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Research Article

Sensitivity Analysis of Soil Erosion on Impacts of Land use Land Cover Change in Phewa Watershed

Krishna P. Bhandari[Å*] and Rotchanatch Darnsawasdi[Å]

[Å]Faculty of Environmental Management, Prince of Songkla University, Hat Yai, Songkhla, 90112, Thailand

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Abstract

Soil erosion is a serious problem in Phewa Watershed. Knowledge of Land Use/Land Cover (LULC) and soil erosion risk represents the foundation for sustainable soil erosion management. Stakeholders' perspectives play key roles in implementing conservation measures in soil erosion management. This study identifies and quantifies major LULC changes over the past 15 years (1995-2010) in the Phewa Watershed, Nepal. Revised Universal Soil Loss Equation (RUSLE) in combination with Remote Sensing and GIS are used to produce potential soil erosion risk maps and to estimate the rate of soil erosion in the watershed. Sensitivity of soil erosion risk increases from 1995to 2010.The extreme sensitivity mainly caused by a major decrease in dense forest, an increase in open forest and increase in human settlement (384.34 to 797.14 ha) in the watershed. Frequent human activities contribute to increase soil erosion. Result of sensitivity analysis helps to stakeholders for the reduction of the soil erosion. The sensitivity of soil erosion in north and west region was higher than south and east region. The high sensitivity area of soil erosion was mainly disturbed in middle hill and mountain of Phewa watershed.

Keywords: *Land Use Land Cover (LULC), change detection, Revised Universal Soil Loss Equation (RUSLE), soil erosion*

1. Introduction

Land use and land cover change has impacts on soil and water quality and they contributes to watershed degradation (Lambin et al., 2000; Schneider and Pontius, 2001). Land use change directly affects soil erosion. Therefore prediction of soil erosion is important with respect to modeling of land use change (Leh et al., 2011). LULC change has two types of driving forces i.e. Direct (proximate) and indirect (underlying). Direct driving forces is the immediate actions of local people to fulfill their needs from land use (Geist and Lambin, 2002), such as agricultural expansion, wood extraction, infrastructure expansion and other causes change the physical state of land cover (Meyer, 1995). Indirect driving forces are fundamental socioeconomic and political processes that push direct causes into immediate action on LULC (Geist and Lambin, 2002). Demographic pressure, economic status, technological and institutional factors influence in LULC combination (Geist and Lambin, 2002). Land use constantly changes due to the dynamic interaction between direct and indirect causes (Lambin, Geist, and Lepers, 2003). Land use is a factor which affects the intensity of surface erosion (García-Ruiz, 2010; Kosmas et al., 1997; Mitchell, 1990). Soil erosion decreases exponentially as the percentage of vegetation cover increases, as it has been demonstrated by many authors (Elwell and Stocking, 1976; Francis and Thornes, 1990; Lee and Skogerboe, 1985). Inappropriate agricultural practices, deforestation, overgrazing, land abandonment, forest fires and construction activities are the main causes of soil erosion (Grimm et al., 2002; Yassoglou et al., 1998). Agricultural land uses generate the highest erosion yield among these factors (Pardini, Gispert and Dunjó, 2003; García-Ruiz, 2010; Hill and Peart, 1999; Nunes, Coelho, Almeida and Figueiredo, 2010; Wang, Li, Yang, and Tian, 2003). In recent 25 years, many infrastructure specially building and road construction were carried out on the Phewa watershed. Few researches in soil erosion sensitivity and distribution have been done in 90's decade. Erosion rates in the middle mountain region of Nepal were increased due to the destabilization of the fragile mountain slope through deforestation, agricultural expansion, excessive grazing and road networks without clear conservation measures (Ives and Messerli, 1989; Thapa, 1990). However, there is still lack of assessment and analysis of spatial difference in soil erosion sensitivity in Phewa Watershed.

