CHAPTER V

RESULTS AND DISCUSSION

The base digital maps of elevation, land use and soil types obtained in the vector format files were imported into IDRISI32 software (Eastman, 2001) for generating the factor maps and soil loss estimation.

5.1 Universal Soil Loss Equation

The Universal Soil Loss Equation (USLE) was commonly used to estimate the average annual soil loss per unit land area resulting from rill and interill erosion. Traditionally, this model has been primarily practiced for conservation planning at the individual farm scale. With computer advancements and the availability of geo-referenced data, it is recently widely practiced for estimating the soil loss and conservation planning at watershed scale.

5.1.1 Factor maps

The factor maps of USLE including rainfall erosivity index, soil erodibility index, topographic factor, crop management factor and conservation factor were generated in IDRISI32 environment. The Image Calculator was used for calculating the rainfall erosivity index and RELASS and ASSIGN modules were used for assigning the soil erodibility index and the crop management factor.

5.1.1.1 Rainfall erosivity index

Annual rainfall from one station in the study area was used to estimate rainfall erosivity index by assigning amount of annual rainfall in equation 4-2. The erosivity index for this area was 683.7 MJ ha^{-1} $year^{-1}$. It fell between 700 and 1,200 MJ ha^{-1} $year^{-1}$ reported by Siem (1999).

5.1.1.2 Soil erodibility index

The soil erodibility index map (Figure 5-1 and Appendix C-1) was estimated using the Nomograph method requiring soil texture, soil organic matter, soil structure, and soil permeability information obtained from soil type (Wischmeier and Smith, 1971).

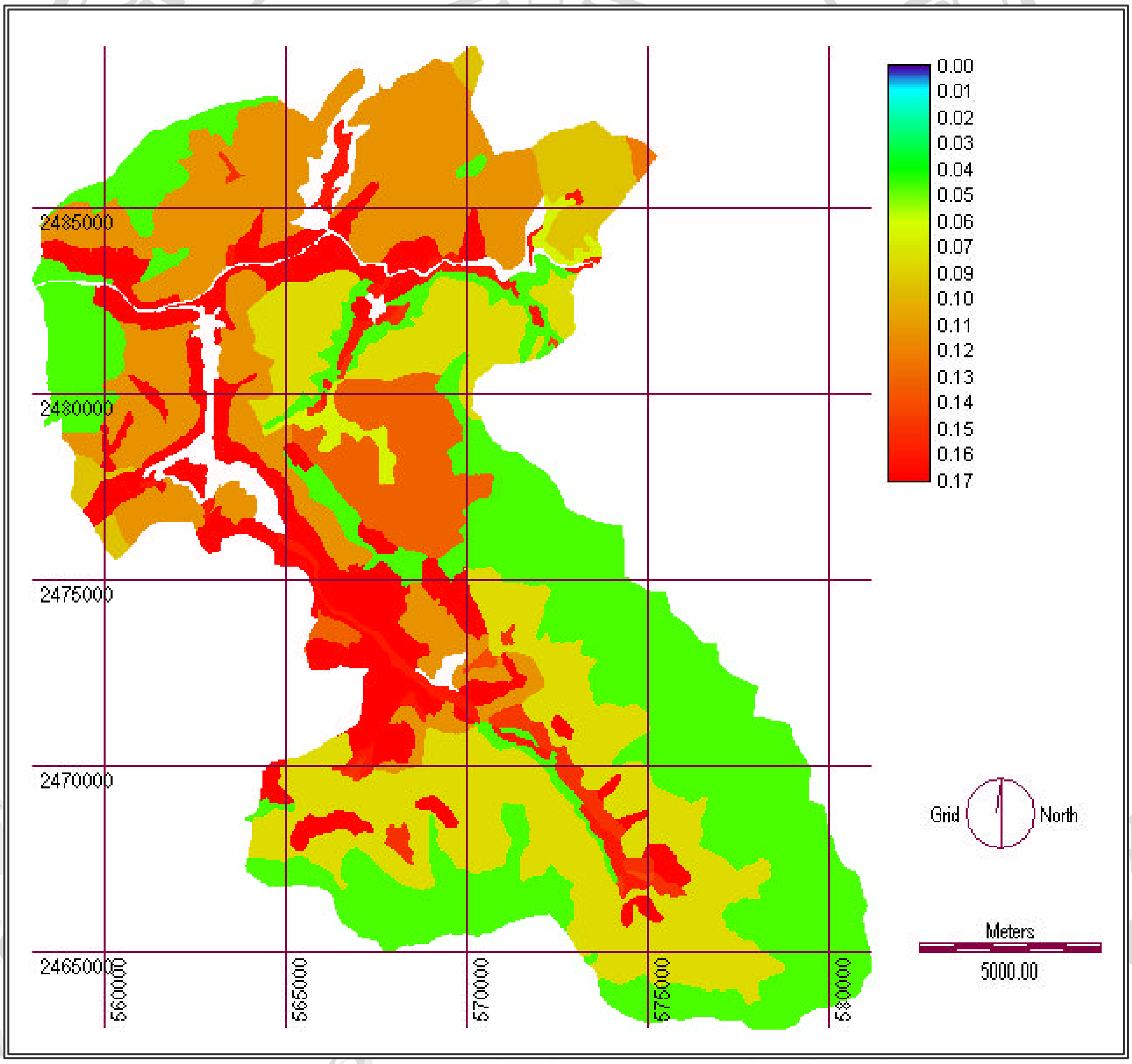

Figure 5-1 The soil erodibility index

It found that soil erodibility index in this area varied from 0.05 (the feralit based bright yellow soil) to 0.17 (the sediment soil without yearly filling-up). This estimation reasonably agreed with a result done by Siem (1999). He reported that the soil erodibility index in the Northern part of Vietnam ranged from 0.09 to 0.31 and this index of most soils fell within the range from 0.2 to 0.3.

5.1.1.3 Factors of slope length and slope steepness

Factors of slope length and slope steepness (Figure 5-2) were calculated using equation 4-3.

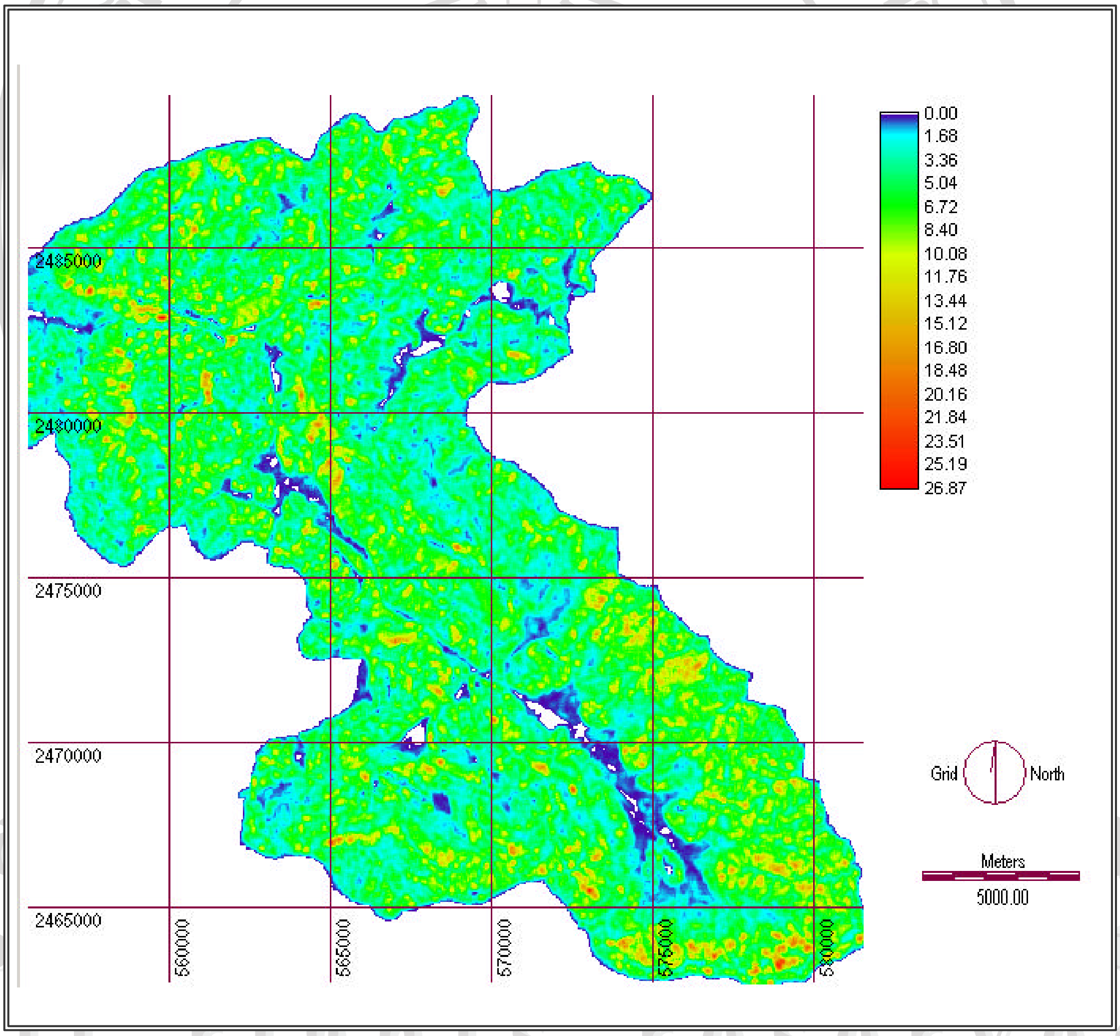

Figure 5-2 The topographic factor

The modified flow accumulation was generated by using Hydrologic Modeling Extension of ARCVIEW and then exported to IDRISI32 to calculate LS factors in Image Calculator. Distribution of LS factor map varied from less than 1 to 26.83. About 63.23 percent of total area had LS value ranging from 1 to 5.36 while LS value ranging from 21.46 to 26.82 covered only 3.05 percent of the total area. Topographic classes of 5.36 - 10.73 and 10.73 - 16.09 occupied about 20.78 and 12.95 percent, respectively.

