Development and Validation of Methods for Measurements of Sediment Transfer Across Fields in a Watershed (Phase 1 of Watershed Function Analysis)

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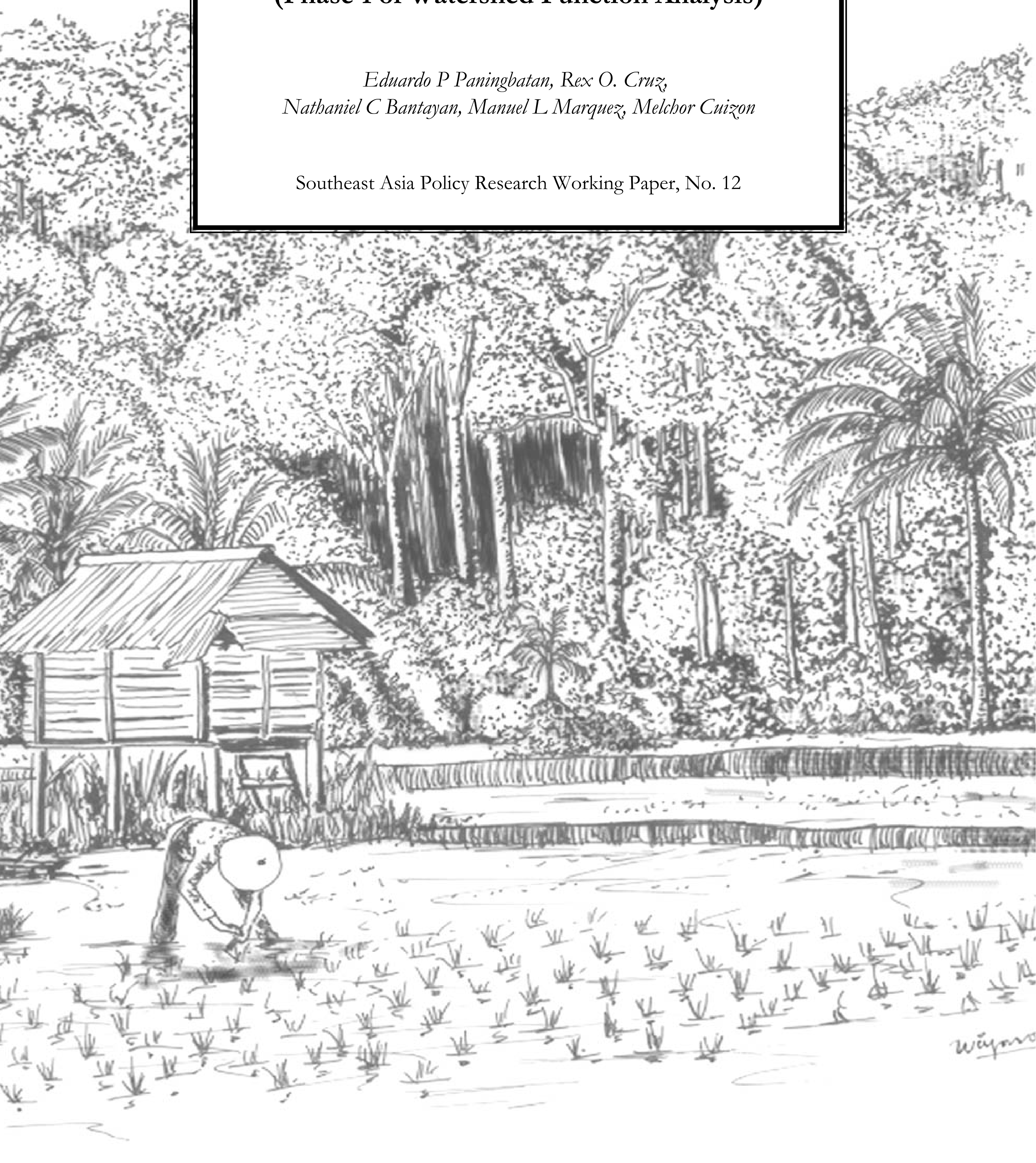

Acknowledgement

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Declaimer

RESEARCH PROJECT

1. **Title**:
   Development and Validation of Methods for Measurement of Sediment Transfer Across Fields In a Watershed. (Phase 1 Of Watershed Function Analysis)

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3. **Introduction**
   The need to quantify and evaluate the impact of various land use changes on the hydrology and soil erosion in a landscape is of prime importance in watershed resource management. With appropriate methodology, the on- site effect of soil erosion on soil productivity and the off-site effect on water quality and quantity are better understood and mitigated. This study was aimed to develop and validate descriptive method, using GIS–assisted soil erosion modelling, that will be able to capture and measure the effects of the major factors that contribute to runoff, erosion and sedimentation at a watershed scale. The approach is sensitive in identifying the areas in a catchment that are erosion proned or “hot spots” so that mitigation works could be successfully targeted. In addition, the stream flow and sediment load are also measured and/or predicted for assessing the off- site effects of soil erosion.

   The specific objectives of the research are the following:
   - development and testing of cost effective methods for measurements of sediment transfer across field boundaries.
   - development and testing of descriptive system and techniques for mapping landscapes on the basis of the presence of some barriers (e.g. filter strips, bunds)
   - between cropped fields and the 'hotspots' of sediment loss at the landscape scale, measurement of streamflow and sediment loads to calibrate and validate the descriptive system.
   - Analysis of water data on stream flow and sediment load to identify the characteristic patterns of sediment loss and Fink these to the descriptive system for the landscape.

The research hypothesis of the study is:
During erosive rainfall events the amount of sediment transfer is the net product of erosion and deposition processes. In a catchment area, composed of several land uses and field boundaries, sediment transfer is controlled and enhanced by the presence of some surface features that dominantly favor either erosion or sediment deposition. The research hypotheses is that sediment transfer beyond field boundaries is small, regardless of land use, despite significant soil loss within fields for some types of land use.

4. Materials and Methods:

A. The Study Area

The project is being conducted in a sub-catchment area of the Manupali Watershed in Bukidnon province in Mindanao. The Manupali watershed is also the research site of the Sustainable Agriculture and Natural Resource Management (SANREM) and the Management of Soil Erosion Consortium (MSEC) of the International Board for Soil Research and Management (IBSRAM). SANREM has been conducting watershed research for the last past five years while MSEC started their catchment research this year.
The study catchment area is situated in sitio Mapawa. barangay Songko of Lantapan municipality in Bukidnon province. It is located about 40 kilometers west of Malaybalay City, the capital of the province.

B. Data Collection

1. Description of catchment attributes and analysis of watershed functions require generation of some spatial and temporal data and information. These data and information are to be described, stored and analyzed with the aid of a GIS softwares ACAD, IDRISI and PCRASTER. Some of these spatial and temporal data and information are as follows;

    - Thematic maps. Field survey, mapping and ground truthing of the general land use, soils, topography and drainage pattern of the Mapawa watershed was conducted by the Bureau of Soils and Water Management for MSEC and this project. The table maps were digitized and edited using ACAD software. The digitized maps were then converted into raster maps using IDRISI and PCRASTER GIS softwares. Parcellary maps of the study area was also prepared and digitized.

