MATERIALS AND METHODS

Materials

1. Data Collection

Data employed for this study were collected from secondary sources that were best available at different government offices of Thailand. The types of data and their sources were shown in Table 9.

Table 9 Types and sources of data employed in this study

Type of data collection	Sources of data
1. Physical data	
1.1 Topographic map	Land Development Department (LDD)
1.2 Hydrological (Precipitation, discharge and sediment)	Royal Irrigation Department (RID)
1.3 Geology map	Department of Mineral Resources (DMR)
1.4 Soil Map	Land Development Department (LDD)
2. Biological	
2.1 Land use maps (1980, 2000 and 2004)	Office of Agricultural Economics (OAE)/ Royal Forest Department (RFD)/National Parks, Wildlife and Plants Conservation Department
3. Socio-economic (Population)	National Statistics Office (NSO)

Methods

2. Data processing and analysis

2.1 Land use data

Land use data of Pasak watershed for three periods (1980, 2000 and 2004) were collected and interpreted from field observation and LANDSAT image processing with GIS techniques. Data were also verified using topographic map and different hard copy map from Royal Forest Department and categorized into five land use types: 1) Forest 2) Agriculture 3) Urban 4) Water and 5) Miscellaneous. The definition and characteristics of each land use type are described as follows:

1) Forest (P1): It involves natural forest, disturbed or secondary growth forest and reforestation. The main natural forests include evergreen forest (Hill evergreen, dry evergreen, pine forest and bamboo forests) and deciduous forest (Mixed deciduous and Dry Dipterocarp forest) type. Reforestation includes teak, eucalyptus, acacia and mixed forest plantation.

2) Agriculture (P2): It includes paddy field, corn, swidden cultivation, cassava, sugarcane, upland rice, maize, mixed orchard, Perennial trees (mango, tamarind), and pasture, farm house (cattle, fish, and poultry).

3) Urban (P4): It includes lowland village, institutional land, city, recreational areas, factory, cemetery, airport and golf field.

4) Water (P5): It includes reservoir, lake, farm pond, river and canals.

5) Miscellaneous (P3): It includes bare land, grassland and mine pit.

Based on above land use definitions, land use types and their areal distribution in 1980, 2000 and 2004 in Pasak watershed are shown in Table 10 and Figure 12,13 and 14.

Table 10 Area of land use types of Pasak watershed in 1980, 2000 and 2004

Land use types	1980		2000		2004	
	Area (ha)	%	Area (ha)	%	Area (ha)	%
Forest	491099	30.89	397668	25.01	370023	23.27
Agriculture	1041238	65.49	1137030	71.51	1165368	73.30
Urban	2166	0.14	9649	0.61	13207	0.83
Water	872	0.05	20208	1.27	20807	1.31
Miscellaneous	54578	3.43	25397	1.60	20547	1.29
Total	1589953	100	1589953	100	1589953	100