5.1.1.4 Crop management factor

Crop management factor map (Figure 5-3 and Appendix C-2) was estimated using the previous works of Wischmeier and Smith (1978).

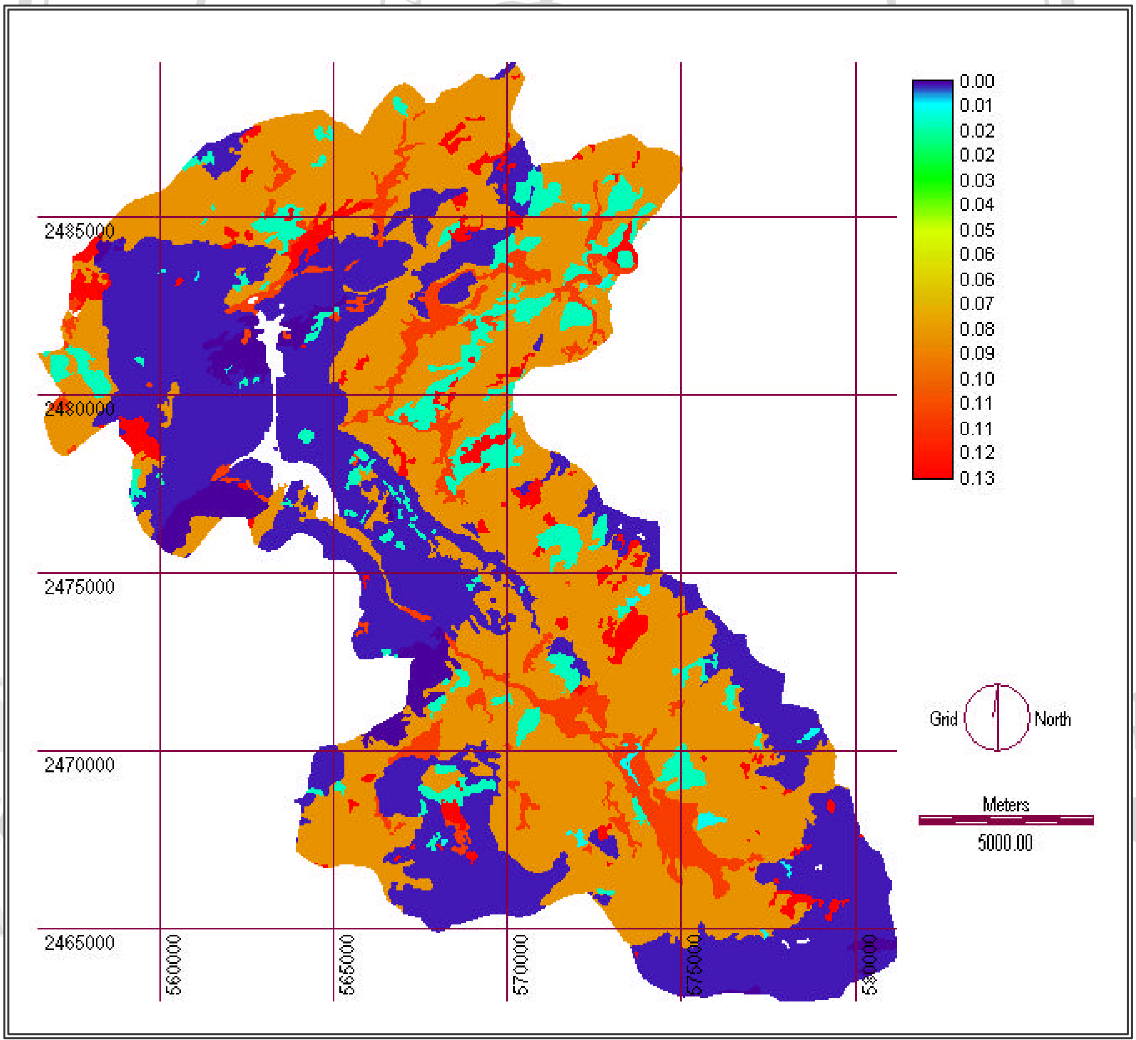

Figure 5-3 The crop management factor

The estimation found to be ranged from 0 to 0.13 dependent on land use cover in year 2000.

5.1.2 Spatial distribution of the potential soil loss

The USLE model was constructed and run within Macro Modeler of IDRISI32 environment. The estimated potential soil loss map (Table 5-1 and Figure 5-4) showed that rate of soil erosion in this area varied from less than 1 to 247.19 ton ha $^{-1}$ year $^{-1}$. It was grouped into 5 classes (Morgan, 1995), namely very low, low, moderate, high and very high rate.

Table 5-1 The potential soil loss estimated by USLE

Rate of soil loss (ton ha $^{-1}$ year $^{-1}$)	Area (ha)	Percentage (%)
<1	10,446	33.2
>1 to <10	8,835	28.1
>10 to <30	9,093	28.9
>30 to 100	3,063	9.7
> 100 to 247	41	0.2
Total	31,480	100

Soil loss at very high level covered a smallest area of 0.13 percent while the minimum level covered about 33.18 percent of the total area. The low and moderate levels occupied approximately 28.07 and 28.89 percent, respectively.