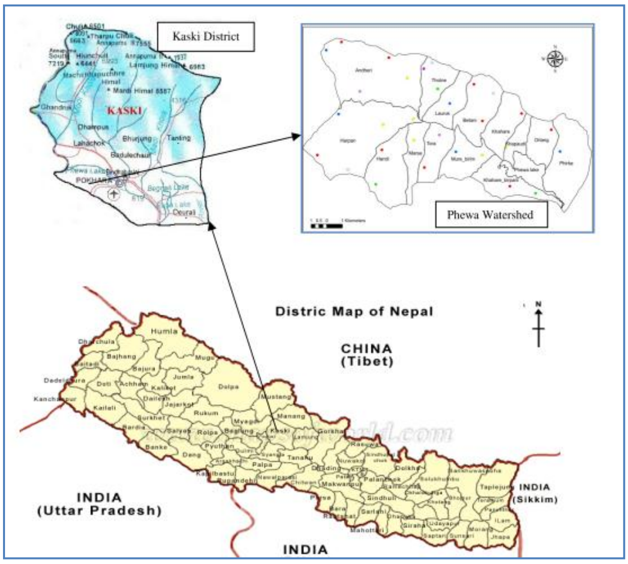
Sensitivity degree of soil erosion can identify areas of soil erosion under human activities (MEP, 2002). Based on RUSLE, this research took advantages of six key factors namely climate, soil erodibility, topography, land cover, conservation practices and population density and analyzed the spatial difference of soil erosion sensitivity in Phewa watershed. This research expected that the result could help to understand the erosion environment changes, LULC changes and the impacts of human activities and further provide scientific support for environmental

*Corresponding author: **Krishna P. Bhandari**

management.

2. Study area

Phewa watershed is middle mountain region located in the western part of Nepal between latitude $28^0\ 11^{'}\ 39^{''}$-$28^0\ 17^{'}\ 25^{''}$ N and $83^0\ 47^{'}\ 51^{''}$– 83^0 59’ 17E longitude. It covers about 123 Km^2 with its east-west average length of 17 km and north-south width of 7 km and variation in altitude 793m to 2508 m above mean sea level. Phewa watershed is divided into 14 sub watershed and Figure 1 shows the study area.



3. Material and Methods

3. 1 Data sources

Data sources was shown as in Table 1

Table 1 The data used and their sources

Data	Data sources
Annual rainfall (1995-2010)	Meteorological department, Government of Nepal
Satellite images (November 1995 and 25 November 2010)	Images from website of Global Land Cover Utility (http://glcf.umiacs.umd.edu/data/lansat/)
Soil map	Forest resource assessment project, Nepal , 2009
Topographic map 1:25 000 scale	Survey department, Government of Nepal

3.2 Methods

3.2.1 Image classification

Topographic map of 1:25 000 from survey department, Government of Nepal was considered as the main secondary tool for supervised classification of Land sat Thematic Mapper TM image (November 1995 and 25 November 2010) of the study area. LULC classes such as dense forest, open forest, bush, terrace cultivation, single crop, double crop, barren land, grassland, water bodies, built up and wet land were identified and their coordinate were recorded with a Garmin GPS device to support for the accuracy analysis of classified image. The image was cross-referenced with ground truth, topographic map and other ancillary data to make the classification as accurate as possible. A nonparametric signature was used based on an Area of interest (AOI). The classification has been done repeatedly to make the classification as accurate as possible.

Classification result was validated through confusion matrix /error matrixes by using 125 field data. Confusion /error matrix consists of row with classification value and columns with fact value from the field. Classified pixels were represented by the diagonal line of the error matrix. The Overall accuracy was calculated from correct classified pixel divided by total number of pixel checked. The producer accuracy index was produced by dividing the number of correct classified pixels. Land use classes and validate points with coordinates in the text format were imported as true classes. The users’ accuracy index was produced by dividing the total number of correct classified pixels that belongs to a class by the sum of the values of the rows of the same class.

The confusion matrix was generated by giving the ground truth points from independent source. Accuracy was quantified by developing a confusion matrix for each image and computing the corresponding users’ accuracy, producers’ accuracy, overall accuracy and the kappa statistic of agreement.