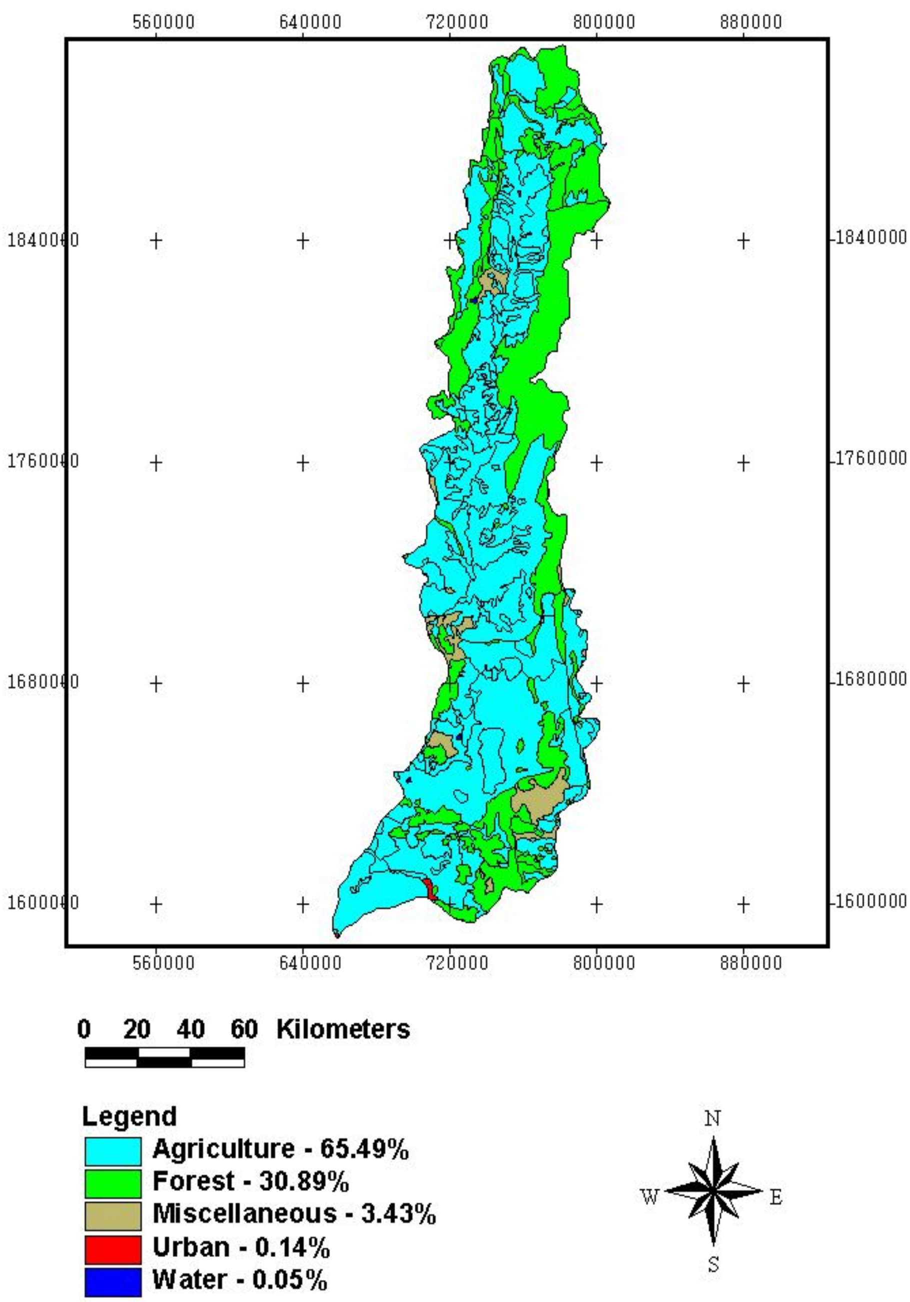

Figure12 Land use map of Pasak watershed, 1980.

