover decreasing to < 30%. In addition, at harvest, the whole plant including residue is exported from the field. Subsequently, the field is tilled and sown with the following rotation crop. This results in an exposed soil surface with no protection from raindrop impacts (Figure 10).


Harvesting and drying of soybean


Tillage before mungbean crop

Figure 10. Tillage operations and harvesting in the soybean – mungbean rotation

This study indicates that the cultivation practice primarily in terms of tillage and vegetative cover has a significant impact on the dynamics of soil erosion. Consequently, this will lead to the development of appropriate land management to improve soil protection and sustain livelihoods.

Gully Erosion

Characterization of the gully

The terminologies used in the study were those proposed by Planchon (1991). The gullies were defined in four terms in relation to the dynamics of erosion (Figure 11). The four terms are:

1. The *proto-rill* which indicates all the forms of incisions concentrated without incision marked on the soil. It is the initial tree structure of the gully.
2. The *rills* which dig the humus horizons by forming small rectilinear channels 5 to 10 cm deep and 10 cm wide. The vegetation is non-existent here. The bottom of the gully can be flat or in V-shaped. There are coarse silts present.
3. The *gullies* which dig the mineral horizons of the soil. The slope of the bottom remains parallel to the surface slope. The banks remain abrupt. The principal form is U-shaped, the bottom of the incision is strongly stony (many coarse elements with up to 10cm in diameter). There are crop residues deposited by the man. The flows in these gullies are still strongly related to the surface phenomena.
4. *Ravines* (or streams) are deep incisions reaching the parent rock. The bottom of the ravine is not all the time parallel to the surface slope. The distinction between a gully and a ravine is the depth of one meter. Perennial vegetation can be present in these deep incisions.

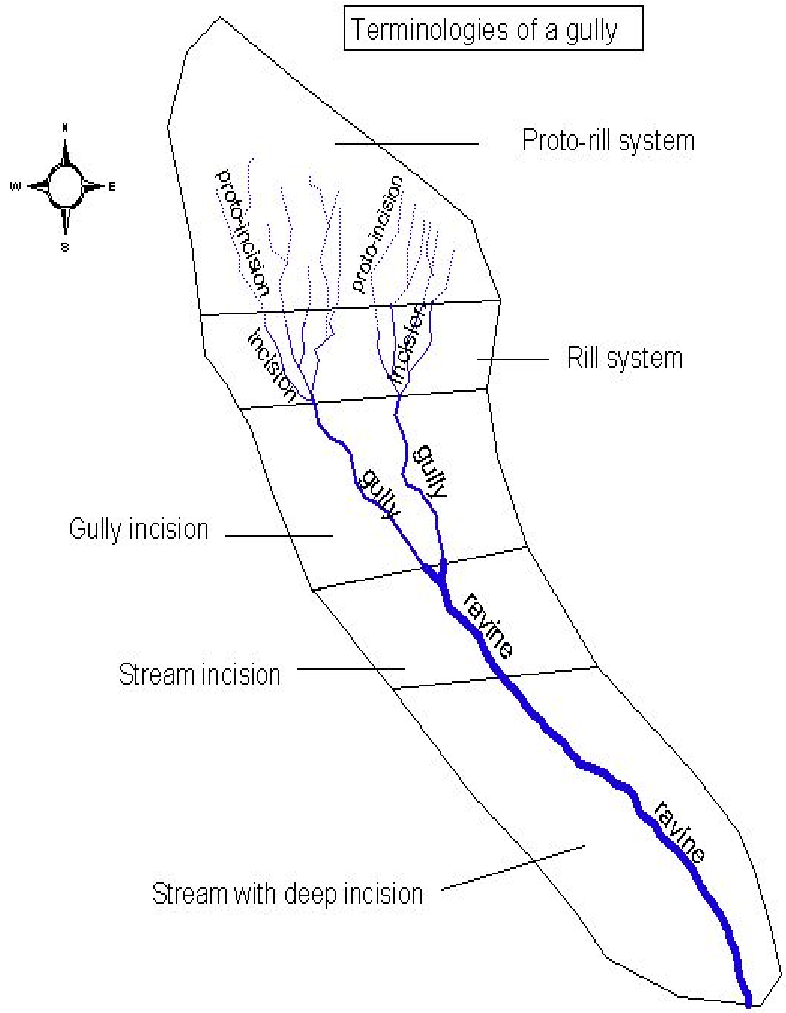


Figure 11. Diagram of terminologies applied to a gully.

Based on these terminologies, the toposequence of the studied gully in the catchment was defined (Figure 12). The toposequence allows understanding of the development of the gullies in a small catchment. The results of Bayer (2001) showed that the gullies are formed on slopes ranging between 30 and 35 % on bare soils. This phenomenon is a function of the interaction between different rain dynamics (intensity and duration), the slope and the particular characteristics of the soils and their surface. Because of these interactions, the dynamics of runoff and infiltration of water are very heterogeneous from one area to another in the same catchment. The variations are demonstrated in terms of compaction, size of the surface crusts, and stone rate (Janeau *et al*, 2003). The consequences are direct on the soil losses with a turbidity of 0 to 5.6 g l^{-1} and a detachability of the soils from 10 to 313 g m^{-2}.

On slopes lower than 25%, the loss of soil is mainly related to the splash effect (function of the kinetic energy of the rain and the slope) of rainfall. Splash effect allows a redistribution of the fine elements of the soil and progressive encrusting. The infiltration becomes lower. Beyond 25%, encrusting is much weaker. The crust is not hardened enough to protect the soil. The loss of soil is much more significant in this slope change. This area corresponds to the first upper quarter of the slope. It is the area where the gullies start.

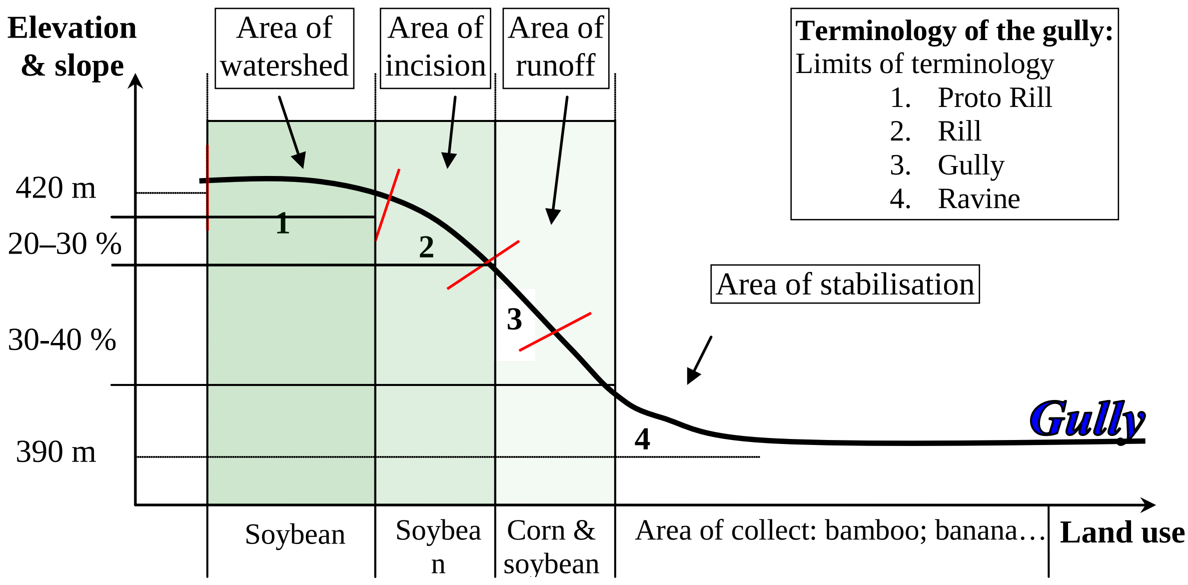


Figure 12. Toposequence of the gully studied in Huai Ma Nai catchment.

Gully development

The development of a gully was defined in four stages by Bergsman (1996). The initial stage consists of the concentration of a significant volume of water on a determinate area. This concentration leads directly to the incision development, then to a maturation stage when there is loss of soil particles. Finally, at the stage of stabilization, vegetation can be established. These four stages are not independent of each other and occur successively. So, the development of a gully can be related to the position in the landscape as follows:

1. An upstream area (which is the area of watershed) where rainfall and runoff are concentrated because of slope and the properties of the soil surface (Bergsman E, 1996);
2. An area of incision, where the incisions are initially formed. Their appearance is directly related to the slope (Bayer, 2001);
3. A development area (or drainage area) where the incision grows into gullies and then ravine. More volume of water can circulate here.
4. An area where the vegetation starts to grow and becomes more stabilized (Bergsman, 1996).

The topography of the gully area (2,496m^2, 104 m long and 24 m wide, visual limits of the gully) was determined using a level (Figure 13) and the data analyzed using "Surfer 7.0". Figure 14 presents the general topography of the studied gully.

Figure 13. Topographic measures with a level.

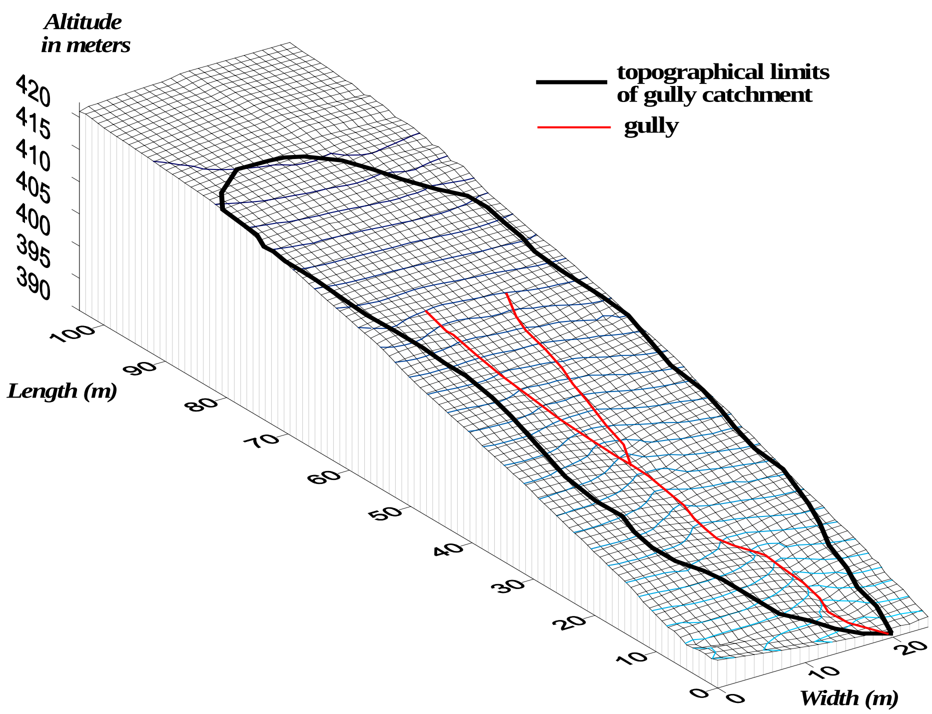


Figure 14. The gully catchment in Huai Ma Nai.

The general topography shows the main evolution of the gully, but during one rainy season the evolution is not very distinct. However, the loss of one outline in the middle of the graph can be observed. This element shows the incision development of the gully. To better appreciate the development of the gully, the surface roughness was measured using a distanciometer (Leica Disto. Pro, laser class 2-635). The result of the analysis is shown in Figure 15

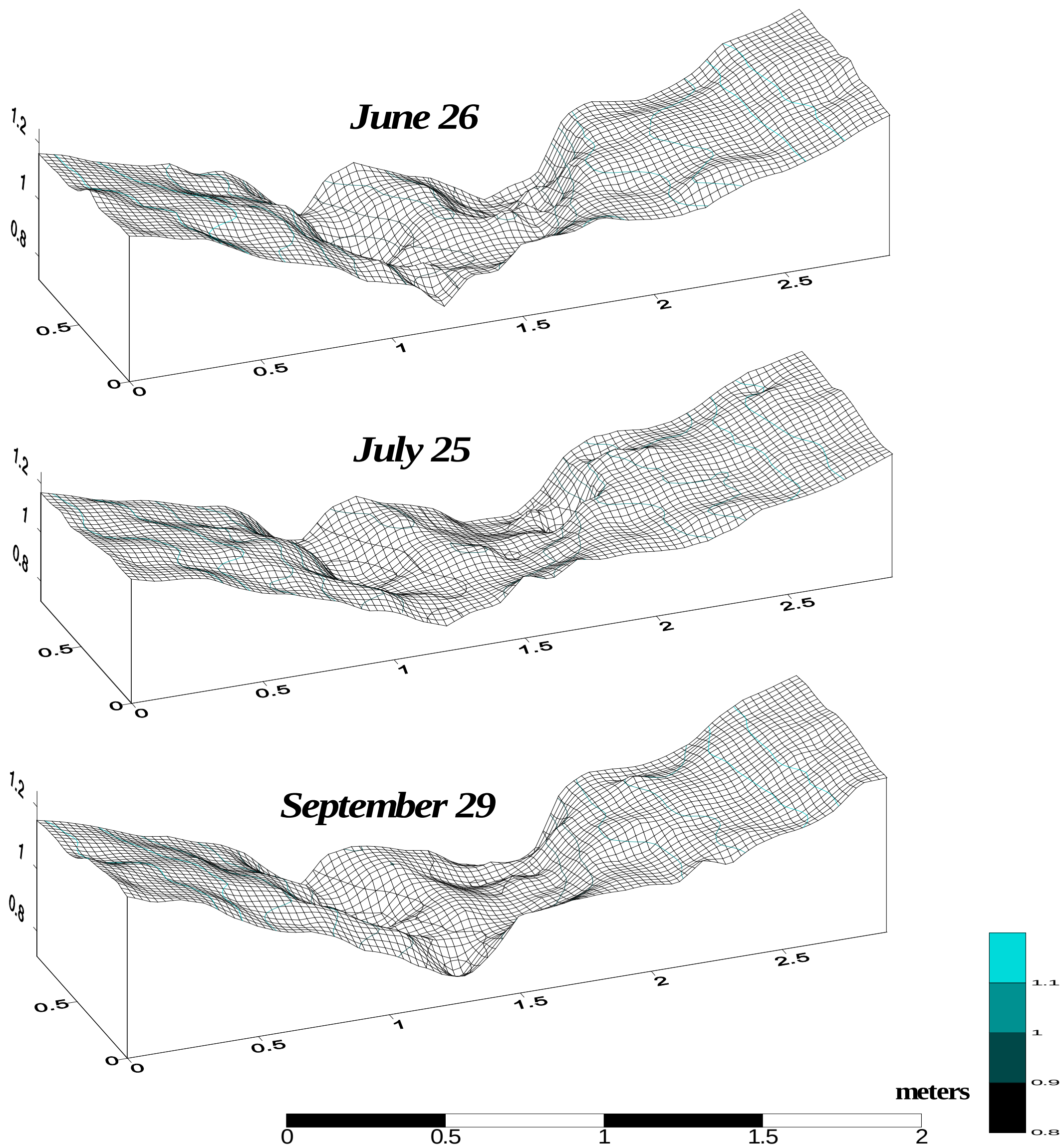


Figure 15. Gully evolution during 2003 rainy season in the incision area

Runoff and soil erosion

The loss of soil and fertility varied within the landscape (see Figure 11 for reference) where the soil characteristics and topography also vary. Figures 16 and 17 show the variation in bulk density and organic matter content, respectively, with depth at different locations in the toposequence. The watershed area has a hardened crust whose bulk density and consequently the porosity is low and infiltration is reduced. This is aggravated by the hardened layer at 15 cm depth. As the slope increases, bulk density decreases and the porosity increases. The maximum porosity is reached at the first part of the runoff area.