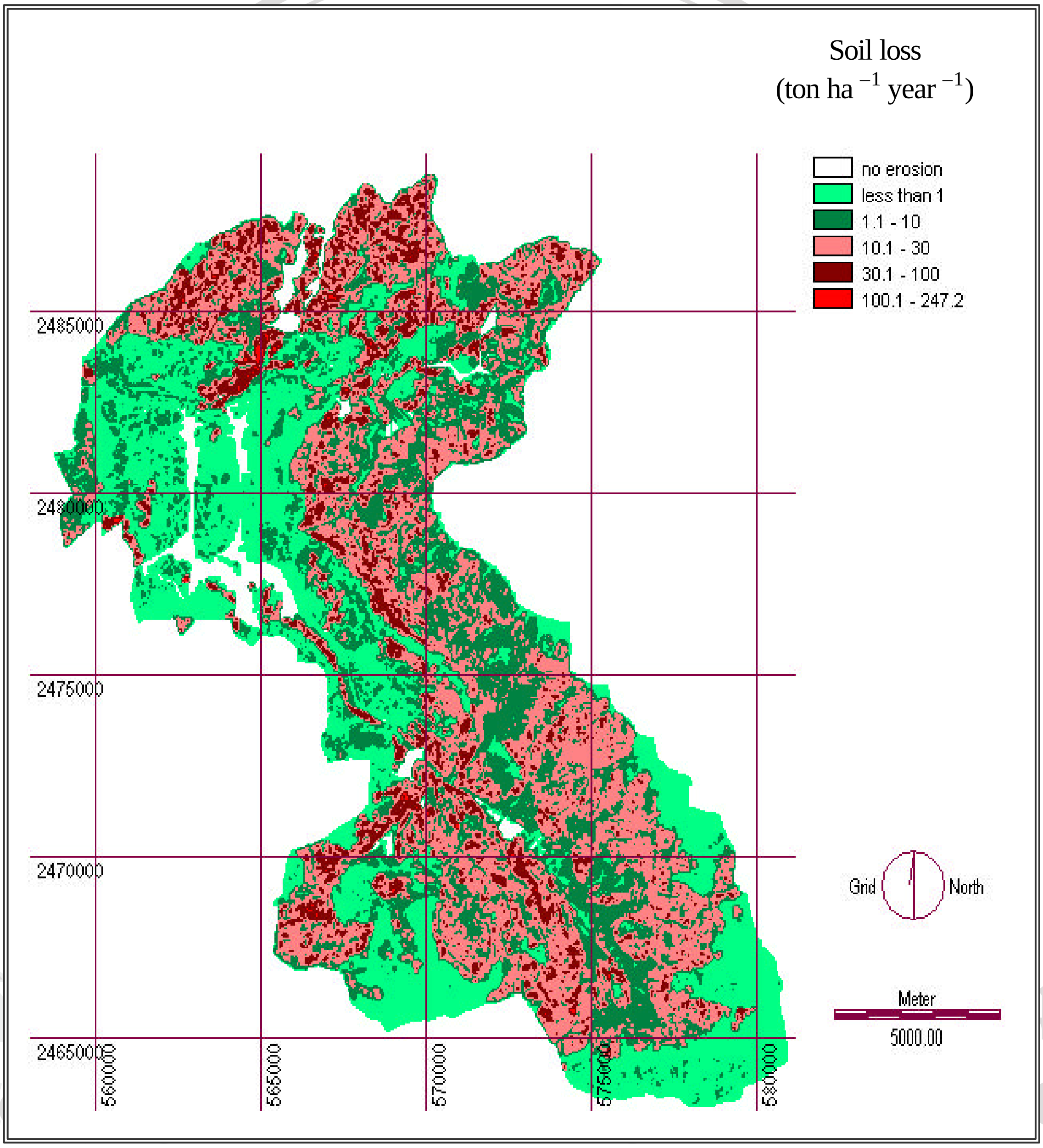

Figure 5-4 The spatial distribution of soil loss estimated by USLE

5.2 Soil Loss Estimation Model for Southern African

SLEMSA has been used as an alternative soil loss estimation method when data inputs are not sufficient (Hudson, 1995). The SLEMSA was integrated within IDRISI32 to generate model variables individually and spatial distribution map of potential soil loss in this area was ultimately estimated.

5.2.1 Factor maps

5.2.1.1 K factor

The K factor was estimated by relating mean annual soil loss to mean annual rainfall energy using equations 4 –5, 4 - 6, 4 -7 and 4 - 8 and annual rainfall (P) was averaged from 12 years in the study area. The soil erodibility was estimated according to soil texture. The result of the K factor estimation (Figure 5-5 and Appendix G-3) showed that K-factor varied in a narrow range of 20.35 to 21.01. Because the annual mean rainfall was constant in the entire area, the soil erodibility was slightly varied.

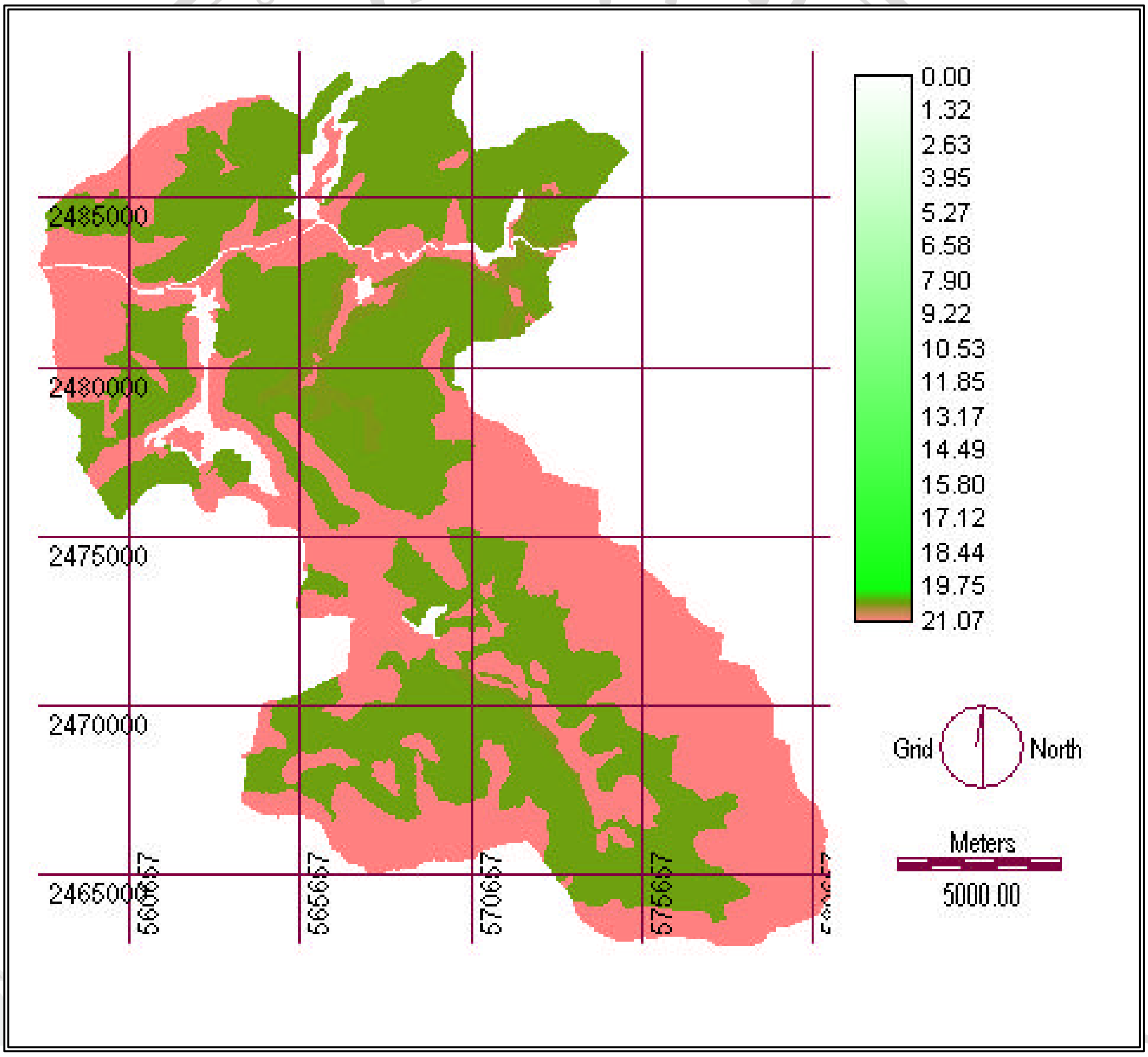

Figure 5-5 The K factor

5.2.1.2 Topographic factor

The topographic factor (Figure 5-6) is derived from a combination of L and S, which adjusts the value of soil loss calculated for the standard condition to that for the actual condition of slope steepness and slope length. It was estimated by using the equation 4-9.

