Use of MMF Model and GIS in Estimating Soil Erosion in Songkhla Lake Basin, Thailand

By

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Objectives of the Study

1) To estimate the rate of soil erosion from each sub-catchment area of Songkhla Lake by using the Morgan, Morgan and Finney (MMF) model.

2) To prepare soil erosion map of Songkhla Lake basin

Study Methodology

The following steps are conducted in this study:

1) Collect relevant data concerning soil erosion in Songkhla Lake basin.

2) Determine suitable values of soil erosion parameters included in the Morgan, Morgan and Finney (MMF) model.

3) Use GIS as a tool to express spatial distribution of various concerned parameters.

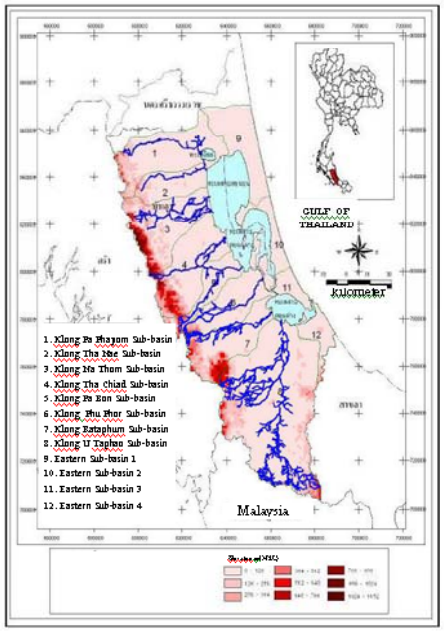
4) Use GIS as a tool to compute soil erosion rate in each sub-catchment area of Songkhla Lake based on the MMF model.

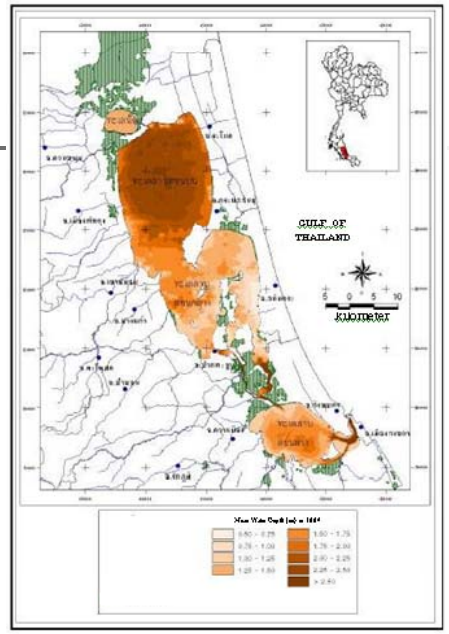
5) Prepare soil erosion map of Songkhla Lake basin.

Study Area

Songkhla Lake is a shallow lake located in 3 provinces in the south of Thailand, namely Nakhon Si Thammarat, Phattalung, and Songkhla. The basin area covers about 8,754 km^2 whereas the lake covers about 1,042 km^2. Water depth varies in the range of 1 - 4 m.

The watershed area of Songkhla lake can be divided into 12 subbasins, with 8 areas on the western side and the another 4 areas on the eastern side.





Coverage Areas of Sub-basins of Songkhla Lake

No.	Name	Area (km^2)
1	Klong Pa Phayom Sub-basin	805
2	Klong Tha Nae Sub-basin	353
3	Klong Na Thom Sub-basin	747
4	Klong Tha Chiad Sub-basin	759
5	Klong Pa Bon Sub-basin	323
6	Klong Phu Phor Sub-basin	500
7	Klong Rataphum Sub-basin	617
8	Klong U Taphao Sub-basin	2,383
9	Eastern Sub-basin # 1	488
10	Eastern Sub-basin # 2	202
11	Eastern Sub-basin # 3	136
12	Eastern Sub-basin # 4	204

Average Monthly Climatic Data in Songkhla Lake Basin

Month	Temperature (C)			Relative Humidity (%)			Monthly Rainfall
	Max.	Min.	Ave.	Max.	Min.	Ave.	(mm)
January	29.6	24.3	27.2	85	68	75	54.6
February	30.4	24.4	27.7	86	66	75	37.0
March	31.4	24.6	28.4	88	65	75	43.9
April	32.4	24.9	29.1	90	64	75	77.6
May	32.9	25.0	29.1	90	63	76	119.5
June	32.8	24.7	28.8	90	61	75	93.1
July	32.7	24.3	28.6	90	60	75	88.0
August	32.7	24.3	28.5	90	59	74	111.4
September	32.1	24.2	28.1	91	63	76	130.0
October	31.0	24.1	27.6	93	68	81	252.2
November	29.5	24.1	26.9	93	74	83	567.3
December	29.0	24.1	26.7	89	73	80	420.3
Annual	**31.4**	**24.4**	**28.1**	**90**	**65**	**77**	**1,994.9**

Morgan, Morgan and Finney (MMF) Model

The MMF model is a combination of empirical and physical based models. It has taken into account various physical mechanisms affecting soil erosion. Some empirical models are also included in the model. With these empirical formula, the appropriate parameters which are suitable for the applied area have to be selected.