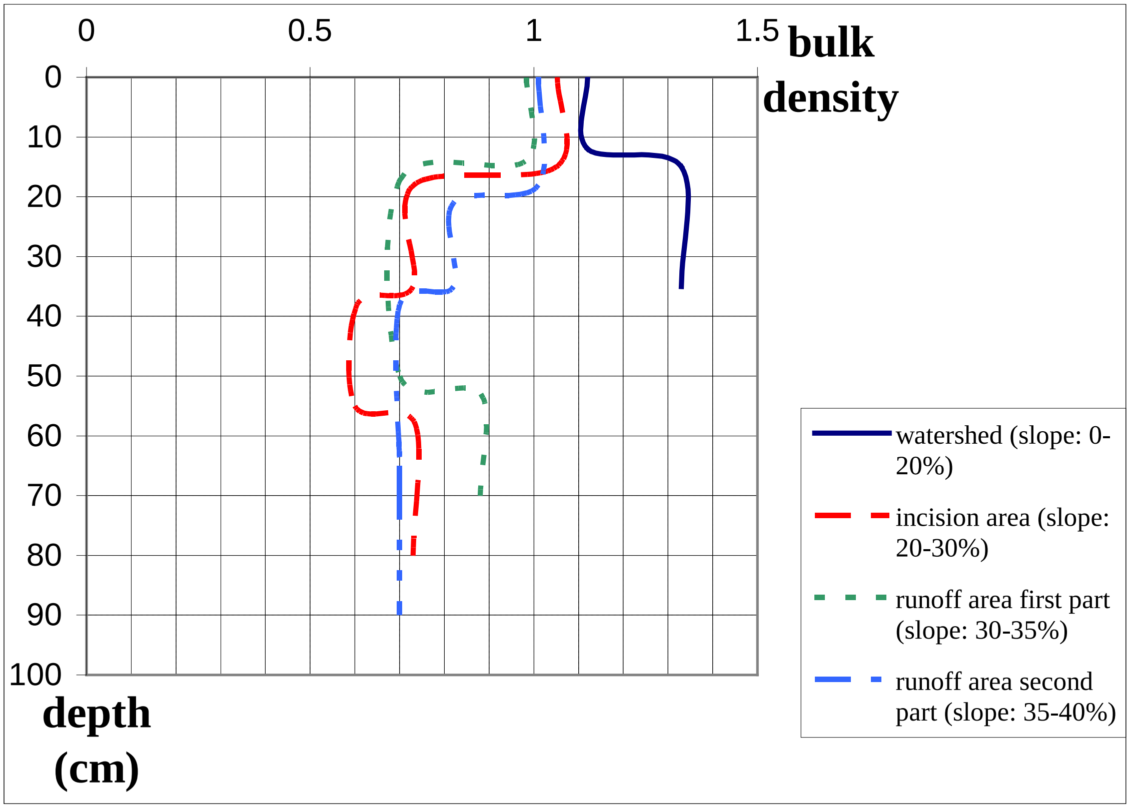


Figure 16. Bulk density of the soil according to the depth and the situation on the slope of the gully.

The analysis of the organic matter content gives an indication of the consequences of soil loss in the catchment. The organic matter is high in the tilled layer but it decreases with depth (Figure 17). The first part of the runoff area has 16 cm of arable soil, but organic matter becomes low further down. The development of the root system of crops becomes restricted. From an agronomic point of view, the incision area is the most fertile. The soil is deep and the organic matter decreases only gradually down the soil profile.

The second part of the runoff area also looks to be a good area. It presents a good evolution of the organic matter rate along the soil profile, almost similar to that in the incision area, despite a lower average amount. These have some influence on the yield of crops. Figure 18 compares the average yields of soybean in the different toposequence.

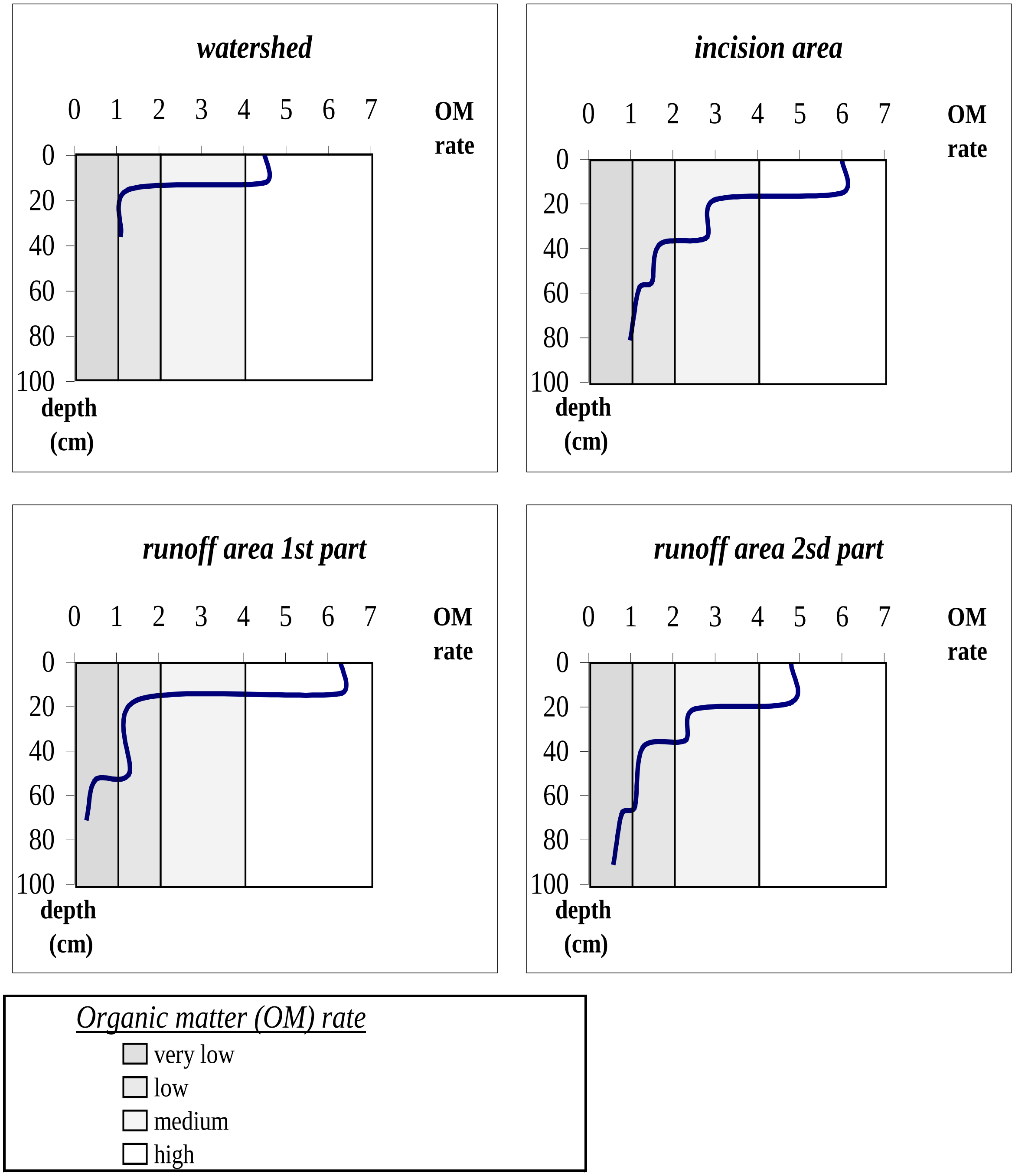


Figure 17. Organic matter rate of the soil according to the depth and the situation on the slope of the gully.

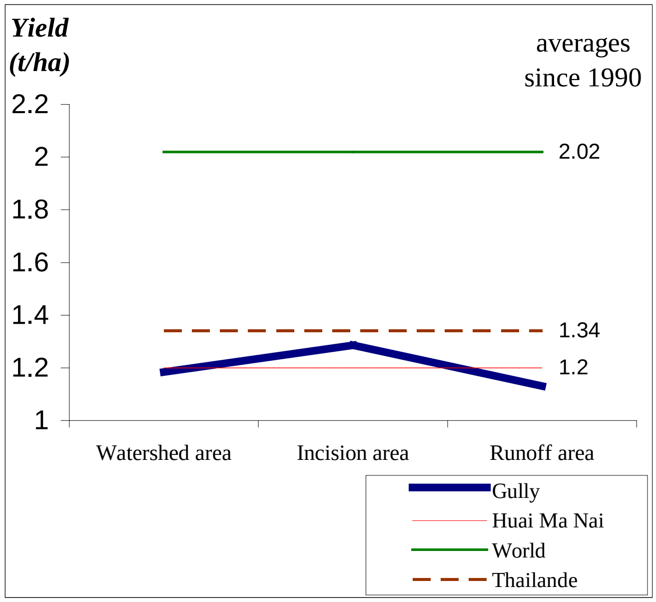


Figure 18. Comparative yields of soybean in the toposequence

The soybean average yield in Thailand is 1.34 t ha^{-1}. This is relatively low compared to the world average of 2.02 t ha^{-1}. In the Huai Ma Nai catchment, the average yield of soybean is lower at 1.2 t ha^{-1}. The major reason could be the problem of soil erosion.

The bulk density also varied within the gully itself. Figure 19 shows that the highest bulk density occurs at the center of the gully. It is where the porosity is lowest. The side of the gully is the least dense which creates an increase in the detachability of the soil particles.

Socio-Economic Dynamics

At this time, the data are still being processed, but it is evident that the production systems of each village are really not the same. The village of Ban Pong had a specific configuration. The houses are very close to one another, and most of them are built Thai style on wooden stilts and closed by concrete. Most of the villagers have land in the upland. They have been encouraged to plant fruit trees to prevent erosion but because of the canopy, they could no plant annual cash crops. They therefore cut the trees.

In Ban Weiang, the houses are also closely spaced, but most of them are of European style. Most of them have TV and computer. Some farmers grow fish in the reservoir and operate restaurants. The villagers say that they do not have good soil and most of the farmers of this village have some of their family members work in factories near Bangkok.

In Huai Hung, the houses are like in Ban Pong but witch much more space to allow them to have a garden where they can grow fruit trees and vegetables for their consumption. Most of the women make dresses for middlemen or for small shops near Phrae. This village is near the end of the irrigated area and with the water from the reservoir, they can crop more than before. In the past, most of the villagers went to work as hired labour in other districts.

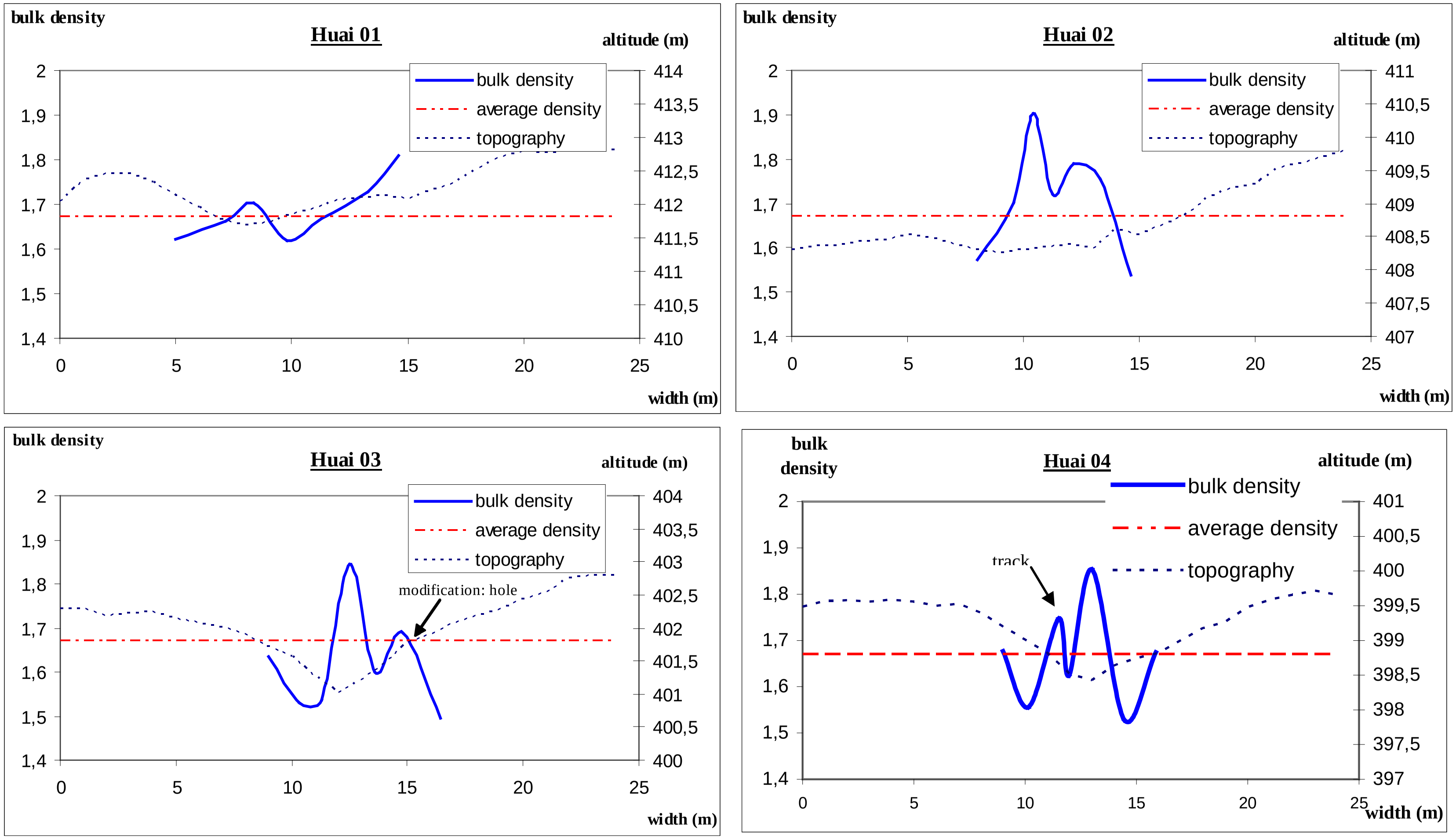


Figure 19. Bulk density of the surface horizons around the gully according to various areas.

The activity in the lowland is mainly cultivation of corn because of the presence of Monsanto Company which moved from the North-East to the North because of the well developed irrigated system. Monsanto works with the cooperative and the agricultural bank. They arrive in Phrae province since few years and progressively farmer crop more and more corn.

Corn is planted at the same month as soybean, so there is a change appears in the organization of the agrarian activity with the decrease in the area for soy bean. And for those who cultivate in the upland, they can have more money to spend for the seeds they need.

Monitoring Dissolved Oxygen Depletion

In the freshwater reservoir of Northern Thailand, preliminary investigations with specific multi parameter probe provide a first-order evidence of severe O_2 depletion below the thermocline in isolated sections of the reservoir that can be related with high surface productivity and limited bottom - surface water exchange. Control of the extent of dissolved metal release in the water column through chemical analysis of water sample aliquots is in progress.

During 2003, monitoring of temperature (T°C), electrical conductivity (EC), chlorophyll-a concentration, redox (Eh), pH, dissolved oxygen concentration (O2), turbidity and light backscatter in the water column of the Maethang reservoir near its outlet. Figure 20 shows the results in September 2003.

General Conclusion

The rainy season in 2003 was quite good with a total rainfall of 959 mm between 15th April and 1st November (1200 mm in 2002). There were very few big events, only 12 events with rainfall higher than 20 mm per day. The rain was well distributed within the months with only few days without rain. Biggest events came late in the season, in September – October. From an agronomic point of view, it was excellent for the crops, water being available during the growing period. Farmers had higher yields this year than last year.

Consequently, there were few runoff events with less amount of water measured at the different stations. The maximum discharge recorded at the flume was 2.35 $m^3\ s^{-1}$, comparable with 2.65 $m^3\ s^{-1}$in 2002 and 2.47 $m^3\ s^{-1}$ in 2001. In terms of total volume, 2003 is the lowest with only 193 000 m^3, compared with 295 000 m^3 in 2002 and 478 000 m^3 in 2001. The situation is similar for the other stations. For example, at the Weir 2, the discharge was 27 100 m^3 in 2003 compared with 47000 m^3 in 2002 and 57 100 m^3 in 2001.

The main reason for these changes, if the rainfall distribution is not taken into account, could be the changes in the crops. This year, many farmers decided to abandon soybean and go to maize. Corn is more effective to protect the soil from rain impact (cover crop is much higher than soybean) and, better, the cropping period is longer than that of soybean. About 60% of the land cropped last year with soybean was cropped this year with maize. Consequently, when some farmers harvested soybean, there was still maize on many fields which reduced rainfall erosion and runoff. The assessment of erosion was easier this year with improved equipment, especially the automatic water samplers.