    - Land Use. Land use survey based on the parcellary map on the study area was conducted (headed by a graduate student supported by the project) in August, 1999. The current land use was compared with the result of land use survey conducted by ICRAF in 1996 to project land use change of the study area. Reasons of the change of land use by farmers were noted. Farming activities such as land preparation, planting harvesting, etc were also determined. Other land uses (forest, tree plantation, roads, residential) and important land surface features (gullies and foot paths) were also noted and included in the GIS - mapping.

    - Rainfall Characteristics. Tipping bucket type rain gages equipped with data loggers (salvaged from previous ACIAR Research Project 8551) were installed to measure rainfall characteristics. The instrument is capable of determining the amount of rainfall at one (1) minute time interval that are recorded and stored in electronic files. Rainfall amounts, rates and durations, and the corresponding hydrographs are then generated using Microsoft EXCEL.

- Streamflow. Time dependent streamflow is being monitored using water height recorders with electronic data logging devices, installed at some strategic locations in the catchment study area. The instrument measures and records time dependent changes of runoff water depth in the drainage channels at one minute time interval. Time element of the data loggers of the automatic rain gage and water height recorders are synchronized with the computer real time.

- Sediment load. In the absence of automatic water sampler, about 250 ml of runoff water samples are collected manually near the water height recording stations at three times (early, mid and late) during each runoff producing rainfall event. The water samples are analyzed for sediment concentration using oven-drying technique.

- Topographic survey. Micro changes in surface topography due to net erosion or net sediment deposition is determined using a simple and inexpensive topographic mapping technique. The technique makes use of carpenters water level hose that could make accurate measurements of elevation changes at Predetermined grid Points spread over a sampling area of about 100 M2 Topographic mapping was done in selected areas along the slopes of the catchment differing in surface vegetation (intensively cropped slope, grassland, forest). This activity will be done again after six months and one year on the same area or spots to determine micro changes of surface elevation.

- Micro changes in surface topography due to erosion or deposition in the sampling area could be assessed using a GIS software, SURFER where the position and volume of the 'cut surface (the eroded area) and the 'fill surface" (the deposition area) after erosive rainfall event(s) are identified and calculated.

C. GIS-Assisted Sod Erosion Modeling

Geographic Information System (GIS)-assisted soil erosion modeling at landscape scale is being developed to quantitatively describe and integrate the various hydrological and biophysical processes occurring in a watershed. The system makes use of a GIS software PCRASTER with built-in cartographic and dynamic modeling capability. The system is capable of simulating the spatial and temporal distribution of runoff and soil erosion in a catchment. The modeling exercise is envisioned to help study the impact of land use change and cropping systems on soil erosion, water quality and water quantity in a watershed. It is specifically designed to assist identify the erosion "hot spots" in a watershed and evaluate the effectiveness of soil conservation practices. Data and other information are now being collected at the Mapawa catchment study area to validate and fine-tune the model. Once validated, the model will be used to estimate soil erosion and evaluate its on-site and off-site effects as affected by the landscape attributes like land use and land use change, slope, soil, etc. in the other catchment area in Lantapan.

1. Activities and Accomplishments (in Progress)

A. Site Selection and Catchment Characterization

Actual field survey study started in mid February, 1999. Results of field survey conducted by the Bureau of Soils and Water Management are topography map, general land use map and soil map of the project site which covers major portion of Sitio Mapawa in Songko, Latapan. Digitized maps of these catchment attributes were prepared and are presented in **Figures 1 2 and 3.**

Sitio Mapawa catchment area has a total land area of 173.1 hectares and is dissected by three intermitently flowing creeks namely:Tongonan creek, Mapawa creek and Kiluya creek as shown in Fig. 1. Rasterized map prepared using PCRASTER is shown in **Fig. 4**. At present the study is concentrated in the 32.2 hectares of land covering the Mapawa creek and its catchment area. It is in this catchment where the measurements of streamflow, sediment load, land use and vegetative cover, soil parameters, among others are being conducted.

B. Instrument Fabrication and Installation, and Man Power Capacity Building.

Used instruments, two (2) tipping bucket type rain gages and eight (8) water height recorders equipped with data loggers, were acquired from previous ACIAR Research Project 8551. Since the instruments were stored since the termination of the ACIAR project in1996, the electronic data loggers were reawakened, some serviceable spare parts were changed and their utility were tested in the laboratory at the Department of Soil Science, UPLB with the assistance of a technician.Instrument holders and other attachments were fabricated using locally available materials. Calibration of the instruments were also done in the laboratory before bring them to the field site in Lantapan.

One automatic rain gage was installed in April, 1999 at the field office of ICRAF-Lantapan which is about two-hundred meters away from the southern end of Mapawa catchment. The other was installed in October, 1999 at the northern end of the catchment.

Of the eight working water height recorders, five (5) were installed along Mapawa creek, one (1) in a gully produced within the road, one (1) in Alanib river and one (1) at the outlet of the Kiluya creek). In determining water discharge rates, the corresponding hydraulic radius and runoff rating curve Should be known. Hydraulic radius was determined from elevation measurements that generate the cross sectional dimension of the water channel where the water height recorders were installed. Rating curve is still to be determined in cooperation with MSEC who have installed some weirs and flow meter in the same catchment.

As part of man power capacity building for the project, training of the research assistant on how to use, calibrate and maintained the instruments was conducted at the Department of Soil Science, UPLB, for two weeks in March 1999. The training includes running computer programs on how to start the data loggers, retrieved the data and initially processed the data into readable forms.

C. Data and Information gathering

1. Rainfall <u>characteristics</u>. The amount of rainfall is measured during each rainfall event starting in May, 1999. Example of these rainfall events during the months of July is presented in **Fig. 5**. The data indicate that in the study area

there are very strong rainfall events. Some events produce more than 50 mm which could generate significant runoff to cause Significant amount of soil erosion in the watershed. One rainfall event on July 18, 1999 gave 133 mm in about 30 minutes of rainfall duration which generated runoff in the unprotected slopes and strong streamflow in Mapawa creek.

Besides the amount of rainfall, rainfall rates and duration are also generated from the data. These time series (1-minute interval) data on rainfall rates are needed as input to the GIS-assisted modeling of soil erosion in a watershed. Examples of these information are presented in **Fig.6**

2. Height of water. Time dependent heights of water flowing in the drainage channels during each runoff producing rainfall event are monitored to quantify water discharge rates. Examples of this information are presented in **Fig. 7** for Mapawa Creek and Fig. 8 for a road gully. The 133 mm rainfall on July 18, 1999 increased water depth by as much 350 mm in the said creek. it is important to note that the time element of both rainfall and water height data loggers are synchronized with real computer time in order to be able to capture the time dependency of runoff flow and rainfall event in a catchment. This kind of information is necessary in the validation of the erosion model

   Although rainy days are frequent in study area, preliminary observation indicates That only few rainfall events, most likely those having 40 mm/event or greater, produced measurable runoff flow in Mapawa Creek. On the other hand, runoffs occur more frequently at the road gully even at lower amounts of event rainfall. Also, it is observed that there is a significant longer time lag from the start of rainfall before runoff commences in Mapawa creek than in the road gully as can be noted in **Figures 7and 8**

3. Sediment Concentration. The general trend of sediment concentration of water samples collected during runoff producing rainfall events are presented in Table 1. As was expected sediment concentrations varied considerably between runoff events and among sampling locations or monitoring stations. The sediment concentrations were very much higher in the road gully, about seven to ten times greater than those collected in the Mapawa creek, implying that road gullies could be a major source of eroded sediments in the watershed.