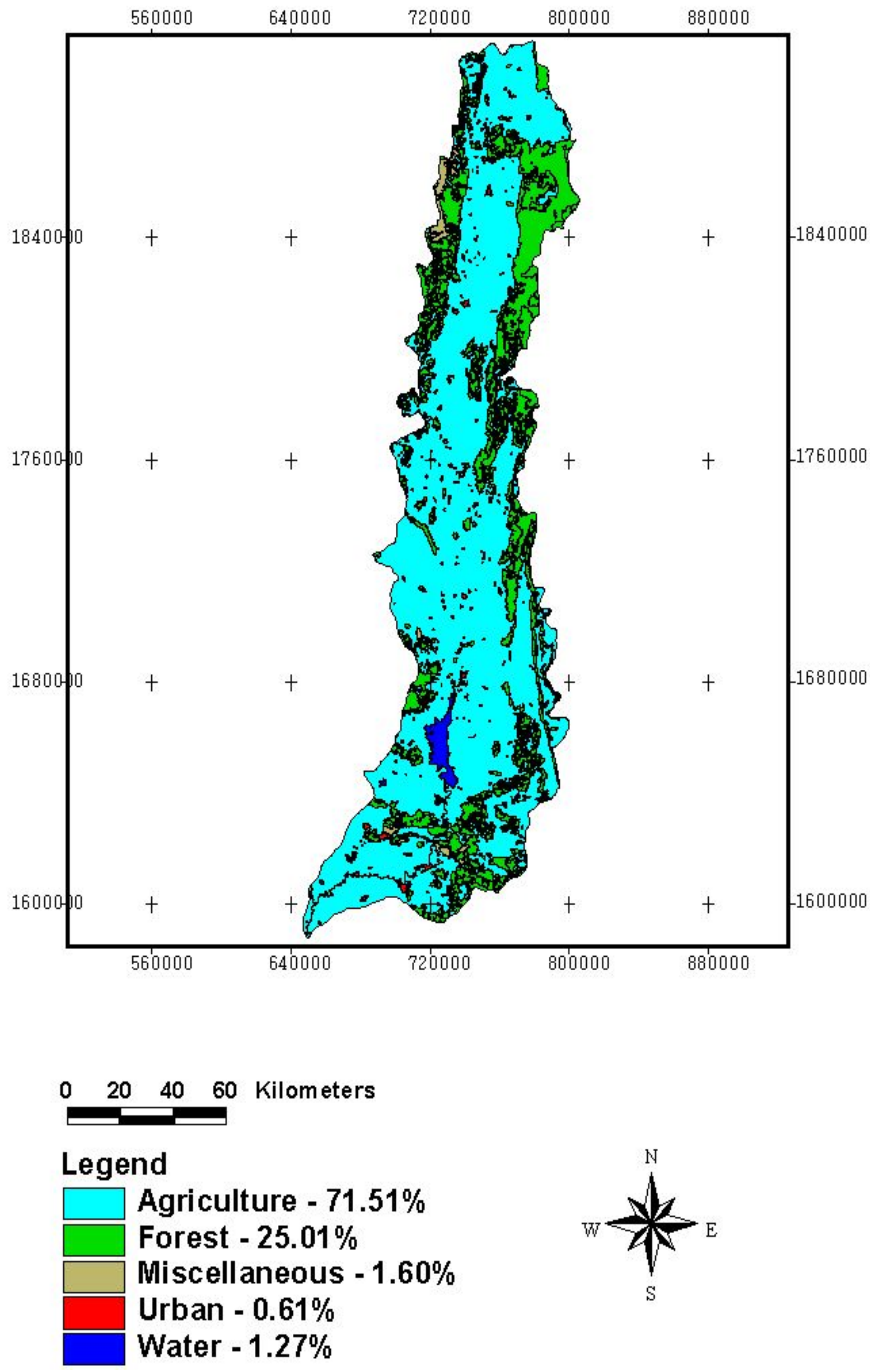

Figure13 Land use map of Pasak watershed, 2000

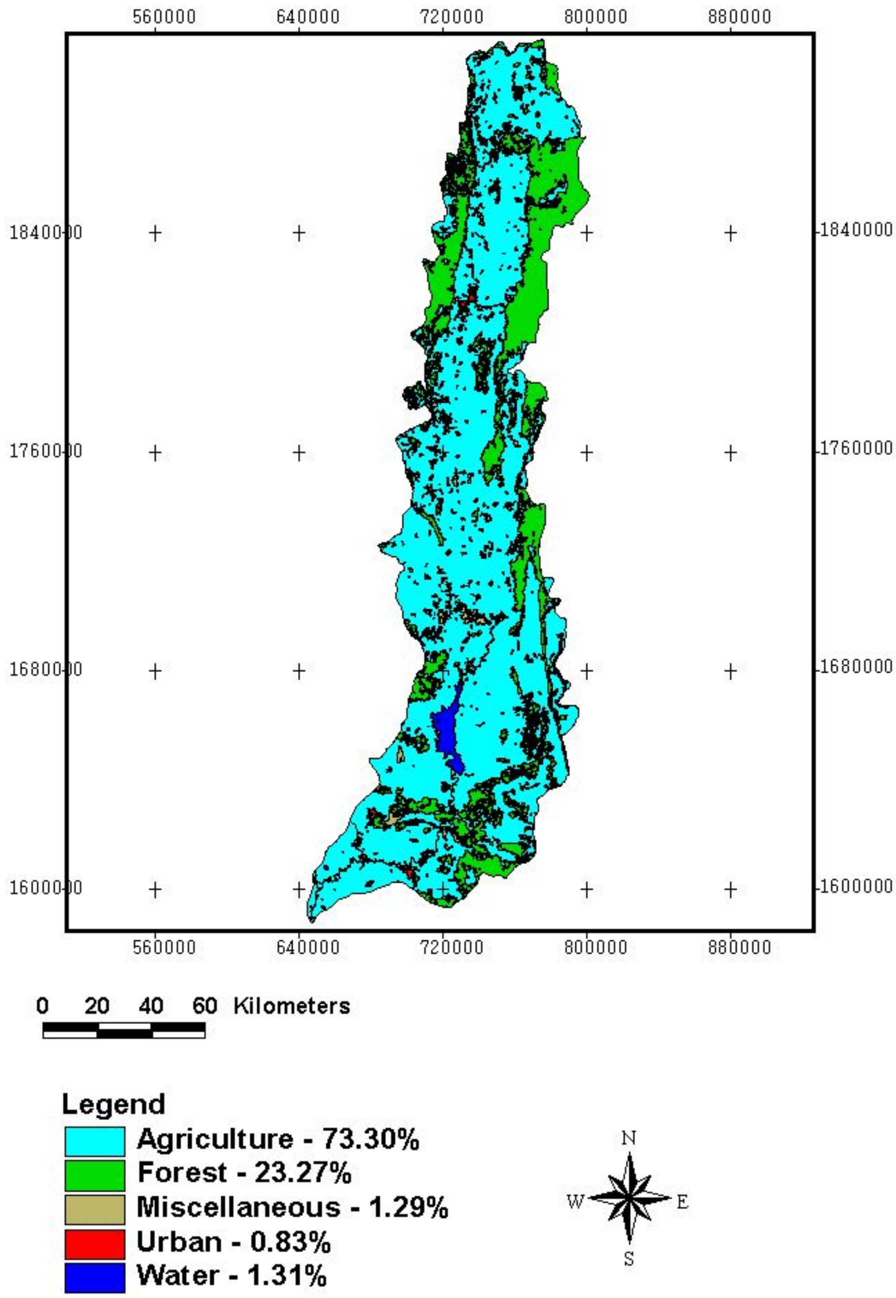

Figure 14 Land use map of Pasak watershed, 2004.

2.1.1 Land use change impact model formulation

2.1.1.1 Conceptual model

Based on the problems mentioned and study objectives, the conceptual land use change model as designed by Huggett, (1993) showing the linkages of the causes of land use change and their impacts on streamflow and sedimentation was illustrated in Figure 15.

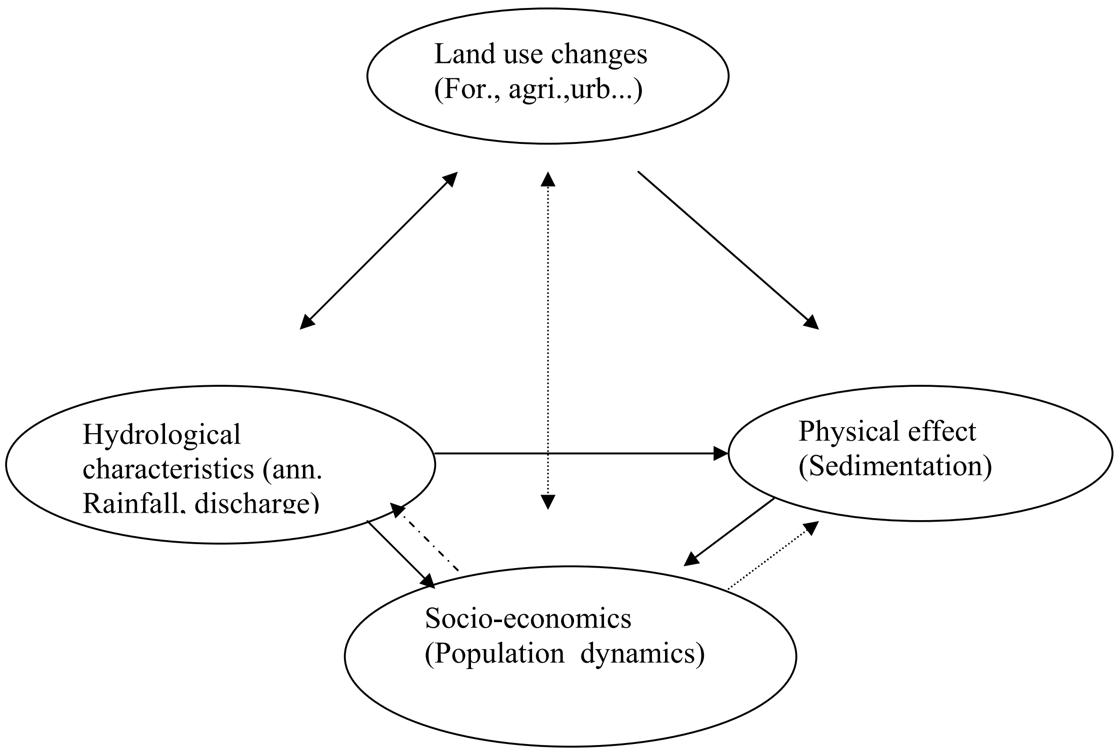

Figure15 Conceptual model of causes and effects of land use changes on streamflow and suspended sediments in Pasak watershed (………:indirect effect, ―――――― direct effect)
Source: Huggett (1993)

