Assessments of land use/ land cover change and soil erosion: A case study of Kalaw Chaung sub-watershed of Inle Lake, Myanmar

Nan Win Zaw*
Apisom Intralawan**

Abstract

This study was focused on the changes of land use and land cover (LULC) and soil erosion of the Kalaw Chaung Subwatershed of Inle Lake which is located in the Nyaung Shwe Township, Taunggyi District, Southern Shan State, Myanmar. The study area covered about 485.42 square kilometers of the whole watershed of Inle Lake. Geographic Information System (GIS) and Remote Sensing (RS) provide as useful tools in the investigation of LULC patterns and the detection of LULC changes over space and time. All Landsat images (1990 TM, 2000 ETM and 2010 ETM) are rectified and registered in Universal Transverse Mercator (UTM) zone 47 N. Unsupervised and Supervised classification system was carried out to classify the images in different land use and land cover categories. The classification has identified five land use classes: Agriculture land, Close forest, Open forest, Scrub grass land and Water body. According to the analysis of LULC changes in the study area, there were major changes in open forest and agriculture land. The Revised Universal Soil Loss Equation was applied to estimate the annual soil loss from the study area in 1990, 2000 and 2010. The annual soil loss in the study area was calculated through five factors such as rainfall erosivity (R) factor, soil erodibility (K) factor, slope length and steepness (LS) factor, crop-management (C) factor and the support practice (P) factor. The grades of soil loss were determined five categories; very low, low, moderate, high. The results show that during the period 2010, 71.26% of the whole watershed was extremely soil erosion potential zone and 25 % of the watershed area is found out to be under slight erosion class. The results of this research are going to provide reference for soil conservation and management in this area.

Keywords: LULC/ GIS & RS/ RUSLE/ NDVI

* *E2 Building, 2nd Floor,333 Moo 1 Tambol Tasood,Muang District, Chiangrai, Institute of the Study of Natural Resources and Environmental Management, Mae Fah LuangUniveristy, Chiang Rai, Thailand 57100*

** *Institute of the Study of Natural Resources and Environmental Management, Mae Fah LuangUniveristy, Chiang Rai, Thailand 57100*

Introduction

The study area, Kalaw Chaung Sub-watershed, is located in north-western part of Inle Lake, Southern Shan State, Myanmar. The study area covered about 485.42 square kilometers of the whole watershed of Inle Lake. The Lake is one of the main tourist attractions in Myanmar because there are many interesting recreational activities such as beautiful landscape, pleasant weather condition, floating garden, floating market, leg rowing, Phaung Daw Oo Pagoda festival, traditional handicraft. Form ecological perspective, the lake is home to wetland species such as migratory and residential birds and Inle Carp locally called Nga-Phane. In this area, topsoil is the major source of river fine sediments in the northern areas as well as the middle reach of Kalaw Chaung, despite the existence of many gullies in the areas of Shan Dolomite Group. Dominant source of fine sediments of entering the delta and lake from Kalaw Chaung varies with time (Furuichi, 2008)

Land use and land cover change (LULC) is one of the major phenomena of global environmental change and vital to the sustainable development debate. For example, in the past two decades between 1980-2000 periods, more than half of forest area in the tropics has been converted to agricultural land due to globalization process and its economic pressures (Lambin and Mayfroidt 2011). These changes have severe impacts on a broad range of environmental and landscape, characteristics including the quality of water, land and air resources, ecosystem processes and function, and the climate system itself through greenhouse gas fluxes and surface. According to the measurement of green house gas (GHG) emissions, 18 percents of total green house gases come from land use/ land and land cover changes by deforestation (World Band 2008)

Land use and land cover are two chief constituents describing the terrestrial environment in the relationship between natural processes and anthropogenic intervention activities. In recent decades, the research on land use and land cover changes has become a well-known research topic, since land use/ land cover change has been recognized as one of the most important factors of environmental modification (Mendoza et al., 2011). There are many meanings of the terms “Land use” and “Land cover” that often used interchangeable but their actual meanings are quite distinct. In general, Land use refers to human activities that take place on the earth’s surface: how the land is being used; such as residential housing, agricultural cropping or industry. On the other hand, Land cover refers to the natural or manmade physical properties of the land surface (Kuldeep & Kamlesh, 2011).

Land use-land cover change analysis provides information to planners and policy makers on what should be done to have reasonable and balanced development that will be sustainable and eco-friendly. The knowledge on land use and land cover is therefore vital for many planning and management activities associated with the surface of the earth.

The spatial information technologies such as Geographic Information Systems, Remote Sensing and Global Position Systems are useful for monitoring and inventorying changes and predictions of LULC based on different practices and management plan. Remote Sensing and GIS technique is quick and efficient approach in the classification and mapping of land use/ land cover changes over difference spatial and temporal scales (Abbas 2012).

Soil erosion is a major problem throughout the world. Soil erosion consists of a three mainly phase phenomena; (i) the detachments of individual soil erosion, (ii) transportation by erosive agents such as running water and wind, and (iii) deposition. The removal of top soil by water may cause by several ways such as sheet erosion, rill erosion, gully erosion, stream bank erosion and river erosion. The long term average annual of soil erosion on a field slope is calculated by Revised Universal Soil Loss Equation (RUSLE) based on rainfall pattern, soil types, topography, crop system and management practices. RUSLE does not calculate for soil losses that results from gully, wind or tillage erosion except the erosion occurring from sheet or rill erosion on a single slope. Economically, the decreasing of arable land and its quality might be occurred by depleting the top fertile soil due to soil loss as well as affecting the land productivity. Moreover, there might be additional effects such as the surface water storage capacity by sedimentation of lakes and reservoirs; and water quality by contaminating the water with suspended soil particles, toxic materials and pesticides (Pal & Samanta, 2011).