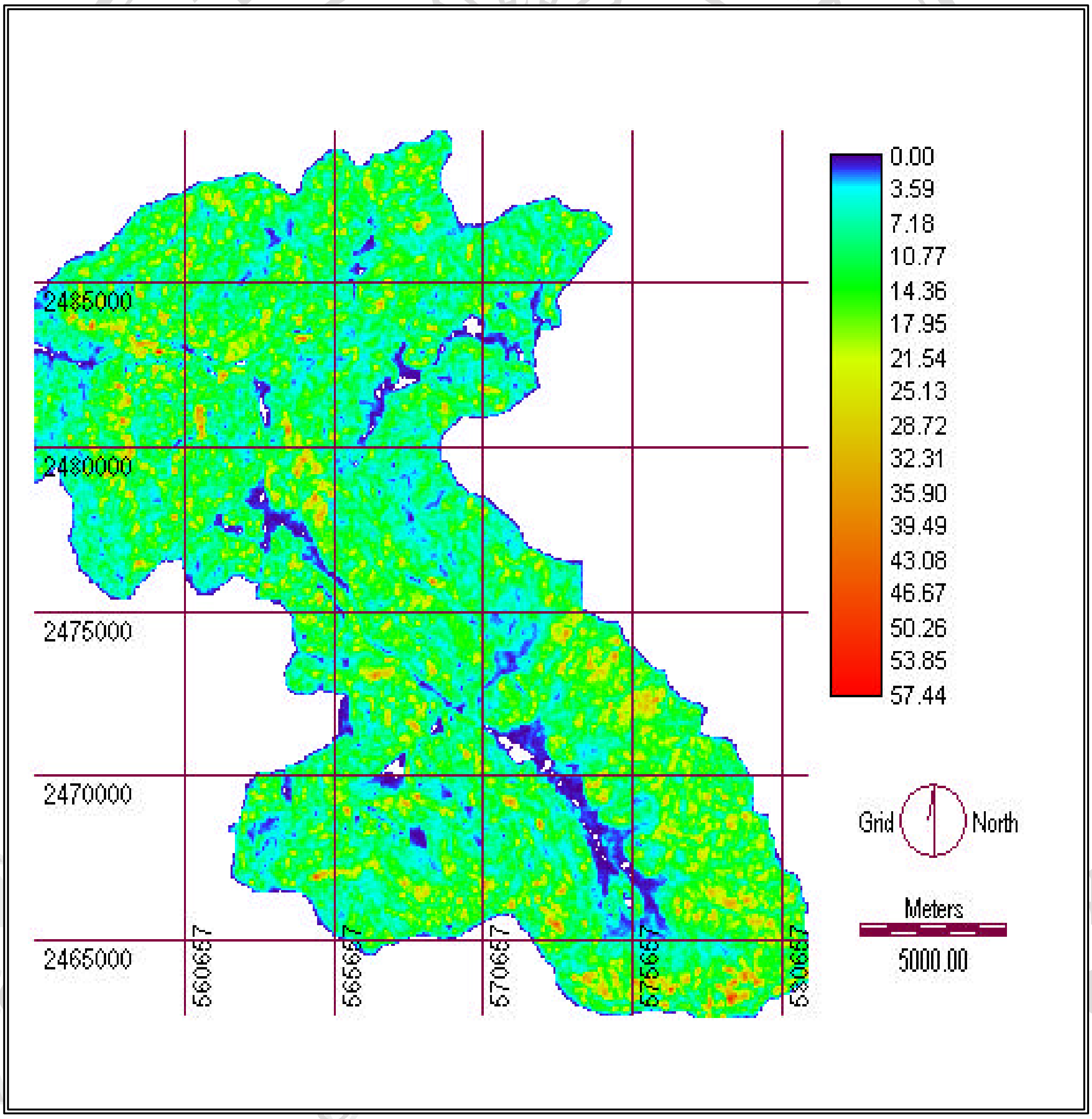

Figure 5-6 The topographic factor

Module SLOPE in IDRISI32 was used to calculate percent slope from Digital Elevation Model (DEM). Module OVERLAY and Image Calculator were then used to multiply factors together following the equation 4-9. The result showed that the X factor varied from less than 1 to 56.81. Most of the study area (63.33 %) has the value of X factor less than 11.6 while X value higher than 11.36 occupied about 36.78 % of the total area.

5.2.1.3 Crop management factor

The equation 4-10 and 4-11 were used to estimate the crop management factor (Figure 5-7 and Appendix C-4).

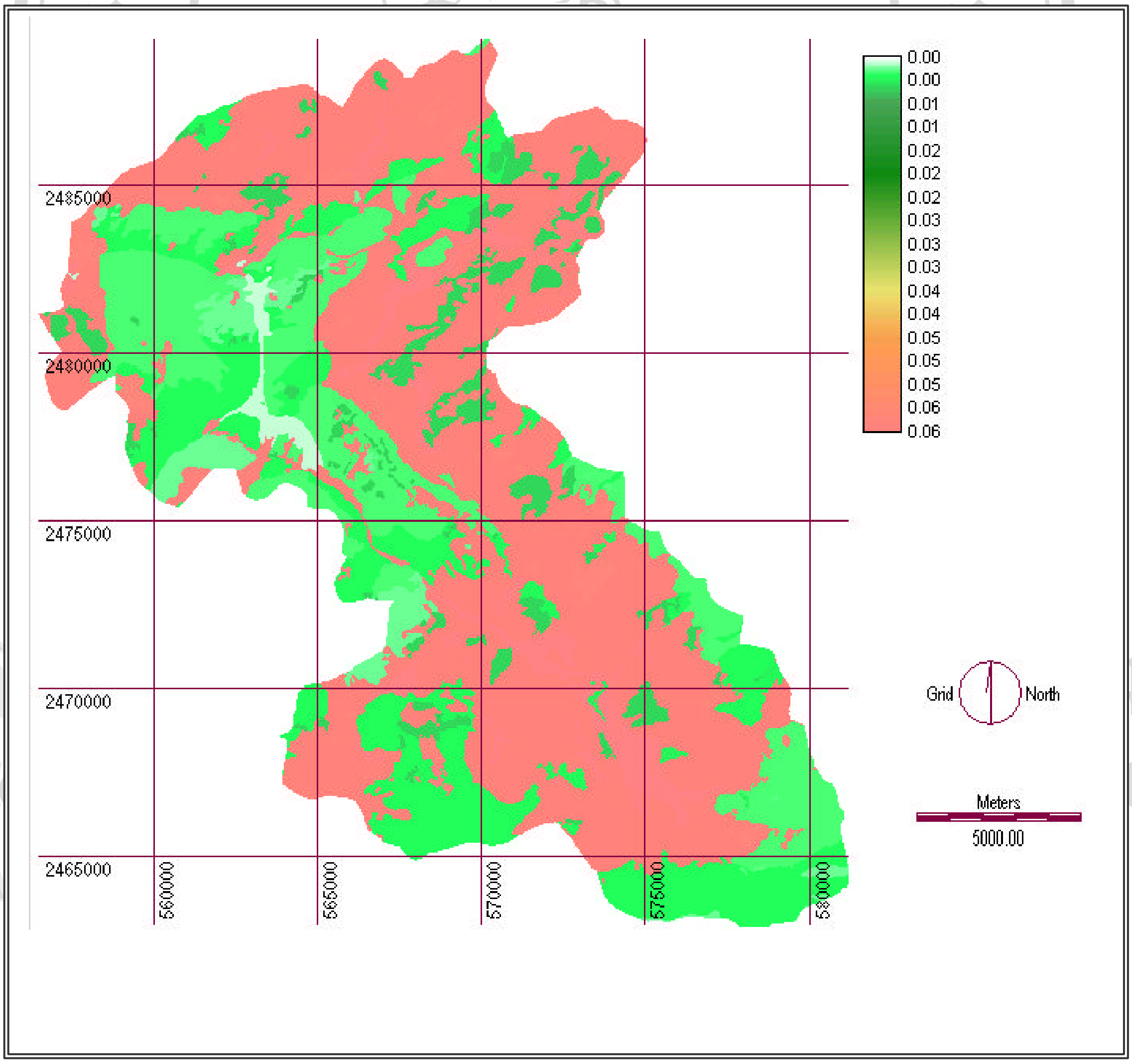

Figure 5-7 The crop management factor

C value of perennial tree land, forestlands are constant throughout the year. While C value of cropland was estimated according to the percentage cover degree for each period of year and proportion of rainfall for that period. The crop management factor map showed that mosaic shrub, cultivation and grassland had higher C value than other land use types.

5.2.2 Spatial distribution of the potential soil loss

The SLEMSA model was constructed and run in the Macro Modeler of IDRISI32. The output of model running was made a statistical summary of distribution of soil loss, which was grouped according to classification of Morgan (1995) (Table 5-2 and Figure 5-8).

The potential soil loss estimated by SLEMSA fell within the range of less than 1 to 71.98 ton ha $^{-1}$ year $^{-1}$. Soil loss at less than 1 ton ha $^{-1}$ year $^{-1}$ covered about 57.16 % of the total area while only 7.05 % of the total area was estimated at rate of more than 30 to 71.98 ton ha $^{-1}$ year $^{-1}$.

Distribution of soil loss estimated by SLEMSA was quite different from that estimated by USLE. About 34 percent of total area estimated by USLE with soil loss higher than 10 ton ha $^{-1}$ year $^{-1}$, but only 19.66 percent of total area estimated by SLEMSA with soil loss higher than 10 ton ha $^{-1}$ year $^{-1}$.