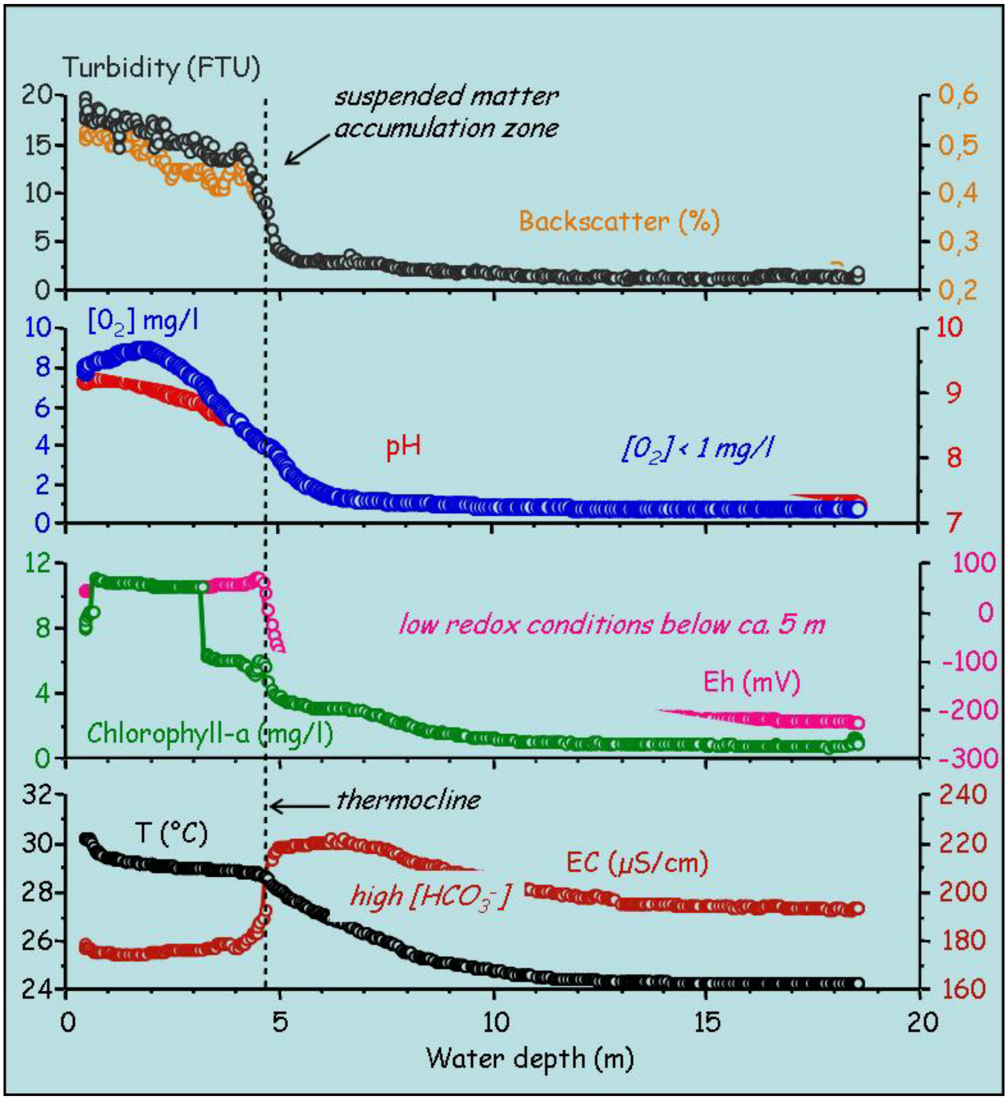


Figure 20. Data obtained with multi parameter probe in September 2003.

A socio-economic survey was started at the lower part of the watershed, particularly in the irrigated area, during the year. It is very important to evaluate the impact of the dam construction on the population and how they use the new resource available.

Another activity started during the year was the study on water quality. The methodology and techniques involved in that survey will generate large amount of data. The determination of water quantity and quality is crucial for the farmers and policy makers. The new association with others teams like medical and anthropologist will give a broader view of the off-site impacts of a watershed.

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Training

This year, two French students joined the programme for their thesis (MsC), and the assistant Warinya Thothong left for AIT for a Masters degree in watershed management. The French students, Jean Philippe Luc and Caroline Boulais, come from a school of agronomy in tropical countries. They spent 4 months in Phrae province to collect data and other information they needed. During the two months they stayed in the office in Bangkok, they wrote the notes and reports. Most of the annual report come from their work.

In October, training on data management and interpretation was conducted in Bangkok. Twenty-five participants from the MSEC countries joined this workshop. The main objectives of the workshop were:

- Improve data management.
- Improve the use of hydrological tools.
- Establish water and sediment balance, with focus on minimum data set
- Integrate socio economic components.

The main expected outputs were an appropriate use of the hydrological software used in MSEC (Hydras 3), an improved understanding of the collected and observed data, and finally a more attractive and intelligible improved presentation of results.

The different resource persons gave a deep comprehension of the database system, how hard it is to build a proper database, and how important it is to know the units we express results.
All participants were enthusiastic about the training. An evaluation was conducted at the end of the week to estimate the impact of those training. A workshop diner was organised on the Chao Praya River

The close collaboration with NPWPCD will continue and the execution of a new MoU will formalize this relationship.

Soil Erosion Management at the Watershed Level for Sustainable Agriculture and Forestry in Vietnam

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Introduction

Watershed management is an important concern in Vietnam not only to protect the existing forest, but also to conserve agricultural lands for sustainable agriculture and biological diversity. It is the best way to minimize land surface runoff and soil loss and prevent frequent and intense flash floods. For the last three years, the Management of Soil Erosion Consortium (MSEC) has supported catchment research and capacity building in Vietnam to better understand and manage land and water resources for sustainable agriculture and improved income of farmers.

The Dong Cao Catchment in Tien Xuan commune, Luong Son district, Hoa Binh Province, 50 km from Hanoi, inside the Red River Basin, is the site of the MSEC project in Vietnam (Figure 1). The catchment of about 45 has a mean slope of 45% and the steepest slopes are around 120%. The steepest slopes are situated in the middle part of the basin and are largely cultivated by farmers from Dong Cao village to crop cassava and fodder in association with some trees (*Venitia montana*, *Acacia mangium*); there is also some husbandry of cows. The farmers (around 40 farm households of 200 inhabitants) share their work time between the lowlands to crop irrigated rice and also to use the uplands to increase their revenue.

The catchment was instrumented for soil erosion and hydrological monitoring to evaluate the interactions between rainfall, runoff, groundwater, topography, soil quality, land cover, and climate (Figure 2). These data are necessary to assess and predict the impact of land use and land management on soil losses, soil fertility, and solute transport in and through the watershed.

The results of three years of research and monitoring showed a high inter-annual variability of soil loss (from 1 to 15 t ha^{-1} $year^{-1}$). Moreover, this variation depends on both the amount and intensity of rainfall and the kind of land use. The project has proved to be very useful for farmers, not only in terms of understanding soil erosion and nutrient loss, which cause land degradation and reduce productivity, but also in terms of farmers' enhanced capacity and improved information dissemination strategies.

To further understand the hydrological processes and land use changes in the catchment and their interactions, the project continued to monitor rainfall, runoff, erosion, land use and other parameters in 2003. This report highlights the activities conducted during the year and the results obtained from them.

Materials and Methods

Five gauging stations, three (W1, W2, W3) built on three streams before their intersection with the main stream, one (MW1) on the main stream at the outlet of the catchment, and another one (W4), on the upper part inside the catchment above W3,

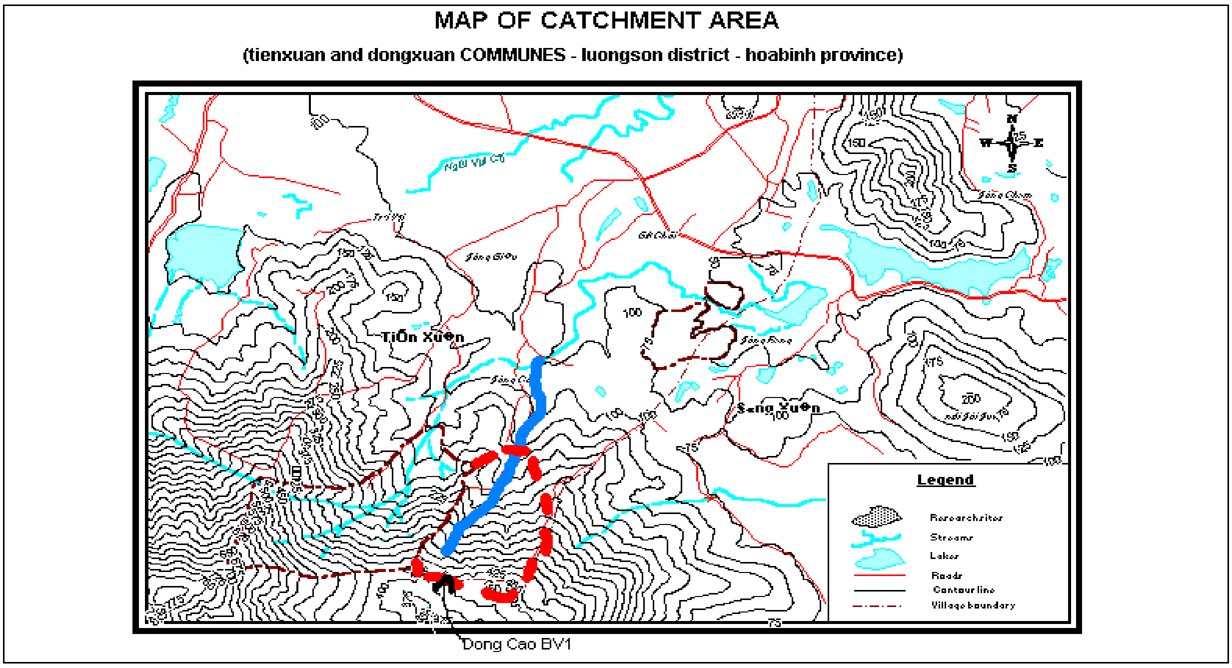

Figure 1. Map of catchment area (Source: MSEC program, IWMI, 2002)

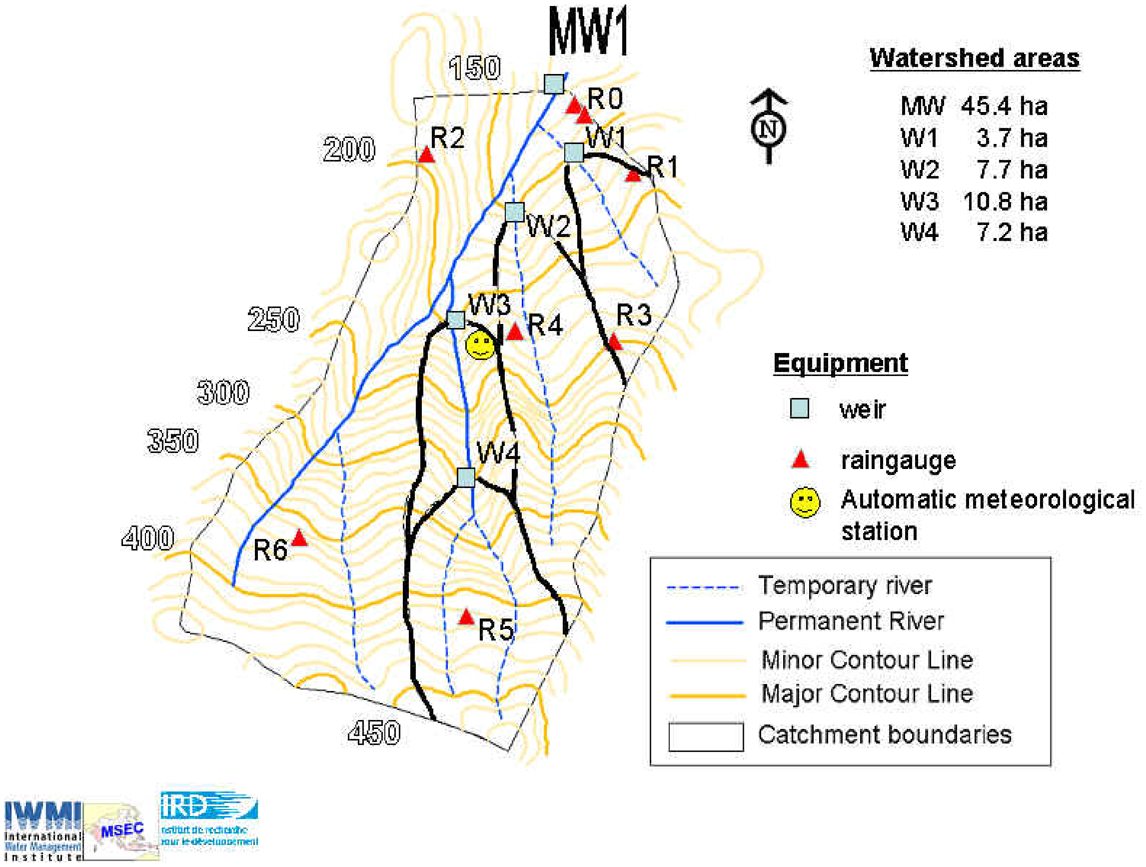

Figure 2. Location of equipment in the Dong Cao catchment.

were used to measure runoff and discharge during rainfall events. The water level in each weir was recorded automatically using Thalimedes type automatic water level recorders. Bed load sediments from each weir trap were entirely weighed after every flood. Some water samples from the weirs were taken for water chemistry and isotopic analyses. In 2002, three automatic suspended sediment samplers (ASS) were installed at the main weir, weir 2 and weir 4. Because of the problems with the ASS, it was impossible to collect the water samples from all weirs. As such, data for suspended load were collected from the main weir during the big storm events (end of July) only. Rainfall was measured by an automatic weather station and seven manual rain gauges distributed within the whole catchment. The use of manual rain gauges and automatic weather station reduces errors in measurement. Groundwater level monitoring, more detailed soil characterization and land use change evaluation were also done during the year.

Results and Discussion

Hydrological Characteristics

Rainfall

The rainy season started at the beginning of April and ended in late October. April was relatively wet in 2003 than in the same month in 2002 (Figure 3). The months of May and June were similar in both years, but July was especially humid (575 mm against 300 mm in an average year). It should be noted that in July, two typhoons passed by north Vietnam between 21 and 25 July, bringing rains amounting to 420 mm. During this big storm event (typhoon Koni), the water level rose to over 1 meter (Figures 4 and 5), and the stream discharge carried more than 20 g/l of suspended matter measured at 0700 on July 23.

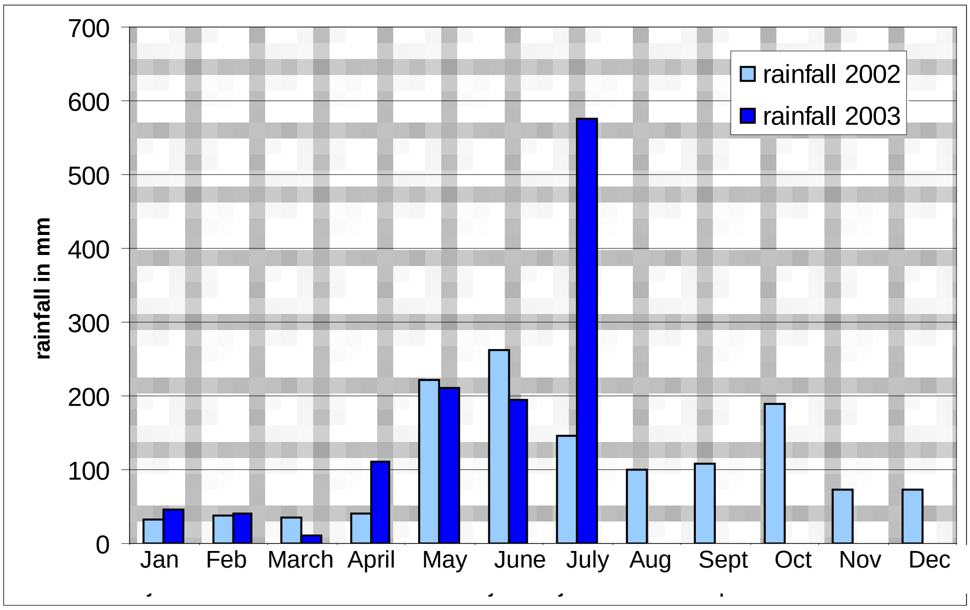

Figure 3. Monthly rainfall (in mm) in the Dong Cao catchment from January 2002 to July 2003.

