MAPPING SPATIAL DISTRIBUTION OF SOIL EROSION AND DEPOSITIONS FOR NORTHERN THAILAND USING REGIONAL SCALE SOIL EROSION AND SEDIMENT TRANSPORT MODEL

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ABSTRACT

It is very important to know the sources and sinks of the sediments at regional scales, i.e., the spatial distributions of soil erosion and depositions. For this purpose annual erosion and deposition maps are generated to illustrate the sediment activity in the catchment, which give a complete picture of when, where and how much erosion and deposition takes place within the catchment. A regional scale soil erosion and sediment transport model has been applied to determine the erosion and deposition rates. For Chao Phraya river basin, model has been calibrated for the Nan river basin (N.13A) and was applied/validated to the Mae Taeng river basin (P.4A) and to the Nam Mae Klang river basin (P.24A). On-site soil erosion results are validated by two ways, one by comparing the extreme values of soil erosion available in the literature with the extreme values of potential detachments estimated by the model for different land-uses, secondly validations are carried out by simulating the plots for sediment discharges and are compared with the experimental plot's soil erosion values for different land uses. Results of the validation show that the simulated outputs by the model for sediment discharge and potential detachments are matching well with the observed plot's soil erosion data and data available in literature, respectively.

1. INTRODUCTION

Soil erosion is a highly dynamic process as about 90 % of the sediment loads are generated in 2-4 rainstorms of few weeks for no reservoir case and 1-2 rainstorms for reservoir case. A distributed model at regional scale for this dynamic process has been developed (Habib *et al*., 2001). Although distributed sediment models yields better results for plot scale areas as compared to regional scale areas yet the regional scale soil erosion models provide useful information for decision-makers and planners to take appropriate land management measures (Hill *et al*., 1996).

2. MAIN FEATURES OF THE MODEL

In the developed regional scale soil erosion and sediment transport model, the catchment's spatial variability is modeled as a regular square grid system with canopy interception, infiltration, depression storage, one-dimensional overland flow and sediment transport in the steepest descent direction. The overland flow is modeled as the equivalent channels, which may represent the cumulative width of all rills and gullies in each grid. The fraction of the ponded surface is determined on the basis of the flow accumulation value of the each grid, grid size and its land use type. The soil erosion processes are modeled as the detachment of soil by the raindrop impact over the entire grid and detachment of soil due to overland flow only within the equivalent channels, whereas sediment is routed to the forward grid considering the transport capacity of the flow and the existing sediment load (Habib *et al*., 2001). The slope averaging effect is taken care by adapting a Fractal analysis approach (Zhang *et al*., 1999).

For one-dimensional forward sediment transport routing, the kinematic mass balance equation (Woolhiser, 1990) has been used, which is applied between centers of two consecutive grids ((i_1,j_1) and (i_2,j_2)) considering the flow direction matrix. Total detachments are calculated as the sum of the splash detachment and detachment due to overland flow. After considering the transport capacity of the flow, the total actually detached load ($e_1(x,t)$: erosion) is determined which is assumed that flow can carry, and this load is considered as the lateral sediment flow and is added at the inlet of the control volume.

3. DATA SOURCES

The meteorological / hydrological, topographical, landuse and sediment discharge/soil erosion data was obtained from Royal Irrigation Department (RID), GTOPO30 (http://edcdaac. usgs.Gov/gtopo30/gtopo30.html), USGS's Earth Resources Observation System (EROS) Data Centre, Soil Fertility Conservation Project (SFCP, 1992) & Department of Land Development (DLD 1980), respectively.

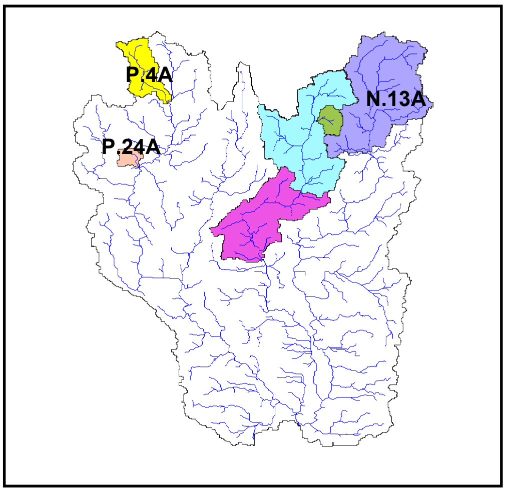

Figure 1: Sub-catchments of Chao Phraya river basin for the study

4. CALIBRATION & VALIDATIONS

The regional scale soil erosion and sediment transport model was calibrated on the Nan River Basin (N-13A) (Figure-1), a sub-basin of the Chao Phraya river basin, Thailand, using a continuous temporal data record for three years (1994-1996). The catchment area of the Nan River basin is 8551 km^2. In this catchment there are five land use types & five soil types (Figure 2(b) & 2(c)). Major land use types are forest and grassland, whereas major soil type is sandy clay loam. Using DEM from GTOPO30, river network and slope maps were drawn as shown in Figures 2(a) & 2(d).

