4. Sediment yield in relation to land use change

4.1 Sediment yield

Annual suspended sediment and sediment yield of three sub-watersheds of Pasak basin were shown in Table 35. These were calculated from the observed data of Royal Irrigation Department, Thailand for the best available period.

Table 35 Annual suspended sediment and sediment yield from available data of 3 sub-watersheds of Pasak Basin

Name of subwatershed	Drainage areas	Period employed	Mean annual Suspended Sediment	Sediment yield	Annual catchments erosion rate
	sq. km		tons	ton/sq.km	mm 1/
Upper Pasak	3480.43	1998-2000	239415	68.789	0.053
Middle Pasak	353.62	1980-2002	81396	230.179	0.177
Lower Pasak	14236.69	1980-1998	763326.54	43.96	0.041
Average			361379.18	114.31	0.09

Note: 1/ The density of suspended sediment is assumed to be equivalent to 1.303 tons/m^3 (EGAT, 1991)

According to Table 35 the average suspended sediment produced by Pasak basin was found to be about 114.31 tons/sq. km. Based on assumption that sediment density of suspended sediment was equivalent to 1.303 tons/m^3, the catchments erosion rate was found to be about 0.09 mm per anum. This amount is low compared to those watersheds in the north and the south of Thailand (EGAT, 1991).

4.2 Relationship between land use change, discharge and sedimentation

The impact of land use changes on sediment yield of Pasak Basin were evaluated in this part. Since the Pasak Cholasid Reservoir was constructed in 1998, so sediment data (for lower Pasak) before that period was employed in this study. For upper Pasak only three years sediment data were available as shown in Table 35.

The multiple regression analysis using annual rainfall, rainfall during wet period and dry period, runoff discharge during wet and dry period, land use area of forest, agriculture, urban, water and miscellaneous were employed in estimating the possible sediment yield with the intention of deriving prediction equations that represent the hydrological events in terms of sediment for Pasak basin. Correlation analysis was done as a first step in this regard.

Correlation among factors such as rainfall, runoff, land use factors and suspended sediments as analyzed in Table 27, 28 and 29 and shown in Figure 33 revealed that in case of upper Pasak suspended sediments (SS) and forest have a high negative correlation (-0.996) whereas agricultural and urban area show positive correlation with SS which is logical also. But this relationship was based on three years data only. In case of Lower Pasak suspended sediment and discharge have found positive correlation. But no correlation was found with land use factor. In case of middle part of Pasak suspended sediment and discharge also have high correlation but no correlation was found with land use factor.

Applying stepwise regression method, linear models as derived from relationship between sediments, and independent variables including discharge during wet, dry and peak period were shown in Table 36. It showed 6 equations. All equations had significant results with 5 equations at 99 % confidence interval and 1 at 95 % confidence interval which indicates that discharge had the major influence on sediment. In case of upper Pasak due to 3 years data it will not be wise to come up with any relationship. In the lower part of Pasak three variables including Qtotal, Rannual and forest have shown significant combined effect on sedimentation but with very low F ratio and R2 value. In the middle part parameters including Wet flow (Qwet) has shown significant effect on sedimentation with high F (78.07) and R2 (79 %) value.

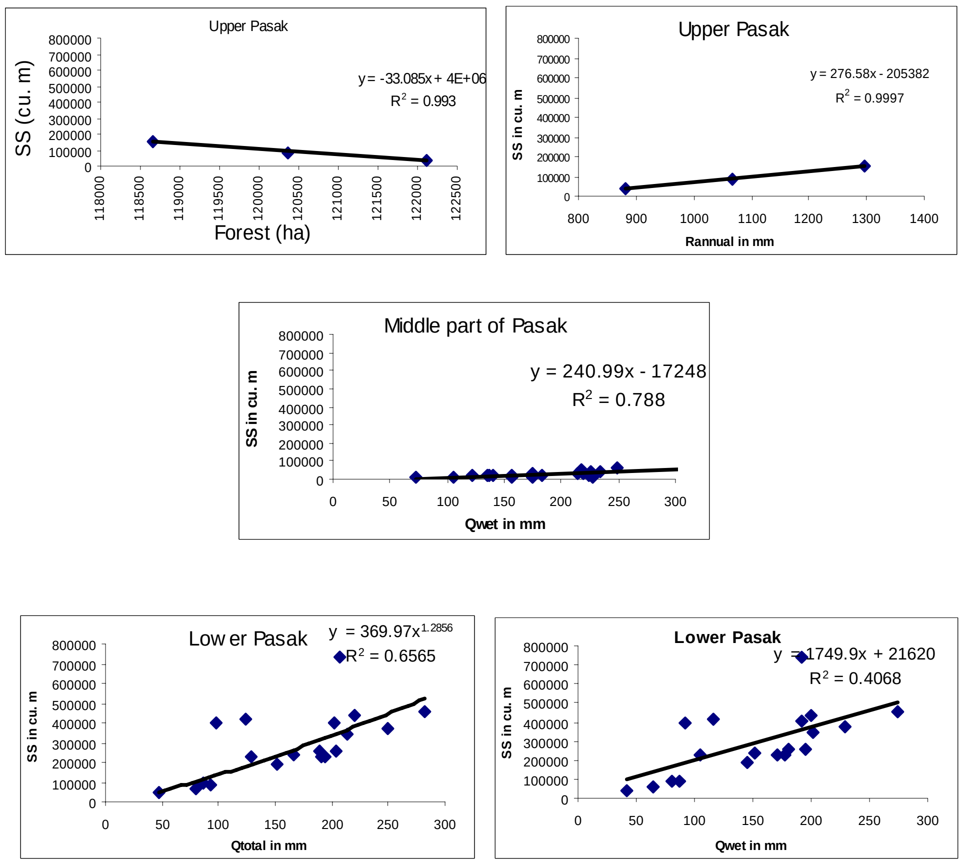

Figure 33 Linear relationship between suspended sediments (SS), discharge (Qtotal, Qwet), rainfall and land use factors