Table 1. Sediment concentration of runoff water samples collected at different sampling stations in the Mapawa watershed.

Location	Number of Samples	Sediment Concentration (g/li)		
		Min. Value	Max. Value	Average
Road	25	15.1	69.3	38.8
St. 1 (sd)	11	0.7	10.1	5.2
St. 2 (su)	12	1.0	7.0	4.4
St. 3 (cd)	11	1.5	7.5	4.2
St. 4 (cu)	13	0.6	6.0	2.9

It was also observed that sediment concentration increases as one moves downstream. It was greater in the downstream monitoring station (St.1) than in the upstream position (St.4) of Mapawa Creek. This is attributed to the presence of more intensely cultivated lands in the downstream slopes of Mapawa Creek. On the other hand, the upstream portions are dominanted by grasslands and shrublands with few cultivated areas, and as such are better protected against soil erosive forces.

The product of water discharge rates and sediment concentration gives the sediment discharge rate that determines water quantity and quality that moves out of the watershed. Sediment concentration and runoff rates are both highly correlated with ground contact cover as predicted by preliminary computer simulations using our soil erosion model. Ground contact cover is observed to be highly affected by the kind of land use and vegetative cover. It is anticipated that the spatial arrangement of the various land uses and conservation measures in the watershed and the time dependent land use change particularly those associated to vegetative cover have strong influence on the magnitude of sediment transfer within and out of the watershed

4. Topographic survey . Topographic mapping using water level hose is being conducted to measure micro changes in surface elevation in selected areas along the slopes of the catchment. it is one method of assessing sediment transfer in the slopes. Initially we mapped areas differing in surface vegetation, two areas in intensively cropped slope, one area in grassland, and one in forest vegetation. This activity will be done again after six months and one year on the same areas or spots to determine micro changes of surface elevation. The change in elevation, which is either areas of removal (cut) or depositional (fill), will be used to assess movement of sediment in the slopes.

D. Land use and land use change

A more detailed survey on land use based *on* parcellary Map was conducted this year in the catchment study area. The survey team was headed by Ms. Nenita dela Cruz, a Ph D graduate student working with the project. The current land uses were compared with those surveyed in 1996 by ICRAF-Lantapan and the reasons given by farmers for changing their land uses are presented in **Table 2**. The summary report of the study is as follows:

The 1996 land use survey based on parcel!ary map of the study area showed that 18 out of 40 parcels were grasslands, 12 were croplands, 8 mixed crops and trees and only 2 timber/forest trees. Among the crops grown were corn, coffee and vegetables (tomato, cabbage and sweet peas). Coffee was also grown during this time.

The 1999 survey revealed that there is a decrease in the number of parcels devoted for grassland (from 18 to 14), increase in cropland from 12 to 15, decrease in mixed crops and trees from 8 to I and a birth of new system, i.e. crop + grassland (starting a small portion of the parcel for cash crop (corn and vegetable production) with a total of 8 parcels. This implies a more intensive cropping in the area which may lead to enhancement of soil degradation considering that majority of the farmers do not employ soil conservation measures to arrest soil erosion/degradation.

Vegetables are the major crops grown followed by corn. Additional crops are also grown in combination with the major crops, which include cassava, pepper, sweet potato and coffee. It is interesting to note, however, that trees dominated by bamboo are grown along the creeks. Likewise, natural vegetation is allowed to grow within the periphery of the parcels and trees are grown in the boundaries. Accordingly, these practices helped in minimizing movement of sediments from one place to another.

Some of the reasons for their change in land use are as follows:

A. Cropland to Grassland
   - Unsustained coffee yield With time due to non-Practice Of fertilizer apphcation by the farmers
   - Owner is not riving in the area anymore; and
   - Decline in soil fertility that led to very low yield of the former crops grown

B. Grassland to Cropland
   - Source of income or for subsistence;
   - Change in person tilling the land; and
   - Need for cash income

C. Grassland to Timber/Forest trees
   - Influenced by the government's program on reforestation
   - Area is being rented by ICRAF for research purposes.

D. On the other hand, some of the reasons for no change in !and use were*
   - Owner not living in the area anymore;
   - Nobody to till the land; and
   - Have another area for crop production

Majority of the farmers in the study area are not practicing soil conservation in spite of their awareness of the high degree of soil erosion occurring in the watershed. According to them, this is additional labor input an their part. A farmer who is practicing soil conservation such as NVS or contour hedgerows have attended training on soil conservation, while another one is an Igorot (migrant indigent from Benguet province in Luzon) who have employed contour farming before and is very much aware of the soil erosion situation in his own farm,

It was observed that 8 out of the 15 farmers growing crops in their farm are preparing their land in up-and-down the slope manner and 7 out of 15 are preparing the lands along the contour.

Many of the vegetable farmers apply organic fertilizers, in the form of chicken manure and incorporate plant residues in the soil to maintain soil fertility. They also use inorganic fertilizers to supplement any available plant nutrients in the soil.

Table 2. Land use and land use change in Mapawa catchment areas

PARCEL NO.	1996	1999	REASEON FOR CHANGE NO CHANGE
1	Cropland (Vegetables)	Cropland (Vegetables)	Good source of income
2	Forest tree	Forest tree	CRAF area
3	Grassland	Cropland (Corn)	Source of income
4	Mixed trees & crop	Cropland (Corn & Vegetables)	Source of income
5	Grassland	Grassland	No other interest
6	Cropland (Corn)	Cropland (Corn & Vegetables	source of income
7	Cropland (Coffee)	Mixed tree & crop	Unsustained coffee yield
8	Mixed tree & crop	Cropland (Vegetables & Corn)	High income derived from it
9	Mixed tree & crop	Cropland + Grassland (Corn + S Potato)	Better promise of crop than trees
10	Cropland (Corn+coffee)	Grassland	Unsustained coffee yield
11	Grassland	Grassland	Change in person tilling the land
12	Cropland + Grassland	Cropland + Grassland	Need of cash income from annuals like corn
13	Grassland	Cropland (Potato, S potato & corn)	Need of cash income from annuals like corn
14	Timber	Cropland (Coffee & corn)	Need of cash income
15	Cropland (Vegetables & Corn)	Grassland	Not living in the area
16	Grassland	Timber + Grassland	Influenced by government's program of reforestation
17	Grassland	Grassland	Have another areas for crop production
18	Grassland	Grassland + Cropland (Vegetable)	Need of cash crop for consumption and cash income
19	Grassland	Grassland	Not living in the area
20	Cropland (Coffee + Vegetables + Corn)	Cropland Vegetable & corn)	Unsustained yield of coffee with time
21	Mixed tree & crop (Coffee, corn &	Grassland	Nobody to till the land due to death of husband
22	Vegetables)	Grassland	Not living in the area