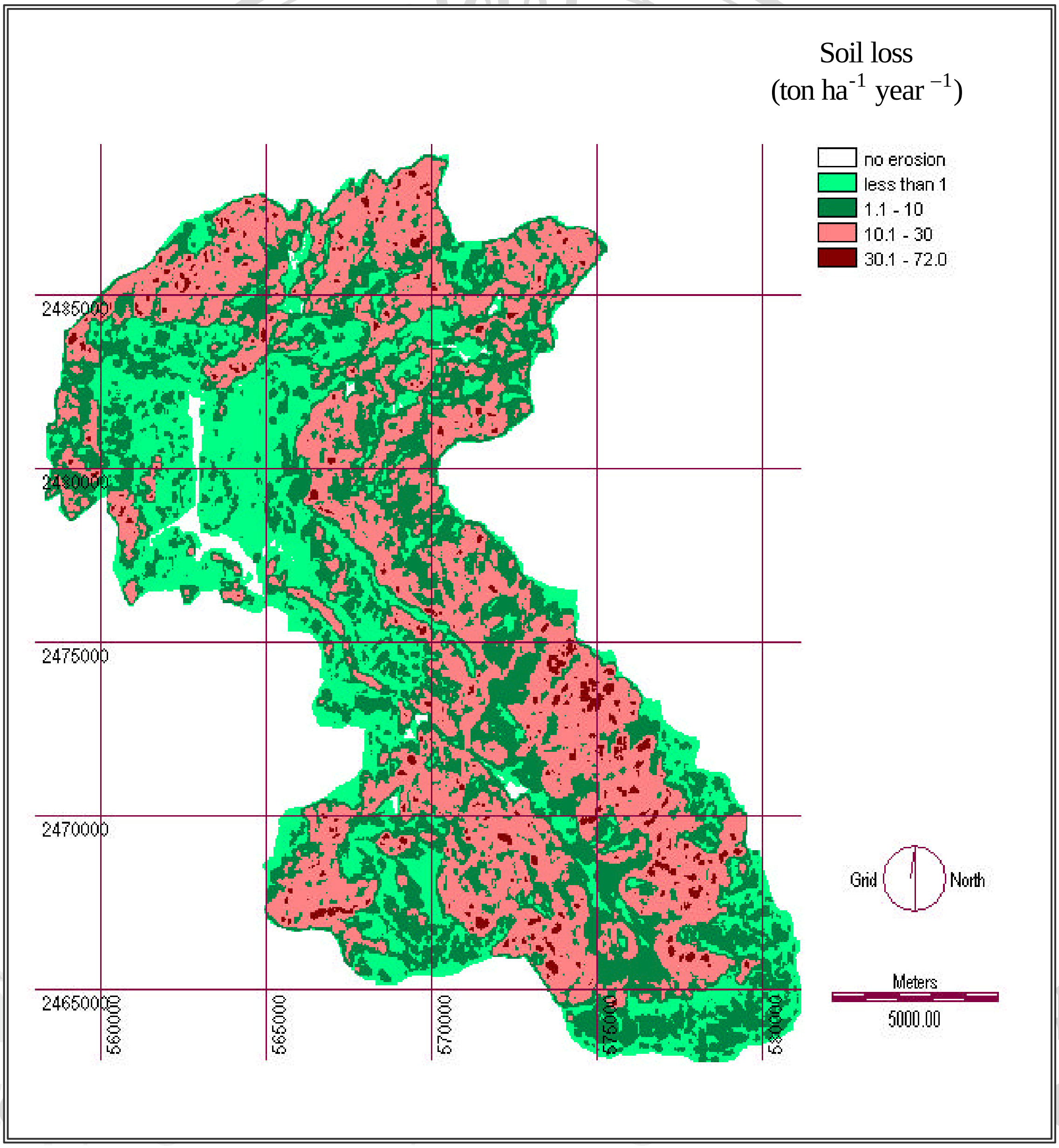

Figure 5-8 The spatial distribution of soil loss estimated by SLEMSA

Table 5-2 The potential soil loss and its proportion estimated by SLEMSA

Rate of soil loss (ton ha $^{-1}$ year $^{-1}$)	Area (ha)	Percentage (%)
< 1	17,994	57.1
> 1 to < 10	7,297	23.2
>11 to < 30	3,970	12.6
>30 to < 71.98	2,219	7.0
Total	31,480	100.0

5.3 Morgan, Morgan and Finney model

Morgan, Morgan and Finney model (MMF) was developed for estimating the rate of soil detachment by raindrop impact and transport capacity of overland flow. In this study, only rate of soil detachment was estimated.

5.3.1 Factor maps

To estimate the rate of soil detachment by raindrop impact, soil detachment index (K), kinetic energy of rainfall (E), typical values of A for different vegetation, and crop types were generated in Image Calculator. And they were then combined into a final map of spatial distribution of soil loss using OVERLAY module.

5.3.1.1 Soil detachment index

Soil detachment index (Figure 5-9) was assigned typical values according to the soil texture (Morgan, 1995). Sandy loam, valley soil and clay loam in this study area were assigned with values of 0.3, 0.02 and 0.4, respectively.

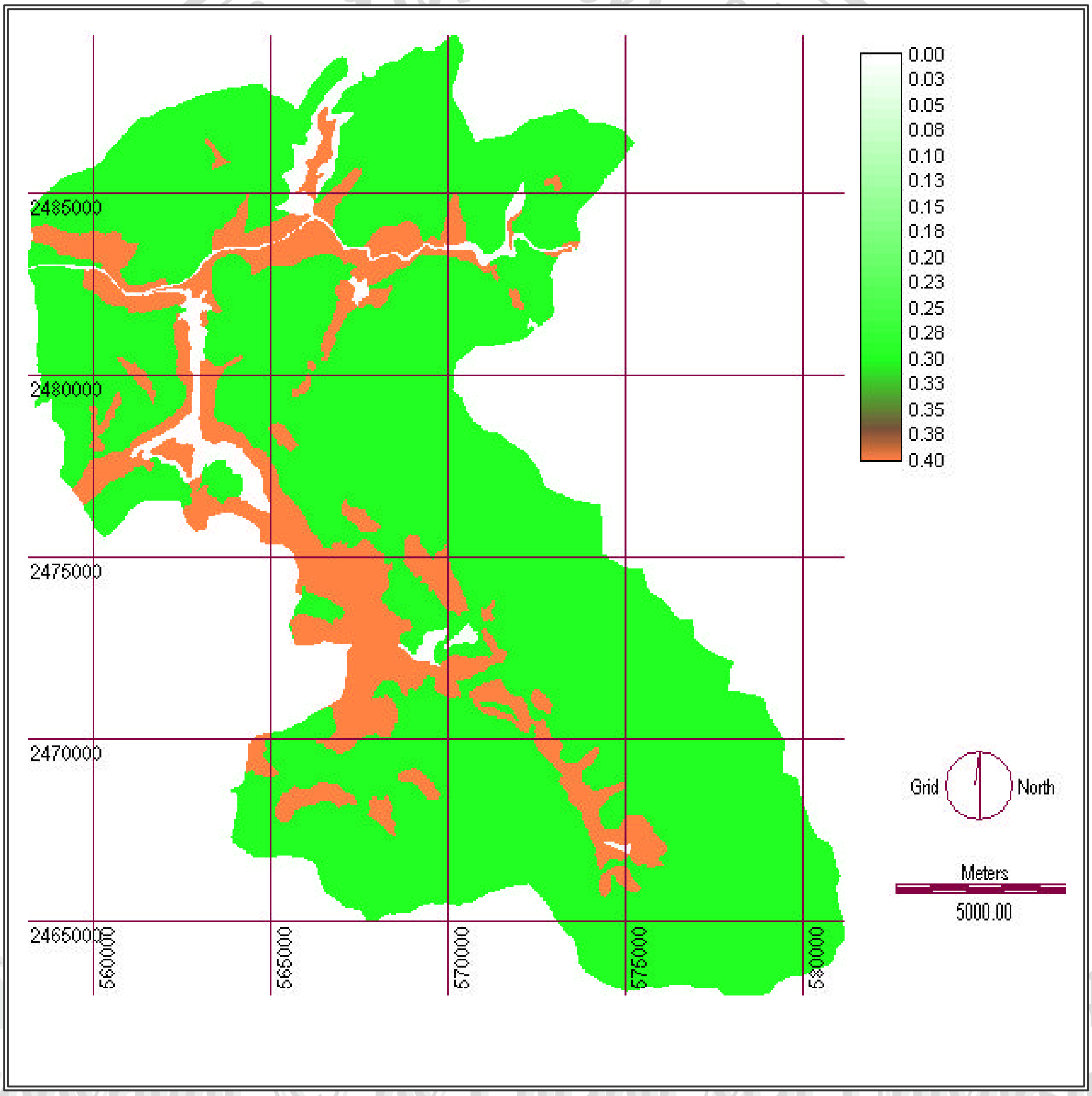

Figure 5-9 The soil detachment index (K)

5.3.1.2 Kinetic energy of rainfall

The kinetic energy of rainfall was estimated by the equation 4 –13, with the annual mean rainfall of 1,362 mm year $^{-1}$, the estimated kinetic energy was 32,722.55 J m $^{-2}$ year $^{-1}$. The typical value of A was estimated from land use map assuming that forest and tree plantation was constant throughout the year. Typical values of the A parameter for coniferous and tropical forest varies from 25 to 35 while temperate broad-leaved forests or woodlands varies from 15 to 25 (Morgan, 1995). With such reference, the A typical values were decided for types of land use as follows (Figure 5-10 and Appendix C-5)

Typical values of the A for maize, wet rice and grass are 25, 43 and 25-40, respectively (Morgan, 1995). Mosaic shrub, the cultivation and grassland; the lowland crops; the upland crops, were averaged according to types of crop in each period of year. Information from PARC survey indicated that maize and paddy rice were grown two seasons within the year. So typical value of the A of 29.5 was averaged from 4 periods including from January to February, from early March to late June, from early July to late October and last period until late December.

Upland maize was grown during raindrop summer, so the typical value of the A parameter was assigned as 25. Bare lands or rocks and water bodies were assigned as zero. Cloud, shadow and the unclassified were assumed as forestlands and assigned with the value of 15.