For surface flow major parameters were adopted from previous hydrological modelling studies (Jha, 1997, and Yang, 1998), while for sediment yield, the parameter's calibration was carried out for monthly temporal scale of observed sediment discharges. The monthly-simulated results for sediment discharge of three years (1994-1996) were compared with observed sediment discharges obtained from RID. Overall a good match of the simulated & observed sediments discharge was obtained (Habib et al, 2001).

For the calibration, the annual spatial distributions of soil erosion and deposition in the catchment are generated and are presented in Figures 3.

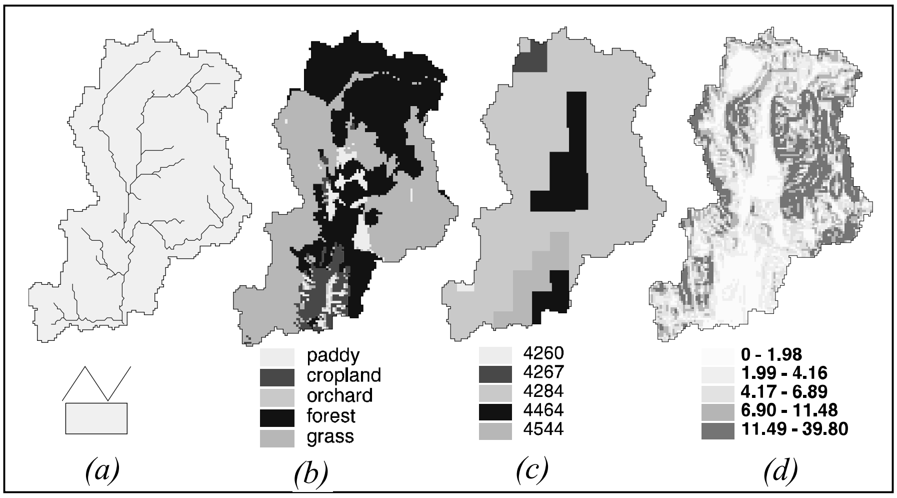

Figure 2: (a) Catchment boundary with river network, (b) land-use map, (c) Soil map, (d) slope map (%) for Nan river basin, Thailand.

The Figure 3 shows that the soil erosion intensities are higher at higher slopes and vice versa. There is also deposition on the top left corner of the watershed, where the slopes are higher. It is due to the reason that here sediment discharge seems to be much more than the transport capacity of the flow. River network is also identified by the erosion and deposition maps, indicating the severity of these processes in the river grids due to accumulations. Paddy fields, agricultural lands and some of the forestland lie in the flatter areas, so they receive depositions as well. In general grass lands and paddy fields have lesser erosion values

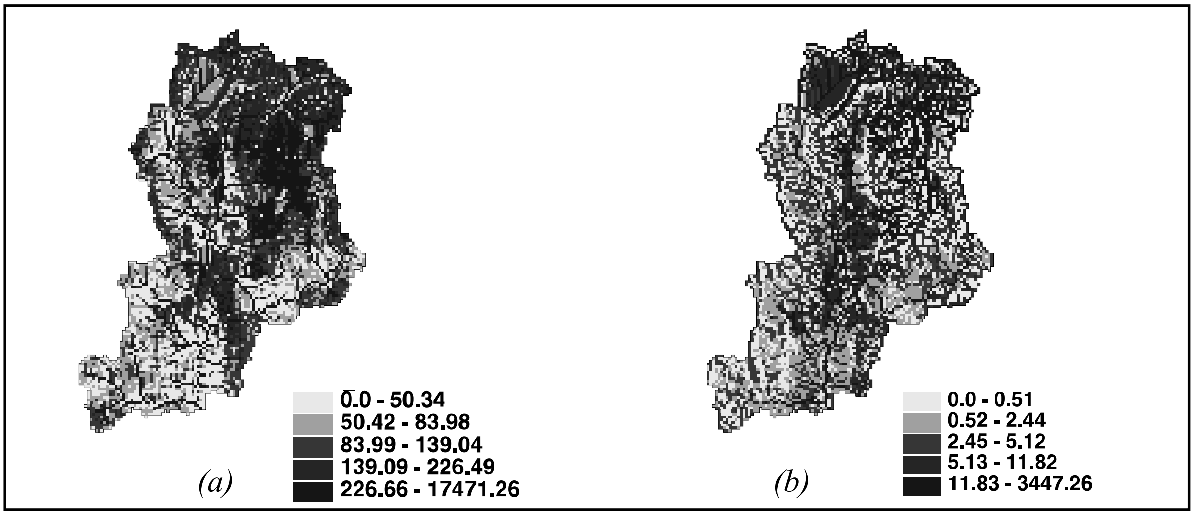

Figure 3: (a) Annual soil erosion map (tons/km^2), (b) annual deposition map (tons/km^2) for the Nan river basin, Thailand (1994).