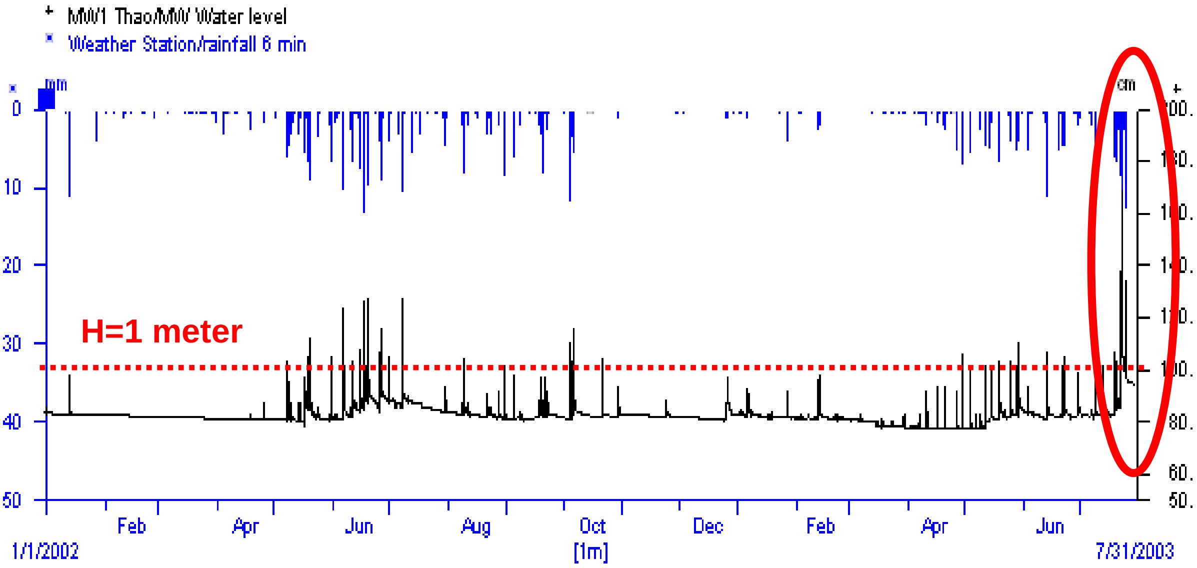

Figure 4. Water level at the main weir showing the increase during the time of the storm in July 2003.

Figure 5. Exceptional storm event (typhoon Koni) from 21 to 25 July 2003

There were fewer rainfall events in 2003 than in 2002, two times less in the month May. There were more events in the month of April although there were only small rains (Table 1. It was also observed that there were more rains falling at night (between 6 PM and 6 AM) (Figure 6). Of the 15 rainfall events that occurred during April to June, 11 events occurred at night or during weekends. These conditions made field measurement of runoff difficult.

Table 1. Rainfall monthly distribution, rainy season 2002 and 2003.

Rainfall (mm)	April 2002	April 2003	May 2002	May 2003	June 2002	June 2003	July 2002	July 2003
0-10	6	14	5	2	8	5	10	3
10-20	2	0	7	1	2	1	3	1
20-30	0	1	2	1	2	1	1	1
30-40	0	0	0	2	3	0	0	3
40-50	0	0	1	2	0	3	1	0
50-60	0	0	0	0	1	0	0	1
60-70	0	1	0	0	0	0	0	1
>100	0	0	0	0	0	0	0	2
Total monthly amount (mm)	**40,5**	**110**	**221**	**212**	**262,5**	**194,4**	**147**	**575**
No. of events	**8**	**16**	**15**	**8**	**16**	**10**	**15**	**12**

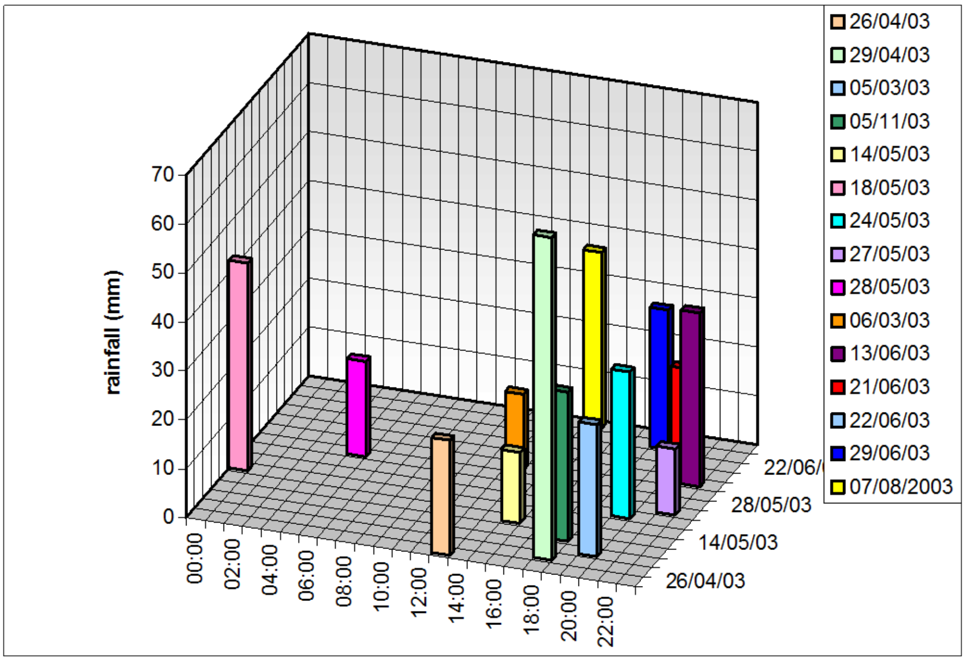

Figure 6. Daily rainfall distribution over Dong Cao catchment, April to June 2003

Runoff

Before any analysis, database cleaning is necessary to have more accurate data. The estimated discharge using the corrected data for 2002 and 2003 (until end of July) is shown in Figure 7. It was observed that there were fewer big floods (> 100 cm) in 2003 than in 2002.

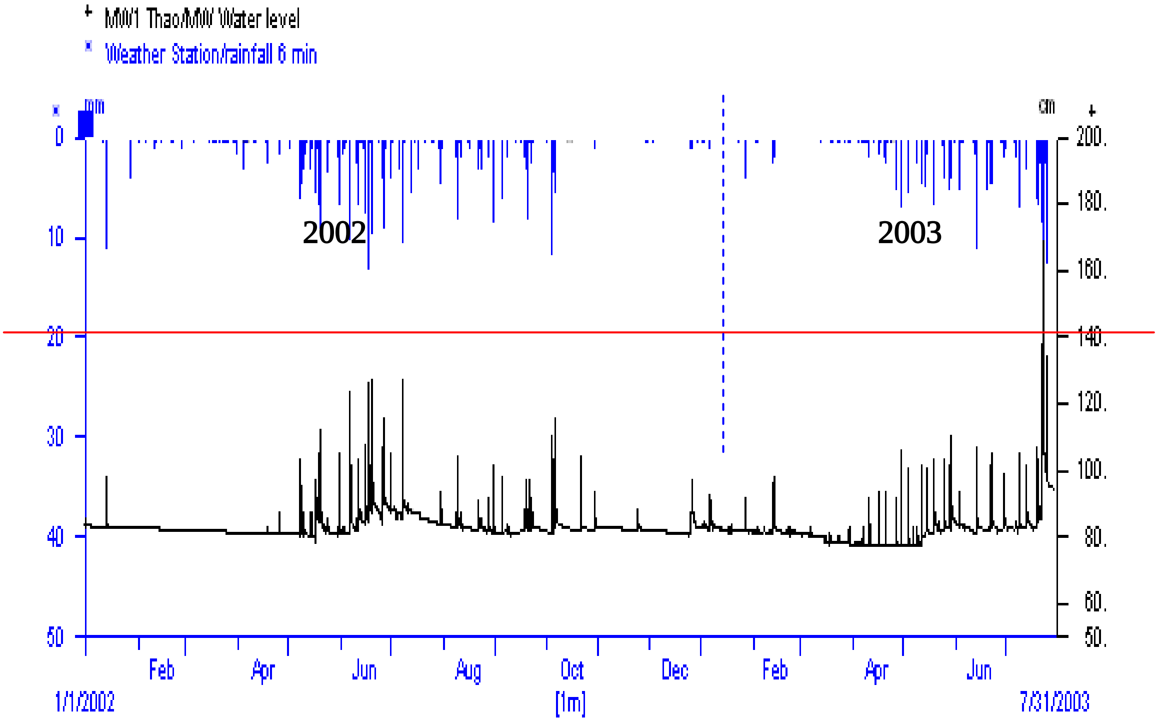

Figure 7. Observed rainfall and water level for 2002 and 2003 (until July)

The flow coefficient which represents the ratio of the total flow and the total rainfall over a certain period was estimated at 30% for 2002 and 40% for 2003 (Table 2). During the dry season, the streamflow in the main outlet is permanent, even if rainfall is limited. The flow coefficient at this period is higher but the flow volume is low. During the wet season, the flow coefficient decreases but the flow volume increases. This shows the important role of ground water on the hydrological process in Dong Cao Catchment. In 2003, the typhoon rains contributed 2/3 of the flow or 40% of rain. During this week, the flow coefficient exceeded 80%. The soil and sub surface horizon were saturated with rain water.

To measure runoff coefficient, the different storage tanks were first determined by doing logarithmic hydrogram separation (Figure 8). This method permits to determine different slopes. Each straight-line intersection shows a new water storage tank. The runoff volume and runoff coefficient were then estimated (Table 3). Runoff in Dong Cao catchment is low (10% for 2002). During the rainy season, the monthly runoff coefficients varied from 0 to 17% except during the typhoon in July 2003 when the soil becomes saturated and runoff coefficient reached 64%.

Table 2. Calculated flow coefficient on the main outlet of the Dong Cao catchment during 2002 and 2003

MW 2002	No. of rainy day > 50mm	Rainfall mm	Effective rainfall (90% of total rain) mm	Surface m^2	Effective rain volume m^3	Flow volume m^3	Flow coefficient %
Jan	0	31.5	28.3	455000	12899.2	10963	85
Feb	0	36.7	33.0	455000	15028.6	8323	55
March	0	36.0	32.4	455000	14742.0	7610	52
April	0	40.5	36.4	455000	16584.7	5677	34
May	0	221.0	198.9	455000	90499.5	12188	14
June	1	262.5	236.2	455000	107493.7	36229	34
July	0	147.0	132.3	455000	60196.5	25921	43
August	0	100.5	90.4	455000	41154.7	11102	27
Sept	0	107.5	96.7	455000	44021.2	8641	20
Oct	1	188.0	169.2	455000	76986.0	16770	22
Nov	0	74.0	66.6	455000	30303.0	9250	31
Dec	0	73.0	65.7	455000	29893.5	9152	31
Total 2002		1318.2	1186.3		539802.9	161826	30

MW 2003		Rainfall mm	Effective rain (90% of total rain)	Surface m^2	Effective rain volume m^3	Flow volume m^3	Flow coefficient %
Jan	0	45.5	40.9	455000	18632.2	10351	56
Feb	0	39.2	35.3	455000	16052.4	6987	44
March	0	10.0	9.0	455000	4095.0	3698	90
April	1	114.0	102.6	455000	46683.0	3915	8
May	0	211.0	189.9	455000	86404.5	13839	16
June	0	194.0	174.6	455000	79443.0	12434	16
July	4	575.0	517.5	455000	235462.5	159030	68
Until June		613,7	552,3	455000	251310.1	51224	20
Until July		1188,7	1069,8	455000	486772.6	210254	43
Flood 21-25/07		420,0	378,0	455000	171990.0	139873	81
Flood 22-24 July		320,0	288,0	455000	131040.0	117000	89

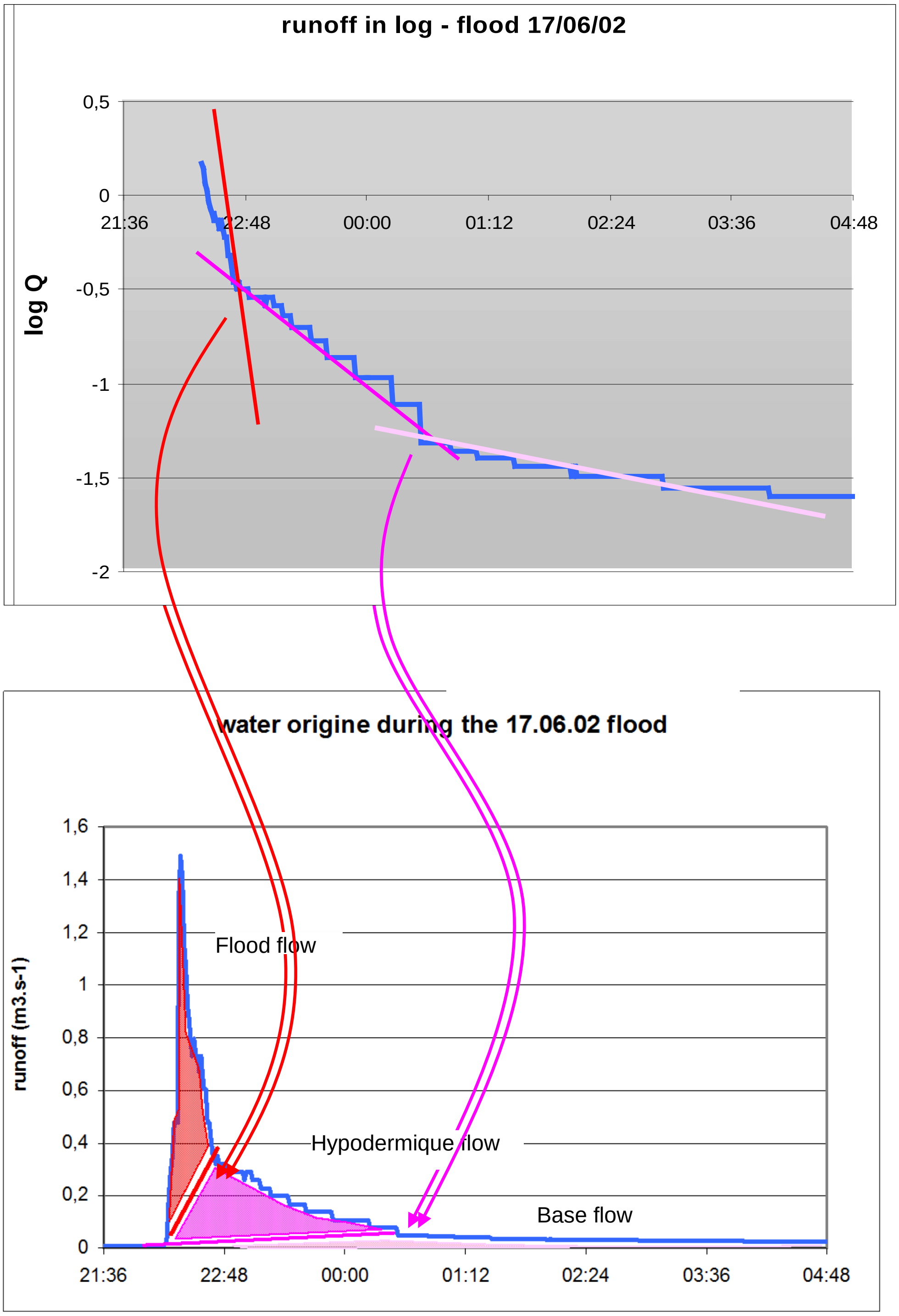

Figure 8. Logarithmic water storage tank separation method.

Table 3. Runoff coefficient in Dong Cao main outlet in 2002 and 2003

MW 2002	Rain (with runoff) mm	Effective rainfall (with runoff) mm	Surface m^2	Effective rainfall volume m^3	Runoff volume m^3	runoff coefficient (%)
Jan	0	0	455000	0	0	0
Feb	0	0	455000	0	0	0
Mrch	0	0	455000	0	0	0
April	0	0	455000	0	0	0
May	112	100	455000	45500	1860	4
June	235	212	455000	96000	14153	15
July	44	40	455000	18200	3053	17
August	44	40	455000	18200	503	3
Sept	0	0	455000	0	0	0
Oct	157	141	455000	64155	5614	9
Nov	0	0	455000	0	0	0
Dec	0	0	455000	0	0	0
Total	592	532		242055	25183	10
MW 2003	Rain (with runoff) mm	Effective rainfall (with runoff) mm	surface m^2	Effective rainfall volume m^3	Runoff volume m^3	runoff coefficient (%)
Jan	0	0	455000	0	0	0
Feb	0	0	455000	0	0	0
March	0	0	455000	0	0	0
Apr	70	63	455000	28665	470	2
May	176	158	455000	71890	5004	7
June	80	72	455000	32760	1209	4
July	490	441	455000	200655	127741	64
Total end June	326	293	455000	133315	6683	5
Total end July	816	734	455000	333970	134424	40
flood 21-25 July	420	378	455000	173810	125843	72
flood 22-24 July	320	288	455000	131040	116207	88

Sediment yields

The yearly bed load measured at the main weir was estimated at 0.5 t ha^{-1} $year^{-1}$ (Table 4, Figure 9). It was observed that the bed load was relatively lower in 2002. This observation can be explained by the lower rainfall and the denser grass cover in 2002. Because 2002 was a relatively dry year, the area that was cultivated was smaller than the previous years and the areas earlier cultivated had been left with wild grasses. The highest bed load was observed in W2 (2.7 t ha^{-1}) where cassava was planted. The other sub-catchments had bed loads of not more than 1 t ha^{-1}.