3.2.2. LULC change detection

Land sat TM (November 1995 and 25 November 2010) images of the study area have been imported to ERDAS 9.3 software. Image pre-processing, enhancement, classification were applied on images. Information on land cover condition and quantification of change has been extracted from the classified image over the last 15 year by using GIS analysis. Post classification comparison method has been applied for change detection and comparison of land cover conditions of two different periods. Finally, LULC changes and dynamics have been quantified and structure of change has been evaluated.

3.2.3 Soil erosion risk

The RUSLE model is the extended version of Universal Soil Loss Equation (USLE) which is an erosion prediction model designed to predict the long term average annual soil loss from the specific slope in specified land use and management system (Renard, Foster, Weesies, & Porter, 1991). The product of five factors quantifies is annual soil loss by the RUSLE model.

$$A = R * K * L * C * P * S \quad (1)$$

Where A is average annual soil loss, R is rainfall and run off erosivity factor. K is soil erodibility factor, L is slope length factor, S is slope steepness factor, C is cover and management factor, P is erosion control practice factor.

Rainfall and run off erosivity factor

R-factor was determined by mean annual rainfall data corresponding to the period 1995-2010. Elevation of meteorological stations was correlated with rainfall data. Rainfall erosivity factor has direct relationship with soil erosion. Regression technique was applied to obtain the equation for the rainfall distribution map. The equation (2) of the rainfall map was

$$\mathrm{Y} = 0.967x + 2901 \quad (2)$$

Where Y= amount of rainfall (mm) and x=elevation (m). The above formula was applied on the map calculation function of Arc GIS 10.0 software. The relationship between elevation and annual rainfall was found to be (R^2 = 0.821). The equation (3) formulated by Renard and Freimund(1994) was used to calculate the R factor because of lack of the rainfall intensity data. Rainfall erosivity factor was calculated.

$$R = 587.8 - 1.219 * \mathrm{P} + 0.004105 * P^2 \quad (3)$$

$For\ P > 850mm$)

Where R is rainfall erossivity ($Mjmmha^{-1}yr^{-1}$) and P is average annual precipitation (mm). R factor value varies from 3666.86 to 5326.23. Then sensitivity of rainfall was classified according to table3.

Soil erodibility factor

Soil texture map was collected from Forest Resource Assessment (FRA) Nepal project to prepare K factor map. Ten different horizon soil samples were collected and verified the soil data. Soil erodobility nomograph (USDA 1978) were used to identify k values of the four soil types of texture classes sandy loam, loamy, silt loam and silt clay loam. K values ranges from 0.02 to 0.39.

Slope length factor

LS factor was calculated by the Arc GIS based technique designed by Bernie (1999). The hydrological and spatial analyst tools were used to estimate LS. The flow accumulation layer to estimate slope length (L) was calculated from Digital Elevation Model (DEM) in hydrologic extension of Arc GIS 9.3version. LS factor was computed by the equation (4) and (5).

$$LS = \left(\frac{A}{22.13}\right) \times 0.6 \left(\frac{sinB}{0.0896}\right) * 1.3\ 8 \quad (4)$$

For use in ArcGIS, Sims used the following Map Algebra expression:

$$LS = [Pow\left([flowaccumulation] * \frac{Cellsize}{22.13}, 0.6\right) * Pow(\sin\left([slopeofDEM] * \frac{0.01745}{0.0896}, 1.3\right)] \quad (5)$$

The LS factor ranged from 0-200.

Cover factor

Crown coverage, ground cover, crop sequence, length of the growing season and tillage practice measures ‘C’ factor for cropping management. LULC map with 12 classes of the study area was generated from Land sat ETM+ satellite data (April, 1995 and April, 2010). LULC layer was generated by supervised classification and using the visual Interpretation (VI). Layer was converted to C layer through reclassification of each cover type into its corresponding C value as in the Table 1.