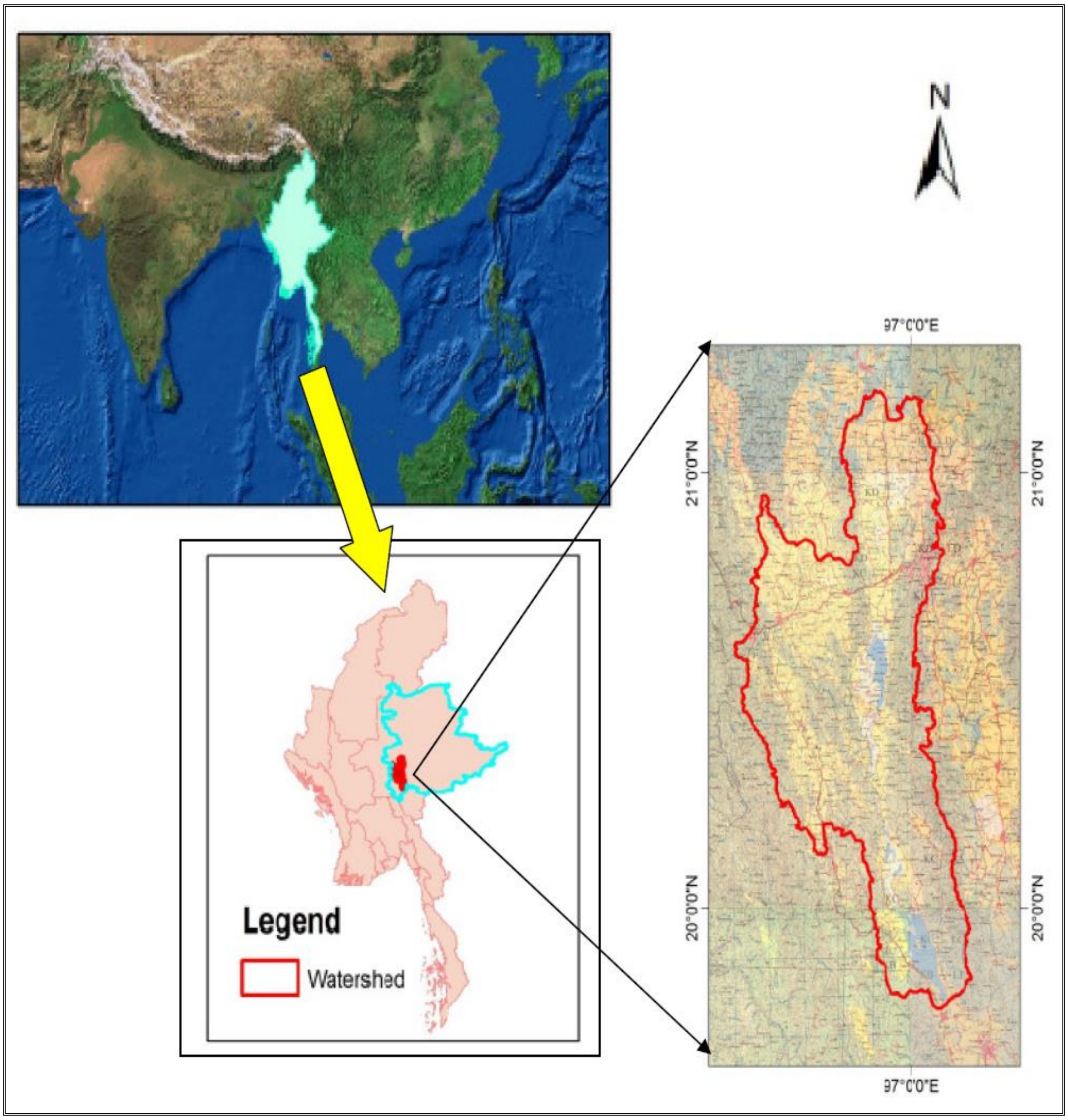

Figure 1 Location Map of Study Area, Background: Topographic Map (1:250,000)

Objectives

The objectives of the study are as follows;

- To analyze and understand LULC patterns of the study area in years 1990, 2000 and 2010 using multi-date satellite imageries.
- To analyze LULC magnitude and trend of changes between 1990, 2000 and 2010.
- To calculate how much soil loss resulting from existing land use in the study area.

Conceptual Framework

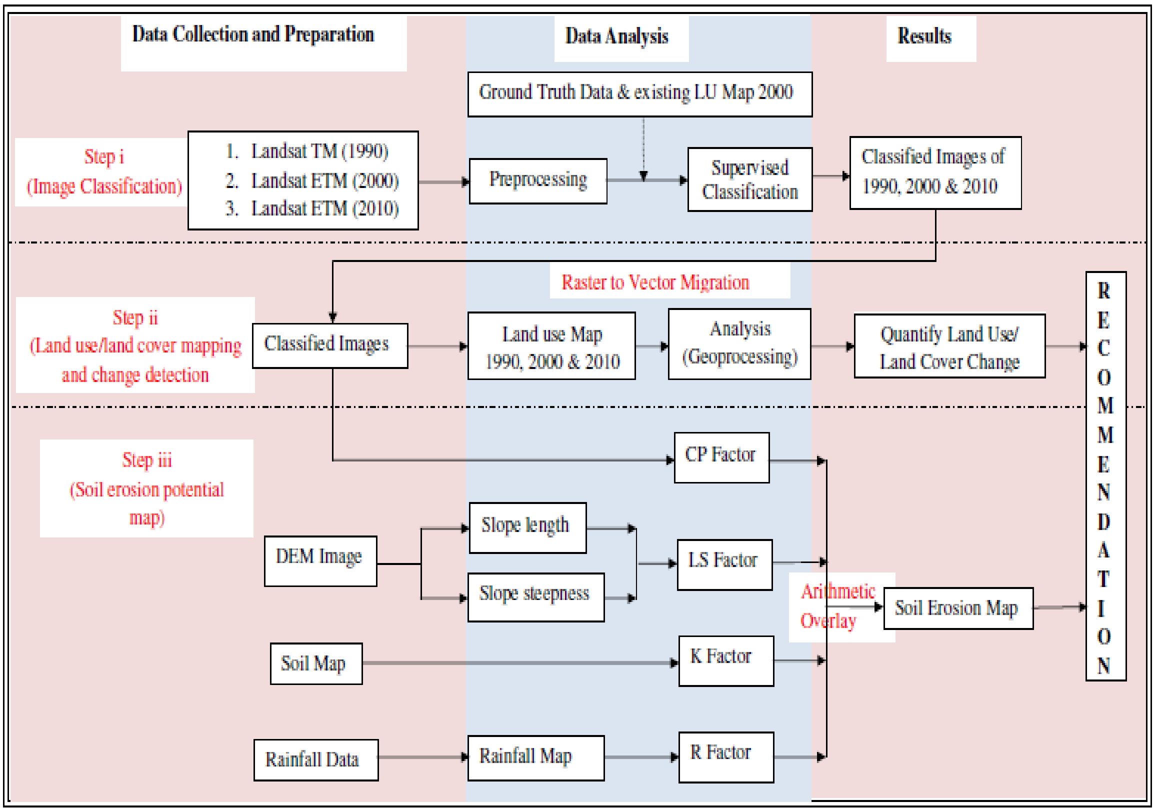

Figure 2 Main Frame of the Study

Methodology

1. Method for Image Classification, Land Use Map and Change Detection

The processing flow of image classification, land use mapping and land cover change detection is showing in Figure 3.1. Four main steps are included as follow:

(i) Data preprocessing

(ii) Image classification

(iii) Land use/ land cover map preparation and

(iv) Quantify land use/ land cover changes.

The preprocessing step includes image registration and data normalization. Unsupervised classification, ground truth data collection, supervises classification and verifies accuracy was carried out in image classification step. Image registration was performed registering Landsat TM 1990, Landsat ETM 2000 and Landsat ETM 2010 images based on 1:50,000 scale topographic map. The images were resembled to 30m by 30m pixels using a Nearest Neighbor Resampling algorithm with a RST (rotation, scale, and transformation) first-order polynomial. The number of ground control points (GCPs) used for the registration varies by images, and the root mean square error (RMSE) of the registration process is shown in Table 3.1.

Then classified images are segmented into separate layers of each class. When map generation was finished, land use land cover map of 1990, 2000 and 2010 were generated. Land use/ land cover classification through supervised classification method is employed to perform the classification based on the field knowledge. Arc GIS 9.3.1 and ENVI 4.5 are powerful tools for extracting the land use and land cover layer from satellite imageries. The classification has identified five land use classes: Agriculture land, Close forest, Open forest Scrub grass land and Water body. Land use land cover changed was quantified follow the procedure of geo-processing (intersection, union and erase).

Ground truth data collection was performed one time field trip from 25th Jan to 4th Feb, 2013. Survey was start from Aungban to Pindaya, Kalaw and Heho Township. GPS coordinates and pictures were taken along the way. The survey was conducted mostly along the Main Road of Aungban-Pindaya and Heho due to unfavorable road condition in many area and limitation of time.

Ground truth represents true land cover. Ground truth can be used as training data for supervised classification and validation data for the validation of the classified result. This ground truth collection was done to obtain accurate location point data for each land use and land cover class included in the classification scheme according to old land use 2000 map (Table 3.2) as well as for the creation of training sites and for generation of signature. Asking some informal questionnaires was also performed to confirm the previous land use during the field trip. Some part of Kalaw Chaung Sub-watershed could not go because of difficulties in transportation. Half of ground truth was used as training data to classify the images and the rest of half of ground truth was used as validation data to calculate the accuracy of classification.