Table 4. Sediments collected in the different weir during the rainy season of 2003.

Date	MW (kg)	W1 (kg)	W2 (kg)	W3 (kg)	W4 (kg)
6-Apr-03	632	0	28	185	74
3-May-03	253	0	3 745	210	74
5-May-03	162	0	0	0	0
15-May-03	401	0	129	0	0
22-May-03	125	0	422	389	39
28-May-03	621	0	3 440	230	0
29-May-03	0	0	4 087	0	0
6-Jun-03	1 135	0	201	69	42
18-Jun-03	857	0	1 427	261	75
24-Jun-03	632	0	1 480	0	0
2-Jul-03	944	0	439	428	0
11-Jul-03	1 398	0	1 455		0
19-Jul-03	814	0	530	252	124
24-Jul-03	6 263	1 450	0	0	0
25-Jul-03	0	0	2776	2409	1 501
27-Jul-03	2 974	0	0	0	0
13-Aug-03	1 071	0	278	508	156
28-Aug-03	731	0	124	220	69
19-Sep-03	5 599	0			
20-Sep-03		0	580	314	121
Year total	**24,612**	**1,450**	**21,142**	**5,475**	**2,274**
Area (ha)	49.7	2.64	7.71	9.92	8.36
In 2003	**0.54**	**0.39**	**2.75**	**0.51**	**0.32**
In 2002	0.46	1.30	1.90	0.79	0.60

6250 : Amounts of sediment collected after the exceptional heavy rains of the 22/23 of July.

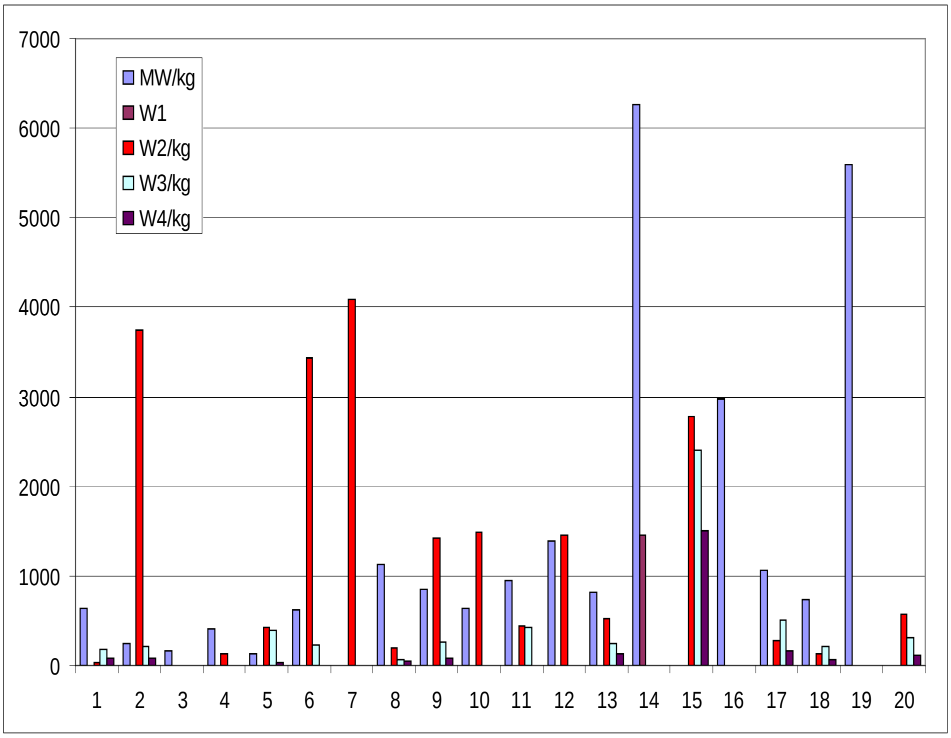

Figure 9. Bed load yields for each rainfall event in Dong Cao watershed, 2003

The analysis of the results points to several observations as follow:

- There is no direct relation between the amount of rainfall and the production of sediments;
- After land clearing, in the month of May, weir 2 shows the highest amount of sediments. Figure 10 shows that in May, watershed 2 had a totally bare soil surface and steep slopes. Erosion occurred as proto-rills.
- After the growth of *Bracharia* on watershed 2, the amounts of sediments collected in weir 2 decreased significantly in August and September;
- Weir 1 with a complete forest cover and weir 4 with degraded forest and under long fallow had little amounts of sediments.

Groundwater table and geology

Since May 2003, ground water level had been recorded. The water level was about 9.50 m from the ground surface in the beginning of May and increased to about 9 m in May and June (Figure 11). Underground water in this part (downstream from main weir), increase two or tree days after a big rainfall event. For the 20-25th rainfall event, the underground water level increased to near 5 m. Normally, for a "normal" rain, underground water level increase by few centimetres. Indeed, this year, for the first time the water level in a well near the main watershed outlet was observed. These records prove the direct connection between rainfall and the rapid change of the groundwater table.

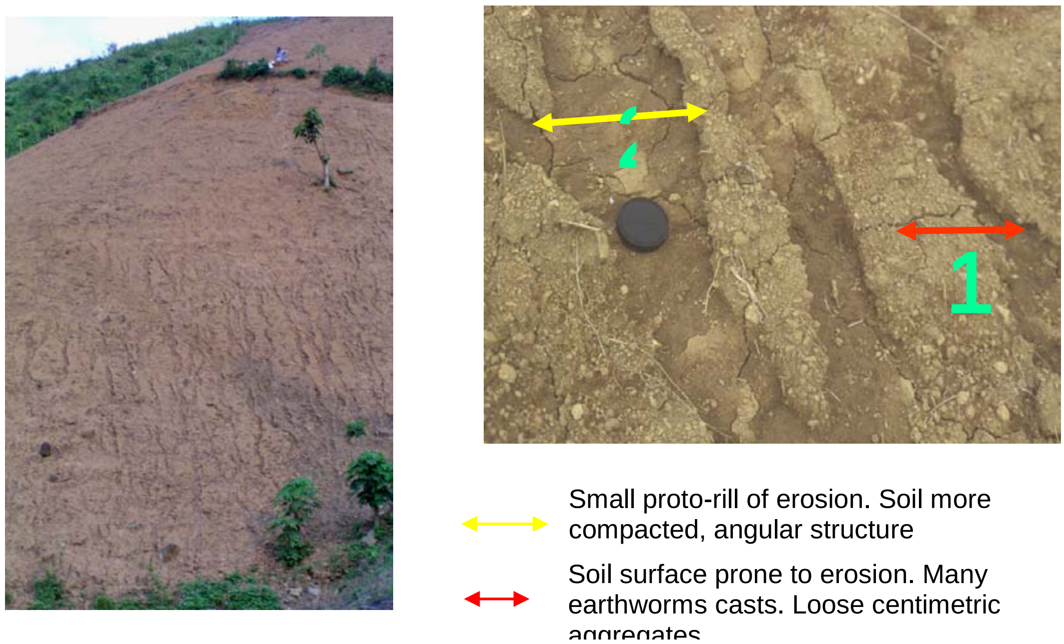

Figure 10. Proto-rills in steep slopes of watershed 2 (left); details of these proto-rills (right)

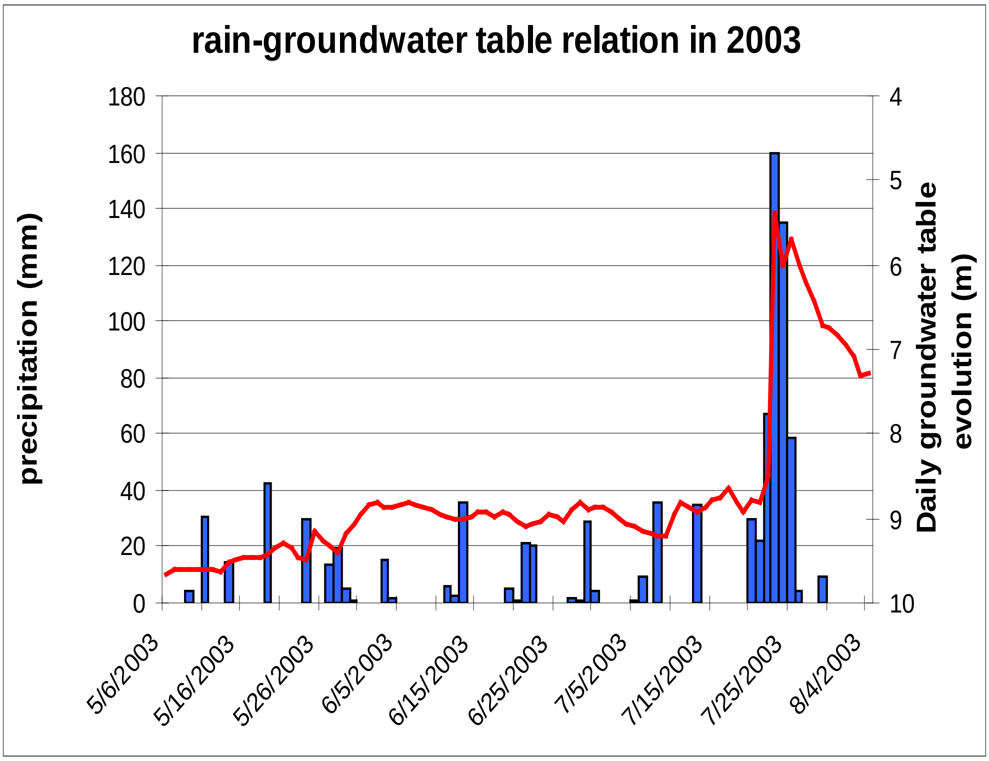

Figure 11. Groundwater table daily evolution in a well near the main watershed outlet of Dong Cao.

During big rainfall, Dong Cao catchment spring have a bigger runoff. Impacts of ground water in Dong Cao catchment seem important, without any hydrogeological analysis, we can only put forward hypothesis. Ground water seems to have a great impact on surface flow.

Field studies and data analysis had shown that geology and groundwater appeared to largely explain the hydrological processes in Dong Cao catchment. Figure 12 shows some geological information about the catchment. It is observed that soil characteristics are similar in the whole catchment. There are temporary streams in sub catchments 1 and 2 and permanent streams in sub catchments 3, 4 and 5 (River near W3). There are aquifers with springs at different places (downstream W2 and MW). Ground water feeds into stream 3 and stream 5 and this is confirmed by isotopic analysis and flow coefficient.

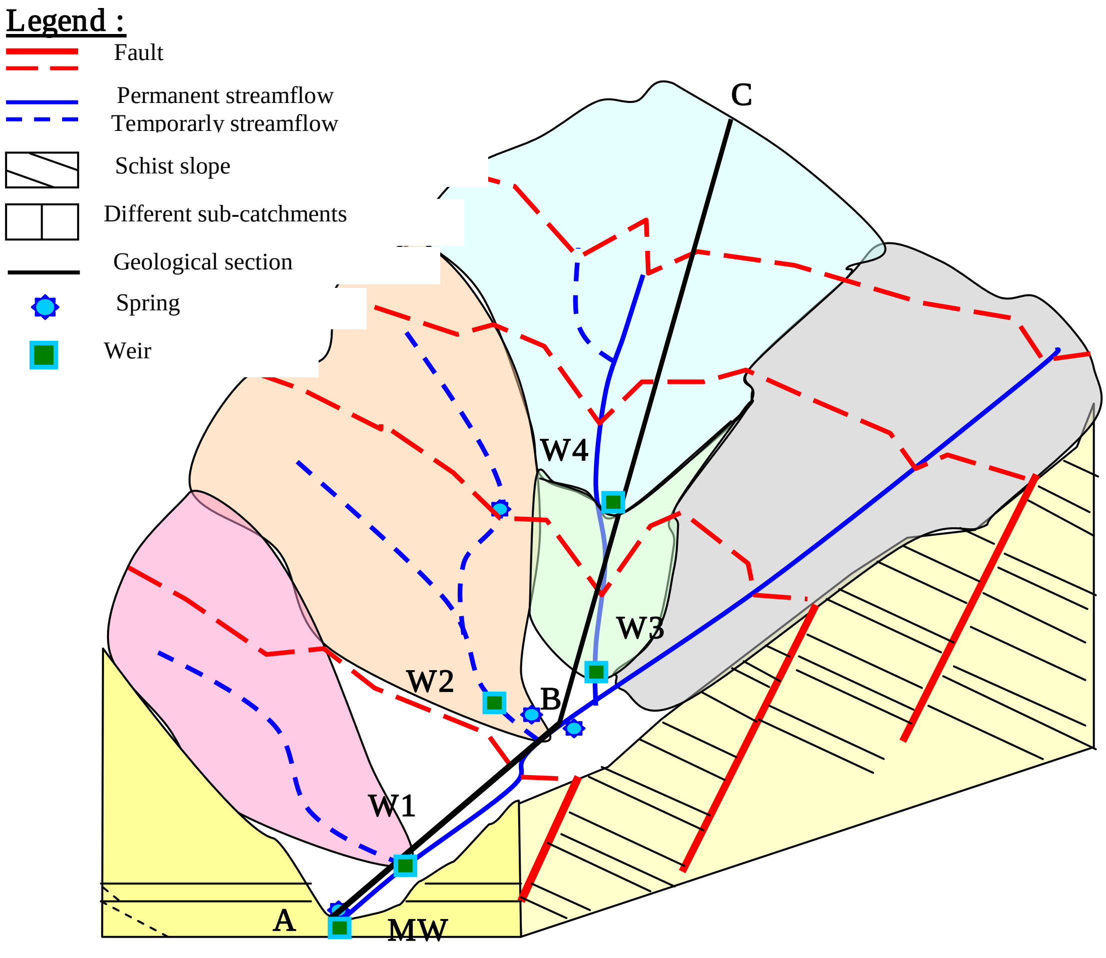

Figure 12. Dong Cao catchment geological diagram.

From the above observations, it can be hypothesized that streamflow begins at the first base of the fault stairs and at the spring in others. In permanent flow catchment, fault layer slope and schistosity cut at right angle to the streamflow and infiltration is low. In temporary flow catchment, fault layer slope and schistosity cut parallel to the streamflow and infiltration is high. Without any hydrogeological analysis, the effect of ground water can not be clearly explained, except by isotopic analysis and determination of flow coefficient.

Isotopic analysis

Isotopic analysis of the water showed three groups. More water is evaporated from the rainfall, followed by the reservoir and then from the Dong Cao streamflow (Figure 13). All the Dong Cao streamflows look similar, and can be considered of the same water family. These initial information suggest the possibility of using isotopic analysis to trace the pathway of surface runoff in the Dong Cao watershed. Dong Cao stream flow appears to come from both rainfall and ground water.

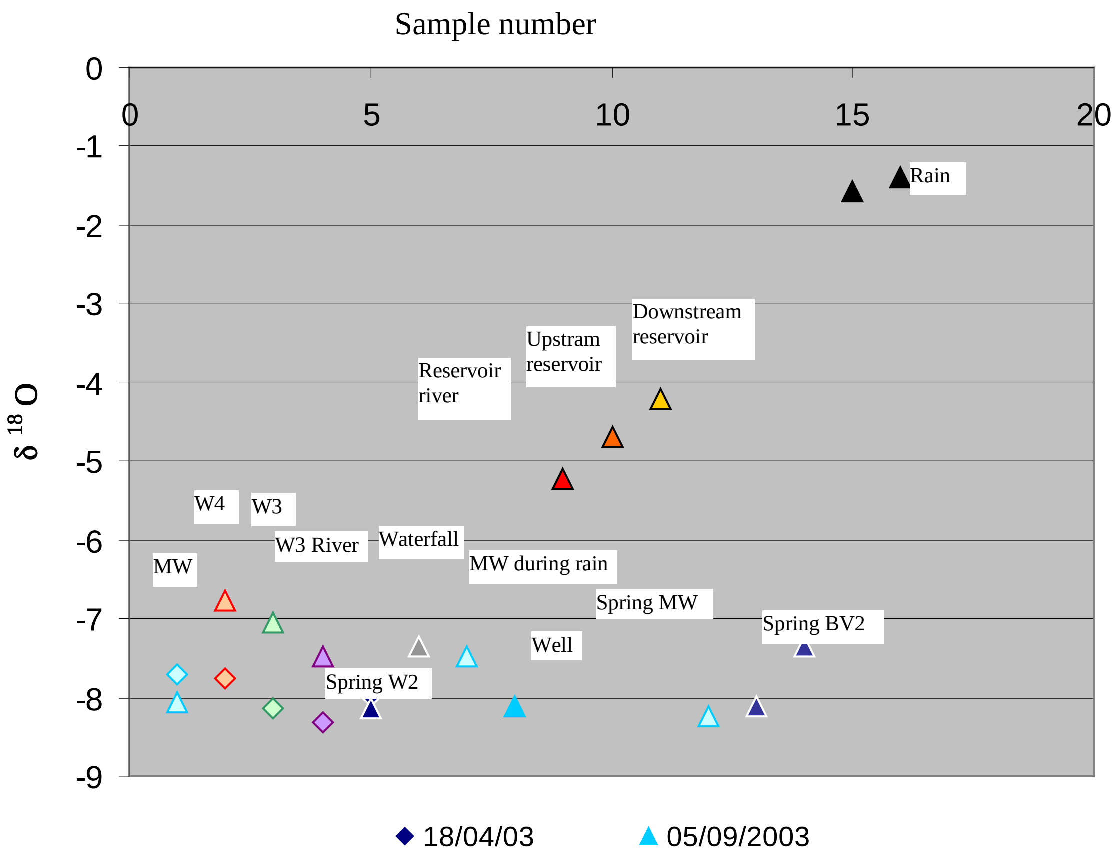

Figure 13. Isotopic water chemistry assessment (oxygen-18 in isotopic delta) in Dong Cao catchment, 2003.