It is shown in Figure 15 that land use change in Pasak watershed has a direct effect on the hydrological behavior and sedimentation and indirect effect on socio-economic condition. On the other hand changes in hydrological characteristics has also influence on land use change, sedimentation and socio-economic condition. Accordingly, socio-economic also causes land use change and thus affect streamflow and sedimentation indirectly. The streamflow and suspended sediment also has negative impact on the socio-economic condition.

2.1.1.2 Mathematical model of land use change

In order to obtain year by year land use changes, the Markov chain model was applied to determine probability of land use change based on land use evolution between two given periods. The general form of the model to predict land use change from the 1st date (year) to the 2nd date (year)) is expressed in Figure 16.

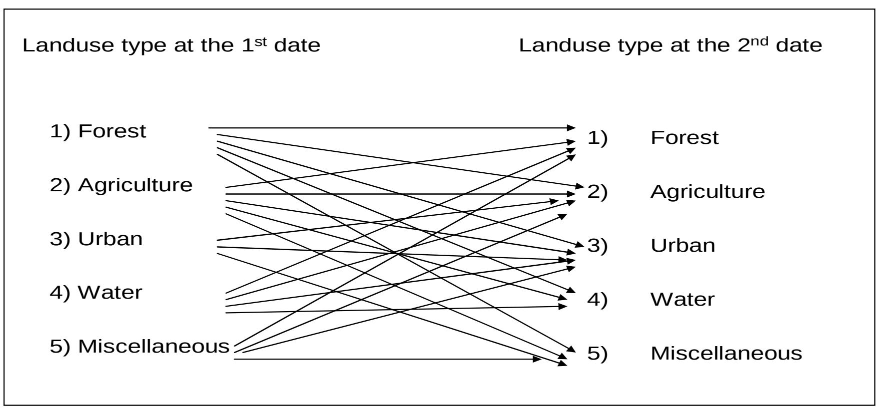

Figure 16 General form of model for land use change prediction

Given P_{ij} as probability of change determined from overlaying two different period of land use map, the prediction of the next (forward and backward) period of land use change as expressed by Wacharakitti *et al*. (1979) can be expressed as follows:

[Proportion of land use of the first date] * [Matrix of probability of land use change] = [Proportion of land use of the second date]

This can be transformed (backward) into general matrix multiplication as

$$[V_1, V_2 \ldots\ldots V_m]_1 \quad * \begin{pmatrix} P_{1,1} & P_{1,2} & \ldots & P_{1,m} \\ P_{2,1} & P_{2,2} & \ldots & P_{2,m} \\ \ldots & . & \ldots & . \\ \ldots & . & \ldots & . \\ P_{m,1} & P_{m,2} & \ldots & P_{m,m} \end{pmatrix} = [V_1, V_2 \ldots\ldots V_m]_2$$

In this study, land use changes in Pasak watershed were approached using modeling techniques recommended by Chunkao and Rakariyatham (1995) steps in deriving year by year land use proportion are:

1) Land use unit design

The term "Patch" that is used to represent the homogeneous appearance of plant community in the landscape that appear uniformly, was initially designed herein as:

P_1 = Forest land
P_2 = Agricultural land
P_3 = Urban
P_4 = Water
P_5 = Miscellaneous

2) Rule for change between periods:

Changes in land use in each patch at any given time vary implicitly according to interaction between population, technology, education, economic and policy. In this study at time t_1, area of each patch is a function of a co-efficient (c_1) at t_1 and the patch area (AP_1) at time t_0 which can be simply written as:

$(AP_1)\ t_1 = c_1\ AP_1\ (t_0)$

$(AP_2)\ t_2 = c_2\ AP_2\ (t_0)$

$(AP_3)\ t_3 = c_3\ AP_3\ (t_0)$

$(AP_4)\ t_4 = c_4\ AP_4\ (t_0)$

$(AP_5)\ t_5 = c_5\ AP_5\ (t_0)$

Where c_1 to c_5 = land use change co-efficients;

t = time

AP_1 to AP_5 = Area for P_1 to P_5

Thus the equation can be re-written as :

$$(AP_n)_{t+1} = c_n\ AP_{n\,(t)}$$

For the year 1980, 2000 and 2004 the size of the area under investigation considered as a function of human activities can be expressed as:

1980: $A\ (t_1) = AP_1(t_1) + AP_2(t_2) + AP_3\ (t_3) + AP_4(\ t_4) + AP_5(\ t_5)$

2000 :$A\ (t_2) = AP_1(t_1) + AP_2(t_2) + AP_3\ (t_3) + AP_4(\ t_4) + AP_5(\ t_5)$

2004: $A\ (t3) = AP_1(t_1) + AP_2(t_2) + AP_3\ (t_3) + AP_4(\ t_4) + AP_5(\ t_5)$

Where

$A\ (t_1) = A\ (t_2) = A\ (t_3)$ = total study area (Pasak watershed area)

3) Estimating annual change of land use units

Changing in land use in each patch at any given time (t_1) varies according to the change (Δ) of population, technology, education, economic and policy among the time interval ($t_0 - t_1$), the changes between different patches are expressed in Table 11.