Table 1 Land Use Land Cover Classes (source: existing land use map 2000)

No	Land Cover Name	Description
1	Water body	Lakes, Reservoir, River
2	Agriculture	Paddy field, crop field, swidden agriculture (Slash & burn), orchard, village garden crop
3	Open Forest	Ever green broad leafed forest
4	Close Forest	Deciduous forest, dries deciduous forest
5	Scrub Grass	Abandoned field covered by shrub

2. Selection of Soil Erosion Model

Revised Universal Soil Loss Equation (RUSLE) is widely applicable for the soil erosion model for calculating the annual soil loss for the study area. There are many models to estimate soil erosion and to develop optimal soil erosion management plans such as Universal Soil Loss Equation/Revised Universal Soil Loss Equation (USLE/RUSLE), Water Erosion Prediction Project (WEPP), Soil Erosion Model for Mediterranean Regions (SEMMED), Areal Non-point Source Watershed Environment Response Simulation (ANSWERS), Limburg Soil Erosion Model (LISEM), European Soil Erosion Model (EUROSEM), Soil and Water Assessment Tool (SWAT), which were used in regional scale assessment. These models have their own characteristics and application. USLE/RUSLE is the dominant model to soil erosion prediction throughout the world because of its convenience in application and compatibility with GIS scopes (Prasannakumar et al., 2012).

Revised Universal Soil Loss Equation (RUSLE) was used to calculate the annual soil loss for my study area. In this RUSLE, It is need to find out five factors such as rainfall factor (R), soil erodibility factor(K), slope length and steepness factor (LS), crop and management factor (C), support practice factor (P). Annual soil loss in the study area was calculated by using the following equation;

$$A = R*K*LS*C*P$$

Where,

A = average annual soil loss (tones/ha/yr)

R = rainfall and run off Factor

K = soil erodibility factor

L S= slope length & steepness factor

C = cover and management factor

P = erosion control practice factor

The methodology for soil erosion is shown in Figure 3.2. The parameters of RUSLE model were integrated separately in ArcGIS 9.3.1 in order to produce soil erosion maps for the years 1990 and 2010. The raster maps of R, K, L S, C and P were prepared and soil loss rate (ton/ha/yr) was calculated by modeling RUSLE based on raster calculation. Soil erosion rate with respect to each land use type was also calculated to differentiate the vulnerable area from conservation point of view.

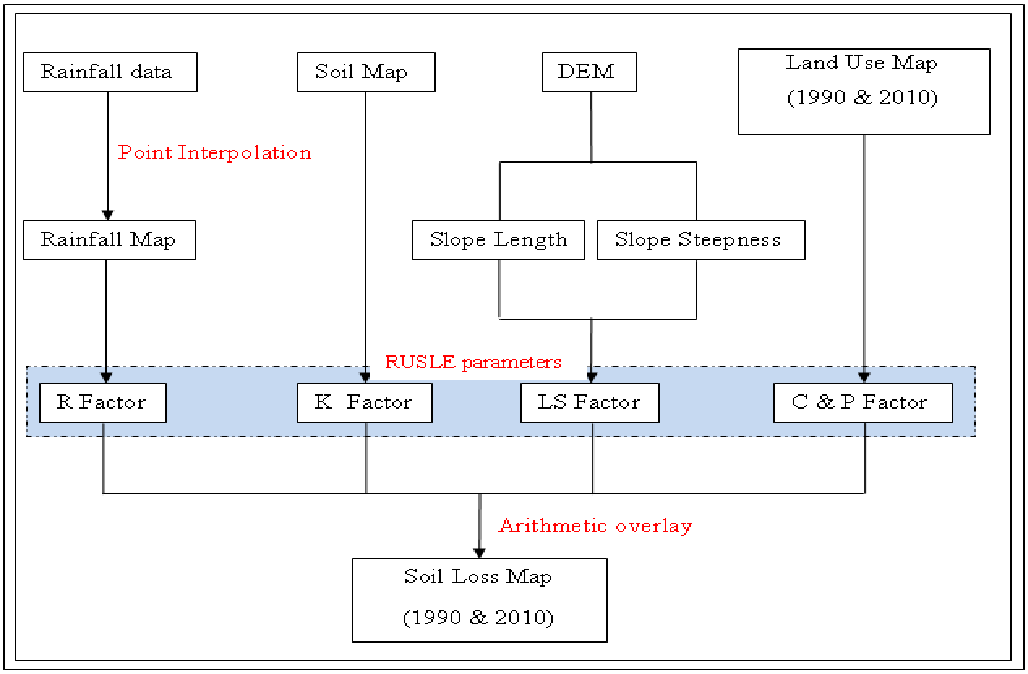

Figure 3.2 Method of Soil Loss Calculation

3 Indicators of Soil Erosion

3.1. Rainfall Erosivity (R) factor

The rainfall erosivity R-factor is a measure of the erosive force of a specific rainfall. Prasannakumar et al. (2012) stated that this can be computed from a single storm and is determined as a function of the volume, or a series of storms to include cumulative erosivity from any time period. Raindrop/splash erosion is the dominant type of erosion in barren soil surfaces. Rainfall data of 20 years (1990 to 2010) collected from Department of Meteorology, Taunggyi, Southern Shan State were used for calculating R-factor using the following relationship developed by Wischmeier and Smith(1978) and modified by Arnoldus (1980) cited in Prasannakumar et al. (2012);

$$R = \sum_{i=1}^{12} 1.735 \times 10^{\left(1.5\log_{10}\left(\frac{p_i^2}{p}\right) - 0.08188\right)}$$

Where, R =Rainfall erosivity factor (MJ mm ha^{-1} h^{-1} y^{-1}), Pi = Monthly rainfall (mm), and P = Annual rainfall (mm).

The rainfall erosivity factor (R) for the years 2010 was found to be in the range of 3602.51 to 12076.6 MJ mm ha^{-1} $h^{-1}y^{-1}$. The average R-factor was observed to be 6410.78MJ mm ha^{-1} $h^{-1}y^{-1}$ for 2010. The highest value (12076.6MJ mm ha^{-1} $h^{-1}y^{-1}$) of R-factor was observed in 2010 and the lowest value (25.39MJ mm ha^{-1} $h^{-1}y^{-1}$) was in 1990.

3.2 Soil Erodibility (K) Factor

The soil erodibility K-factor is a parameter of the average soil loss for a particular soil in the study area. It influences both detachment and transport of soil materials. It is a measure of the susceptibility of soil particles to detachment and transport by rainfall and runoff. Texture is the principal factor affecting K, but structure, organic matter and permeability also contribute. In this study, local soil name is compared with global soil name (FAO) to calculate K factor by considering the particle size, organic matter content and permeability class. K-factor was calculated from the following equation (Htun, 2006);

$$K = \left[2.1 * 10^{-4}(12 - OM)M^{1.14} + 3.25(S-2) + 2.5(P-3)\right]/100$$

Where, K= Soil erodibility

OM= % of Organic Matter (%OM=1.724*%OC)

M= Particle Size Parameter [%silt + %very find sand) * 100-%clay]

S=Classes for Structure (1=very fine granular, 2=fine granular, 3=medium or coarse granular,4=blocky, platy or massive)

P=Permeability class (1=rapid, 2=moderate to rapid, 3=moderate, 4=slow to moderate, 5=slow 6=very slow)

3.3 Slope length and Steepness (LS) Factor

LS factor represents a ratio of soil loss under given conditions to that at a site. In this case, the steeper and longer the slope, the higher is the risk for erosion. The combined LS factor will be computed for the study area by means of ArcGIS Spatial analyst extension using the DEM following equation;

$$LS = (Flowaccumulation \times Cell\,size/22.13)^{0.4} \times (\sin slope/0.0896)^{1.3}$$

Where, LS = the combined slope length and steepness factor, Flow accumulation = the accumulated upslope contributing area for a given cell, Cell size = size of grid cell, Sin slope = slope degree value in sin.