Soils

Orientation of the landscape

The Dong Cao catchment is surrounded by hills with a general slope of over 30%, sometimes reaching 100%. The hills are scaled in space with steps and alternate occurrence of gentle slope (15-20%) and very steep slopes (over 80%) (Figure 14) . This disposition is probably linked to a series of faults oriented to the north (in the same direction of the main flow).

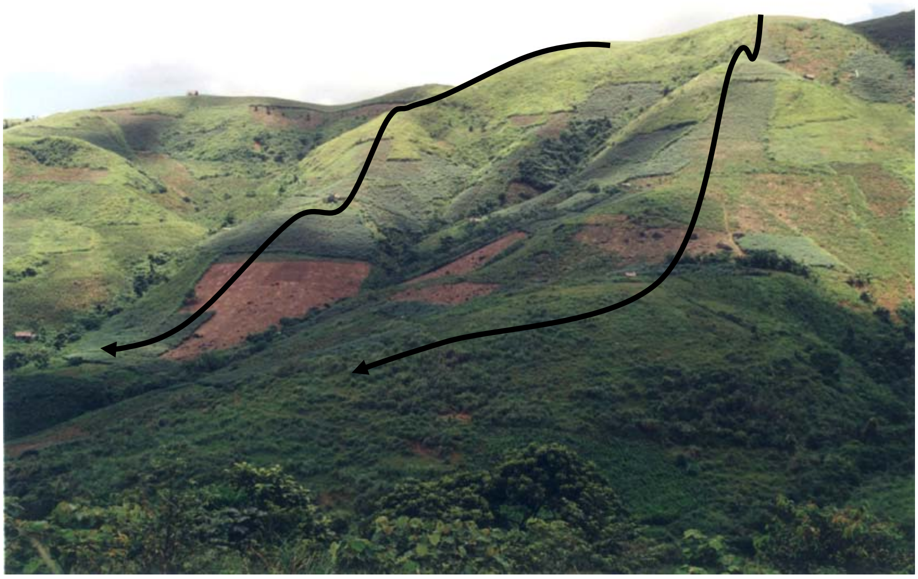

Figure 14. Step-form steep slopes on Dong Cao watershed

Orientation of the parent rock

The parent rocks are schists in centimetric layers with a steep dip oriented to the south, opposite the slope (Figure 15). For this reason, the soil depth will depend on the weathering rate of the schist layers. Therefore the succession of hills will have different soil depth.

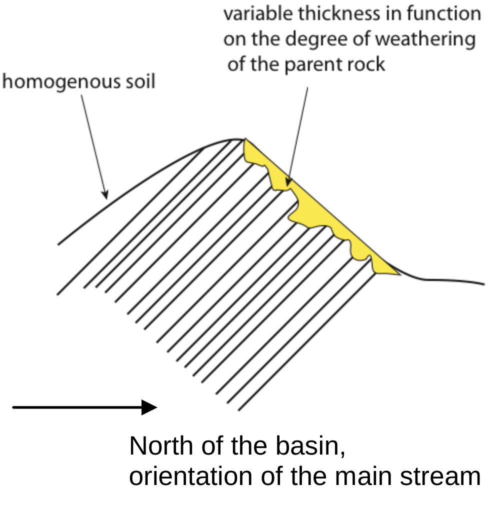

Figure 15. Orientation of the schist dip in the watershed.

Distribution of the soil types

Acrisols

The general soil type in the landscape is an Acrisol (FAO, 1998) or Ultisol (SSS, 1999). Soils are generally thick, over 1.0 m deep, clayey, very porous, with micro aggregates on the topsoil resulting from a strong biological activity of termites and ants. They show a homogenous brown colour 10YR4/4 to 7.5 YR 4/6 with a weak differentiation. The general clay type is kaolinite with low CEC; pH is low, below 5.0 (Tables 5 and 6). The soils present a small clay enrichment at 40-cm depth with a Bt horizon (Table 7), some cutans are visible. Along the main slope, there are four different kinds of soil profiles (Figure 16).

Table 5. Chemical data of soil surface horizon of different soil types

	C	N	C/N	pH	pH	Ca^{++}	Mg^{++}	Na^{+}	K^{+}	CEC	S/T	P_2O_5T	KT
	g kg^{-1}	g kg^{-1}		H_2O	KCl		Cmol$^{(+)}$ kg^{-1}				%	%	%
STA1	11.1	1.46	7.42	5.2	3.7	0.40	0.36	0.04	0.10	7.0	12.9	0.140	0.036
STA2	44.5	2.97	14.83	4.8	3.9	2.88	1.12	0.04	0.41	13.4	33.2	0.147	0.054
STA3	23.7	2.24	10.79	4.9	3.9	1.80	0.11	0.04	0.08	11.2	18.1	0.101	0.066
STA4	24.9	3.19	7.77	4.9	4.0	2.78	1.79	0.04	0.21	13.8	34.9	0.140	0.527
Dcao 1.1	28.9	4.26	6.73	4.4	3.8	2.67	0.18	0.09	0.26	18.2	17.6	0.100	0.451
Dcao 4.1	34.5	3.64	9.58	4.3	3.7	1.91	0.19	0.09	0.46	14.6	18.2	0.108	0.211
Dcao 14.1	27.8	2.97	9.28	4.2	3.7	3.43	1.21	0.09	0.13	15.6	31.2	0.204	0.385
Dcao 17.1	32.1	2.97	10.70	4.3	3.8	3.74	2.35	0.09	0.26	11.8	54.6	0.114	1.791
Dcao 22.1	25.9	2.86	8.93	4.5	4.0	6.69	2.26	0.09	0.26	14.6	63.7	0.247	0.247
Dcao 23.1	36.7	3.36	10.80	4.3	3.8	8.72	5.75	0.09	0.18	22.5	65.5	0.214	0.163
Dcao 25.1A	30.8	3.40	9.06	4.1	3.9	3.60	1.73	0.04	0.28	16.6	34.0	0.211	0.069
Dcao 25.1B	27.8	7.39	3.76	4.1	3.9	2.80	2.34	0.04	0.10	17.6	30.0	0.234	0.066
W2-4/5/03	27.3	2.35	11.39	4.1	3.8	3.95	1.77	0.04	0.28	18.4	32.8	0.096	0.078
LAC13	29.2	3.25	8.85	5.3	4.9	9.14	4.19	0.04	0.15	18.2	74.3	0.224	0.385

STA1: deep Acrisol soil without clast;STA 2: earthworm clast; STA 4: compacted Acrisol close to bamboo plantation; STA4: Cambisol below forest.
Dcao 1.1: Acrisol top of hill; Dcao 4.1: Acrisol on steep slope below forest; Dcao 14.1: shallow Acrisol below cassava; Dcao 17.1 Leptosol below opened forest; Dcao 22.1: Arenosol; Dcao 23.1: Cambisol on fallow ; Dcao 25.1A : Acrisol on steep slope, erodible aggregates of Fig. 12; Dcao 25.1B: Acrisol on steep slope, not eroded soil of Fig. 12;
W2: Sediments of weir 2 the 4th of May; LAC13: surface sediments collected in the reservoir.

1. On the top of the hills, soils are moderately deep, and laying directly on parent rock (Figure 17).
2. On slopes, soils develop on former colluvial material (Figure 18). This colluvium is composed of free stones and gravels embedded in a clayey matrix similar to the Bw horizon matrix, with the same geological origin than the parent rock but removed in different directions. The clayey horizon is over 70 cm thick and the colluvium is at least 50 cm thick (profile 02, 05, 07, 09)
3. When the slope decrease on the more horizontal part of the steps forming the landscape, the colluvium became very thick (over 1.0) and the soft soil without stones becomes shallower, >0.50 cm (profile 04, 08, 12).

Table 6. Soil grain size composition in Soil sequences n°1 (on the left bank) and in watershed 3

Sample	Hz	CS	FS	CSi	FSi	C
Cao 11.1	A	2.79	1.86	15.09	36.79	43.47
Cao 11.2	Bw1	2.79	1.92	17.15	36.21	41.92
Cao 11.3	Bw2	3.62	1.74	14.20	35.96	44.49
Cao 11.4	Bw3	2.34	2.65	28.51	21.85	44.65
Cao 12.1	A	1.43	1.22	11.68	30.18	55.49
Cao 12.2	Bt	1.53	0.89	7.80	22.44	67.32
Cao 12.3	Bw1	1.75	0.89	9.74	28.23	59.39
Cao 12.4	Bw2	1.07	0.72	14.73	28.48	55.00
Cao 13.1	A	1.57	0.98	7.79	39.95	49.70
Cao 13.2	B	4.07	0.80	15.22	19.98	59.92
Cao 14.1	A	3.54	1.08	10.50	32.43	52.46
Cao 14.2	AB	2.81	0.68	7.73	24.12	64.67
Cao 14.3	Bw	2.37	0.64	7.50	27.19	62.29
Cao 15.1	A	4.20	2.37	12.14	36.44	44.85
Cao 15.2	Bt	3.30	1.78	7.60	23.73	63.59
Cao 15.3	Bw1	1.67	0.71	20.50	27.33	49.78
Cao 15.4	Bw2	0.40	0.29	31.78	33.77	33.77
Cao 16.1	A	13.13	7.06	12.77	30.33	36.71
Cao 16.2	Bt	8.14	6.59	7.68	34.11	43.48
Cao 16.3	Bw1	12.95	7.40	7.97	34.25	37.44
Cao 16.4	Bw2	9.61	5.85	5.07	31.28	48.18
Cao 31.1	A	5.26	4.21	9.05	27.16	54.32
Cao 31.2	AB	2.47	1.65	10.54	32.60	52.74
Cao 31.3	Bw	5.69	4.48	6.29	37.73	45.82
Cao 32.1	A	9.85	7.24	10.74	28.53	43.64
Cao 32.2	AB	5.66	3.57	15.43	33.58	41.75
Cao 32.3	Bw	6.98	3.21	9.88	29.64	50.29
Cao 33.1	A	5.47	3.75	12.71	29.05	49.02
Cao 33.2	AB	0.87	1.84	16.54	53.51	27.24
Cao 33.3	Bw	7.95	3.51	14.16	31.87	42.50

CS: Coarse sand; FS: Fine sand; CSi: Fine silt; Fsi: Fine silt; C: Clay
Data obtained in 2002, after the 1st soil survey made by Pascal Podwojewski in 2001.

Cao 11, 12, 14: deep Acrisols on parent rock; Cao 15 and Cao 16: deep Cambisol on colluvium; Cao 13 and Cao 31: shallow eroded Acrisol; Cao 32 Cambisol on colluvium; Cao 33 deep Acrisol on colluvium on very steep slope

Table 7. Soil surface grain size composition in Soil sequences made for ^{137}Cs measurements

Sample	CS	FS	CSi	FSi	C
DC1	17.56	11.47	9.39	30.73	30.85
DC3	6.02	4.52	6.26	26.84	56.36
DC4	2.11	1.85	6.73	27.85	61.46
DC5	4.09	3.15	6.49	27.83	58.44
DC6	4.57	5.34	5.66	29.56	54.88
DC7	6.35	7.88	5.96	25.70	54.10
DC8	6.37	6.98	8.67	29.46	48.53
DC9	6.07	6.51	7.00	29.72	50.70
DC10	13.94	8.49	9.30	34.14	34.14
DC11	14.06	9.88	6.08	29.67	40.32
DC12	16.28	10.50	5.60	31.71	35.91
DC13	12.31	9.00	8.66	30.69	39.34
DC14	2.82	4.27	5.04	31.81	56.05
DC15	2.07	2.22	5.74	24.88	65.09
DC16	3.08	1.55	7.63	28.61	59.13
DC17	2.90	1.73	10.49	29.57	55.31
DC18	3.40	2.03	13.24	36.88	44.45

Data obtained in 2002, after the ^{137}Cs prospection in year 2000.

DC1 to DC13 correspounding to the Soil sequence n°0 ;
DC14 to DC18 are localized in the sequence 1, on the left bank of the watershed.
DC10, 11, 12 and 13 correspound to eroded and shallow Acrisols

4. At the lower part of the hills, in the concave and rectilinear part of the slope, when the slope decreases, soils are shallower, developing on old colluvial material, and with a probable erosion of their upper part (Figure 19). This erosion occurred probably during the last decades after cultivation and tillage (profiles 13 and 14).

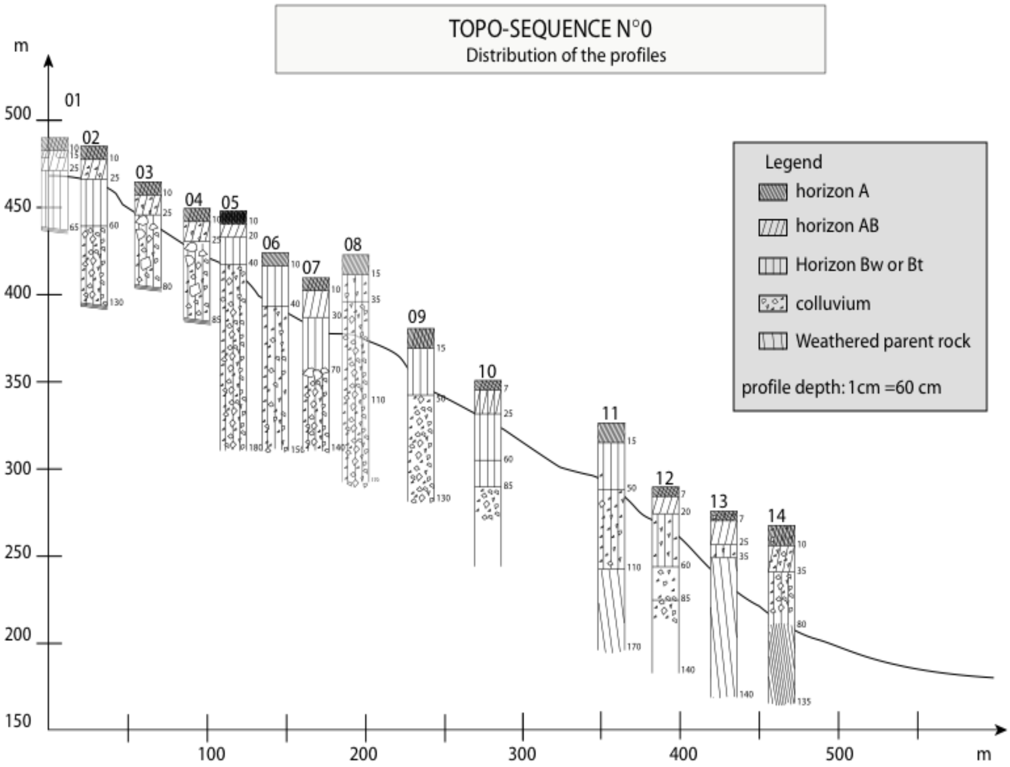

Figure 16. Main soil sequence from the top of the watershed to weir 3

Figure 17
Acrisol on parent rock

Figure 18
Acrisol on colluvium Shallow

Figure 19
Acrisol on colluvium

Cambisols

In the main drainage pathways, on recent colluvium, the soils present cambic horizon characteristics with darker color and no evidence of clay accumulation (Figure 20, profile 23). On the water pathways, soils are often shallower and with coarse material. These soils have often an enrichment in organic matter, water and nutrients.