23	Cropland (Vegetables)	Cropland + Grassland (Vegetable + corn)	Good source of income
24	Cropland (Vegetables)	Grassland	Not living in the area anymore
25	Cropland (Vegetables)	Grassland	Not living in the area
26	Grassland	Grassland	Not living in the area anymore
27	Grassland	Cropland + Grassland (Corn)	Need of cash income
28	Cropland (Vegetable)	Grassland	Not living in the area anymore
29	Grassland	Cropland (Corn, Coffee & Vegetable)	Change in person tilling the land
30	Mixed tree & crop (Corn)	Cropland (Corn & Vegetables)	Change in person tilling the land
31	Cropland (Corn)	Cropland (Corn inter-cropped with cassava)	No answer
32	Cropland (Corn)	Grassland	Decline in soil fertility that led to low yield
33	Cropland (Corn)	Cropland + Grassland (Vegetable & corn)	Decline in soil fertility
34	Cropland (Corn)	Cropland (Corn & vegetable)	No answer
35	Grassland	Cropland (Vegetable & corn)	Change in person tilling the land
36	Grassland	Cropland (Corn)	Change in person tilling the land
37	Mixed tree & crop	Cropland (Corn)	Need of cash income
38	Grassland	Cropland (Vegetable & corn)	No answer
39	Cropland (Vegetable)	Cropland (Vegetable & corn)	No answer
40	Cropland (Vegetable)	Cropland (Vegetable & corn)	No answer

E. Development of GIS- Assisted Modeling of Soil Erosion

GIS-assisted soil erosion model that can simulate surface water and sediment transfer at a catchment or watershed scale was developed with the assistance of a graduate student (Master of Science Major in Soil Science), Mr. Reynaldo L. Lanuza.

The title of his thesis research (partly supported by this ICRAF project) is "Modeling Soil Erosion in a Watershed". Four copies of the final thesis manuscript were given to ICRAF. Also, a poster paper entitled "GIS-Assisted Modeling of Soil Erosion and Runoff in a Watershed' was presented and the simulation model was demonstrated during a scientific meeting on "Environmental Services and Land Use Change" conducted in Chiang Mai, Thailand in June, 1999. Abstract of the MS theses and the poster paper are attached below.

The soil erosion model is GIS-assisted (using PCRASTER computer software) in order to capture the temporal and spatial nature of the hydrological processes occurring in a three dimensional watershed. It simulates movement of surface runoff and transfer of eroded sediments in a landscape. Basic information inputs to the model are raster maps of the attributes of the landscape such as soil, land use cover, digital elevation and time series of rainfall rates. Major accomplishment of the project is the development of the procedure on how to prepare these raster maps which is composed of digitizing using ACAD, rasterizing using IDRISI and finally converting into PCRASTER maps.

From the basic input maps, other raster maps are generated using PCRASTER. These include rain distribution map, slope map, surface cover map, soil infiltration map, local drain direction map, among others. Running the dynamic simulation of the model will give the following major outputs: time series water discharge and soil loss at the monitoring station and also, time series raster maps of the catchment showing height of runoff water and mass of eroded sediments. The basic equations and assumptions, and application of the computer simulation are briefly discussed in the following abstracts.

ABSTRACT

LANUZA, REYNALDO L., University of the Philippines Los Banos, October 1999.
Modeling Soil Erosion in a Watershed.
Master of Science Thesis
Major Professor: Dr. Eduardo P. Paningbatan, Jr.

Most erosion models have been conducted at plot scale and have limited application to a watershed due to the difference in areal scale. In order to address this limitation, a GIS-assisted methodology for modeling soil erosion was developed using PCRaster to predict the rate of soil erosion at watershed level, identify the location of erosion prone areas and analyze the impact of land use changes on soil erosion. The general methodology of desktop modeling of soil erosion at watershed scale is composed of the following: a) model development and structuring, b) formulation of assumptions, c) gathering of information, d) database creation , manipulation and processing, and e)dynamic modeling with PC Raster.

The GIS-assisted model was validated at Tanghaga Watershed using the observed values from previous experiment. The predicted peak rates, Qp, showed a highly significant relationship with the observed Qp, however, the r^2 value was only 0.75. For soil loss prediction, a significant relationship was also noted with r^2 value of 0.74.

Sensitivity analysis using four parameters was done. The model response was most sensitive to Manning's roughness coefficient (n) for the peak rate. An increase of n from 0.02 to 0. 1 3 resulted in a decrease of 546% of the predicted Op. On the other hand. the predicted soil loss was most sensitive to the vegetative cover. Increasing the vegetative cover from 0.20 to 0.95 resulted in a decrease of about 1,567%.

The model was applied to Mapawa Watershed. Computer simulation showed higher Qp values at Mapawa than at Tanghaga. Moreover, the model was also used to predict and evaluate the impact of landuse change and different farming activities, A change in the existing farming practice (cropland area) to agr0forestry-based farming system reduces both the predicted Qp values and the soil loss. Among the farming activities considered, land preparation was predicted to be the most erosive. On the other hand, simulation by completely removing the vegetation of the whole catchment has tremendously increased the predicted Qp and soil loss, however, the runoff rate was greatly reduced and did not reach a peak rate under a forested catchment.

The location of erosion hotspots was predicted along the section near the tributary channels and in areas with steeper slope gradient. The capability of GIS-assisted model in predicting the location of erosion hotspots is a significant finding and this approach is a valuable tool in the formulation Of a good watershed rehabilitation program.

POSTER PAPER ABSTRACT

GIS-Assisted Modeling of Soil Erosion and Runoff in a Watershed

E P Paningbatan and R L Lanuza: Dept of Soil Science, University of the Philippines Los Banos, College, Laguna, Philippines

A GIS-aided methodology of modeling the spatial and temporal distribution or runoff and soil erosion in a landscape is currently being developed and validated in some sub-catchments of the Manupali watershed in Lantapan, Bukidnon, Philippines. This modeling exercise is envisioned to help study the impact of land use change and cropping systems on soil erosion, water quality and water quantity in a watershed. It is specifically designed to assist identify the erosion 'hot spots- in a watershed and evaluate the effectiveness of soil conservation Practices.

The inputs to run the model include time series rainfall rates, digital elevation map (DEM), soil map, land use map, cropping system map, and monitoring station map. Slope map and local drain direction map are generated from the DEM. On the other hand, the outputs include time series maps of runoff, sediment concentration and soil erosion. Also, the water discharge, sediment concentration and amount of soil loss at the outlet monitoring stations are also predicted.

GIS-based PCRASTER that run on ordinary desktop computers which has the capability of supporting dynamic modeling is used in the simulation.

Runoff (R) in each raster cell is calculated from the difference of rainfall (P) and infiltration (i). Infiltration rate generated as a function of soil, cropping system and land use. Surface water is routed to neighboring cells using a Local Drain Direction (LDD), a built-in subroutine of the GIS software. Water flow velocity is estimated using the Mannings equations.

Sediment concentration (C) is calculated using the simplified Rose equation,

$$C = 2700\ \eta\ S\ (1 - Co)$$

Where: η = efficiency of sediment entrainment; S= sine of slope angle; and Co = fraction of surface area that is not exposed to erosion.