3.4 Crop/Vegetation and Management (C) Factor

The crop/vegetation and management factor is used to determine the relative effectiveness of soil and crop management systems in terms of preventing soil loss. It is a ratio comparing the soil loss from land under a specific crop and management system to the corresponding loss from continuously fallow and tilled land. It is also can be determined by selecting the crop type and tillage method. In this case, the satellite remote sensing data sets were used for the assessment of C-factor due to the variety of land cover patterns with spatial and temporal variations. To generate the C-factor value image for the study area, the Normalized Difference Vegetation Index (NDVI) was firstly estimated from satellite image (Landsat -7 ETM) with the following relationship (Zaeen, 2012):

$$NDVI = \frac{NIR - R}{NIR + R}$$

Where, NIR= the reflection of the near infrared portion of the electromagnetic spectrum

R= the reflection in the upper visible spectrum

After that, the C factor was calculated by replacing the NDVI value in the following exponential equation (ibid):

$$C = \exp\left[-\alpha \frac{NDVI}{(\beta - NDVI)}\right]$$

Where α, β: parameters determining the shape of the NDVI-C curve. A α-value of 2 and a β-value of 1 seem to give reasonable results.

4.3.5 Erosion Control Practice (P) Factor

The P-factor reflects the effects of practices that will reduce the amount and rate of the water runoff and thus reduce the amount of erosion. It is the ratio of soil loss by a support practice to that of straight-row farming up and down the slope. The most commonly used supporting cropland practices are cross slope cultivation, contour farming and strip cropping. The P value will be estimated by land use / land cover mapping. The value will range 0 for built-up area and 1 for forest cover (non practice).

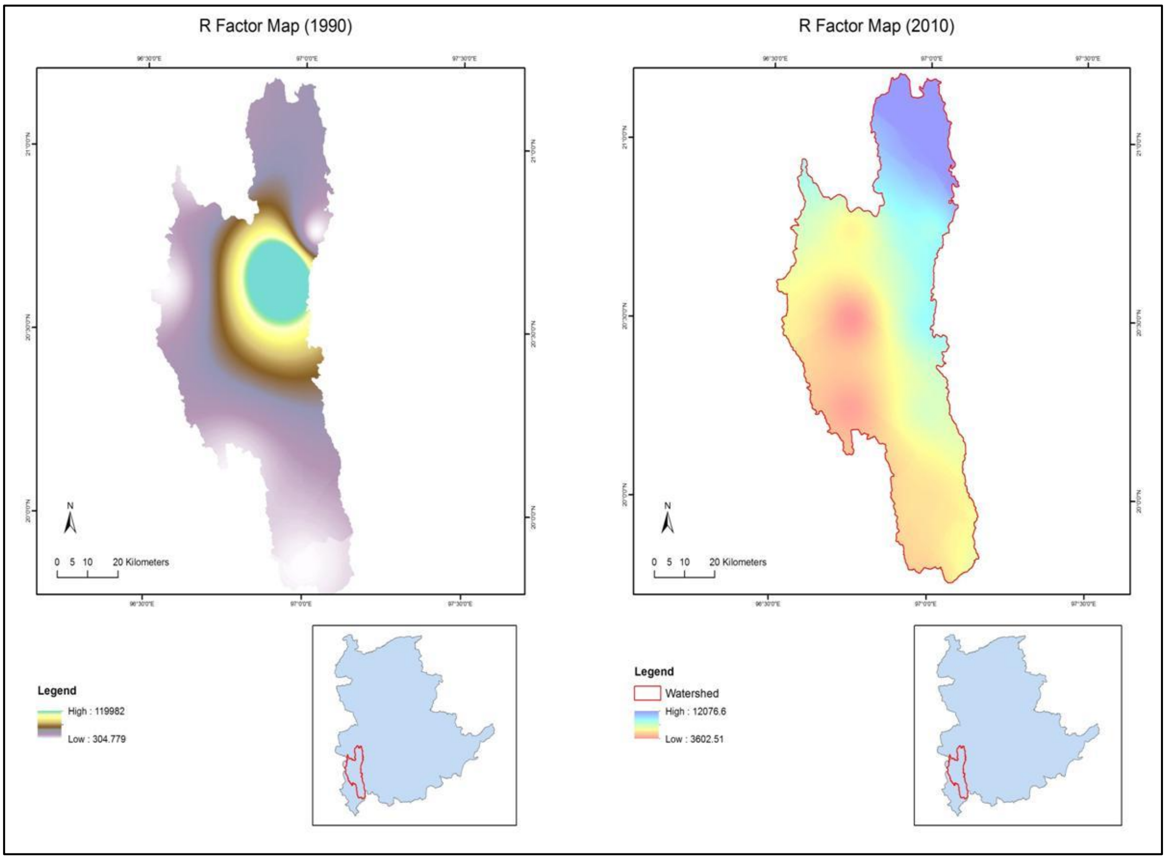

Figure 3.3 Rainfall Erosivity (R) Factor Maps of 1990 and 2010

Table 3.3 Major soil types found in the study area and their properties

No.	Soil Type	Code Name	OC	OM	Sand (%)	Silk (%)	Clay (%)	M	s	p	k
1	Meadow & meadow alluvial soils	B1-B2	2.08	3.58592	32.35	32.6	32.5	6462.5	3	5	0.06
2	Gley and Gley swampy soils	B13-A7	4.6	7.9304	10.85	31.6	56.1	4188.9	4	3	0.02
3	Red brown forest soils	B8-7	2.66	4.58584	36.7	31.5	30.1	6789.9	2	3	0.05
4	Yellow brown forest soils	KS4	0.8	1.3792	4.8	63.05	30.1	6754.9	1	5	0.08
5	Red earths & yellow earths	B9-C2	4.33	7.46492	6	22.5	70.3	2779.7	4	3	0.01
6	Mountainous brown forest soils	B7-C2	1.8	3.1032	18.1	40.2	40.5	5789.5	2	3	0.06
7	Mountainous red forest soils	HK-3	1.1	1.8964	6.5	36.6	55.5	4254.5	4	5	0.04