According to Table 36 non-linear regression implies the better prediction of SS than the simple linear with higher F ratio and R2 value with less SEE. In case of lower Pasak parameter Qtotal produce high correlation with SS when its linear equation transformed into power function.The derived equation is

$$SS = 369.97 * Qtotal^{1.2856}$$

Where F = 32.28; R^2 = 0.65; SEE = 0.449

Table 36 Linear and non-linear regression equations for sedimentation in Pasak watershed forecasting by stepwise regression method

	Dependent variable	Step no.	Model types	Equation	Regression no.	Statistical parameters r	R^2	SEE	F ratio	P
Lower part	SS	1	Linear	SS= 8850.07+1696.22*Qtotal	1	0.64	0.41	134136	11.77	0.003
of pasak	SS	2	model	SS = 21623.4 + 1749.91*Qwet	2	0.64	0.41	134390	11.66	0.003
				SS = 784546. + 1936.54*Qtotal - 134.172*.Rannual - 1.4569*.For			0.45	137351	4.15	0.025
Upper part	SS	1	-do	SS = -205385. + 276.58*Rannual	3	1.00	1.00	1514	2885	0.012
Middle part	SS	1	-do-	SS = -17247.4 + 240.985*Qwet	4	0.89	0.79	10335	78.07	0
Non-linear equations										
Lower	SS	1	Power	$SS = 369.97{*}Qtotal^{1.2856}$	6	0.81	0.66	0.449	32.48	0
Part of	SS	2	Exponential	$SS = 54675{*}e^{0.0088{*}Qtotal}$	7	0.76	0.57	0.501	22.76	0
Pasak	SS	3	Power	$SS = 1.342752{*}Rannual^{-0.191015}{*}Qtotal^{1.41739}{*}For^{-3.38877}$	8	0.85	0.72	0.1869	12.93	0.0002
Upper part	SS	1	Power	$SS = 1.3564{*}Rwet^{-1.19148}{*}Qwet^{1.56235}{*}For^{-3.04068}$	9	0.85	0.72	0.1861	13.1	0.0002
Middle part of	SS	1	Power	$SS = 9.588{*}Qwet^{1.503}$	10	0.848	0.72	0.388	53.84	0
Pasak	SS	2	Exponential	$SS = 5559.078 * e^{0.007{*}Qwet}$	11	0.84	0.70	0.398	50.05	0
	SS	3	Power	$SS = 4.593{*}Qwet^{238.537}{*}Agri^{-4.18269}$	12	0.91	0.82	0.138	45.83	0

Note: SS = Suspended sediment, Q total = Total annual flow in mm, Qwet = Flow during wet season in mm, Qdry = Flow during dry season in mm, Rwet = Rainfall during wet season in mm, Rannual = Annual rainfall in mm, For = Forest in ha, Agr = Agriculture in ha.

5. Selection of equations for runoff discharge and sediment transportation prediction in Pasak Basin

In order to represent the hydrological events in terms of suspended sediment and discharge for Pasak Basin and apply it to forecast the sediment and water yield produced by Pasak Basin in future in case of various change of rainfall and land use types that are given, prediction equations in simpler form are the useful tools. Several dependent and independent variable were made available in this study. But the model to be developed does not necessarily have to contain all of the independent variables. Selection of equations for total runoff, wetflow, dryflow and sediment transportation were considered from the criteria of 1) better statistical significance i.e. P value with < 0.05 and < 0.01; 2) high co-efficient of determination (R^2) that showed more compliance and accuracy of the equation 3) less slandered error of estimate (SEE); 4) high F ratio. Based on the Table 30, 31, and 36, following equations (Table 37) could be summarized as the best fitted equations for runoff and sediment transportation forecasting in the Pasak Basin.

Table 37 Summerized the suitable equations for runoff and sediment transportation by stepwise regression method

Drainage areas	Dependent variable	Equations	Statistical Parameter				
			r	R^2	SEE	F	P
Upper part of pasak (S4B)	Qtotal	$-0.9625 * \text{Rannual}^{1.46352} * \text{For}^{1.3688}$	0.77	0.60	0.104	6.86	0.016
	Q wet	Qwet = -66.6419 + 0.219323*Rannual	0.82	0.67	29.7591	20	0.001
	Qdry	Qdry = -86.831 + 0.001*For	0.84	0.71	8.9470	24.06	0.001
Middle part (S13)	SS	SS = -17247.4 + 240.985*Qwet	0.89	0.79	10335	78.07	0
Lower Part of Pasak (S9)	Q wet	$\text{Qwet} = 5.79 - 009 * \text{Rwet}^{3.517}$	0.84	0.706	0.273	40.86	0
	SS	$\text{SS} = 369.97 * \text{Qtotal}^{1.2856}$	0.81	0.66	0.449	32.482	0

Note: *Rannual – Annual rainfall, Rwet – Rainfall during wet period, Qdry – Runoff during dry period, Qwet – runoff during wet period, For – Forest, Agri – agriculture, SS – Suspended sediment. Unit: Rannual – mm, Rwet – mm, Qdry – mm, Qwet – mm, For – ha, Agri – ha, SS – m3*.