To measure discharge rates in the field, water height recorders and flow meters with data logger attachment are installed at the monitoring stations strategically located in the watershed. Rainfall rate and duration are measured using tiping bucket type pluviometer with data logging device. Likewise, sediment concentration of runoff is also measured at the
monitoring stations.

6. **Work Plan** (4th Quarter of the project, November, 1999 to February, 2000)

Activities	**Nov. 99**	**Dec. 99**	**Jan. 00**	**Feb. 00**
Continue Data Collection				
Data Processing, Data Analysis and Model Validation				
Final Report Preparation and Submission				

This Project is a one year program which was started in mid February, 1999. The above work plan is for the last quarter of the project.

Data collection will be continued until January. These data collection include the time series rainfall, depths of streamflow, and micro changes in elevation (topographic survey). These additional information will give us enough observed data and information for the validation and fine-tuning of the watershed erosion model.

The project still need to determine the precise coordinate Position of the monitoring instruments installed in the field, some reference position in the catchment and the sampling area that is being used in the topo-survey activity. The accuracy of the GPS that was used before has an accuracy of + or - 20 meters and this could affect our mapping Preparation and computer simulation. A more precise GPS instrument with an accuracy of 1 meter become available to us only recently.

On data Processing, one big Problem we encountered is data time element related (or Y2K related). The water height data logger is an old model and does not have the four digit year system which makes data processing More difficult to handle. Contingency is being prepared so that the data loggers will still work in year 2000.

Data analysis, model validation and report writing will be the major activities during the last quarter of our study. A more detailed research proposal and work plan for the next phase of this study will also be prepared.

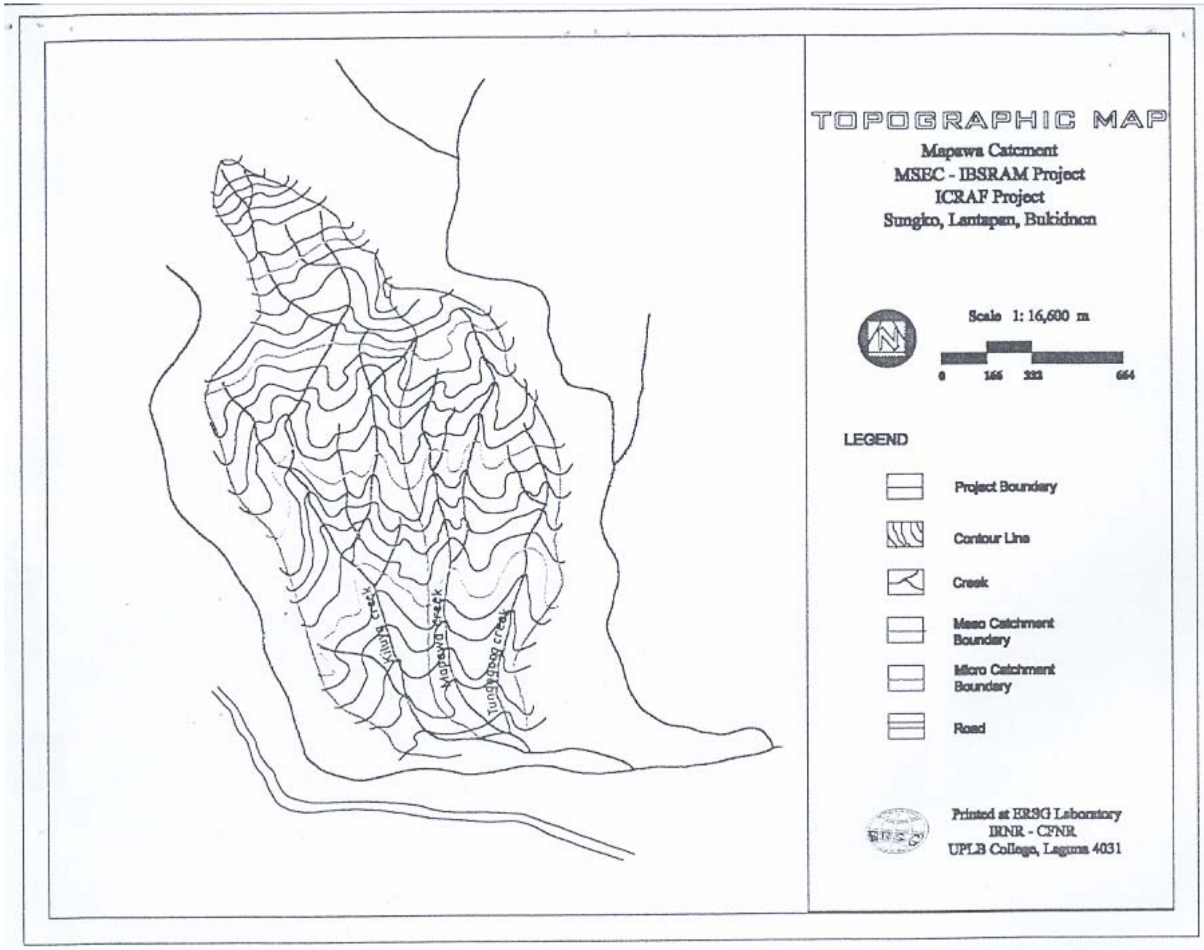


Fig. 1. Topographic map of the experimental area.

