Sediment Yield Characteristics of Chao Phraya river basin, Thailand.

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1. Introduction

Mankind has faced serious problems caused by erosion, transportation and deposition of sediments ever since the civilizations had developed in the fertile valleys of the rivers. Major consequences of soil erosion are loss of productivity of agricultural lands, transport of pollutants to down stream, depletion of reservoir capacities, braiding of river reaches, reduction of clearance below bridges, reduction in river bed slopes and flow velocities and rise in river bed levels which makes the river levee maintenance expensive.

Analysis of sediment discharge data affords one of the most objective method for evaluating the intensity of erosion, although sediment discharge of a river is not a precise measure of all erosion occurring within the drainage basin. A considerable portion of load is not transported out of the basin, which accumulates on the slopes and valley bottoms. Many researchers have concluded that in the plain regions this represents over half of all the products of erosion with in the river basin. Nevertheless, the river sediment load is directly related to the erosion rate. Therefore, sediment discharge data can be used to estimate the relative rate of erosion (Alexy P. 1996).

The basic purpose for the sediment yield analysis is to explore the major factors affecting the soil erosion and sediment yield at catchment scales.

2. Data Sources

Daily water and suspended sediment discharge data was obtained from the Thailand hydrological year books, volumes 35 to 40, for the water years (April to March) from 1992 to 1997. For the water year 1997, the Chao Phraya river basin has maximum number of sediment gage records. These data books are published by the Royal Irrigation Department (RID), Hydrology Division Bangkok, Thailand. Daily rainfall data too were obtained from the RID.

3. Methodology

Fourteen sub catchments of the Chao Phraya river basin were selected on the basis of having daily sediment discharge data for the water year 1997. River network for the basin was generated by the flow accumulation method from 1 Km GTOPO30 DEM and fourteen sub catchments were delineated at each gauging station by using the same information. Out of fourteen sub catchments, five were having reservoirs whereas nine were reservoir free. In this way sub catchments for the analysis purpose were divided into two groups, i.e. with and without reservoirs. For each sub catchment the average daily rainfalls were estimated at the outlet from the available number of rain gauges contributing precipitation to the sub catchment, using thiessen polygon method. Slopes were also approximated for each sub catchment using arc/info software.

4. Results and Discussion

The specific suspended sediment yields for the Chao Phraya river basin are ranging from 10.66 tons/year/km^2 to 165.97 tons/year/km^2, with an average value of 55.36 tons/year/km^2, for the water year 1997. These values are in good agreement as compared to work of Walling & Webb (1983), as they had reported a range of 50 to 250 tons/year/km^2. Whereas land denudation rates as reported by Lvovich et al. (1991) are 200 to 1000 tons /year/km^2, which seems to be too large in comparison with the current analysis.

Sediment yield analysis of the Chao Phraya river basin reveals that soil erosion is a highly dynamic process as in most cases about 90% of the total sediment loads are generated in few events of 10-81 days (3% - 22% of year) for the catchments having no reservoirs, and 14-164 days (3.83-44.93%) for catchments having dams (see fig. 1 & 2).

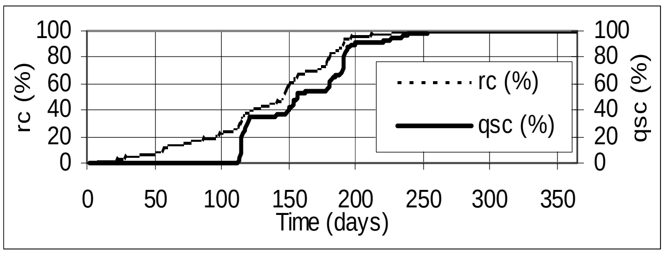

Fig. 1: Cumulative rain & sediment discharge at P4A, 1997.

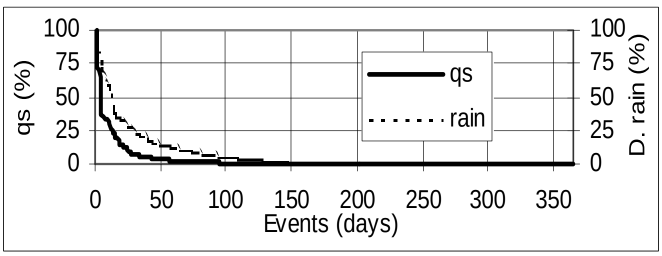

Fig. 2: Rain & sediment discharge duration curves at P4A, 1997.

The obtained relation between daily specific sediment discharge and daily rainfall is very poor with correlation coefficient ranging from 0.0021 to 0.289. Whereas it is relatively better on annual basis for the all sub catchments of Chao Phraya river basin (0.3312 for no reservoir and 0.7658 for reservoir case).