Soil Detachment and Soil Transportation

In the MMF model, the mechanisms affecting soil erosion are divided into 2 groups, i.e., soil detachment and soil transportation. In soil detachment, kinetic energy of rain drops required to break the soil is considered. In soil transportation, transport of detached soil to downstream area due to surface runoff is considered. The smaller value between soil detachment and soil transportation is considered as the rate of soil erosion.

Factors affecting Soil Detachment and Soil Transportation

Factors affecting soil detachment and soil transportation include:

- rainfall intensity
- annual rainfall
- kinetic energy of rainfall
- soil bulk density
- evapotranspiration
- covered vegetation
- soil moisture
- soil detachment index (which depends on soil type, rooting depth, rate of overland flow and slope gradient)

$E = R\left(29.8 + \frac{127.5}{I}\right)$

Empirical Formula

The empirical formula used in the MMF model are:

1) <u>Kinetic energy of rainfall</u> :

$$E = R\left(29.8 + \frac{127.5}{I}\right)$$

where

E = kinetic energy of rainfall (Joule/m2)
R = annual erosive rainfall (mm.)
I = rainfall intensity (mm./hr)

2) Soil detachment :

$$D = 10^{-3} K\left[E.e^{-0.05A}\right]$$

where

D = soil detachment (kg/m2)

K = soil detachment index (g/Joule)

E = kinetic energy of rainfall (Joule/m2)

A = crop interception percent factor

3) Soil moisture capacity under actual vegetation :

$$R_c = 1000 M_s B_d R_d (E_t / E_0)^{0.05}$$

where

Rc = soil moisture capacity under actual vegetation (mm)

Ms = moisture content at field capacity (ratio by weight)

Bd = bulk density (mega gram/m3)

Rd = rooting depth (m)

Et/E0 = ratio of actual to potential evapotranspiration

4) Rate of overland flow :

$$Q = Re^{-R_c / R_0}$$

where

Q = overland flow (mm)

R = annual erosive rainfall (mm.)

Rc = soil moisture capacity under actual vegetation (mm)

R0 = mean rainfall per erosive rainy day (mm)

5) Soil transportation :

$$T = 10^{-3} C Q^2 \sin(S)$$

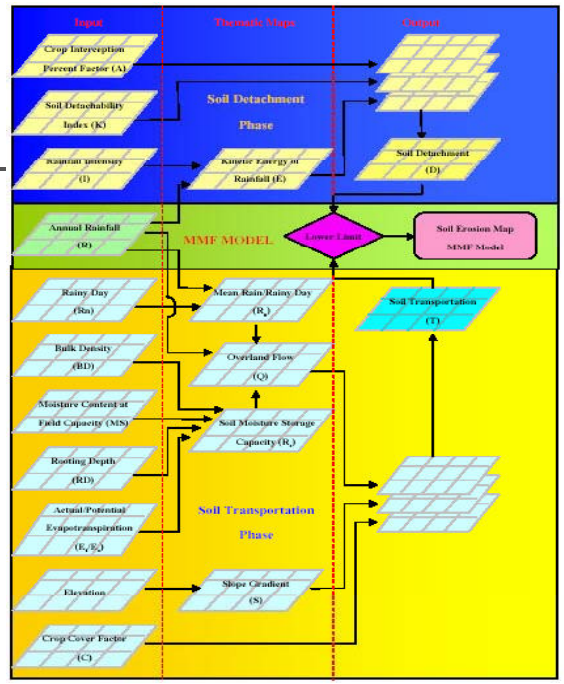
where

T = soil transportation (kg/m2)

C = crop cover factor

Q = overland flow (mm)

S = slope gradient



Values of Parameters for the Classified Land Use Types in Songkhla Lake Basin

Land Use Type	Crop cover factor, C	Crop interception percent factor, A (%)	Rooting depth, R_d (m)	Ratio of actual to potential evapotranspiration E_t/E_0
Savanna	0.032	20	0.88	0.14
Animal feeding grass field	0.100	20	0.88	0.14
Trees	0.150	20	0.90	0.15
Field crops	0.340	25	0.60	0.12
Evergreen forest	0.001	35	0.90	0.20
Paddy field	0.280	35	1.35	0.12
Urban area	0.000	0	0.00	0.00
Water body	0.000	0	0.00	0.00
Mines	0.800	0	0.05	0.05

Results and Discussion

1) Data Collection

Data in the Songkhla Lake Basin are collected and prepared as data layers using ArcGIS 9.1. A total of 11 data layers are obtained as follow:

1) Annual erosive rainfall. This data layer is the distribution of annual erosive rainfall over the whole basin. It is obtained from erosive rainfall data (daily rainfall higher than 12.5 mm) at 99 rainfall stations in the study area. It is found that the annual erosive rainfall varies in the range of 575 - 2,885 mm per year.