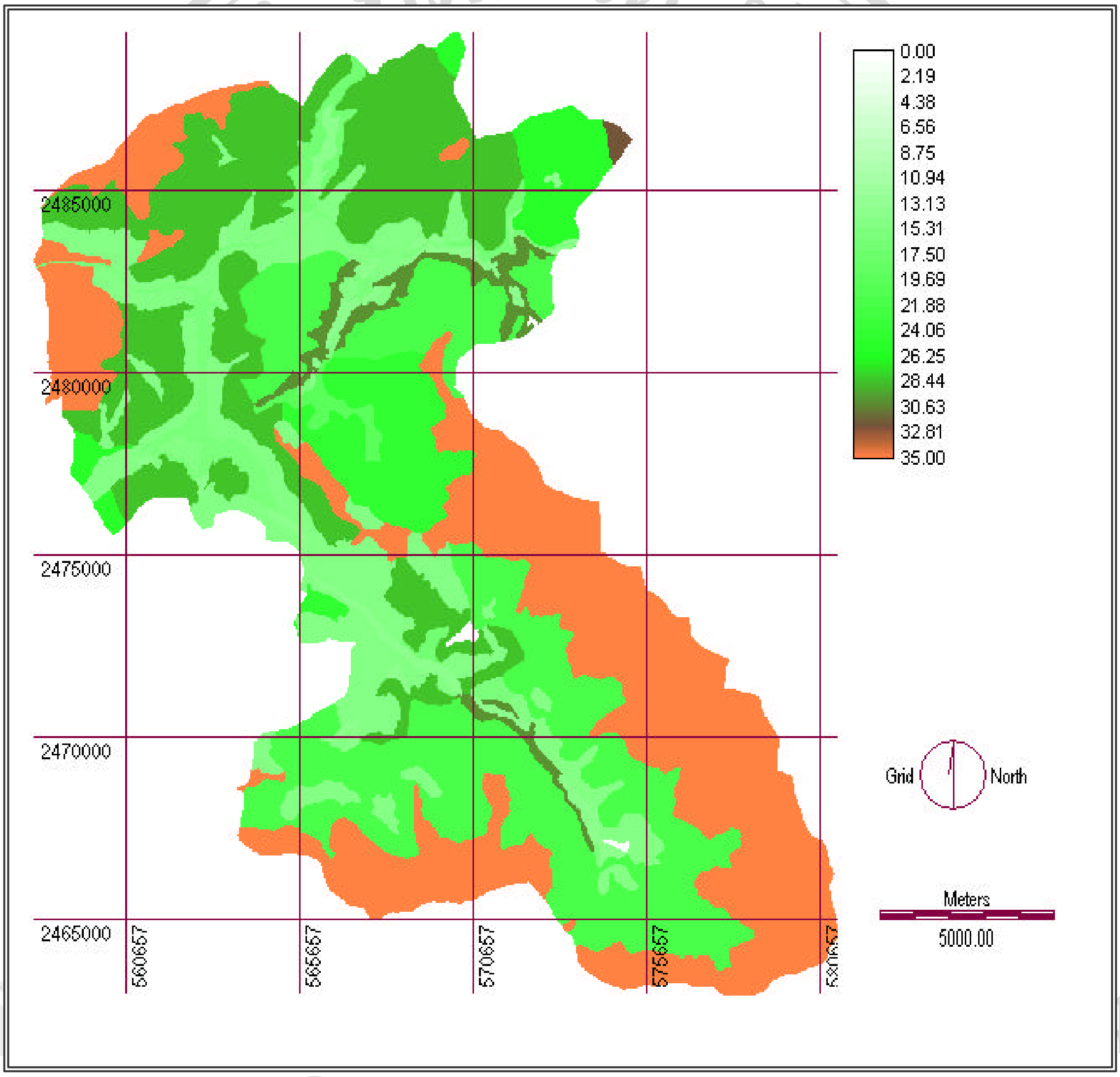

Figure 5-10 The parameter of rainfall interception and steam flow

5.3.2 Spatial distribution of the potential soil loss

The spatial distribution of soil loss (Table 5-3 and Figure 5 –11) indicated that the soil loss estimated by MMF model was quite different from USLE and SLEMSA. The rate of the eroded land was mostly fallen within two classes, one of which was class from more than 10 to less than 30 and the other was from more than 30 to less than 100 ton ha $^{-1}$ year $^{-1}$. Soil loss at rates of less than 1 and more than 100 ton ha $^{-1}$ year $^{-1}$ occupied 0 and 2.77 percent, respectively.

Table 5-3 The potential soil loss and its proportion estimated by MMF model

Rate of soil loss (ton ha $^{-1}$ year $^{-1}$)	Area (ha)	Percentage (%)
< 1	0	0.00
>1 to < 10	49	0.2
>10 to < 30	12,714	40.9
>30 to < 100	17,842	56.7
> 100	873	2.8
Total	31,480	100.0

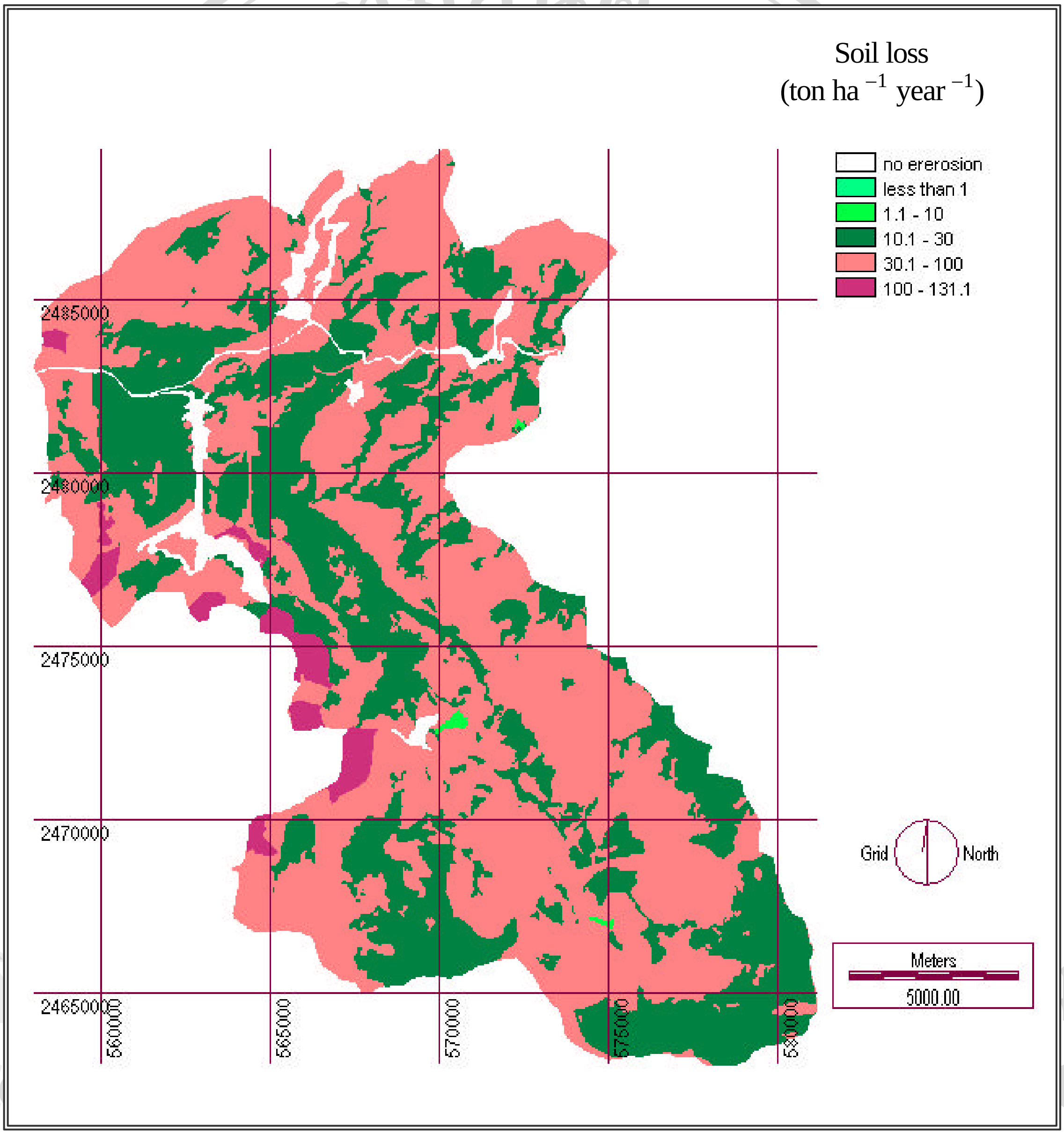

Figure 5-11 The spatial distribution of soil loss estimated by MMF model

5.4 Model comparison

The comparisons were carried out at three sites in the study area where soil loss were measured. The soil loss values obtained from experimental data converted into annual soil loss (ton ha $^{-1}$ year $^{-1}$). Each final map of spatial distribution of soil loss estimated by USLE, SLEMSA and MMF models were used to locate and pick up data for each site comparison (the section 4.3 of the Chapter IV). The measured and estimated soil loss statistics were summarized for each model.

The measured soil loss values from experimental plots at three sites in this area were compared with soil loss values estimated by USLE. The calculated average RMSE was 3.62 ton ha $^{-1}$ year $^{-1}$ (8.40 %). The estimated soil loss values averaged from every fifteen location were 42.47, 29.47 and 65.52 ton ha $^{-1}$ year $^{-1}$(Table 5-4) and had higher soil loss values of 40.06, 28.9 and 60.06 ton ha $^{-1}$ year $^{-}$1 than in the experimental plots. Therefore, the USLE model overestimated soil loss at three sites in the study area.