Table 11 Matrix co-efficient land use change between t_0 to t_t

Patch	P_1	P_2	P_3	P_4	P_5
P_1	γ_{11}	γ_{12}	γ_{13}	γ_{14}	γ_{15}
P_2	γ_{21}	γ_{22}	γ_{23}	γ_{24}	γ_{25}
P_3	γ_{31}	γ_{32}	γ_{33}	γ_{34}	γ_{35}
P_4	γ_{41}	γ_{42}	γ_{43}	γ_{44}	γ_{45}
P_5	γ_{51}	γ_{52}	γ_{53}	γ_{54}	γ_{55}

Change of patch P_1 between t_0 to t_t to other land use can be logically expressed as:

$$(AP_1)\, t_1 = c_1\, AP_1\, (t_0)$$
$$= AP_{11}\, (t_0) - \gamma_{12}\, AP_1\, (t_0) - \gamma_{13} AP_1\, (t_0) - \gamma_{14} AP_1\, (t_0) - \gamma_{15} AP_1\, (t_0) + \gamma_{21}\, AP_2\, (t_0) + \gamma_{31} AP_3\, (t_0) + \gamma_{41} AP_4\, (t_0) + \gamma_{51} AP_5\, (t_0)$$

In the same manner change of patch P_1, P_2, P_3, P_4 and P_5 between t_0 to t_t to the other land use patches can be expressed as

$$(AP_2)\, t_1 = c_2\, AP_2\, (t_0)$$
$$= AP_2\, (t_0) - \gamma_{22}\, AP_2 (t_0) - \gamma_{23} AP_2\, (t_0) - \gamma_{24} AP_2\, (t_0) - \gamma_{25} AP_2\, (t_0) + \gamma_{12}\, AP_1\, (t_0) + \gamma_{32} AP_3\, (t_0) + \gamma_{42} AP_4\, (t_0) + \gamma_{52} AP_5\, (t_0)$$

$$(AP_3)\, t_1 = c_1\, AP_3\, (t_0)$$
$$= AP_3\, (t_0) - \gamma_{32}\, AP_3\, (t_0) - \gamma_{33} AP_3\, (t_0) - \gamma_{314} AP_3\, (t_0) - \gamma_{35} AP_3\, (t_0) + \gamma_{13}\, AP_1\, (t_0) + \gamma_{23} AP_2\, (t_0) + \gamma_{43} AP_4\, (t_0) + \gamma_{53} AP_5\, (t_0)$$

$$(AP_4)\, t_1 = c_1\, AP_4\, (t_0)$$
$$= AP_4\, (t_0) - \gamma_{142}\, AP_4\, (t_0) - \gamma_{143} AP_4\, (t_0) - \gamma_{144} AP_4\, (t_0) - \gamma_{145} AP_4\, (t_0) + \gamma_{14}\, AP_2\, (t_0) + \gamma_{24} AP_3\, (t_0) + \gamma_{34} AP_4\, (t_0) + \gamma_{54} AP_5\, (t_0)$$

$$(AP_5)\, t_1 = c_1\, AP_5\, (t_0)$$
$$= AP_5\, (t_0) - \gamma_{51}\, AP_5\, (t_0) - \gamma_{52} AP_5\, (t_0) - \gamma_{53} AP_5\, (t_0) - \gamma_{54} AP_5\, (t_0) + \gamma_{15}\, AP_1\, (t_0) + \gamma_{25} AP_2\, (t_0) + \gamma_{35} AP_3\, (t_0) + \gamma_{45} AP_4\, (t_0)$$

Where,

$(AP_1)\ t_1$ = Area of patch P_1 at time t_1

$(AP_1)\ t_0$= Area of patch P_1 at time t_0

c_1 = Co-efficient of change for patch p1 which implicitly caused by human activities in the study area during period t_0 to t_1

γ_{ij} = Co-efficient indicating probability of land use change from patch Pi to patch Pj

In equation 'plus' indicates the transformation from patch 'P_2, P_3, P_4, P_5' to patch P_1 and 'minus' indicates the conversion from patch 'P_1' to patch P_2, P_3, P_4, P_5. the other equation with the same pattern of 'plus' and 'minus' also explain the land use transformation according to γ_{ij} and APi.

4) Model formulation for generating land use change in the given dates

The land use categories were separated into five land use types- Forests, agriculture, urban, water and miscellaneous. The land use change over time was predicted by the following equation:

$$dA/dt = A*r$$

A = Land use area at year number t.

r = Rate of change of land use within the given period.

t = Time interval between two dates

So, $dA/ A = r*dt$

or, $A_t = A_0 * (1+ r)^t$

where, A_0 = Area of land use type at 1st date

A_t = Area of land use type at 2nd date.

r = Rate of change of Land use in the given period

$= (A_t^{1/t} - A_0^{1/t}) / A_0^{1/t}$

2.2 Rainfall and run-off data

Historical rainfall data were collected from 19 scattered hydrological stations of RID (as shown in Figure 17 and Appendix Table A1) for the available period of 1952-2003. The average monthly and annual rainfalls were calculated by Theissen polygon method (Appendix B). Observed mean monthly and annual precipitations were shown in Table 12. For the missing data the arithmetic mean method and correlation analysis were applied to the nearby stations and only the stations that had significant correlation were subjected to arithmetic mean method.

Historical discharge data in Cubic Meter per Second (cms) on daily basis as measured by RID at outlet S4B, S13 and S9 (considered as Upper Pasak, Middle part of Pasak and lower Pasak in this study as shown in Figure 6 and Appendix Table A2) based on Thailand Water Year basis (April 1 to March 31) for the period of 1980 to 2002 were collected and employed in this study.