2) Number of erosive rainy days. This data layer is the distribution of number of rainy days with rainfall higher than 12.5 mm. It is found that the number of erosive rainy days varies in the range of 40 - 140 days per year.

3) Rainfall intensity. This data layer is the distribution of rainfall intensity over the whole basin, concentrating upon rainfall intensity higher than 25 mm/hr which is used for the tropical region.

4) Soil moisture content at field capacity. This data layer is obtained from data on average soil moisture contents of various soil groups in the Songkhla lake basin. The values are found to vary in the range of 0.00 -0.5 (ratio by weight).

5) Soil bulk density. This data layer is the distribution of soil bulk density over the whole basin. The value varies in the range of 0.0 - 1.6268 mega grams per m^3. The soil bulk density of 0.0 represents water body or area with rock outcrop.

6) Soil detachability index. This data layer is obtained by applying the value for each type of soil texture suggested by Morgan (2001) to soil types in the study area. It is found that the soil detachability index in the Songkhla Lake basin varies in the range of 0.00 - 1.20.

7) Crop cover factor. This data layer is obtained by using data from the Land Development Department (2002). It is found that the crop cover factor in the Songkhla Lake basin varies in the range of 0.000 - 0.800. The area with low crop cover factor will have less soil transportation by surface runoff.

8) Crop interception percent factor. This data layer is obtained from data on cropping types and land use in the study area. It is found that the crop interception percent factor in the Songkhla Lake basin varies in the range of 0 - 35%. The area with low crop interception percent factor will get more kinetic energy from rain drops and results in more soil detachment.

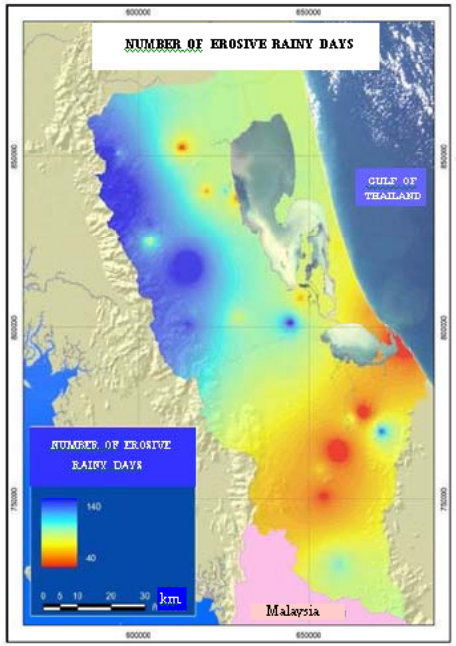
9) Rooting depth. The rooting depth means depth of water in the soil which crops can utilize. This data layer is obtained from data on land use types in the study area. It is found that the rooting depth in the Songkhla Lake basin varies in the range of 0.00 - 0.20 m. In the area with more rooting depth, crops can utilize more infiltrated rain water and the amount of surface runoff will decrease.

10) Ratio of actual to potential evapotranspiration. This data layer is obtained from data on land use and crop types in the study area. It is found that the ratio of actual to potential evapotranspiration. in the Songkhla Lake basin varies in the range of 0.00 - 1.35. In the area with higher ratio of actual to potential evapotranspiration, more water will be utilized by crops and the amount of surface runoff will decrease.

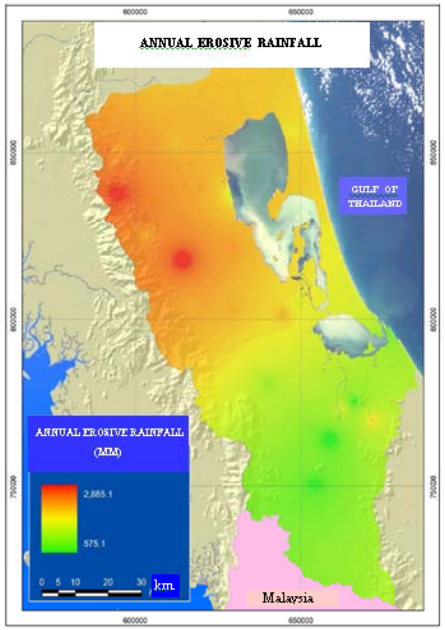
11) Elevation. This data layer is obtained from topographic contour of the study area. It is found that the elevation of the Songkhla Lake basin varies in the range of 2 - 1,280 m (MSL).