Source: Land Use Department, Yangon

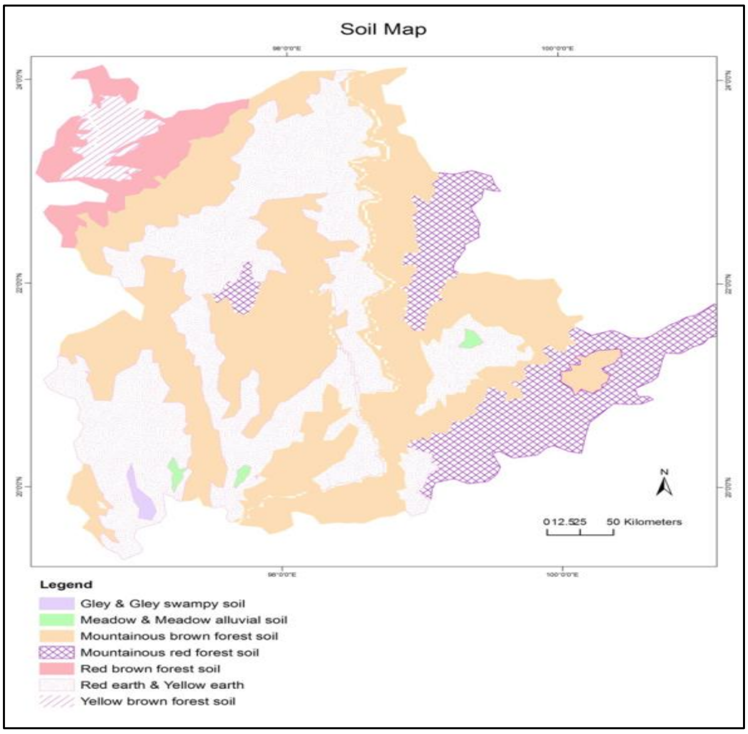

Figure 3.4 Major Soil types map of Shan State, Myanmar

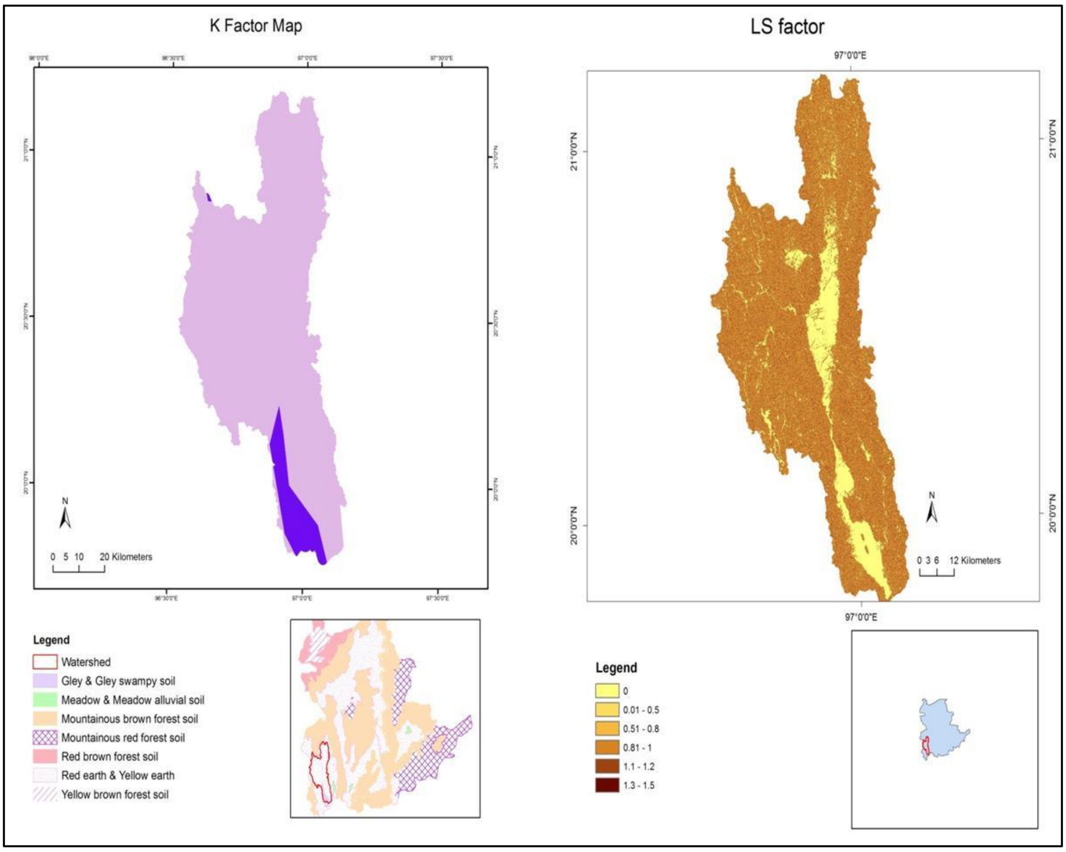

Figure 3.5 Soil Erodibility (K) Factor & Slope Length and Steepness (LS) Factor Map