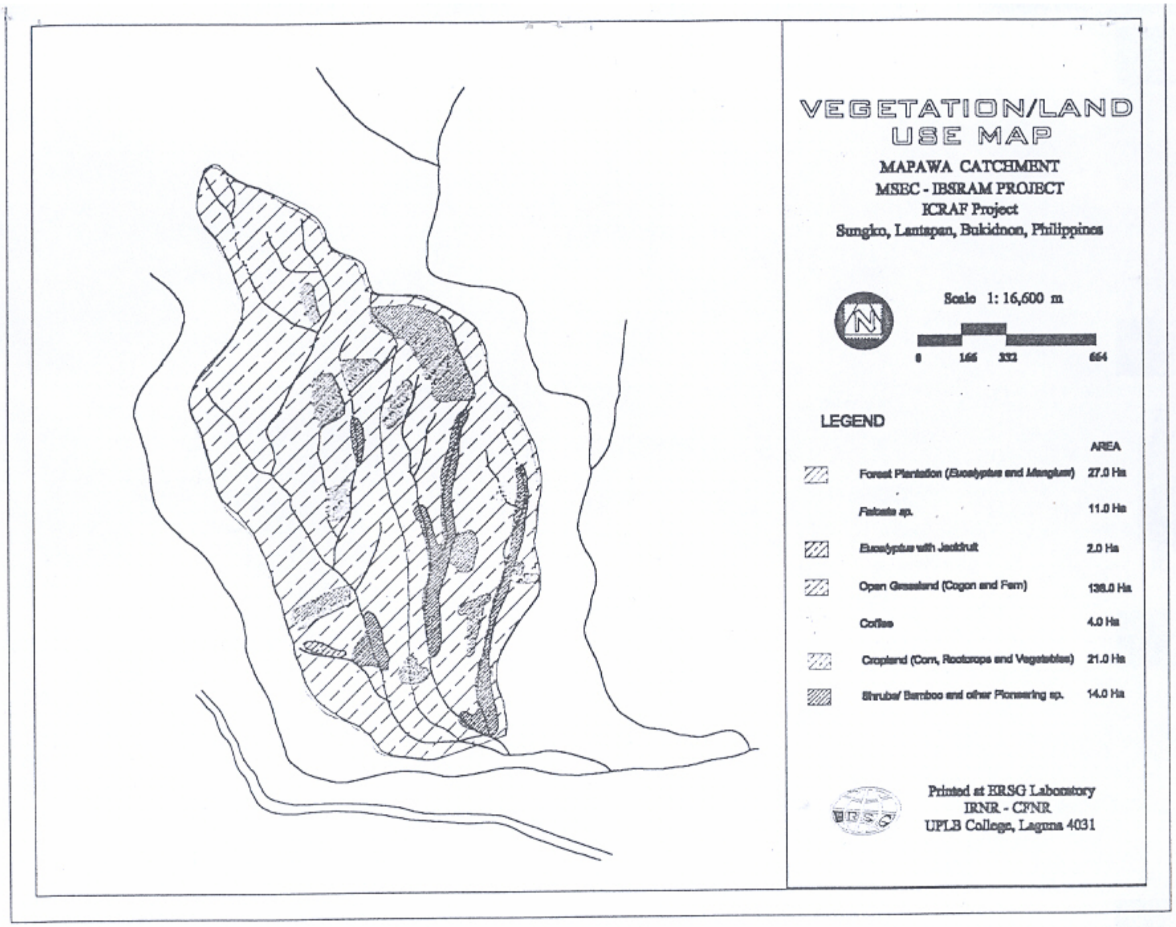


Fig. 2. vegetation/Land use map of the experimental site.

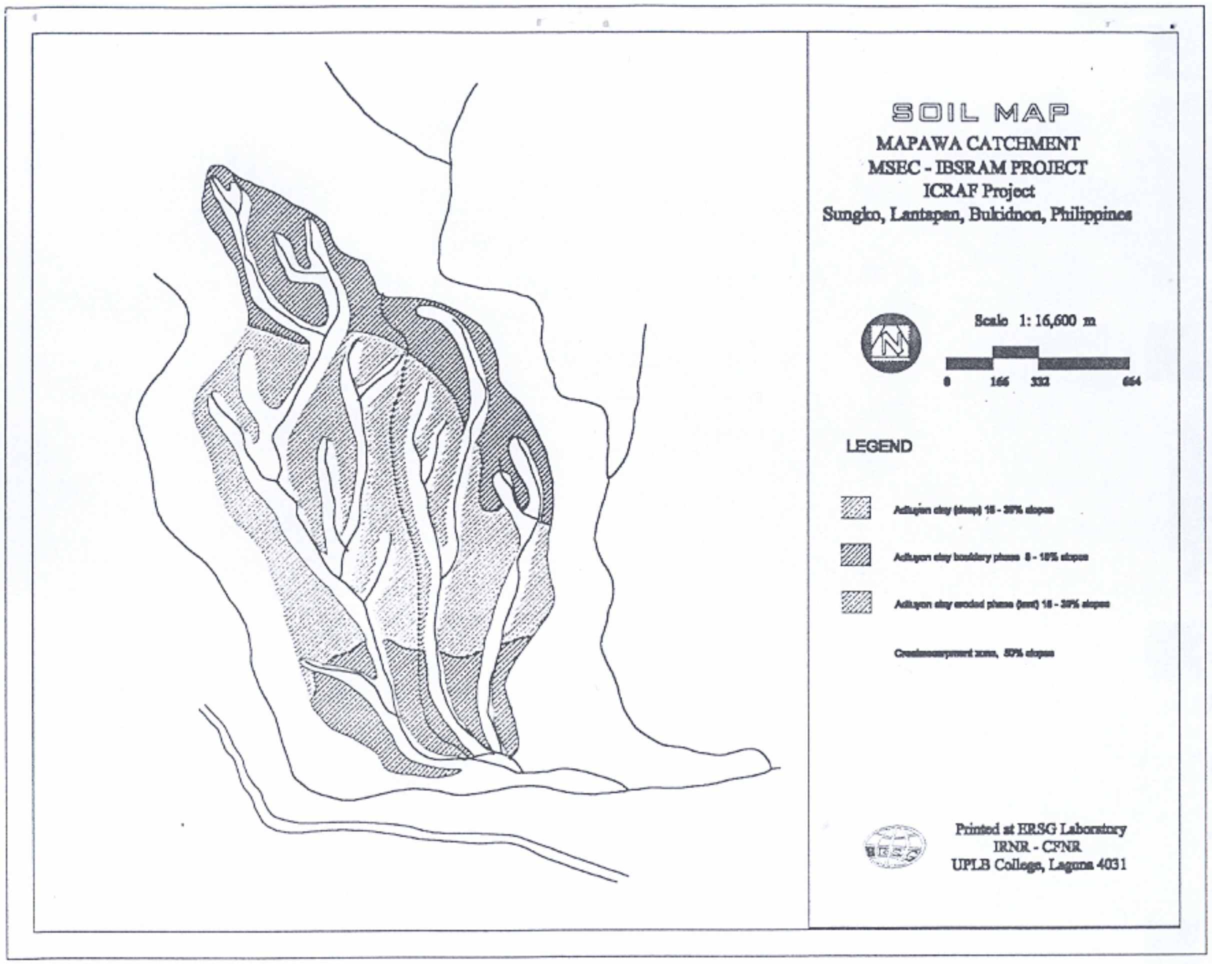


Fig. 3. Soil map of the experimental site.