Values of Parameters for the Classified Land Use Types in Songkhla Lake Basin.

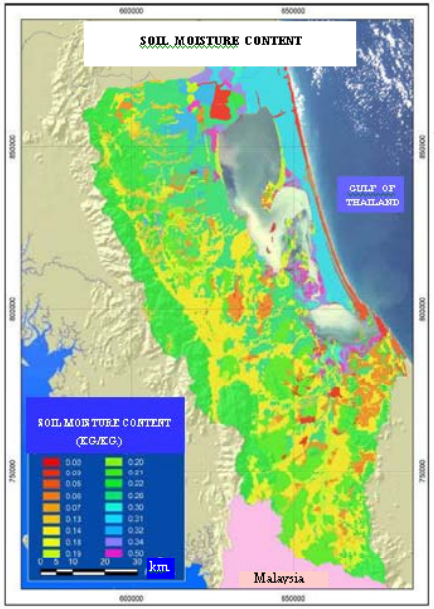
Land Use Type	Crop cover factor, C	Crop interception percent factor, A (%)	Rooting depth, R_d (m)	Ratio of actual to potential evapotranspiration, E_r/E_0
Savanna	0.032	20	0.88	0.14
Animal feeding grass field	0.100	20	0.88	0.14
Trees	0.150	20	0.90	0.15
Field crops	0.340	25	0.60	0.12
Evergreen forest	0.001	35	0.90	0.20
Paddy field	0.280	35	1.35	0.12
Urban area	0.000	0	0.00	0.00
Water body	0.000	0	0.00	0.00
Mines	0.800	0	0.05	0.05


NUMBER OF EROSIVE RAINY DAYS
GULF OF THAILAND
NUMBER OF EROSIVE RAINY DAYS
140
40
0 5 10 20 30
km
Malaysia

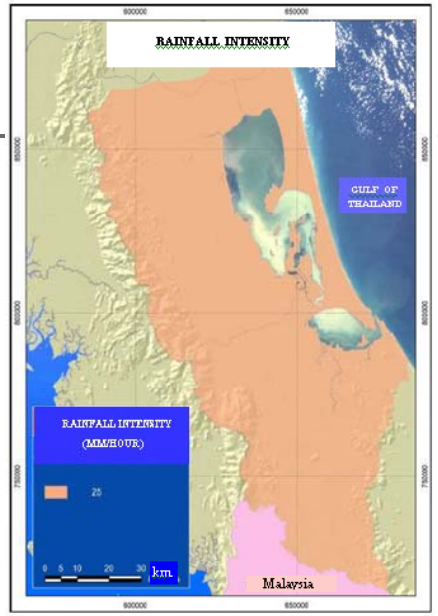
25


ANNUAL EROSIVE RAINFALL
GULF OF THAILAND
ANNUAL EROSIVE RAINFALL (MM)
2,885.1
575.1
0 5 10 20 30
km
Malaysia

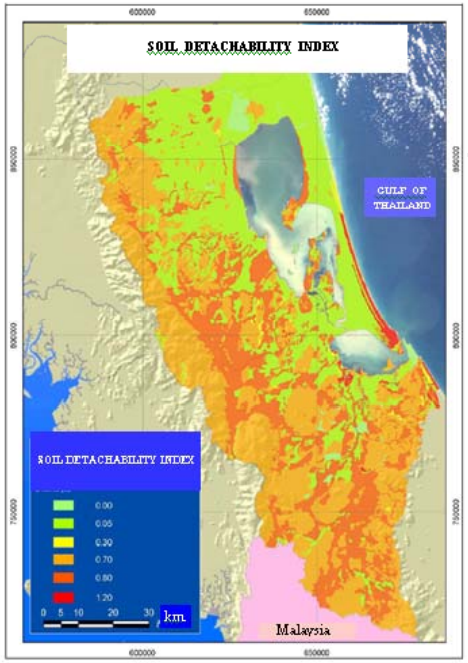
26


SOIL MOISTURE CONTENT
GULF OF THAILAND
SOIL MOISTURE CONTENT (KG/KG)
0.00
0.03
0.05
0.09
0.07
0.13
0.14
0.18
0.19
0.20
0.21
0.22
0.26
0.30
0.31
0.32
0.34
0.50
0 5 10 20 30
km
Malaysia