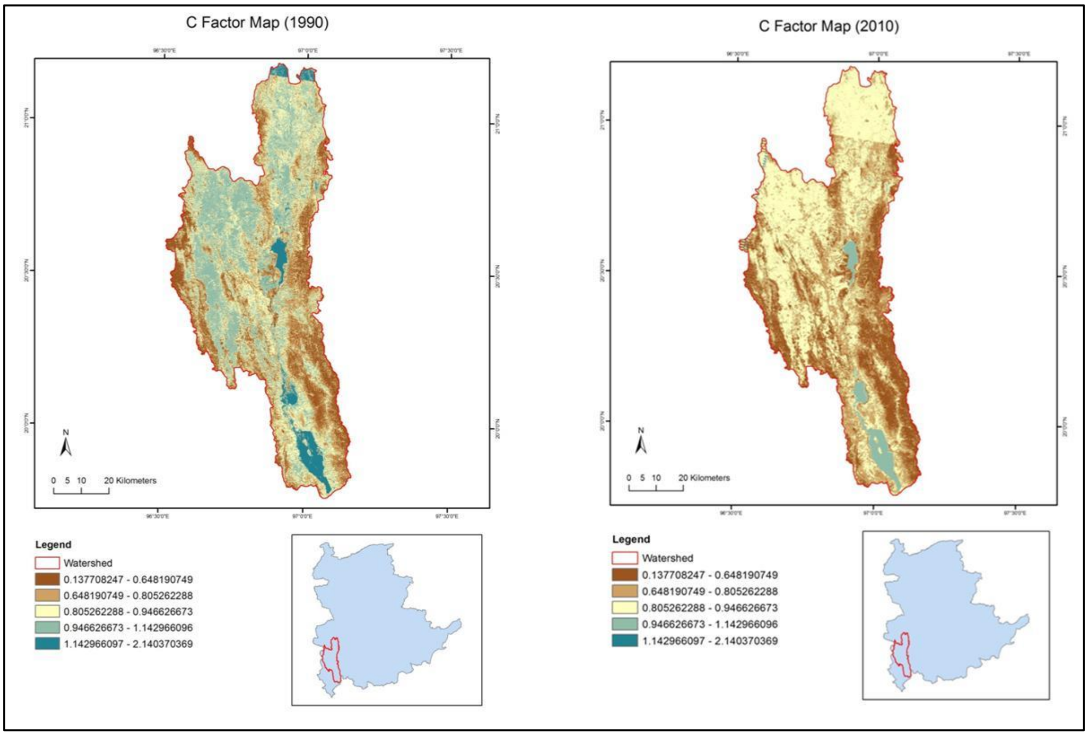

Figure 3.6 Crop Management (C) Factor Maps of 1990 and 2010

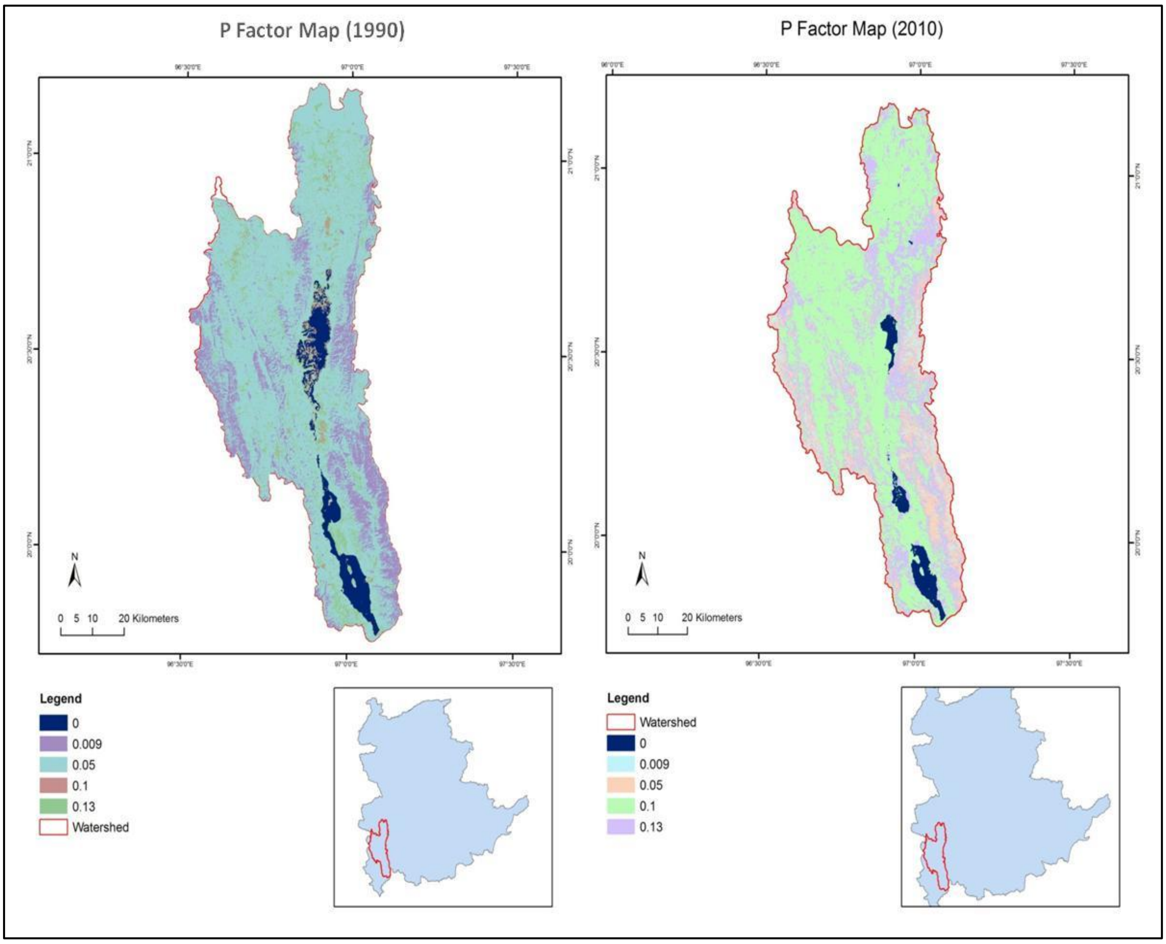

Figure 3.7 Erosion Control Practice (P) Factor Maps of 1990 and 2010

Result and discussion

1. Land Use and Land Cover Classification

The land use and land cover classification of the study area was analyzed by using Landsat TM data in 1990, Landsat ETM data in 2000, and Landsat ETM data in 2010. There was some confusion in satellite images during setting region of interest (ROI). The deciduous forest and paddy fields have changed according to season so they are indistinguishable on single date image.

The wet season image and NDVI images of each year also was used as reference images during the classification step because deciduous forest, harvested paddy field, scrub grass land were confused with the other classes or each other. It was impossible to separate, some part of scrub grass land area and harvested paddy field.

The overall accuracy of classified image of Landsat TM 1990 was 81.6%, Landsat ETM 2000 was 85% and Landsat ETM 2010 was 87.5 %. These classified images' accuracies were more than an acceptable accuracy of 80%.

Segmenting the images into separate layers of each class and converting into vector format was generated in ArcGIS 9.3.1. Manual digitizing and map generalization such as simplification and aggregation were also done as described in previous section in order to get the accurate land use map. The results of land use land cover map of 1990, 2000 and 2010 are shown in Figure 4.1.

The statistic data of each land use class for each year were calculated using query language in ArcGIS 9.3.1. Open forest cover was 66 % in 1990, 28 % in 2000 and 10 % in 2010. Agriculture land was 2 % in 1990, 15 % in 2000 and 56 % in 2010. Detail information based on land use types for years 1990, 2000 and 2010 are shown in Figure 4.2.

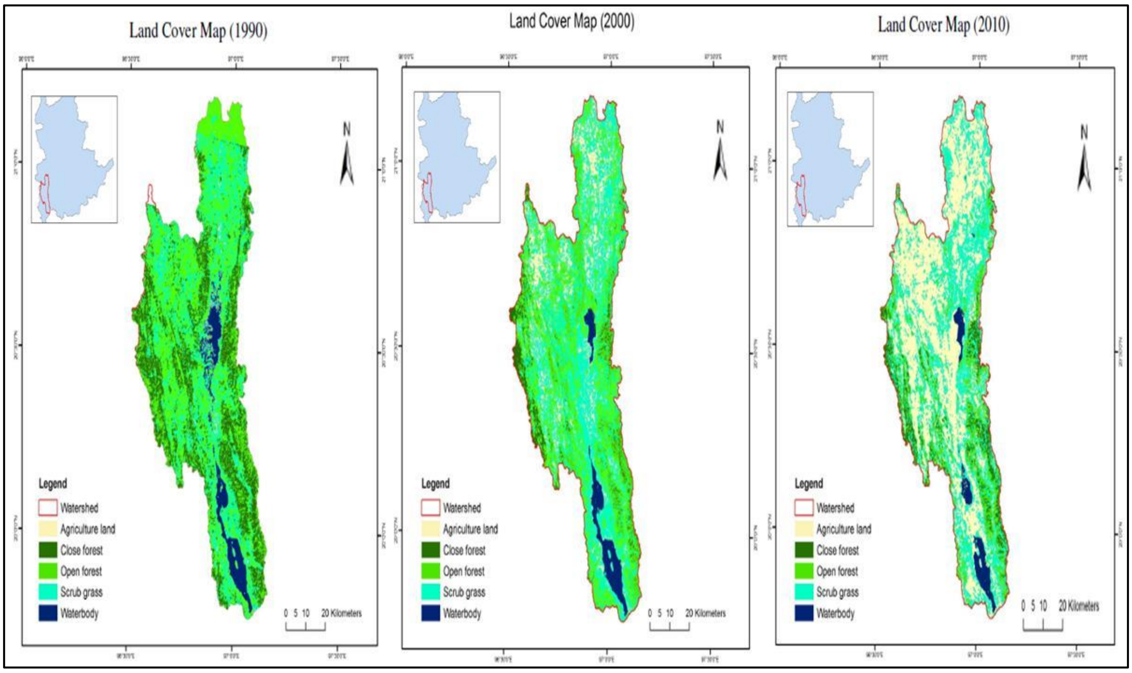

Figure 4.1 Land Use/ Land Cover Map of the study area for the years 1990, 2000 & 2010

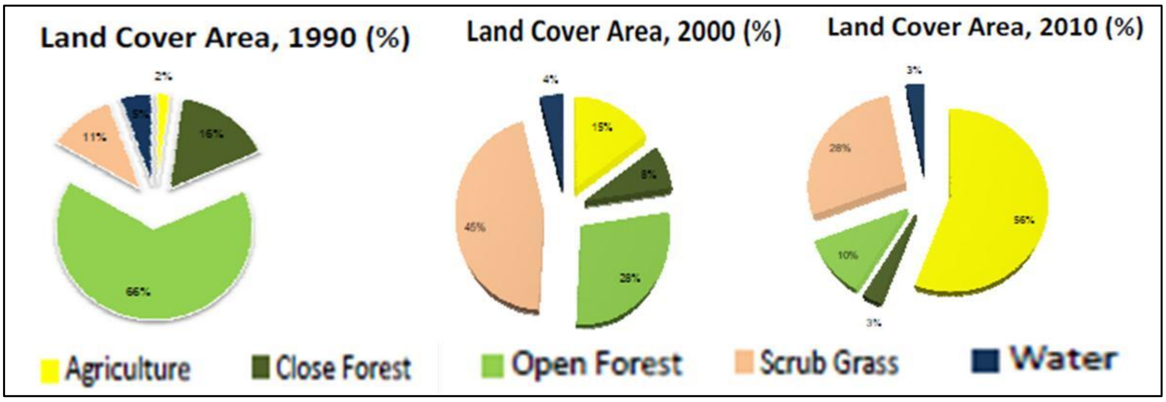

Figure 4.2 Land Use/ Land Cover percentages of the study area (1990, 2000 & 2010)

2. Quantitative Change Detection and Discussion

The result indicates that land use land cover changes between year 1990, 2000 and 2010 in Inle Watershed, Myanmar. The analysis method was detected based on geo-processing (union, intersection and erase). Result of intersection between two maps gave unchanged area and result of intersection using together with erase and union predicted changed area (lost area and gain area) within 20 years. The statistical data of change detection is shown in Table 4.2.