2.2.1 Determining streamflow charateristics in concurrence of land use changes

Streamflow characteristics were evaluated in terms of water yield, rainfall-runoff relationship, monthly and seasonal distribution of runoff. Annual and seasonal variation of flow were determined by calculating mean annual runoff, monthly averages, classifying runoff as wet season runoff (6 months) during May-October, dry season runoff (6 months) during November-April and peak runoff or highest daily peak of the year. Monthly hydrographs showing runoff distribution for the three drainage areas (upper, middle and lower part of Pasak watershed) were illustrated.

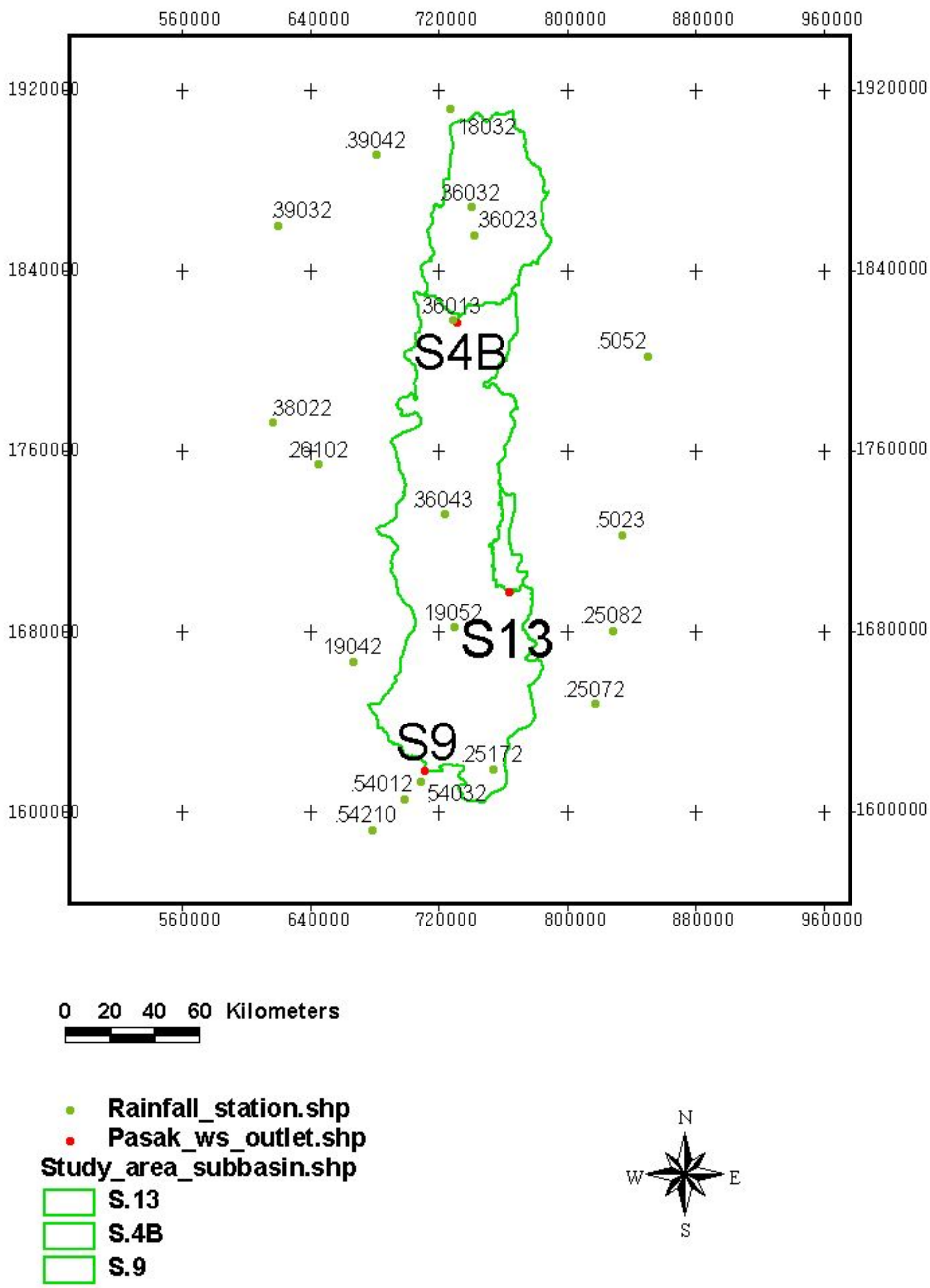

Figure17 Locations of rainfall station within and around Pasak Basin

Table12 Observed mean monthly and annual precipitations of various stations within and around Pasak Basin for the period 1952-2003