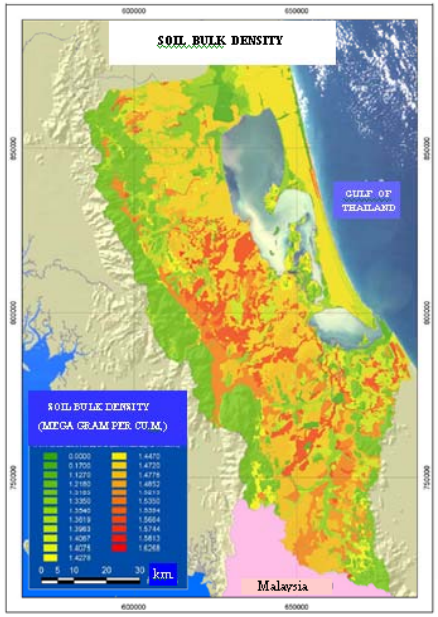
27


RAINFALL INTENSITY
GULF OF THAILAND
RAINFALL INTENSITY (MM/HOUR)
25
0 5 10 20 30
km
Malaysia

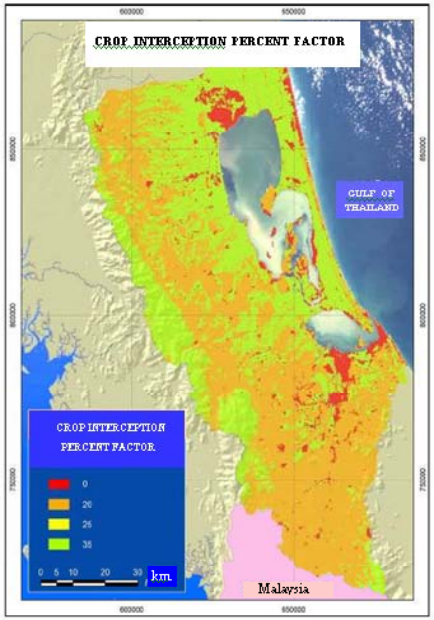
28


SOIL DETACHABILITY INDEX
GULF OF THAILAND
SOIL DETACHABILITY INDEX
0.00
0.05
0.30
0.70
0.80
1.20
0 5 10 20 30
km.
Malaysia