Once the parameters of the model were calibrated, it was applied on two other basins of northern Thailand i.e. Mae Taeng river basin (P.4A) for the year 1992 & Nam Mae Klang river basin (P.24A) (Figure 1) for the year 1997.

Model validations were carried out separately for both, i.e. on-site soil erosion and sediment discharges. Figures 4 & 5 depict the soil erosion / deposition for these catchments. Spatial distribution of soil erosion & deposition well represent the effects of slope, landuse and soil types.

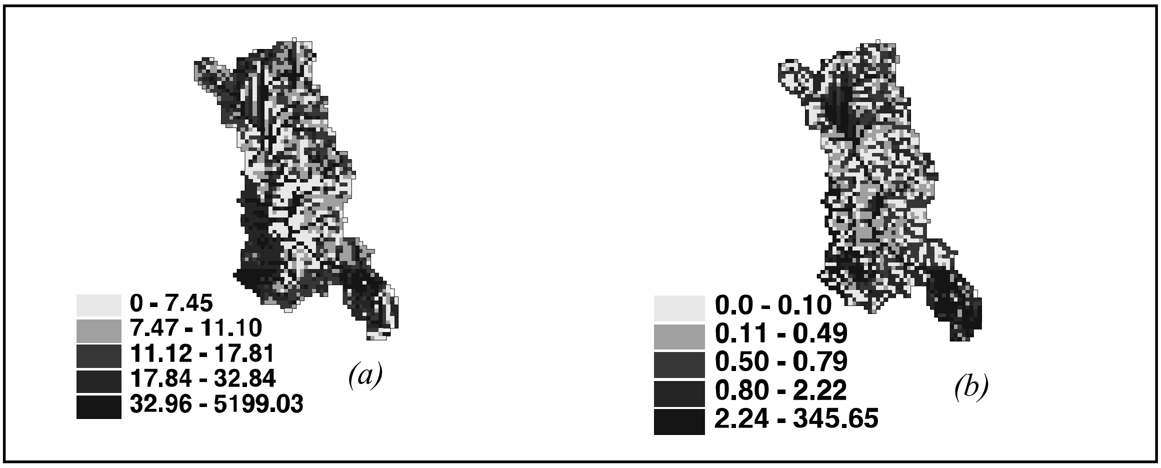

Figure 4: (a) Annual soil erosion map (tons/km^2), (b) annual deposition map (tons/km^2) for the Mae Taeng river basin, Thailand (1992).

The results of the model were validated by comparing with the data available in the literature. Through extensive literature review, soil erosion experimental plot studies data was obtained for Northern Thailand. The studies selected for comparing the soil erosion simulated by the model are from Department of Land Development (1980), Prasad (2000), UNEP (1991), IBSRAM (1995), Inthapand (1990) and Tangtham (1991).

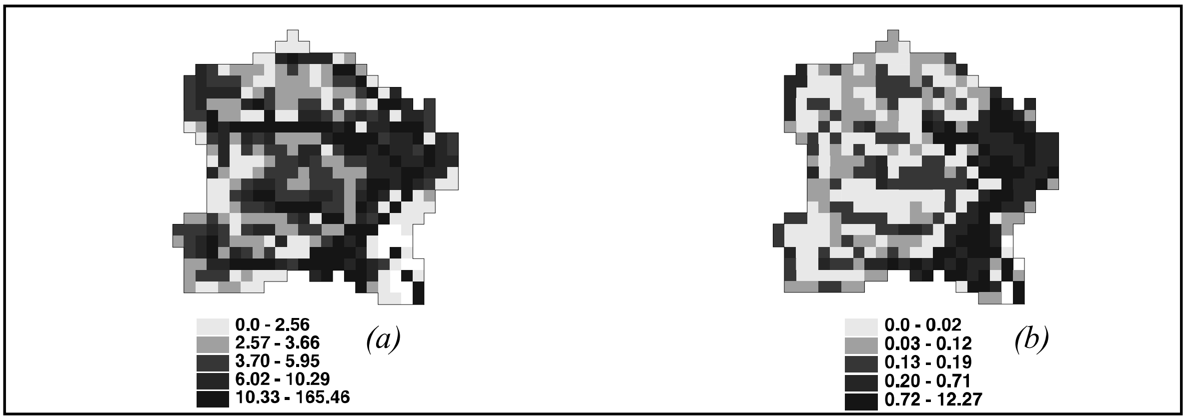

Figure 5: (a) Annual soil erosion map (tons/km^2), (b) annual deposition map (tons/km^2), for the Nam Mae Klang river basin, Thailand (1997).