In table 4.2, there were major changes in open forest agriculture land and scrub grass land. Open forest had been reduced up to 39.63% between year 1990 and 2000 and scrub grass land had been increased up to 35.80 %. Between 2000 and 2010, agriculture area was highly in increased up to 50.44 and open forest was decreased up to 21.51 % at the same period. According to the change detection of land use/ land cover between 1990 and 2010, open forest had been reduced up to 38.87 % and agriculture land was increased up to 38.33 %.

The most change occurred in open forest because of the demand on expand the land for agriculture was increased due to shifting cultivation and the pressure of population. Other additional changes of land use/ land cover are shown in Table 4.1 & 4.2.

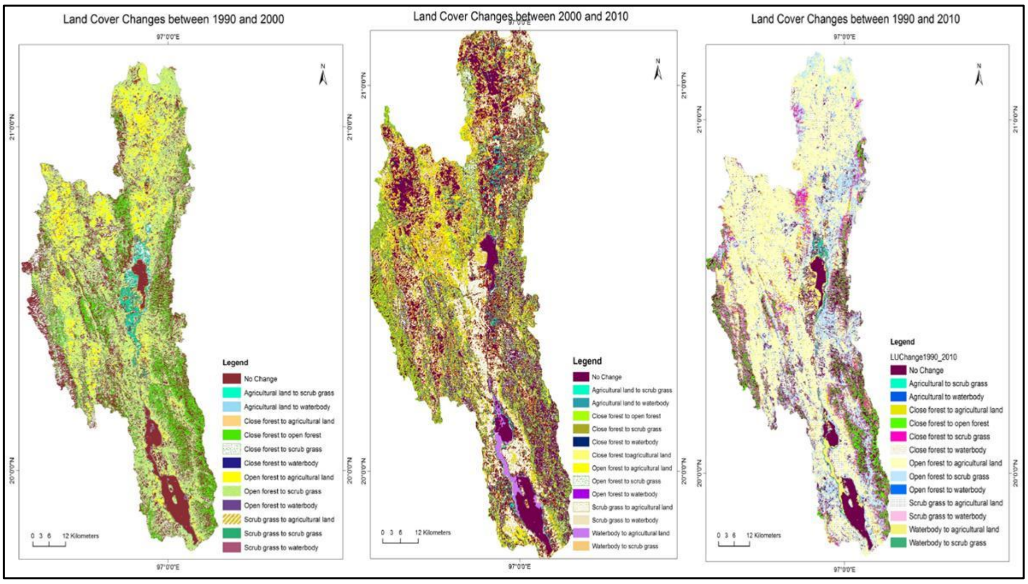

Figure 4.3 Land Use and Land Cover Changes Map within twenty years (1990-2010)

Table 4.1 Changes of Land Use/ Land Cover of the study area among the years of 1990, 2000 & 2010

No	Change Class	Land use/ land cover changes between 1990 and 2000		Land use/ land cover changes between 1990 and 2010		Land use/ land cover changes between 2000 and 2010	
		Area (ha)	Area (%)	Area (ha)	Area (%)	Are a(ha)	Area (%)
1	Agricultural land to scrub grass	6214.05	1.20	2422.89	0.45	10574.46	1.95
2	Agriculture land to close forest	-	-	-	-	1.08	0.00
3	Agriculture land to open forest	-	-	-	-	199.62	0.04
4	Agricultural land to water body	908.55	0.18	310.14	0.06	501.93	0.09
5	Close forest to agricultural land	986.22	0.19	16318.80	3.02	4453.92	0.82
6	Close forest to open forest	49206.87	9.53	30228.12	5.60	15611.13	2.87
7	Close forest to scrub grass	13391.46	2.6	28905.84	5.36	10444.14	1.92
8	Close forest to water body	1.62	0.00	53.64	0.01	3.06	0.00
9	No Change	175657.77	34.03	74426.31	13.79	201439.53	37.06
10	Open forest to agricultural land	61098.39	11.84	220953.69	40.94	52859.16	9.73
11	Open forest to close forest	-	-	-	-	5649.57	1.04
12	Open forest to scrub grass	184702.95	35.78	105691.23	19.58	59695.65	10.98
13	Open forest to water body	523.71	0.10	48.87	0.01	17.91	0.00
14	Scrub grass to agricultural land	18425.07	3.57	47856.24	8.87	168709.68	31.04
15	Scrub grass to close forest	-	-	-	-	381.06	0.07
16	Scrub grass to open forest	-		-	-	6479.55	1.19
17	Scrub grass to scrub grass	4433.13	0.86	-	-	-	-
18	Scrub grass to water body	638.73	0.12	145.26	0.03	66.24	0.01
19	Water body to agricultural land	-	-	10776.69	2.00	5468.85	1.01
20	Water body to scrub grass	-	-	1520.73	0.28	928.53	0.17
	TOTAL	516188.52	100.00	539658.45	100.00	543485.07	100.00

Table 4.2 Statistical Data of Land cover changes between 1990, 2000 and 2010

Statistical Data of Land Cover Change between 1990 and 2000

No	Class Name	Area (ha)	Area (%)
1	Agriculture	72,148.14	14.05
2	Close Forest	-47,957.85	-9.34
3	Open Forest	-203,519.88	-39.63
4	Scrub Grass	183,842.73	35.80
5	Water	-6,112.26	-1.19
	Total Change Area	513,580.86	100.00

Statistical Data of Land Cover Change between 2000 and 2010

No	Class Name	Area (ha)	Area (%)
1	Agriculture	221,873.67	50.44
2	Close Forest	-24,306.30	-5.53
3	Open Forest	-94,609.89	-21.51
4	Scrub Grass	-93,184.56	-21.19
5	Water	-5,877.81	-1.34
	Total Change Area	439,852.23	100.00

Statistical Data of Land Cover Change between 1900 and 2010

No	Class Name	Area (ha)	Area (%)
1	Agriculture	294,021.81	38.33
2	Close forest	-72,264.15	-9.42
3	Open forest	-298,129.77	-38.87
4	Scrub Grass	90,658.17	11.82
5	Water	-11,990.07	-1.56
	Total Change Area	767,063.97	100.00

3. Soil Erosion Hazard Map Discussion

Rainfall erosivity, soil erodibility, slope length and steepness, crop management and erosion control practice factors were calculated as it shown above. After completing data input procedure and preparation of R, K, LS, C and P maps as data layers, they were multiplied in the GIS to provide erosion risk map which shown in figure 4.4 spatial distribution of soil loss in the study area.