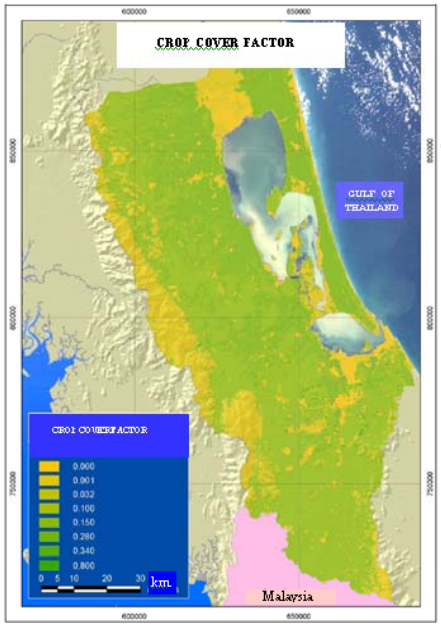
29


SOIL BULK DENSITY
GULF OF THAILAND
SOIL BULK DENSITY
(MEGA GRAM PER CU.M.)
0 5 10 20 30
km.
Malaysia

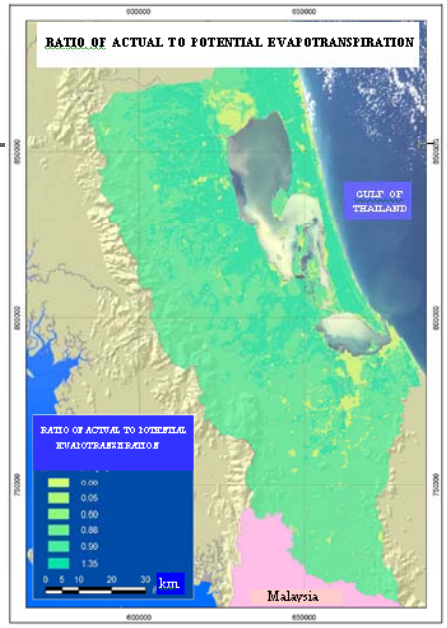
30

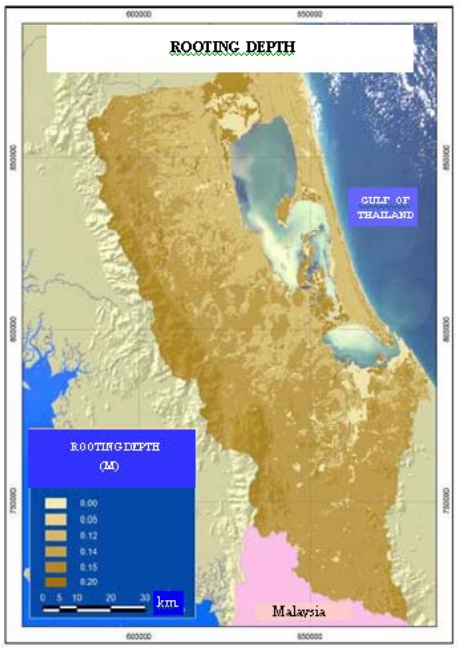

CROP INTERCEPTION PERCENT FACTOR
GULF OF THAILAND
CROP INTERCEPTION
PERCENT FACTOR
0
20
25
35
0 5 10 20 30
km.
Malaysia

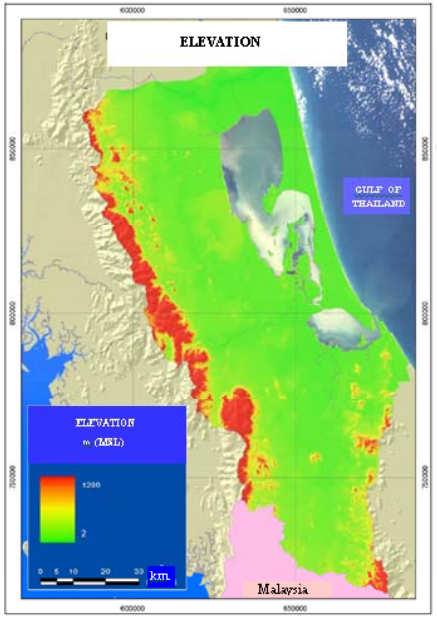
31


CROP COVER FACTOR
GULF OF THAILAND
CROP COVER FACTOR
0.000
0.001
0.032
0.100
0.150
0.280
0.340
0.800
0 5 10 20 30
km.
Malaysia

32





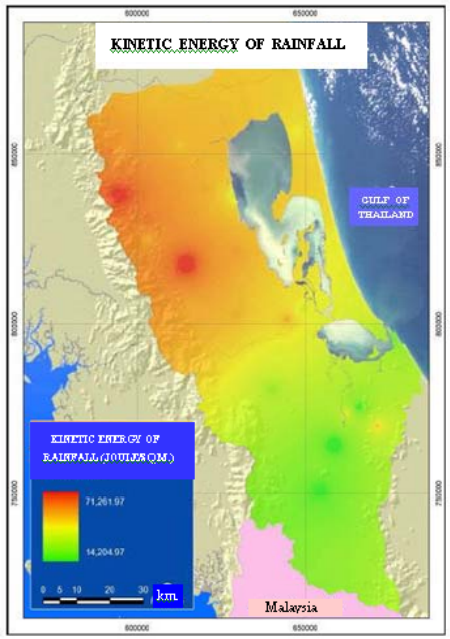


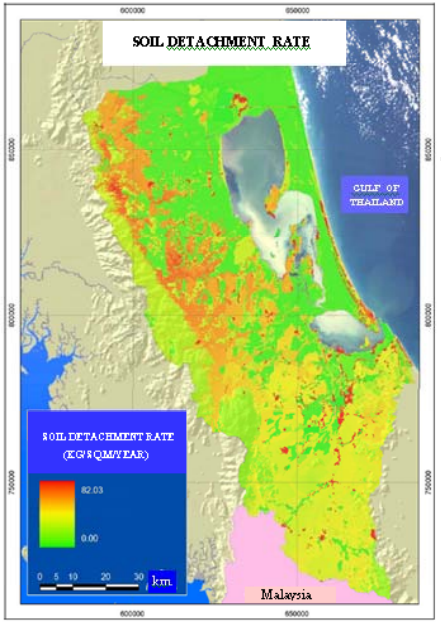
2) Estimation of Soil Detachment and Soil Transportation

2.1 Soil Detachment

<u>Kinetic energy of rainfall</u> ***It is found that the values vary in the range of 14,205 - 71,262 Joules/m^2.***

<u>Soil detachment</u>. It is found that the values vary in the range of 0.00 - 82 kg/m^2/year.