Rainfall Station	Rainfall amount in mm											
	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
Upper part of Pasak												
18032	100	168.7	126.2	141	183	204.2	99.3	15	3.9	8.8	20.4	53.5
39042	74.8	172.9	181.6	209.4	255	233.6	83.5	8.9	4.6	5.9	19.1	38.6
36023	63.4	154.7	151.8	140.7	194.1	217.4	81.8	11.5	4.5	4.9	19.6	46.5
36032	60.7	132	140.4	146.5	214.6	220.7	84.5	7.2	3.8	5.5	17.1	37.4
39032	55.7	179.5	182.9	199.1	240	262.1	125.2	29.5	5	8.2	14.9	30.8
36013	67.5	156.5	149.3	159	196.4	216.2	84.7	11.4	5.1	8.2	17.6	42.9
Middle part of Pasak												
5052	53.7	110.1	78.5	84.7	121.3	198	102.6	13.8	2.6	1.9	6.2	35.1
38022	45.6	149.7	122.4	132.5	158.5	239.4	114.8	22.2	1.7	2.4	5.3	21.5
26102	67	168.2	142.8	144.4	195.6	238.9	124.3	23.7	5.4	2.8	12	30.7
36043	77	165.6	131.8	162.1	192.5	240	120	17.4	3.7	8.2	20.4	48.2
5023	91.65	157.83	115.82	116.00	135.99	240.49	112.47	19.38	3.62	6.90	11.52	48.94
Lower part of Pasak												
19052	103	170.2	126.7	126.4	182.9	267.8	148.8	16.8	1.9	5.3	17.5	57.9
19042	70	132.7	95.6	123.6	146.8	223.3	121.1	20.4	4.7	8.9	11.9	33
25082	75.1	148.5	88	96.9	110.2	235.7	121.2	20.9	1.9	5.1	14.6	36.7
25072	77.3	147.6	84.2	93.5	106.5	231.8	156.2	24.5	2	4.2	14.4	40.5
25172	109	173.5	127.5	155.8	203.5	280.9	186.2	32.6	6.2	13	27.2	68.3
54012	62.6	148.2	189	187	227.6	268.6	133.7	31.4	6	8.9	13.8	29.5
54032	72.6	135.5	187.7	202.2	243.4	277.2	160.7	36.7	5.5	5.6	15.1	39.8
54210	69	161.8	189.3	195	233.1	288.9	146.1	38.8	4.6	3.5	21.9	27.5

Mean annual flow as an average discharge (cms) was computed by averaging daily data from complete years, which gave an indication of the size of the catchments, its climate and the typical amount of water delivered from it. Mean annual runoff (in mm) was obtained by dividing the mean annual flow volume (MCM) by the catchments area (sq. km) and multiplying by 1000. Generally, mean annual runoff decreases as basin area increases. However, Mcmahon (1982) showed a great deal of variability in this relationship worldwide, particularly in the streams of arid zones. He demonstrates that the annual co-efficient of variation of runoff for Australia and southern Africa is nearly twice than that of other continents.

Monthly averages are important in determining seasonal variation in discharge. Hughes and James (1989) found that streams in high rainfall areas had less variable monthly flows than rivers in dry regions. Average monthly flows are also expressed as a percentage of the average annual flows.

Relationship between rainfall, runoff and land use change over the mentioned period was determined followed by regression analysis. For analyzing rainfall–runoff relationship, simple linear regression equation employed by Ruangpanit and Tangtham (1982), Gordon *et al*. (2004) for the same purpose was applied as follows:

$$Y = \beta_o + \beta_1 X + \varepsilon$$

Where, Y = Dependent variable (the one which is to be predicted)

X = Independent variable

β_o / β_1 = Regression co-efficient

ε = Error

For analyzing relationship between more than one independent variable (i.e., rainfall and land use factor) with dependent variable (runoff discharge), multiple regression equation was applied in the following form:

$$Y = \beta_o + \beta_1 X_1 + \beta_2 X_2 + \ldots\ldots + \beta_p X_p + \varepsilon$$

Where, β_o , β_1 , β_2 … β_p = Parameters of the model

X_1 , X_2…. X_p = Independent variables

Y = Dependent variable

ε = Error

2.2.2 Streamflow timing investigation

Streamflow timing was determined in terms of flow date (1st quartile flow, half flow and 3rd quartile flow dates) and flow intervals (1%, 5%, quarter flow and half flow). For this, daily discharge in cms were first converted into

CM/Day and then cumulative flow volumes for each date of the water year starting from first April as the first date for three studied area at outlet S4B, S13 and S9 over the period 1980-2002 were calculated.

Based on the method partly adopted by Ruangpanit and Tangtham (1982) as mentioned in literature review the annual cumulative hydrograph of streamflow data (over the period of 1969 – 2001 in case of Upper Pasak (S4B), 1979 – 2002 in case of Middle part of Pasak (S13) and 1974 – 2002 in case of Lower Pasak (S9) were drawn. Flow date (1^{st} quartile flow date, half flow date and 3^{rd} quartile flow date) and flow intervals (quarter flow, half flow, 5% and 1% flow interval) for the high and low flow period were then determined for the three investigated part of watershed. Moving averages using 5, 10 and 15 years time series data were then computed and tendency line were drawn using simple linear regression equation.

2.3 Sediment data

Sediment data measured for the three studied drainage areas of Pasak watershed at S4B, S13 and S9 outlets for the period 1998 – 2000, 1978 – 2002 and 1975 – 2002 respectively by Royal Irrigation Department (as shown in Table 13, 14 and 15) were collected. The technique used by RID for collecting sediment data in Pasak watershed is as follows:

The collected suspended-sediment samples were analyzed for concentration and particle size in a laboratory. The concentration is the ratio of sediment (dry weight) to the total water-sediment mixture, expressed as milligrams per litter (mgm/l).The particle size is defined as the size of the sediment particles. Depending on their size, they are classified as sand, silt or clay. To find out how much material is transported by a river to the reservoir, the concentration is multiplied by stream discharge. This gives the sediment load which indicates the total amount of sediment transported (in tons) over a certain time period.

Table 13 Suspended sediment data (in tons) of Upper Pasak at Mueang, Muang Phechabun (S4B) during 1998-2000 by Royal Irrigation Department (RID)

Year	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Annual
1998	1	555	2310	21973	46358	23023	4397	591	220	1	1	1	99431
1999	45	5291	11586	1550	32183	135376	24871	12362	2196	295	44	47	225846
2000	1689	29223	46527	57486	81444	128157	40185	6300	1122	47	277	512	392969
Avr.	578	11689	20141	27003	53328	95518	23151	6417	1179	114	107	186	239415
Max.	1689	29223	46527	57486	81444	135376	40185	12362	2196	295	277	512	392970
Min.	1	555	2310	1550	32183	23023	4397	591	220	1	1	1	99430
Average Sediment Yield - 68.789 tons/sq.km.													