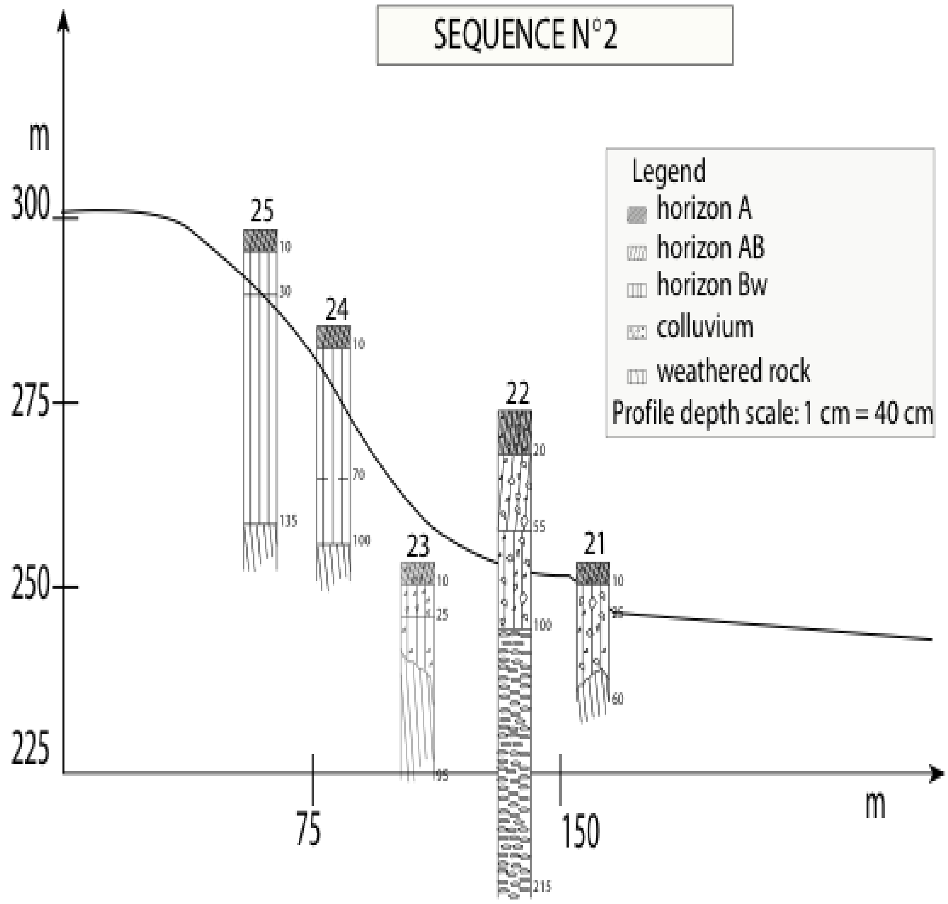

Figure 20. Soil distribution in the sequence2, located in the watershed 2

Regosol on Fluvisol

Just downstream weir 3 and upstream of weir 2, there are big colluvial rounded blocks over 50 cm in diameter outcrops. Between these blocks, deep Fluvisol with arenic properties are formed. These areas have limited area (Figure 20, profile 22).

Leptosols

In some places where the schist layers are harder, soils are very shallow, < 30 cm thick, and with a high stone content > 20%. Soil surface is covered with stones 1-15 cm long. This narrow area (20 m) is localised close to the main weir and is oriented perpendicular to the main drainage way (Figure 21).

Figure 21. Contact between deep Acrisols (brown-orange colour) and Leptosol (grey colour) close to the main weir.

Carbon sequestration in the landscape

To measure the effect of the slope on the general carbon content, and to appreciate the evolution of the carbon content before and after land use changes, soil samples were taken from two horizons at a depth of 0-10 and 15-25 cm in 75 sites and arranged in 11 soil sequences. The selected samples were from watershed 2, watershed 3, and a smaller trial on main weir site. The land use represents an intensive cassava cropping (watershed 3), grass cover after bare fallow (watershed 2), and eventually bamboo and *Tephrosia sp.* hedgerows plantations (main weir) after cassava cropping and young fallow.

The land use changes that have occurred in these areas are as follow:

- In 2002, the main part of watershed 2 was cultivated with cassava and then maintained in bare fallow (Figure 22), while close to main weir and watershed 3 were fallow after cassava cultivation in 2001 and several years before. Cassava cropping generates intense erosion in the early stages of the development of the vegetation, at the beginning of the rainy season (April and May) with bare soils and tilled soil surface.

- During the year 2003, watershed 2 and 3 and also a plot close to Main weir changed their land use.

  - Close to the main weir, on the right bank of the river, the LUSLOF project (University of Uppsala, Sweden) leads a bamboo crop trial associated to *Tephrosia candida* (Fabaceae) hedgerows along the slope.
  - In Watershed 2, the MSEC programme decided to plant a new cover crop, *Bracharia ruziziensis*, a Poaceae with a C4 chlorophyll cycle (Figure 23) to provide the farmer fodder for the cow raised for milk, to improve the soil carbon content, and to reduce the soil erosion,

Figure 22. Watershed 2, bare soil, month of May

Figure 23. Same site in August, grass cropping

- Watershed 3 was cultivated with a cassava crop, with less soil cover than grass and less effects on the soil carbon. To maintain the soil fertility especially in nitrogen, *Stylosanthes guyanensis* (Fabaceae) was planted with cassava.

- End of the year 2003 ,

  - In Watershed 2, *Bracharia* was cut two times, first in mid-August with a yield of 2.5 t ha^{-1} and second in October yielding 3.8 t ha^{-1} in dry matter. The water content was around 80%. Half of the *Bracharia* cover was cut for fodder for the cow of the farmers, the other half left on soil as a mulch to maintain the soil fertility and improve the soil carbon content.
  - In Watershed 3, the cassava was harvested end of November. Yields varied with the soil depth (water and nutrient reserves).

In 2004, it is planned to measure the carbon content in the same locations. In watershed 2, the effect of the grass cover should be a rapid increase of carbon content which is expected after regular cuttings to be higher than in the fallow land. The amount of carbon eroded from the grassland soil cover can be measured by the C13 content of the sediment deposits in weir 2.

Earthworm activity

In Don Cao watershed, earthworm activity is very high. The earthworm casts may have an important role in the erosion process. The casts formed are very hard and are composed of rounded centimetric sub-aggregates that are prone to erosion on steep slopes. Many rounded aggregates have been found in weir 2 when bare soil of watershed 2 was exposed to water erosion before the grass cover. In addition, the earthworm may concentrate some elements in their casts. Blanchard *et al* observed that carbon, nitrogen and exchangeable calcium and magnesium are higher in the cast than in the soil. The first results of chemical analysis confirm this observation (see Table 5).

Therefore, earthworms play an important role in the redistribution of soil and soil nutrients from upslope to down slope. The earthworms seemed to be very important on recently transformed lands. In front of the MSEC house, the hill was earlier planted to forest trees (*Acacia mangium*, Eucalyptus). After 10 years, the trees were cut and the area was cleared. On this cleared land the earthworm activity was very high as evidenced by accumulation of the casts (Figure 24).

Figure 24. Earthworm casts at soil surface

Using three observation plots of 20 m^2 (20m x 1 m) along the slope of the cleared forest, all casts from each plot were collected, air-dried and weighed. The earthworm cast density varied from 5 m^{-2} in the upstream portion to 20 m^{-2} downstream. The cast measured about 9 cm long and 3 cm in diameter and 90 g in weight on the average. Some casts reached as long as 15 cm and 160 g (Figure 25). They are composed of the aggregated rounded centimetric hardened pellets. The bulk density is about 1.6 kg dm^{-3} and moisture content of fresh casts of 25% (250 g kg^{-1}), and 3 %(30 g kg^{-1}) for the air-dried sample.

Soil structure stability

The soil morphology of the soil sequence 0 or on the sequence 2 (see Figure 20) shows that the eroded soils are located at the foothills at less steep slopes decrease (profile 21), while on steep slopes, the soil depth is over 1.0 m. This soil evolution could be attributed to 3 factors:

- Tillage of the soil especially for land clearing and weeding;
- Expose bare soil surface especially during the first stages of the cassava cropping;
- Decrease of soil organic matter content which reduces the stability of aggregates.

Figure 25. Earthworm cast in Dong Cao

The soil structure stability is an important parameter for understanding of erosion processes. Many samples have been taken in 2003 and we must measure the aggregate structure stability. The stability of aggregates can be affected by different land uses, mineral composition of the soils, and activity of the earthworms.

Organic matter is an important factor affecting aggregate stability, and therefore it will be important to compare the situation under different land uses, i.e., fallow, cassava fields, former cassava fields and new grass cover and compare them with the soil carbon storage. Shallow Acrisols are more eroded and their clayey composition shows an increase in interstratified material coming from the early stages of rock weathering. These soils may have a different aggregate stability than the deep Acrisols.

Land Use and Land Ownership

Land use and land use changes were monitored by actual ground survey and interviews. The watershed was divided in 41 plots in 2002, 40 belonging to 18 different households, and one state owned. In June 2003, the watershed was occupied by only six owners, including the State. All or some part of the watershed lands of 14 farmers had been bought by one farmer of Dong Cao (Mr.Bon). Land use maps were prepared showing the plots and the owners.

Land use changes between 2002 and 2003

Between 2002 and 2003, the areas of *Acacia mangium*, secondary forest and *Venicia montana* remained the same (Table 8). The fallow area decreased by 4%, while the area of cassava decreased by 65%. The arrow root was completely stopped and 55% of the Eucalyptus was cut down. A small area was planted to bamboo and *Tephrosia candida* (by LUSLOF project).

The main changes on the MSEC watershed was the cultivation of fodder crops (by MSEC program), and the planting of trees (by one farmer of Dong Cao, Mr Bôn). Thus, 4.3 ha was planted to *Bracharia ruziziensis*, a fodder grass, and 1.1 ha to *Stylosanthes guyanensis*, a leguminous fodder, in association with cassava (Figure 26). In the lower part of the watershed, 4.1 ha was planted to *Canarium trandenus*, 13.8 ha to *Chukrasia tabularis*, mainly in the middle part of the watershed, and 22 ha to Styrax, mainly in the upper part of the watershed. These trees were planted on areas already covered by other crops, or in fallow areas, on almost all the watershed (Table 9). At the end of 2003, 80% of the watershed was thus planted to these trees.

Table 8. Area (ha) per kind of crop in 2002 and 2003

CROP	2002	2003
Acacia Mangium	7.4	7.4
Arrow root	0.5	0
Bamboo	0	0.3
Bracharia Ruziziensis	0	4.3
Canarium Trandenus	0	4.1
Cassava	4.4	1.5
Chukrasia Tabularis	0	**13.8**
Eucalyptus	6.4	2.9
Fallow	**24.9**	**24.0**
Secondary forest	9.4	9.4
Stylosanthes Guyanensis	0	1.1
Styrax	0	**22.0**
Tefrosia Candida	0	0.8
Venicia Montana	0.8	0.8

(Source : Koïkas J. Renaud J. & al. Dong Cao GIS Arcview project, with former inquiry, 2003)

Table 9. Area per land use in 2003

LAND USE	Area (ha)
Acacia Mangium in fallow 1 year + Chukrasia Tabularis	1.7
Acacia Mangium in fallow 1,5 year + Chukrasia Tabularis	1.4
Acacia Mangium + Styrax	1.1
Acacia Mangium + Canarium Trandenus	0.5
Acacia Mangium	1.2
Acacia Mangium in fallow 7 months	0.5
Bamboo + Tefrosia Candida	0.3
Bracharia Ruziziensis + Styrax	0.4
Bracharia Ruziziensis + Chukrasia Tabularis	3.3
Bracharia Ruziziensis	0.6
Canarium Trandenus	3.5
Cassava & Stylosanthes + Acacia + Chukrasia Tabularis	1.1
Cassava + Tefrosia Candida	0.5
Eucalyptus	2.9
Fallow 1,5 year + Chukrasia Tabularis	0.8
Fallow 10 years + Styrax	14.1
Fallow 10 years + Chukrasia Tabularis	1.0
Fallow 12 years + Chukrasia Tabularis	2.2
Fallow 3 years + Chukrasia Tabularis	0.6
Fallow 6 months + Chukrasia Tabularis	0.2
Fallow 7 months + Chukrasia Tabularis	1.5
Secondary forest	3.0
Secondary forest + Styrax	6.4
Venicia Montana + Canarium Trandenus	0.1
Venicia Montana	0.7
TOTAL	49.5

(Source : Koïkas J. Renaud J. & al. Dong Cao GIS Arcview project, with former inquiry, 2003)

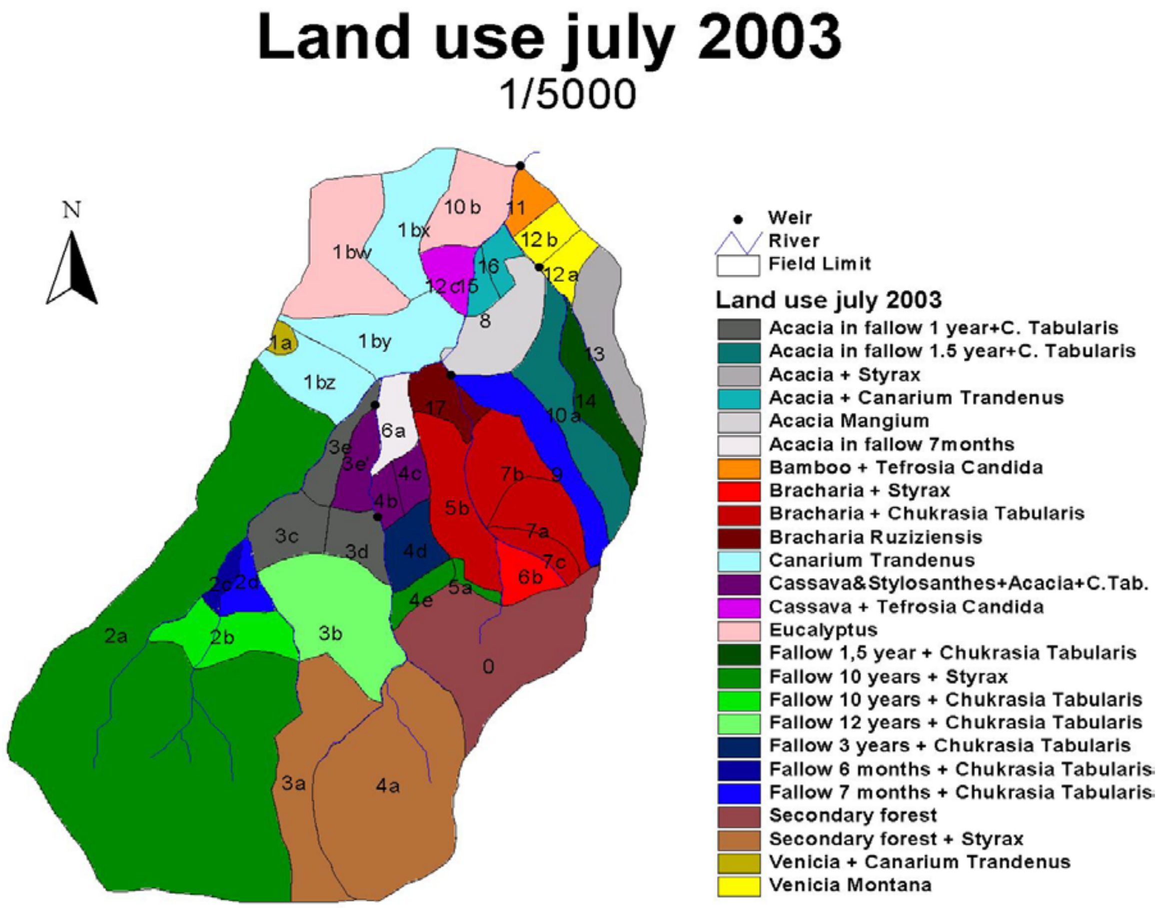

Figure 26. Land use map of the catchment in 2003 showing the plots

Land ownership in 2002 and 2003

In 2002, there were 19 different owners of the land in the watershed (Tables 10 and 11 and Figures 27, 28, and 29). The biggest owner was the chief of the village, Mr Tuoi, with 15.3 ha (31%). There were 3 farmers owning between 5 and 7 ha (between 11 and 13%), 3 ha was owned by the state. In the upper part of the watershed, 9 farmers owned between 1 and 3 ha (2 to 4%), and 5 farmers owned less than 1 ha.

In 2003, one farmer, Mr Bôn, who owned 5.5 ha (11%) in 2002, bought 75% percent of the rest of the watershed, bringing his ownership to 86% of the watershed or 42.5 ha. As a a result, there were only six owners on the watershed, including the State. The four other remaining farmers owned between 0.7 and 1.2 ha or 2% or less of the total area.