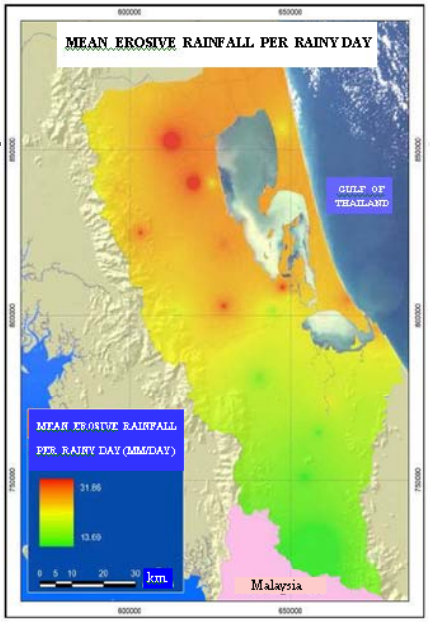




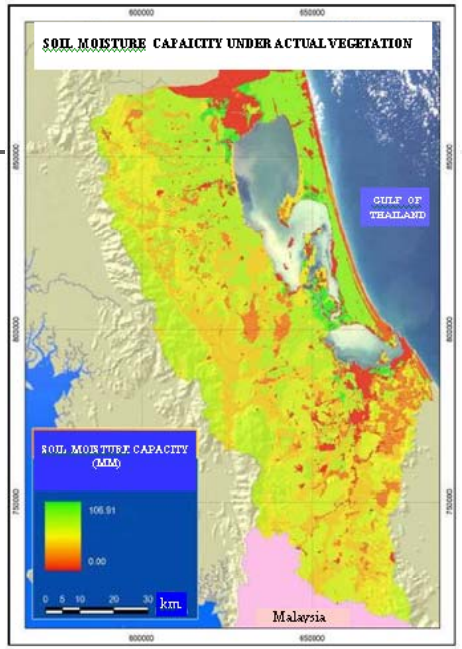
2.2 Soil Transportation

<u>Mean erosive rainfall per rainy day</u>

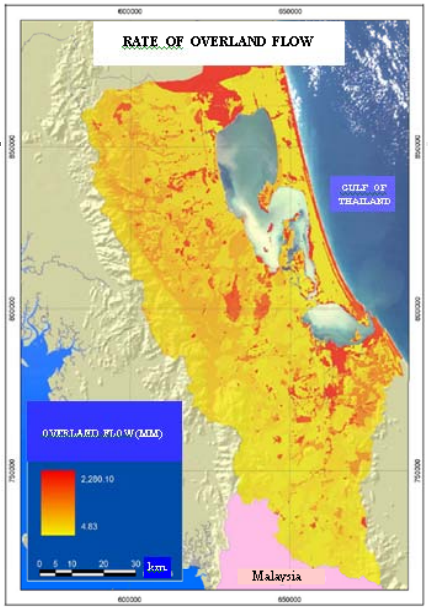
The value of mean erosive rainfall per rainy day is obtained from dividing the annual erosive rainfall by the number of erosive rainy days. It is found that the values vary in the range of 13.7 - 31.9 mm./day.



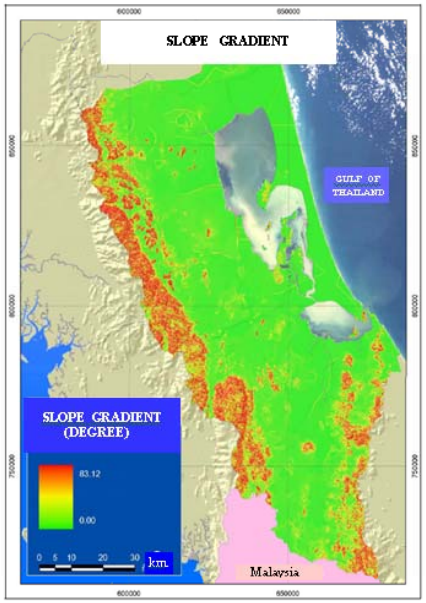
Soil moisture capacity under actual vegetation *It is found that the values vary in the range of 0.00 - 106.9 mm.*



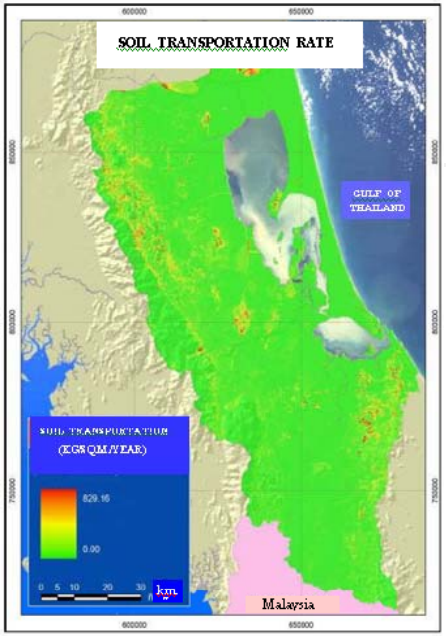
The rate of overland flow *It is found that the values vary in the range of 4.8 - 2,280 mm./year.*



Slope gradient *The slope gradient can be computed from the topographic contours of the watershed area. It is found that the values vary in the range of 0.0 - 83.12 degrees.*



Soil transportation **It is found that the values vary in the range of 0.00 - 829.16 kg/m^2/year.**



3) Determination of Soil Erosion Rate

The value of soil erosion rate is obtained by comparing the values of soil detachment and soil transportation. The smaller value between these two values indicates the soil erosion rate. Based on this concept, annual soil erosion rate in each sub-basin can be estimated as shown in the following tables.