The comparison between measured and SLEMSA estimated soil loss showed that the mean RMSE was 9.89 ton $^{-1}$ ha $^{-1}$ year $^{-1}$ (22.95 %). Most of the soil loss values at every fifteen location estimated by SLEMSA were less those than in the experimental plots (Table 5-5). The estimated soil loss means of 34.82, 24.93 and 45.07 ton ha $^{-1}$ year $^{-1}$ were lower than the measured soil loss values of 40.06, 28.9 and 60.07 ton ha $^{-1}$ year $^{-1}$ at site 1, 2 and 3. Thus, the SLEMSA model underestimated soil loss at three sites in the study area.

Table 5-4 Comparison between measured and estimated values by USLE

Locations	MS1*	Est**	D1***	MS2*	Est**	D2***	MS3*	Est**	D3***
	(ton ha^{-1} year^{-1})			(ton ha^{-1} year^{-1})			(ton ha^{-1} year^{-1})		
1	40.06	45.16	5.10	28.9	28.40	0.50	60.07	69.12	9.05
2	40.06	42.32	2.26	28.9	32.00	3.10	60.07	68.21	8.14
3	40.06	44.75	4.69	28.9	30.82	1.92	60.07	60.43	0.36
4	40.06	35.96	4.10	28.9	28.88	0.02	60.07	66.26	6.19
5	40.06	42.82	2.76	28.9	32.41	3.51	60.07	68.05	7.98
6	40.06	43.43	3.37	28.9	29.84	0.94	60.07	59.77	0.3
7	40.06	36.65	3.41	28.9	29.01	0.11	60.07	67.09	7.02
8	40.06	43.57	3.51	28.9	32.67	3.77	60.07	67.93	7.86
9	40.06	46.00	5.94	28.9	28.50	0.40	60.07	61.73	1.66
10	40.06	38.04	2.02	28.9	30.08	1.18	60.07	67.94	7.87
11	40.06	44.21	4.15	28.9	26.40	2.50	60.07	67.13	7.06
12	40.06	42.81	2.75	28.9	31.39	2.49	60.07	65.38	5.31
13	40.06	45.45	5.39	28.9	27.65	1.25	60.07	62.68	2.61
14	40.06	44.77	4.71	28.9	27.84	1.06	60.07	65.62	5.55
15	40.06	41.11	1.05	28.9	26.04	0.50	60.07	65.37	5.3
Mean	40.06	42.47		28.9	29.47		60.07	65.52	
RMSE (ton ha^{-1} year^{-1})			3.68			1.71			5.48
Mean RMSE (ton ha^{-1} year^{-1})				3.62					
Mean RMSE (%)				8.40					

MS1, MS2, MS3* = Measured values at site1, 2 and 3 from Upland Management Project, Bac Kan Department of Agriculture and Rural Development

Est** = Estimated values at site 1, 2 and 3

D1, D2, D3*** = Deviations at site 1, 2 and 3

Table 5-5 Comparison between measured and estimated values by SLEMSA

Locations	MS1*	Est**	D1***	MS2*	Est**	D2***	MS3*	Est**	D3***
	(ton ha^{-1} year^{-1})			(ton ha^{-1} year^{-1})			(ton ha^{-1} year^{-1})		
1	40.06	32.21	7.85	28.9	26.10	2.80	60.07	48.21	11.86
2	40.06	37.28	2.78	28.9	26.45	2.45	60.07	46.32	13.75
3	40.06	28.28	11.78	28.9	17.41	11.49	60.07	49.21	10.86
4	40.06	35.56	4.50	28.9	18.36	10.54	60.07	36.93	23.14
5	40.06	43.31	3.25	28.9	23.45	5.45	60.07	48.65	11.42
6	40.06	28.46	11.60	28.9	25.43	3.47	60.07	43.25	16.82
7	40.06	25.62	14.44	28.9	29.25	0.35	60.07	37.09	22.98
8	40.06	33.27	6.79	28.9	34.16	5.26	60.07	53.19	6.88
9	40.06	53.16	13.10	28.9	33.25	4.35	60.07	45.60	14.47
10	40.06	29.34	10.72	28.9	16.03	12.87	60.07	48.64	11.43
11	40.06	28.61	11.45	28.9	16.68	12.22	60.07	49.83	10.24
12	40.06	44.19	4.13	28.9	24.34	4.56	60.07	40.16	19.91
13	40.06	27.16	12.90	28.9	14.76	14.14	60.07	38.31	21.76
14	40.06	39.06	1.00	28.9	37.09	8.19	60.07	41.31	18.76
15	40.06	36.73	3.33	28.9	31.19	2.29	60.07	49.42	10.65
Mean	40.06	34.82		28.9	24.93		60.07	45.07	
RMSE (ton ha^{-1} year^{-1})			7.97			6.70			15.00
Mean RMSE (ton ha^{-1} year^{-1})				9.89					
Mean RMSE (%)				22.95					

MS1, MS2, MS3* = Measured values at site1, 2 and 3 from Upland Management Project, Bac Kan Department of Agriculture and Rural Development

Est** = Estimated values at site 1, 2 and 3

D1, D2, D3*** = Deviations at site 1, 2 and 3

For MMF model, it found that the mean RMSE was 6.73 ton $^{-1}$ ha $^{-1}$ year $^{-1}$ (15.61 %). Most of soil loss values at 15 locations were also less those than in the experimental plots. The estimated soil loss means of 38.82, 22.78 and 55.22 ton ha $^{-1}$ year $^{-1}$ (Table 5-6) were lower than the measured soil loss values of 40.06, 28.9 and 60.07 ton ha $^{-1}$ year $^{-1}$ at site 1, 2 and 3 respectively. Thus, the SLEMSA model underestimated soil loss at three sites in the study area.

Table 5-6 Comparison between measured and estimated values by MMF model

Locations	MS1*	Est**	D1***	MS2*	Est**	D2***	MS3*	Est**	D3***
	(ton ha^{-1} $year^{-1}$)			(ton ha^{-1} $year^{-1}$)			(ton ha^{-1} $year^{-1}$)		
1	40.06	28.43	11.63	28.9	25.69	3.21	60.07	58.51	1.56
2	40.06	44.56	4.50	28.9	27.08	1.82	60.07	48.43	11.64
3	40.06	36.69	3.37	28.9	25.03	3.87	60.07	53.57	6.5
4	40.06	51.62	11.56	28.9	17.70	11.20	60.07	52.36	7.71
5	40.06	36.01	4.05	28.9	18.25	10.65	60.07	48.06	12.01
6	40.06	33.38	6.68	28.9	24.15	4.75	60.07	49.01	11.06
7	40.06	38.63	1.43	28.9	25.69	3.21	60.07	63.23	3.16
8	40.06	45.86	5.80	28.9	24.06	4.84	60.07	52.94	7.13
9	40.06	29.71	10.35	28.9	25.73	3.17	60.07	63.43	3.36
10	40.06	36.64	3.42	28.9	27.02	1.88	60.07	56.12	3.95
11	40.06	57.02	16.96	28.9	18.19	10.71	60.07	70.35	10.28
12	40.06	38.04	2.02	28.9	14.23	14.67	60.07	46.98	13.09
13	40.06	28.05	12.01	28.9	26.17	2.73	60.07	47.65	12.42
14	40.06	37.41	2.65	28.9	15.05	13.85	60.07	63.18	3.11
15	40.06	37.89	2.17	28.9	27.67	1.23	60.07	54.47	5.6
Mean	40.06	38.66		28.9	22.78		60.07	55.22	
RMSE (ton ha^{-1} $year^{-1}$)			6.57			6.12			7.51
Mean RMSE (ton ha^{-1} $year^{-1}$)			6.73						
Mean RMSE (%)			15.61						

MS1, MS2, MS3* = Measured values at site1, 2 and 3 from Upland Management Project, Bac Kan Department of Agriculture and Rural Development

Est** = Estimated values at site 1, 2 and 3

D1, D2, D3*** = Deviations at site 1, 2 and 3

5.5 Extra production cost estimation

The loss of soil nutrient is not only dependent on amount of soil erosion but also nutrient content in the soil solution.

Three models for estimating cost of erosion were constructed and run within Macro Modeler of IDRISI32 package. The spatial distribution of the derived potential soil loss was quite different among three models. It found that USLE was probably more realistic than other models of SLEMSA and MMF. So USLE model was selected to calculate the extra production cost. To estimate losses of nutrients, it assumed that proportions of total nitrogen (N), phosphorous (P) and potassium (K) were the same across each soil-mapping unit.

5.5.1 Loss of nitrogen

The loss of nitrogen was estimated for each soil-mapping unit with assumption that it was totally transformed into ammonium nitrogen (NH_4^+) or nitrate nitrogen (NO_3^-) for crop uptake. The HISTO module in IDRISI 32 was used to generate table of the frequency of soil loss classes with the width of 1 ton ha $^{-1}$ year $^{-1}$.