These studies declare the particular range of soil erosion (extreme values). Therefore on-site soil erosion estimated by the model was validated by two methods. Firstly, it was compared with the range of estimated potential soil detachments with the available ranges of observed/estimated soil erosion for specific land use types of northern Thailand, as shown in Table 1. Secondly soil erosion results were also validated by simulating the plots of 36 m length using 5 m grid sizes to compare the simulated results with the observed soil erosion rates for the IBSRAM (1995) sites for each land use type as shown in Figure 6. The plots were simulated for 6 years of available data record using the same calibrating parameters for the same soil and land use type. Then the annual average plot erosion values were estimated.

As available plot soil erosion data (IBSRAM) was available for slopes of 18-40%, so plot simulations were carried out at 18, 20, 30 & 40% slope values.

Table 1: Range of Soil Erosion (tons/ha/year) from Literature & from Model

DATA SOURCES	LAND USES									
	Paddy		Orchard		Grassland		Forestland		Cropland	
	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
UNEP	0.00	50.00					50	300		
DLD	0.06	6.25	31.31	625			0.06	625		
PRASAD			0.00	260	0.03	2388	0.00	104	0.01	2612
IBSRAM					20	20	36.00	36	58.00	58
TANGTHAM							0.02	8		
INTHAPAND									2.00	89
MODEL	**0.16**	**26.3**	**0.58**	**200.7**	**0.03**	**171**	**0.54**	**281**	**0.22**	**246**

6. RESULTS & DISCUSSION

For Chao Phraya river basin, in general, simulation results are well reproduced using the similar calibrating parameters for soil and land use types.

As far as validation by comparing with the range of estimated potential soil detachments with the available ranges of observed/estimated soil erosion for specific land use is concerned (Table 1), the results are matching more with the observed IBSRAM's (1995) sites as compared to Prasad (2000) & UNEP (1991). The reason for the poor match with the above stated two studies is that they have used USLE to estimate the soil erosion, & the USLE does not consider the transfer of mass and energy within the catchment, whereas the Model does consider the transfer of mass & energy within the catchment. So it is quite possible that simulated soil erosion values are drastically different for the same soil type, land use type and slope but with cells of different flow accumulation values. In addition author thinks that these discrepancies are due to two of the shortcomings of the model i.e. ignoring the human-induced effects (road construction, & weir) & ignoring the ground water flow contributions. It is also due to the fact that there is high variability even in the replicated plot data under the similar treatment & conditions.

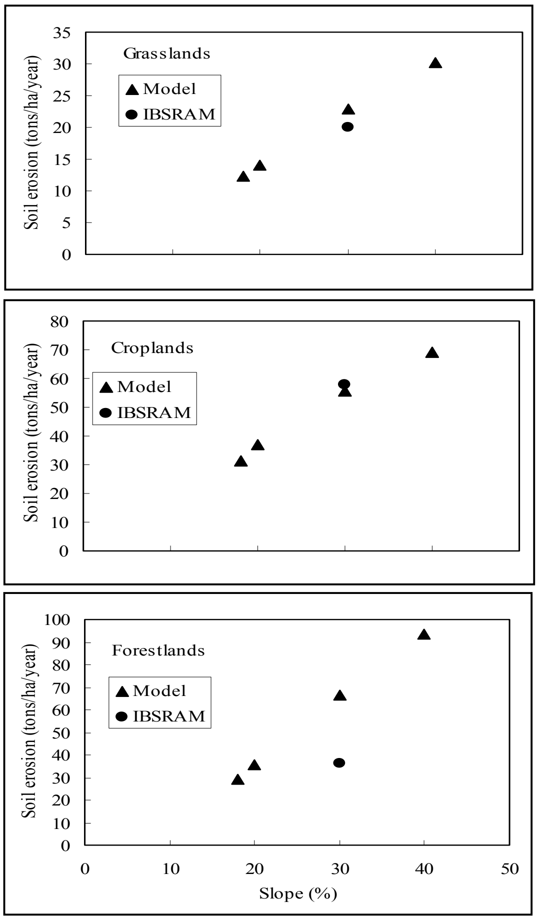

Figure 6: Soil erosion validation by plot simulation

7. CONCLUSIONS

It is concluded that on average basis the simulation results are well reproduced for soil erosion in northern Thailand. Validation by comparing the average plot erosion values of the model & IBSRAM show that the simulated results by the model for sediment discharge are matching well with the observed plot soil erosion data (sediment discharge). The response of slopes, land uses and soil types are well reproduced in the simulations, which can be seen from the annual spatial distributions of soil erosion and deposition. Erosion and deposition activity is much severe in the river grids as compared to surface grids.

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