Soil Erosion Rates in the Songkhla Lake Sub-basins

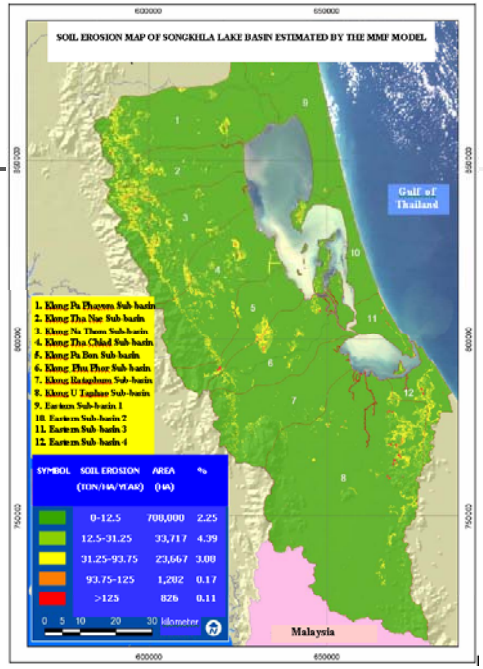
Sub-basin	Area with the specified soil erosion rate (ha)					Total
	Soil erosion rate (tons/ha/year)					Area
	0-12.5	12.5-31.25	31.25-93.75	93.75-125	>125	(ha)
Klong Pa Phayom	75,559	4,089	3,635	146	8	83,437
Klong Tha Nae	31,648	1,876	1,587	313	1	35,175
Klong Na Thom	64,067	4,212	6,808	394	125	75,606
Klong Tha Chiad	69,287	4,564	2,754	106	50	76,606
Klong Pa Bon	30,066	1,417	1,108	87	111	32,789
Klong Phu Phor	45,734	2,806	1,596	204	11	50,351
Klong Rataphum	59,075	2,931	368	0	0	62,374
Klong U Taphao	222,363	7,898	3,755	150	368	234,533
Eastern Sub-basin # 1	52,913	29	70	43	0	53,055
Eastern Sub-basin # 2	18,974	532	239	115	0	19,859
Eastern Sub-basin # 3	12,998	121	113	4	74	13,309
Eastern Sub-basin # 4	16,022	2,510	1,476	0	80	20,088
Islands	4,266	732	151	0	80	10,150
Total	708,000	33,717	23,667	1,292	826	767,492

Amount of Annual Soil Loss in Songkhla Lake Basin

Sub-basin	Annual Soil Loss (ton/year)	Area (ha)
Klong Pa Phayom	385,676	83,437
Klong Tha Nae	177,526	35,175
Klong Na Thom	648,082	75,606
Klong Tha Chiad	387,945	76,606
Klong Pa Bon	165,816	32,789
Klong Phu Phor	221,231	50,351
Klong Rataphum	139,373	62,374
Klong U Taphao	759,084	234,533
Eastern Sub-basin # 1	45,997	53,055
Eastern Sub-basin # 2	43,538	19,859
Eastern Sub-basin # 3	27,138	13,309
Eastern Sub-basin # 4	183,527	20,088
Islands	29,353	10,150
Total	3,213,385	767,492

Summary of Soil Erosion Severity in the Songkhla Lake Basin

Soil Erosion Severity Level	Soil Erosion Rate (tons/ha/year)	Area	
		(ha)	percent
Very slight	0 - 12.5	708,000	92.25
Slight	12.5 - 31.25	33,717	4.39
Moderate	31.25 - 93.75	23,667	3.08
Severe	93.75 - 125	1,282	0.17
Very severe	> 125	826	0.11
Total		767,492	100.00



Conclusion

~~The results obtained from the~~ MMF model show that the total amount of soil loss in the Songkhla Lake watershed is about 3.2 million tons per year or about 4.19 tons per hectare per year. Soil erosion rates in the western sub-basins are higher than those in the eastern sub-basins due to higher slope gradient. Based on the criteria of the Land Development Department, the severity level of soil erosion in most parts (92%) of the Songkhla Lake Basin is classified as very slight erosion (erosion rate less than 12.5 tons/hectare/year).

Thank You