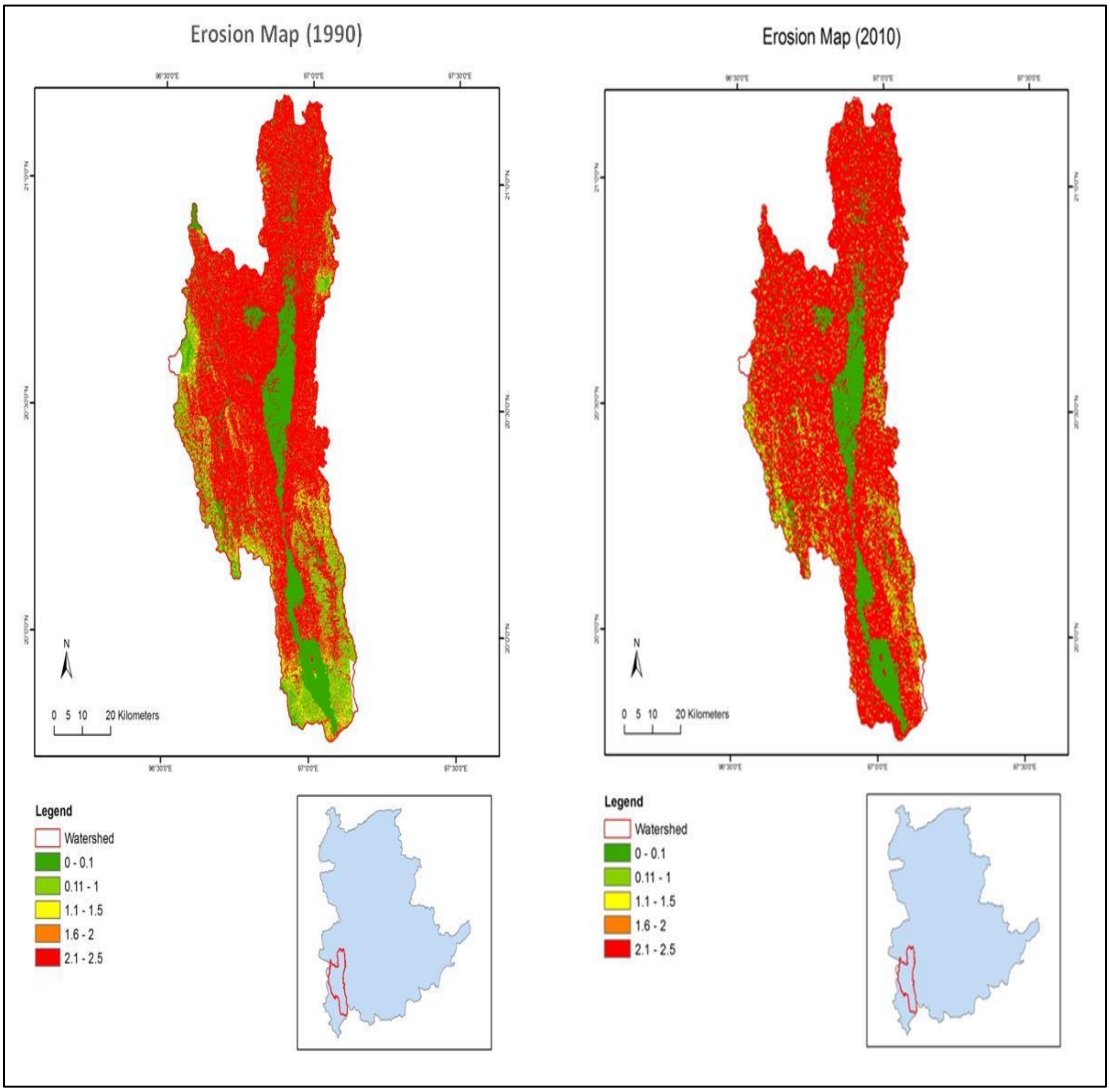

Figure 4.4 Soil Erosion Map of the study area (1990 & 2010)

Observation of the areas identified as extremely erosion potential zone, namely more than 4 t ha^{-1}yr^{-1}, indicated that they have already undergone severe erosion due to undulating topography and faulty method of cultivation practices. According the analysis result, it is seem that 71.26% of the whole watershed was extremely soil erosion potential zone in 2010. In Kalaw watershed (Catchment I), erosion rate was more than 7.0 t ha^{-1}yr^{-1} in 2010. Compare with the year 1990 and 2010, the area percentage of extremely soil erosion potential zone is the highest in 2010. It is also apparent from LS Map and Land Cover Map (2010) that contribution of maximum sediment yields are in the areas of LS factor of 3.37 and agricultural land type, undulating topography and in areas where large percentage is still not covered by conservation measures. In fact, topography plays a critical role in controlling soil movement in a watershed. About 25 percent of the watershed area is found out to be under slight erosion class in 2010.Areas covered by very low , low, moderate, high, and extreme severe erosion potential zones for 1990 and 2010 are shown in Table (4.3, 4.4 & 4.5).

Due to the existing human activities in the watersheds, it is speculated that the sediment yield in the area is likely to increase in the future. Sediment yield may also increase due to the necessity of bringing more area under cultivation by felling of tress to meet the demand of food for the growing population. Therefore, there is a need to take up soil conservation measures specially in the areas with average sediment production rate of more than 4.0 t ha—1yr—1.

About 71.26 percent of the watershed area is found out to be under critical erosion prone area, where the average sediment production rate is more than 7.0 t ha—1yr—1. Hence, those areas of the watershed are also need to be treated.

Table 4.3 Estimated Soil Erosion rates in the Study Area (2010)

NO	Soil Erosion Class (ton ha^{-1}yr^{-1})	Area		Soil Loss (ton yr^{-1})	
		ha	%	ton	%
1	Very Low (0-0.1)	98630.08	18.02	44.38	0.00
2	Low (0.11-1)	32454.58	5.93	1135.91	0.02
3	Moderate (1.1-1.5)	10071.94	1.84	342.45	0.01
4	High (1.6-2)	16190.46	2.96	28171.41	0.44
5	Extreme (>2)	390126.26	71.26	6320045.45	99.53

Table 4.3 Estimated Soil Erosion rates in the Study Area (2010)

NO	Soil Erosion Class (ton ha^{-1}yr^{-1})	Area		Soil Loss (ton yr^{-1})	
		ha	%	ton	%
1	Very Low (0-0.1)	104193.10	19.03	75.36	0.01
2	Low (0.11-1)	69960.26	12.78	5177.06	0.90
3	Moderate (1.1-1.5)	18982.05	3.47	1062.99	0.19
4	High (1.6-2)	13603.16	2.48	802.59	0.14
5	Extreme (>2)	340734.76	62.24	1567397.90	98.76

Conclusion

In this study, three Landsat images acquired in 1990, 2000 and 2010 were used for land use and land cover change detection of the Kalaw Chaung Sub-watershed of Inle Lake in Myanmar. Land use/ land cover mapping and change detection has progressively more been recognized as one of the most effective tools for management of environmental resources.

Different types of Land use/ Land cover mapping and their change detection were carried out using digital image processing techniques cooperating with remote sensing and geographic information system.

The major change of land use and land cover was occurred in agricultural land and close forest in 1990, 2000 and 2010. Spatial modeling of land use and land cover change with the application of Remote Sensing (RS) and Geographic Information System (GIS) proved cost effective environmental monitoring and evaluation.

The average annual soil erosion for study watershed was found to be average 4 t ha—1yr—1 in 1990. R factor value was more than that of the base year, and there has been increase in the soil erosion rate, which can be attributed to change in land cover particularly in decreasing forest cover and increasing in agricultural and open land. Gullying erosion was found in study area and the potential soil loss will be more than the total soil loss that has occurred in that area. This eroded soil will ultimately carried by surface runoff into the lake (wetland), thus adding to the siltation problem.

A quantitative assessment of soil loss on grid basis was made using the well-known RUSLE with a view to identify the critical erosion prone zones of study watershed for conservation planning. The use of GIS and remote sensing data enabled the determination of the spatial distribution of the RUSLE parameters. Creation of database through conventional methods is time consuming, tedious and is difficult to handle. In the present study, attempt was made to utilize remote sensing data for generating land use/land cover data which are essential prerequisites for generation of RUSLE factors. Thus, remote sensing and GIS can play significant role in generation of parameters from remote areas of watersheds/river basins for sediment yield modeling and watershed management.

Suggestions

In this study, land use land cover change categories only considered five major types of land. The category should be considered more detail as further analysis based on the classification criterion of the world.

Forest plantation should be set up to diminish soil erosion in deforested area. On the other hands, the expansion of shifting cultivation and cutting of firewood in the study area should be strictly prohibited by the concerned department and local authorities. In densely populated areas, firewood plantations are needed to prevent further deterioration of over exploited areas.

Contour ploughing, grassed waterways, windbreaks, terracing and other stabilization structures such as crop and vegetation management, soil management should be used to fulfill the strategy for erosion control.

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