Table 14 Suspended sediment transportation (in tons) in Middle part of Pasak at Ban Tha Yiam, Chai Badan, Lopburi (S13) during the period 1980-2002 by RID

Year	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Annual
1980	0	543	1061	16914	2015	37746	35347	341	177	8	0	0	94152
1981	-	1584	1115	33205	17518	8128	5070	8276	372	265	169	96	75798
1982	0	914	617	22	2998	149777	7141	566	184	76	21	0	162316
1983	11	163	301	782	601	17649	65912	536	184	91	41	106	86377
1984	61	384	6612	7299	2765	16660	19276	203	40	16	5	2	53323
1985	53	919	2652	13419	21917	117685	12265	788	254	132	63	24	170171
1986	337	643	183	234	42327	5805	463	99	53	32	22	27	50225
1987	15	32	533	1046	1671	150450	18823	696	246	168	139	120	173939
1988	260	20427	3542	1280	1695	4441	16431	284	176	132	91	64	48823
1989	3	125	583	2602	13449	787	6528	69	13	7	4	77	24247
1990	105	229	848	720	2705	55088	36450	433	177	104	38	260	97157
1991	205	123	945	288	30438	39646	8293	124	48	40	6	0	80156
1992	9	16	131	2149	11557	860	1498	41	18	8	4	6	16297
1993	319	4850	3527	2205	20582	10826	237	89	906	849	198	0	44588
1994	9	780	7343	18367	30005	22018	1001	105	55	22	11	25	79741
1995	23	625	6252	4852	97208	52829	24635	206	76	48	33	30	186817
1996	271	3933	3240	1008	11646	21582	11141	6196	226	154	72	23	59492
1997	80	53	118	2465	9392	10729	19811	203	88	45	19	10	43013
1998	1030	1740	4492	447	8951	16768	18639	276	61	0	0	202	52606
1999	2031	1740	1069	543	1311	10730	8262	940	68	7	1	0	26702
2000	309	11412	4188	5474	141000	11731	5921	672	288	103	46	68	181212
2001	65	637	612	2428	15584	4012	1338	777	427	375	338	302	26895
2002	1012	756	787	800	1182	25195	1952	1001	382	48	28	151	33294
Avr.	271	2314	2103	7507	21245	43440	15749	942	193	124	59	67	89714
Max.	2031	20427	7343	68389	141000	288879	66412	8276	906	849	338	302	186818
Min.	0	16	118	22	601	787	237	41	13	0	0	0	16298
Average sediment yield: 253.7 tons/sq. km													

Table 15 Suspended sediment transportation (in tons) of Lower Pasak watershed at Ban Pa, Kaeng Koi, Saraburi (S9) during the period of 1980-2002 by RID*

Year	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Annual
1980	632	881	8097	31365	46509	162503	393382	15385	3905	1587	568	1093	665907
1981	999	2860	2337	47923	232288	185878	100160	21878	4309	1097	334	219	600282
1982	1214	4400	7773	1623	4754	936179	863113	52597	9537	2645	1001	691	1885533
1983	505	888	2072	2466	26444	81710	405521	51534	9507	4541	2031	1624	588843
1984	1444	1980	9671	19242	16843	155144	336948	33971	5863	2037	1005	1164	585312
1985	2570	7194	9702	29198	81579	353538	336213	112465	15142	4795	2521	1931	956848
1986	2042	8684	9940	4158	41780	62876	20821	5219	3247	1739	1015	998	162519
1987	324	999	3372	2959	3518	480788	353902	23075	6883	2321	1358	719	880218
1988	3077	72136	75522	21349	48109	76683	160173	101131	16197	6376	3048	2408	586209
1989	632	1047	48289	10476	25085	37095	66847	25178	2876	730	190	399	218844
1990	109	1618	43899	22911	32387	62329	271448	39318	4312	832	285	221	479669
1991	925	2423	15356	8229	107836	523519	351849	8767	4535	5880	1963	1032	1032314
1992	356	551	4057	2203	64404	41131	109917	6335	2742	897	385	323	233301
1993	588	1379	2455	1315	6226	60281	34640	889	553	436	376	821	109959
1994	459	4568	19776	49298	64094	337680	182267	3023	3118	668	374	280	665605
1995	364	2105	2625	17495	253091	636477	221107	20036	3920	1011	519	576	1159326
1999	1722	7754	877	328	4169	74337	158927	41461	1544	7638	7139	9163	315059
2000	14453	13832	41027	1E+05	82246	413700	165365	17637	6881	5990	16747	3306	927639
2001	6591	5535	15734	6934	50506	14867	12586	5451	459	3742	7730	5222	135357
2002	6544	3912	386	4971	1017	259512	77508	9287	1484	2823	4607	3122	375173
Avr.	2079	7025	14355	22434	57701	228281	250771	27697	5211	2889	2659	1608	625859
Max.	14453	72136	75522	1E+05	253091	936179	1004867	112465	16197	7638	16747	9163	1885533
Min.	109	551	386	328	1017	14867	12586	889	459	436	190	219	109957

Average Sediment Yield: 43.96 ton/sq. km

2.3.1 Determining factors contributing to streamflow and sedimentation

Factors causing discharge and sedimentation in Pasak watershed were determined by correlation analysis among the dependent and independent variables. Simple regression and stepwise multiple regression analysis in the form of linear and non-linear were applied for analyzing the cause and effect relationship between suspended sediment, discharge, rainfall, different land use types including forests, agriculture, urban, water and miscellaneous. The relationships were then justified by statistical parameters including correlation coefficient (r), co-efficient of determination (R^2), standard error of estimate (SEE), F-test ratio and statistical significant factor (P) at 95 % and 99 % confidence interval.