Table 10. Area per owner on MSEC watershed in 2002 and 2003

Owner 2002	Area (ha)	%	Owner 2003	Area (ha)	%
Tuoi	15.3	31	Bôn	42.5	86
Tháo	6.5	13	State	3.0	6
Cân	5.8	12	Phú	1.2	2
Bôn	5.5	11	Khuyen	1.1	2
State	3.0	6	Nhón hô	1.0	2
Luc	2.1	4	Bûi	0.7	1
Tám	1.4	3	Tuoi	0.0	0
Bây	1.4	3	Tháo	0.0	0
Bûi	1.2	2	Cân	0.0	0
Phú	1.2	2	Bây	0.0	0
Quý	1.1	2	Lý	0.0	0
Khuyen	1.1	2	Luc	0.0	0
Nhón hô	1.0	2	Quý	0.0	0
Lý	1.0	2	Tám	0.0	0
Tiên	0.8	2	Xuân	0.0	0
Hien	0.6	1	Tiên	0.0	0
Xuân	0.3	1	Hoi	0.0	0
Tho	0.3	1	Tho	0.0	0
Hoi	0.2	0	Hien	0.0	0
TOTAL	49.5	100	TOTAL	49.5	100

(Source : Koïkas J. Renaud J. & al. Dong Cao GIS Arcview project, with former inquiry, 2003)

Table 11. Land owners in Dong Cao watershed in 2002 and 2003

Reference	Plot	Area (ha)	Owner 2002	Owner 2003
1	0	3.03	State	State
2	1A	0.12	Bôn	Bôn
3	1Bw	1.86	Bôn	Bôn
4	1Bx	1.25	Bôn	Bôn
5	1By	1.35	Bôn	Bôn
6	1Bz	0.93	Bôn	Bôn
7	2A	13.72	Tuoi	Bôn
8	2B	1.01	Tuoi	Bôn
9	2C	0.18	Tuoi	Bôn
10	2D	0.34	Tuoi	Bôn
11	3A	2.06	Tháo	Bôn
12	3B	2.15	Tháo	Bôn
13	3C	0.72	Tháo	Bôn
14	3D	0.54	Tháo	Bôn
15	3E	0.47	Tháo	Bôn
16	3E'	0.51	Tháo	Bôn
17	4A	4.35	Cân	Bôn
18	4B	0.25	Cân	Bôn
19	4C	0.29	Cân	Bôn
20	4D	0.61	Cân	Bôn
21	4E	0.29	Cân	Bôn
22	5A	0.10	Bây	Bôn
23	5B	1.27	Bây	Bôn
24	6A	0.51	Lý	Bôn
25	6B	0.44	Lý	Bôn
26	7A	0.77	Luc	Bôn
27	7B	0.95	Luc	Bôn
28	7C	0.35	Luc	Bôn
29	8	1.15	Phú	Phú
30	9	1.11	Quý	Bôn
31	10A	1.40	Tám	Bôn
32	10B	1.04	Nhón hô	Nhón hô
33	11	0.33	Xuân	Bôn
34	12A	0.34	Bûi	Bûi
35	12B	0.38	Bûi	Bûi
36	12C	0.45	Bûi	Bôn
37	13	1.05	Khuyen	Khuyen
38	14	0.83	Tiên	Bôn
39	15	0.21	Hoi	Bôn
40	16	0.27	Tho	Bôn
41	17	0.55	Hien	Bôn

(Source : Koïkas J. Renaud J. & al. Dong Cao GIS Arcview project, with former inquiry, 2003)

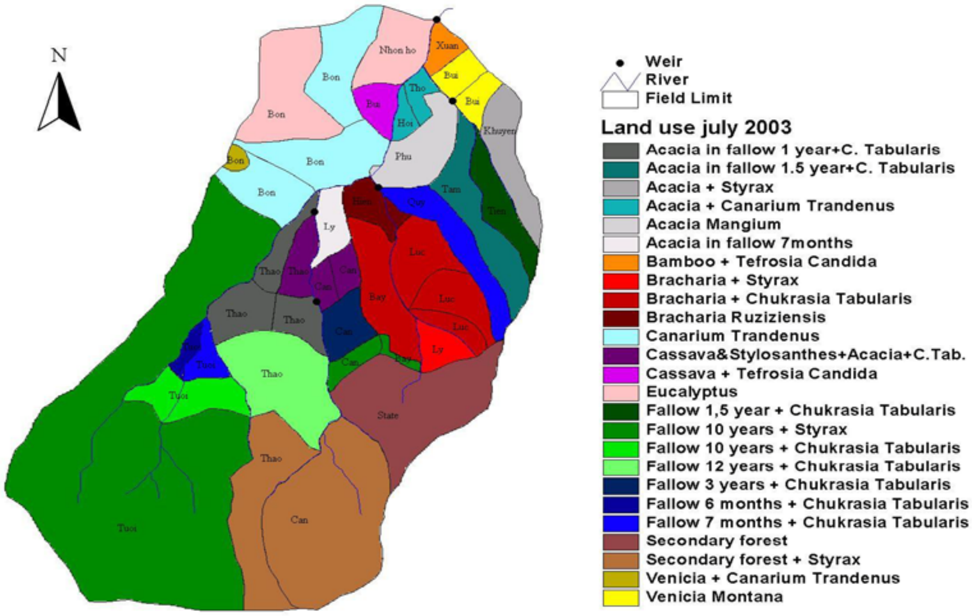

Figure 27. Land use map in 2003 showing the owners in 2002 (1/5000)

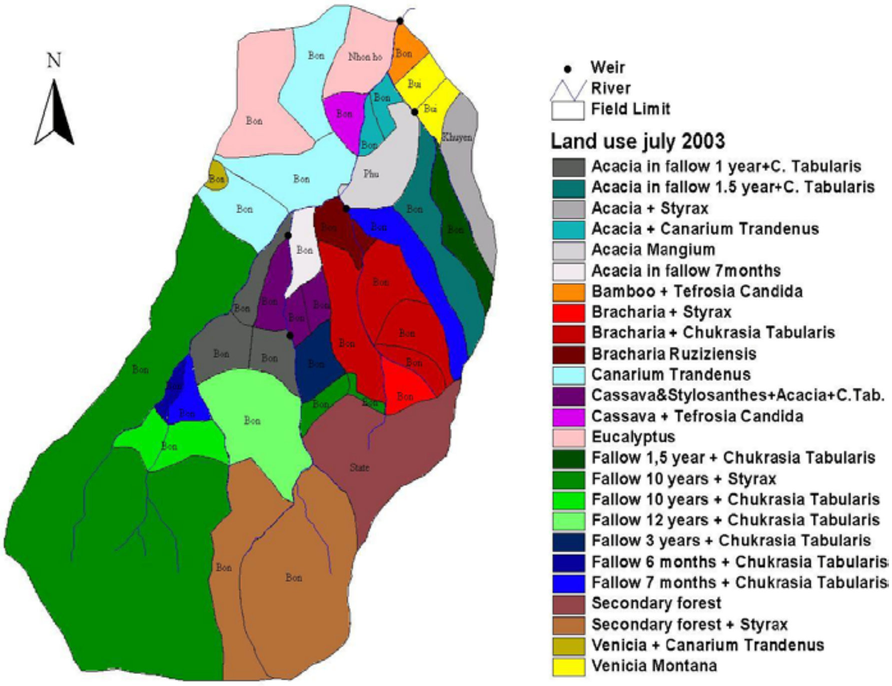

Figure 28. Land use map in 2003showing owners in 2003 (1/5000)

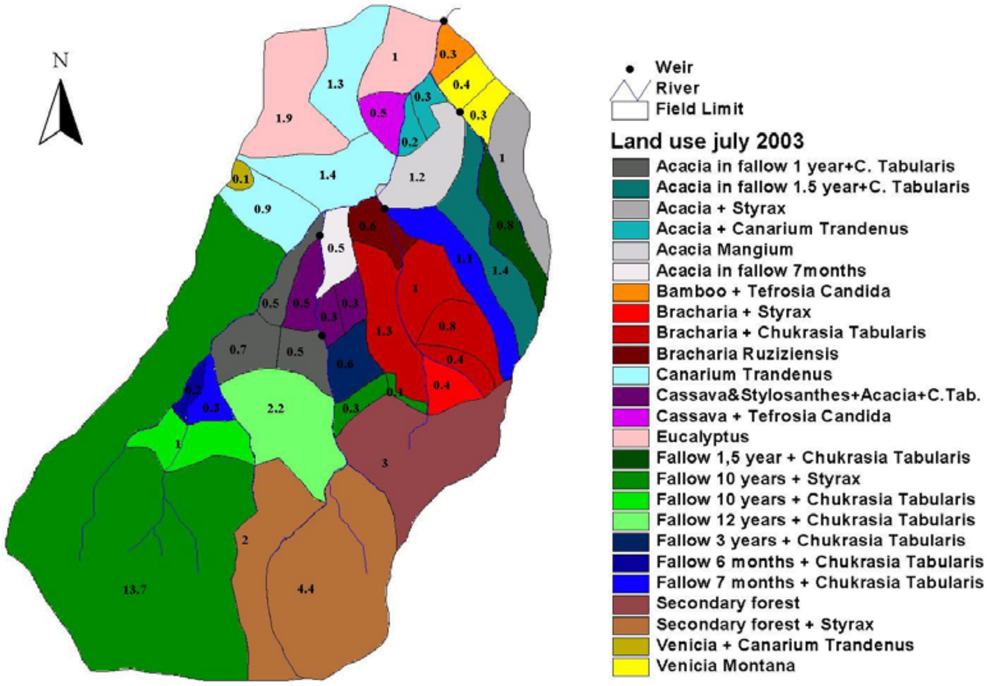

Figure 29. Land use map in 2003 showing plot areas (1/5000)

Conclusion

The results of three years of research and monitoring showed a high interannual variability of soil loss in the Dong Cao Catchment in northern Vietnam. Moreover, this variation depends on both the amount and intensity of rainfall and the kind of land use. Soil loss in 2001 was six times more than in the other years. It is notable that during this year, the total annual rainfall was highest and a large proportion of the catchment was cropped with cassava. There was relatively less erosion in 2002 when the rainfall was lower and the land use was significantly changed to fallow and natural grass.

During the rainy season of 2003, studies permitted to understand better the hydrology of this catchment. The results show that hydrology in Dong Cao catchment depends principally on geology. Permanent streamflow in catchment 3 and 5 show the impact of underground water and geology. In theses catchments, streamflow cut geological structure, dip and schistosity perpendicularly. Rivers collect underground water and infiltration is limited by schistosity. In others catchments, streamflows are in same side than dip and schistosity. Infiltration is maximal and so rivers non-permanent. These results are confirmed by isotopic and chemical analysis. These studies are required to understand better hydrological process on Dong Cao catchment and also are a database to measure soil erosion. It is also necessary to manage field modelisation in south East Asian sloppy catchment.

The project has proved to be very useful for farmers, not only in terms of understanding soil erosion and nutrient loss, which cause land degradation and reduce productivity, but also in terms of farmers' enhanced capacity and improved information dissemination strategies. The farmers are now more aware of the need to conserve soil fertility to sustain high agricultural productivity. Some of the technologies they have become aware of include contour hedgerow farming, agroforestry, intercropping systems, etc. Dialogue with farmers and different stakeholders from the local government, agricultural institutes, and research programs has been conducted to develop better understanding of how river basins respond to socio-economic changes. With this program of research and development, it is expected that the local government will change their thinking on soil management. The research activities in the Dong Cao Watershed have demonstrated to farmers, policy-makers, and extension workers how much sediment yield and bedload would be lost if appropriate soil and water management technologies were not used.

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Capacity Building

Students

In 2003, there were four Vietnamese students (two in first level of Bsc, two in second level of Bsc) and two French students (one in DESS, one in MSc). The four Vietnamese students will continue in 2004.

- -Do Duy Phai for a Msc in Hanoi University, supported by IRD/IWMI during 2004 and 2005.

Study work : Hydrological modeling in a small agricultural watershed.

- -Three students from SLU in collaboration with Luslof project and ICRAF-Bogor

The research activities and the *focus for the thesis work* for the three students are agreed as follows:

As one team, the three students will support each other in the fieldwork in Vietnam as well as in the simulation work, together with the ICRAF modelling team in Bogor and in closely exchange with the MSEC team in Vietnam (by email with D. Orange). The focus of the thesis work of the three the students are as follow:

- ***La Nguyen*** *thesis with focus on role of Bamboo as filter species in transect 1 and simulation with WaNuLCAS.*
- ***Lina Norlin*** *thesis with focus on (1) Calibration of WaNuLCAS and (2) the "on-site" effects of trees as filter using WaNuLCAS in transect 2,*
- ***Carina Ortiz*** *thesis with focus on (1) Calibration of GenRiver and (2) "on-site" and "off-site" effects of trees as filter, simulation with GenRiver on watershed leve*

- -Co-coordination of a doctoral thesis in Paris VI (Miss Le Thi Phoung Quynh) with Josette Garnier (Paris VI) and Minh Van Chau (NCSTV) supported by CNRS (2002-2005).

Study work: *Hydrological modeling and matter flux transport in a large river basin : the Red River Basin.*

- -Three French students.

Study work1: *GIS assisted modeling: PLER model for MSEC Vietnam study.*
Study work2: *Modelling of event-based soil erosion in North Vietnam.*
Study work3: *Agricultural land-use and hydrological behavior in a small farming watershed in the North Vietnam.*

Training

- Training on Hydrological data management with Hydras-3 software, in IWMI-Bangkok, coordinator: J-P Bricquet and **the participation of D. D. Phai as trainer**.
  Vietnamese trainees: N. D. Phuong, P.H. Hai An (student)

Capacity building.

Information Dissemination

Scientific Papers

Erosion control within a cultivated sloping land in North Vietnam. 2003. Tran Duc Toan, Orange D., Podwojewski P., Do Duy Phai, Thai Phien. *Oral paper presented at the Symposium on Soil quality and evolution mechanism and sustainable use of soil resources, ISSAS / Yingtan, Jiangxi Province, China September 23-28, 2003*

An environmental DSS for a large tropical flooded ecosystem: the inner Delta Niger River. 2004. Didier ORANGE, Marcel KUPER, Christian MULLON, Yveline PONCET , *International Environmental Modelling and Software Society, IEMSs : "Complexity and Integrated Resources Management", Osnabrück, 14-17 June 2004*

Reports

Bayer A., 2003. Comportement hydrologique d'un petit bassin versant agricole sur fortes pentes au Nord Vietnam. Memoire DESS, Universite de Grenoble.

Renaud J., 2003. Cartographie des sols de la région de Dong Cao (bassin du fleuve rouge, Vietnam du Nord) Creation d'un SIG et modélisation de l'érosion sur des basins versant à fortes pentes. Mémoire de Maîtrise. IUP Montagne CISM, Université de Savoie, Le Bourget du Lac.

Workshop, Congress, Seminar

1. "Dialogue", Water and Food, IWMI, Hanoi, October 2002
2. Scientific Seminar on "Water quality and treatment in Hanoi", NCSTV-CNRS, Hanoi, February 2003
3. "National workshop for pro-poor project", VIWRR-IWMI, Hanoi, May 2003
4. "MSEC meeting" in Laos, October 2003
5. Seminar on "Information Technology and Communication for Natural disaster warning and mitigation", ISTED-MARD, Hanoi, November 2003

Collaboration and Opportunities

Visitors to Vietnam

- Vincent Chaplot (IRD/IWMI Laos), 1 week
- Sylvain Huon (Univ. Paris VI), 2 weeks
- Matthew Kurian (IWMI-SEA), 1 week
- Christian Valentin (IRD/IWMI Laos), 3 days
- Jean-Pierre Bricquet (IRD/IWMI Bangkok), many times
- Jean-Louis Janeau (IRD/IWMI Bangkok), 1 week
- Guillaume Lestrelin (IRD Laos), 1 week
- Norbert Silvera (IRD/IWMI Laos), many times
- Jean-Pierre Thiebaux (IRD/IWMI Laos), many times
- Josette Garnier (CNRS, Paris VI), 1 week

Trips Abroad

- Tran Duc Toan: Sweden, Laos, Thailand, China
- Do Duy Phai: Thailand, Laos
- Pham Ha Hai An: Thailand
- Pascal Podwojewski: Laos, Thailand, China
- Didier Orange: Laos, Thailand, China, France

Faculty of Chemistry,Univ. of Hanoi

Scientific purpose: Nitrogen and carbon cycle in the rural environment.
Four students.

Institute of Chemistry, NCSTV

Scientific purpose: Particulate and Dissolved Organic Carbon in the streams, matter flux transported by the rivers.
One student (doctoral thesis) and one BSc in detachment..