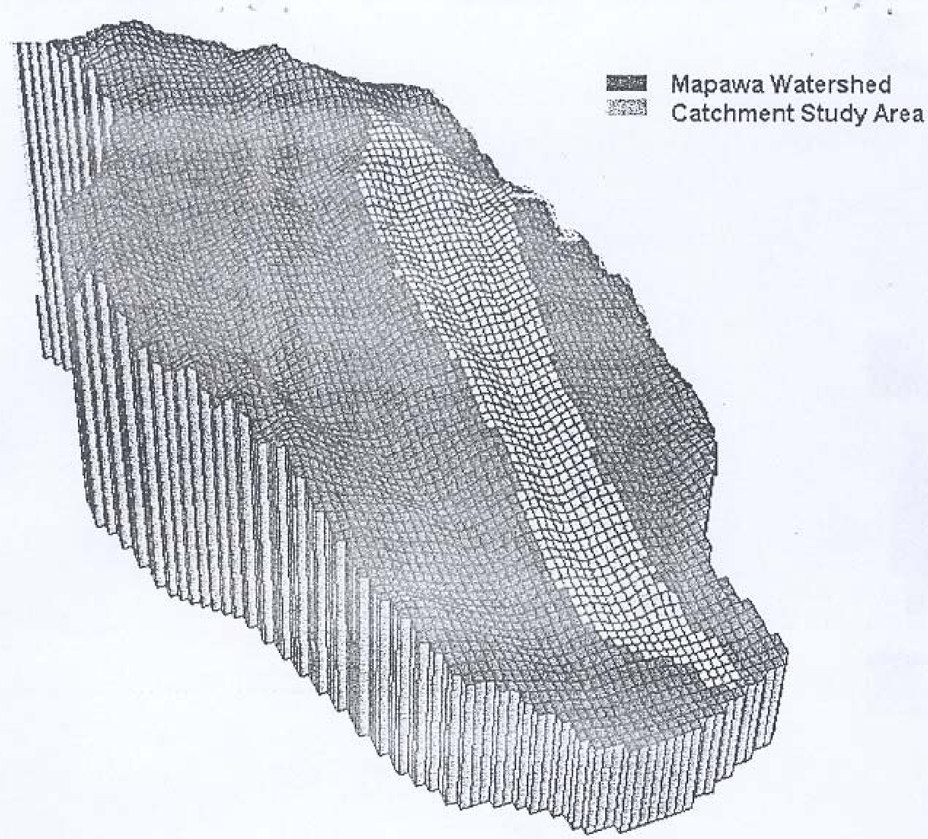


Fig. 4. The catchment study area in the Mapawa watershed.

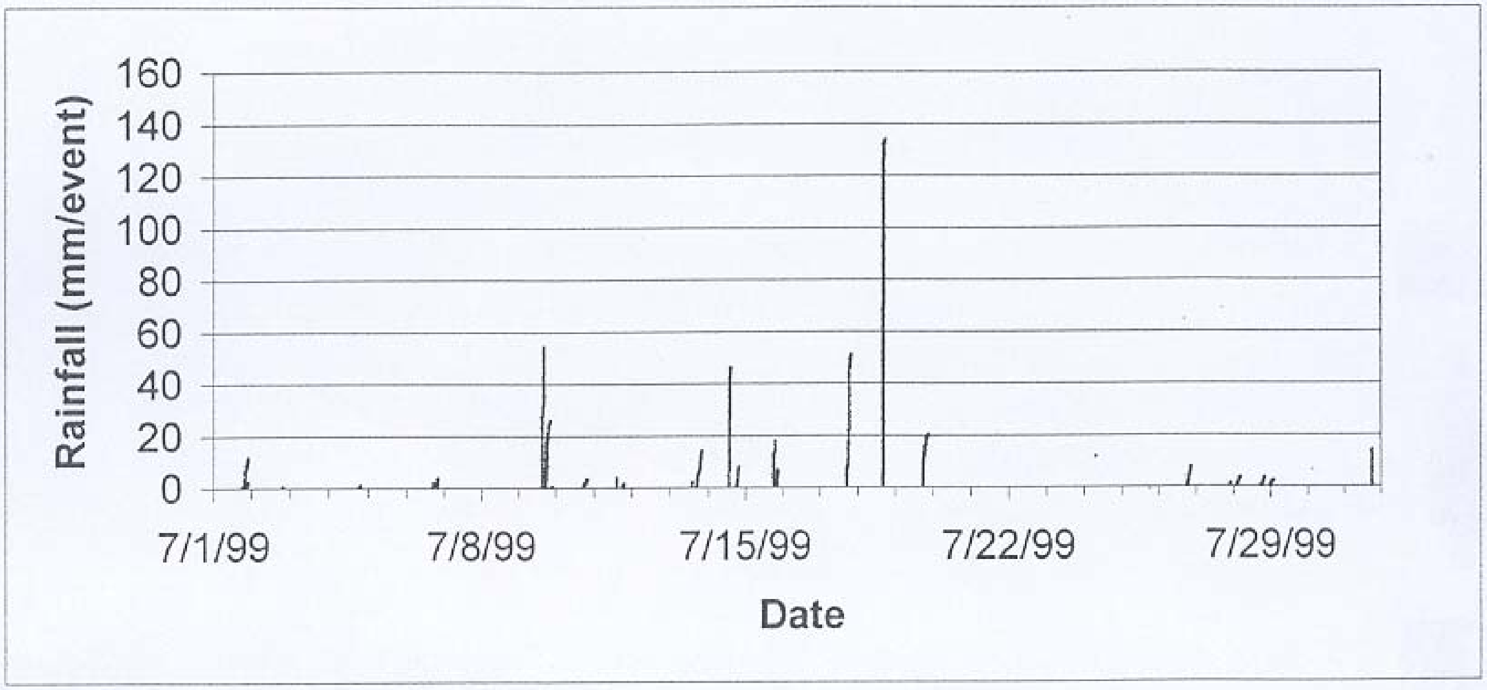


Fig. 5. Rainfall events during the monts of July, 1999.