Key Words: Sediment Yield, Soil erosion, Chao Phraya, Correlation, Black box model, Rain storms

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Specific sediment discharge (q_s) has a very strong relation with the specific water discharge (q_w) on daily basis with goodness of fit values ranging from 0.9585 to 1, having a power relationship which can be expressed as $q_s = a.(q_w)^b$. where values of coefficient 'a' and exponent 'b' depends on the characteristics of the each sub catchment.

For Chao Phraya river basin, analysis shows that the daily cumulative specific sediment discharge (q_{sc}) has a strong relation with the cumulative average daily rainfall (r_c) over the sub catchment, with an average regression squared value of 0.9556. It can be expressed by an exponential relationship of the form $q_{sc} = c.e^{(rc*d)}$, where values of 'c' and 'd' also depends on the characteristics of the each sub catchment.

The average specific suspended sediment yield without reservoirs is about 53.36 tons/year/km^2 as compared to average suspended sediment load from sub catchments having reservoirs which is about 15.73 tons/year/km^2. Which shows that reservoirs in the Chao Phraya river basin have traped the sediment loads roughly by 70%.

Table 1: Sediment yield characteristics for nine sub catchments without reservoirs in Chao Phraya river basin, Thailand.

S. #	Basin Name	Basin Area (km^2)	Annual Rain (mm)	Max rain (mm/ day)	Aver. Basin Slope	SSSY (Tons/year/ km^2)	Time for 90 % Sediment Yield		q_s ~ rain R^2	q_s ~ q_w R^2	q_{sc} ~ r_c R^2
							(days)	(% year)			
1	P4A	1857	1200.46	50	1/83	86.61	25	6.85	0.2895	0.9846	0.9739
2	P24A	417	702.51	64	1/22	10.66	13	3.56	0.1061	1	0.9443
3	Y1C	7590	1173.79	88	1/321	37.32	46	12.6	0.0356	0.9872	0.9622
4	Y6	12984	1091	67	1/475	28.7	53	14.52	0.0425	0.998	0.9776
5	Y24	603	1192.44	70	1/41	14.05	18	4.93	0.0218	0.9585	0.8941
6	N13A	8551	1131.2	58	1/270	165.97	46	12.6	0.0623	0.9999	0.96
7	N22	4865	1198.66	50	1/162	60.12	81	22.19	0.0676	1	0.9611
8	N63	808	865.57	80	1/87	31.39	10	2.74	0.0021	1	0.9676
9	N65	634	1307.8	98	1/76	63.44	29	7.94	0.0361	0.9795	0.9598
	AVR		1095.94	69.44	1/171	55.36	35.66	9.77	0.0737	0.9897	0.9556

4.1. Landuse effect

Major landuse classes are grass land and forest in the study area. Statistical analysis shows that sediment load decreases with increase in grassland percentage, and increases with increase in forest percentage, both for with and without reservoirs. Perhaps it indicates the deforestation activity in the region, which generate gullies and enhance the sediment loads. Whereas increase in percentage of paddy field reduces the sediment loads, as ponding by water provides a shield to the ground from erosion. Results shows that with the increase in orchard percentage the sediment load also increases, whereas presence of water bodies and built up area has inverse relationship with the suspended sediment load as water bodies entrap the sediment load and built up areas have a stronger surface with sufficient resistance against erosive forces of water.

5. Conclusions

Specific daily sediment load has the best relation with specific daily river flow (power relationship), then next is cumulative daily specific sediment load with the cumulative daily rain (exponential relationship), and the least relation is between daily sediment yield and daily rain over the sub catchment (linear relationship).

It is concluded that total annual sediment load in the river is generated by three major long term rainstorms, on 6 years average, first and last rain storms produce a sediment load of 17 % and 16 % respectively, while middle rain storm produces a sediment load of about 57 % of the total annual sediment yield.

Annual rainfall has good relation with the annual river flows but no more good relation with the annual sediment yields. Which indicates the significance of runoff (presence or absence) over the hill slopes and its due consideration in the model development.

Sediment yield at catchment scale is very much sensitive to the runoff rates over the hill slopes which depends on the rainfall rate, infiltration capacity of the soil and slope of the ground surface, and hence cannot be directly related only with the rainfall amounts and river flows. More over empirical approaches which do not consider runoff generations can not be successfully applied at catchment scales to simulate the sediment yields. For proper simulation of sediment yields, it is necessary to integrate the physically based erosion processes with the hydrological processes by considering the hydraulic and mechanical properties of soil and topography of the area.

6. References

1) Alexey P. Dedkov & Vladimir I. Mozzherin, *Erosion and sediment yield on the earth*, Erosion and sediment yield: Global and regional perspectives, proceedings of the Exeter Symposium, july 1996, IAHS Publication no. 236, pp. 29-33.
2) D.E. Walling & B.W.Webb., *Erosion and sediment yield: a global overview*, Global and regional perspectives, proceedings of the Exeter Symposium, july 1996, IAHS Publication no. 236, pp. 3-17.