The loss of nitrogen and its cost had high variation (Table 5-7 and Table 5-8). Nitrogen loss in this area was about 425.34 tons. The loss of nitrogen was converted into its corresponding monetary value of 2,034.22 millions Vnd or US$ 132,092.48.

Table 5-7 The estimated potential soil loss and its loss of nitrogen in SMUs

SMU*	Area (ha SMU^{-1})	Soil loss (ton SMU^{-1})	Nitrogen (%)	N loss (ton SMU^{-1})	Loss of urea (ton SMU^{-1})	Loss of urea (kg ha^{-1})
1	700.25	6495.69	0.132	8.57	18.64	26.61
2	8,936.87	61,237.68	0.135	82.67	179.72	20.10
3	121.12	1,331.75	0.115	1.53	3.33	27.48
4	215.56	2,471.19	0.112	2.77	6.02	27.91
5	6,792.43	75,377.93	0.111	83.67	181.89	26.77
6	876.05	10,761.49	0.102	10.98	23.86	27.23
7	1,648.93	26,805.43	0.121	32.43	70.51	42.76
8	54.37	1,183.25	0.105	1.24	2.70	49.67
9	6,098.56	87,381.69	0.107	93.50	203.26	33.32
10	0.22	0.22	-	-	-	-
11	49.69	899.94	0.189	1.70	3.70	74.41
12	398.31	11,216.19	0.141	15.81	34.38	86.31
13	92.31	2,013.44	0.139	2.80	6.08	65.90
14	696.50	15,937.88	0.129	20.56	44.70	64.17
15	3,852.66	39,910.66	0.162	64.66	140.55	36.48
16	583.11	1,111.67	0.148	1.65	3.58	6.13
17	362.87	1,122.56	0.071	0.80	1.73	4.77
Total	31,479.81	345,258.62		425.34	924.65	

Table 5-8 The cost of the loss of the nitrogen in SMUs

SMU	Cost (1,000 Vnd ha^{-1})	Total cost (mill Vnd SMU^{-1})	Cost (US$ ha^{-1})	Total cost (US$ SMU $^{-1}$)
1	58.56	41.01	3.80	2,662.82
2	44.24	395.38	2.87	25,674.18
3	60.47	7.32	3.93	475.62
4	61.41	13.24	3.99	859.542
5	58.91	400.16	3.83	25,984.31
6	59.93	52.50	3.89	3,408.91
7	94.07	155.12	6.11	10,072.84
8	109.29	5.94	7.10	385.84
9	73.32	447.17	4.76	29,036.77
10	-	-	-	-
11	163.72	8.13	10.63	528.22
12	189.89	75.64	12.33	4911.43
13	145.00	13.38	9.42	869.15
14	141.18	98.33	9.17	6,385.04
15	80.26	309.22	5.21	20,079.27
16	13.49	7.87	0.88	510.95
17	10.50	3.81	0.68	247.520
Total		2,034.22		13,2092.48

5.5.2 Loss of phosphorus

The loss of the phosphorus estimated according to soil mapping units (SMU). It found that there was about 132.89 tons of phosphorus (P_20_5) equal to 830.56 tons of supper phosphorous fertilizer (Table 5-9).

Table 5-9 The estimated potential soil loss and loss of phosphorous in SMUs

SMU	Area (ha SMU $^{-1}$)	Soil loss (ton SMU $^{-1}$)	P_20_5 (%)	P_20_5 (ton SMU^{-1})	Supper P (ton SMU^{-1})	Supper P (kg ha^{-1})
1	700.25	6,495.69	0.032	2.08	12.99	18.55
2	8,936.87	61,237.68	0.036	22.05	137.78	15.42
3	121.12	1,331.75	0.029	0.39	2.41	19.93
4	215.56	2,471.19	0.025	0.62	3.86	17.91
5	6,792.43	75,377.93	0.036	27.14	169.60	24.97
6	876.05	10,761.49	0.028	3.01	18.83	21.50
7	1,648.93	26,805.43	0.029	7.77	48.58	29.46
8	54.37	1,183.25	0.036	0.43	2.66	48.97
9	6,098.56	87,381.69	0.031	27.09	169.30	27.76
10	0.22	-	-	-	-	-
11	49.69	899.94	0.051	0.46	2.87	57.73
12	398.31	11,216.19	0.055	6.17	38.56	96.80
13	92.31	2,013.44	0.052	1.05	6.54	70.89
14	696.50	15,937.88	0.053	8.45	52.79	75.80
15	3,852.66	39,910.66	0.063	25.14	157.15	40.79
16	583.11	1,111.67	0.068	0.76	4.72	8.10
17	362.87	1,122.56	0.027	0.30	1.89	5.22
Total	31,479.81	345,258.62		132.89	830.56	

The loss of the phosphorous was converted into its corresponding monetary value of 664.45 millions Vnd or US $ 43, 146.10 (Table 5-10).

Table 5-10 The cost of the loss of the phosphorus in SMUs

SMU	Cost (1,000 Vnd ha^{-1})	Total cost (mill Vnd SMU^{-1})	Cost (US$ ha $^{-1}$)	Total cost (US$ SMU^{-1})
1	14.84	10.39	0.96	674.88
2	12.33	110.23	0.80	7,157.65
3	15.94	1.93	1.04	125.39
4	14.33	3.09	0.93	200.58
5	19.98	135.68	1.30	8,810.41
6	17.20	15.07	1.12	978.32
7	23.57	38.87	1.53	2,523.89
8	39.17	2.13	2.54	138.30
9	22.21	135.44	1.44	8,794.91
10	-	-	-	-
11	46.19	2.29	3.00	149.02
12	77.44	30.84	5.03	2,002.89
13	56.71	5.23	3.68	339.93
14	60.64	42.24	3.94	2,742.56
15	32.63	125.72	2.12	8,163.54
16	6.48	3.78	0.42	245.43
17	4.18	1.52	0.27	98.41
Total		664.45		43, 146.10

5.5.3 Loss of potassium

The loss of the potassium was also estimated according to soil mapping units (SMU). There was 91.17 tons of potassium loss, which was equivalent to 151.98 tons of KCL fertilizer (Table 5-11). The total cost of loss of the potassium was estimated at 334.35 millions Vnd or 21,710.81 US $ in this area (Table 5-12).

Table 5-11 The estimated potential soil loss and loss of potassium in SMUs

SMU	Area (ha SMU-1)	Soil loss (ton SMU^{-1})	K_20 (%)	K_20 (ton SMU^{-1})	KCL (ton SMU^{-1})	KCL (kg ha^{-1})
1	700.25	6495.69	0.0294	1.91	3.18	4.55
2	8,936.87	61,237.68	0.0272	16.66	27.76	3.11
3	121.12	1,331.75	0.0212	0.28	0.47	3.89
4	215.56	2,471.19	0.0203	0.50	0.84	3.88
5	6,792.43	75,377.93	0.0136	10.25	17.09	2.52
6	876.05	10,761.49	0.0242	2.60	4.34	4.95
7	1,648.93	26,805.43	0.0234	6.27	10.45	6.34
8	54.37	1,183.25	0.0236	0.28	0.47	8.56
9	6,098.56	87,381.69	0.0287	25.08	41.80	6.85
10	0.22	-	-	-	-	-
11	49.69	899.94	0.0321	0.29	0.48	9.69
12	398.31	11,216.19	0.0317	3.56	5.93	14.88
13	92.31	2,013.44	0.0368	0.74	1.23	13.38
14	696.50	15,937.88	0.0379	6.04	10.07	14.45
15	3,852.66	39,910.66	0.0404	16.12	26.87	6.98
16	583.11	1,111.67	0.0418	0.46	0.77	1.33
17	362.87	1,122.56	0.012	0.13	0.22	0.62
Total	31,479.81	345,258.44		91.17	151.98	

Table 5-12 The cost of the loss of potassium in SMUs

SMU	Cost (1,000 Vnd ha^{-1})	Total cost (mill Vnd SMU^{-1})	Cost (US$$ha^{-1}$)	Total cost (US$ SMU^{-1})
1	10.00	7.00	0.65	454.70
2	6.83	61.07	0.44	3,965.87
3	8.55	1.04	0.56	67.22
4	8.53	1.84	0.55	119.44
5	5.53	37.59	0.36	2,440.81
6	10.90	9.55	0.71	620.07
7	13.95	23.00	0.91	1,493.45
8	18.83	1.02	1.22	66.49
9	15.08	91.95	0.98	5,971.08
10	-	-	-	-
11	21.32	1.06	1.38	68.78
12	32.73	13.04	2.13	846.56
13	29.43	2.72	1.91	176.42
14	31.80	22.15	2.06	1,438.20
15	15.35	59.12	1.00	3,839.03
16	2.92	1.70	0.19	110.64
17	1.36	0.49	0.09	32.07
Total		334.35		21,710.81