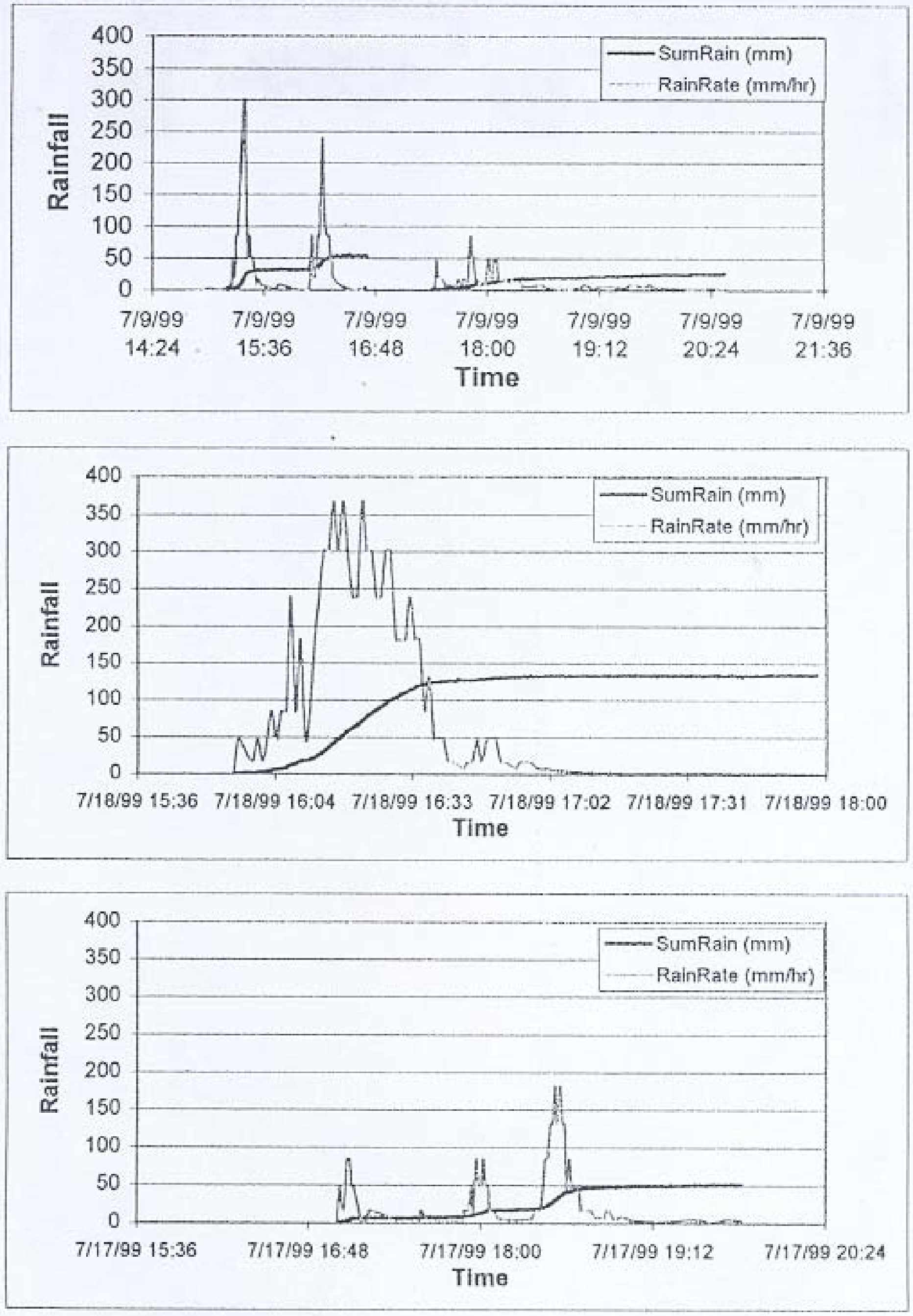


Fig. 6. Rainfall rate and amount of rainfall event.

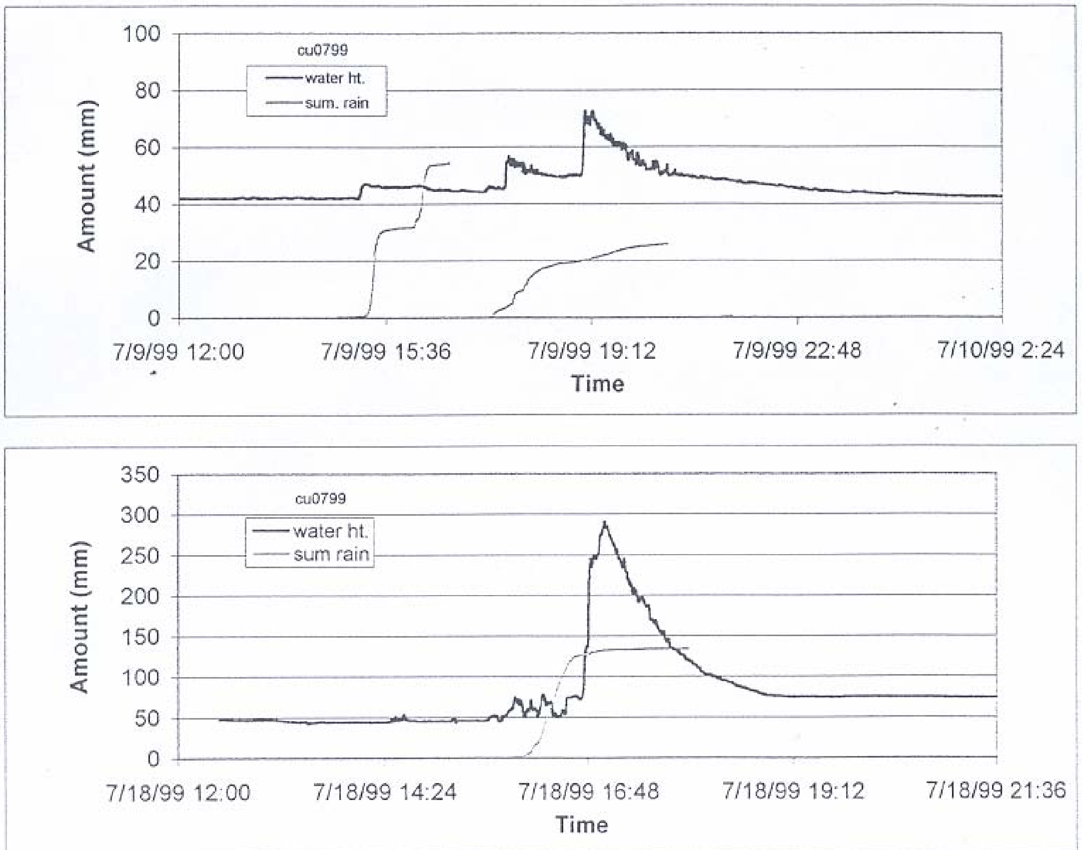
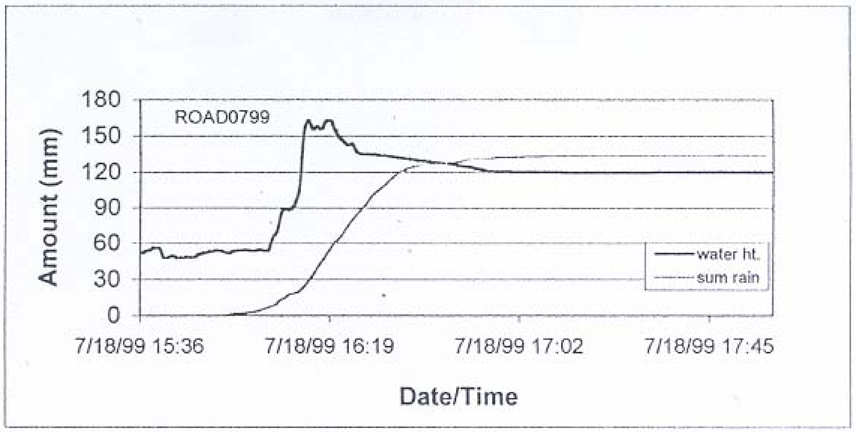


Fig. 7. Examples of depth of water in Mapawa creek as recorded by the water height recorder and rainfall depth as recorder by the rain gage data logger.



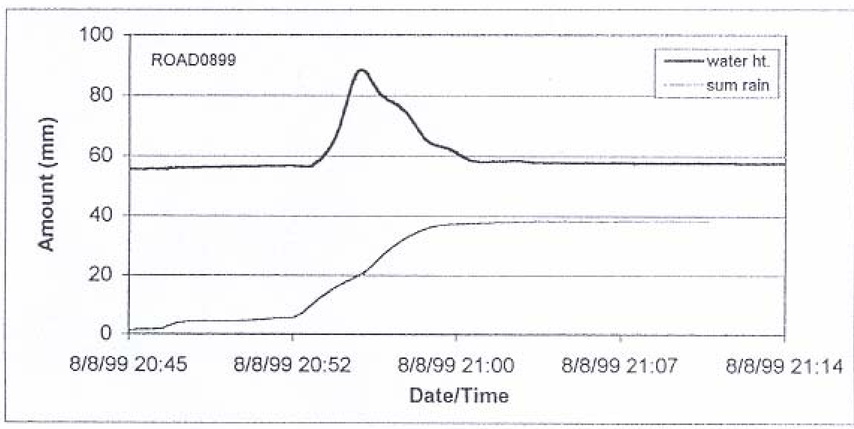


Fig. 8. Examples of depth of water as recorded by the water height recorder in the road gully and the summation of rainfall depths as recorded by rain gage logger.

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