Table 1 Adopted value of C for different land use

S.N.	Land covers	Average C value
1	Open forest	0.07
2	Double crop	0.37
3	Single crop	0.55
4	Built up land	0.05
5	Water body	0.0
6	Wet land	0.0
7	Bush and scrub	0.02
8	Grass/fallow land	0.03
9	Terrace cultivation	0.55
10	Waste land /land slide	1.00
11	Dense mixed forest	0.001
12	Barren land	1.00

Sources: Roose (1977) Hurni (1987), Morgan (1986), Hashim and Wong (1988) and field observation.

Conservation practice factor

In this study, population and socioeconomic activities were used to reflect intensity of human activities as socioeconomic factor statistical yearbook for regional economic statistics (CBS, 2010) was applied for spatial interpolation and correlation. The general practice of the farmers in cropland is ploughing / tilling along the contour lines either against the slope length or perpendicular to the slope length. Soil conservation practices slow down the run-off water by protection of crops cultivated on slope against erosion. The conservation practice ‘P’ can be found from the equation (6) and presented as in Table 2.

Table 2 Adopted value of the practice management in different land use

Land use type	Slope %	Pc	Ps	Pt	P factor
Agriculture	1 – 4	0.57	0.55	0.5	0.11
	5 – 10	0.65	0.55	0.3	0.09
	11 – 20	0.80	0.55	0.6	0.19
	21 – 40	0.95	0.55	0.2	0.0
	> 40	1.00	0.55	0.4	0.20
All		1.00	1.00	1.00	1.00

Source: Schwab et. Al. (1993) and field observation

$$P = P_c * P_s * p_t \quad \text{(Schwab et al., 1993)} \quad (6)$$

Table3. Sensitivity classification of soil erodibility based on the directly used factors

Sensitivity level	Non sensitivity score =1	Light sensitivity score=3	Middle sensitivity score =1	High sensitivity Score =7	Extreme sensitivity score=9
Factors					
Rainfall	≤2000	2000-2500	2500-3000	3000-3500	≥ 3500
Soil texture	Gravel, sand	-	Coarse sand	-	silt loam sand
Slope	≤ 2	2-4	4-6	6-14	≥ 14
Cover	Dense forest	Open forest	Agriculture	Waste land	Bare land
Population density	<100 person/Km^2	100-200	200-300	300-400	>400

Sources: Adapted from liu, et al, 2010 and field observation

Table 4 Classification accuracy of classified land use in 1995 and 2010

Classes		1995				2010			
	Reference Total	Classified Total	Number Correct	Producer Accuracy	Users Accuracy	Classified Total	Number Correct	Producers Accuracy	Users Accuracy
Open forest	19	18	15	94.1	88.9	18	17	94.4	94.4
Single crop	13	13	12	92.3	92.3	13	12	92.3	92.3
Double crop	17	18	16	94.4	94.4	18	17	94.4	94.4
Wetland	4	5	4	100	80	5	4	100	80
Water bodies	10	8	8	80	100	8	8	80	100
Grass land	7	8	5	71.4	62.5	8	5	71.4	62.5
Terrace cultivation	19	17	16	88.8	94.1	17	16	88.9	94.1
Waste land	6	8	5	83.3	62.5	8	5	83.3	62.5
Bush	7	6	5	75	100	6	6	85.7	100
Barren land	7	7	6	85.7	85.7	7	6	85.7	85.7
Built-up	8	7	6	75	85.7	7	8	75	85.7
Dense mix forest	9	9	8	88.8	88.9	9	8	88. 9	88. 9
Total	125	125	108						
Overall classification Accuracy =87.2%						Overall classification Accuracy =88%			
Overall Kappa statistics = 0.86						Overall Kappa statistics = 0.87			

Where, P_c = Contouring factor based on slope
P_s = Strip cropping factor for crop strip width
p_t =Terrace sedimentation factor
Annual soil erosion cover was generated from the five factors R, K, LS, C and P of the RUSLE equation**.**

Population density factor

Higher the population density then higher the pressure on agriculture land and natural resources. This will increase the soil erosion.

3.2.4 Assessing sensitivity of integrated soil erosion

Single factor sensitivity reflects about the role of each factor. Integrated soil erosion sensitivity can be calculated spatially in formula (7).

$$SSj=\sum_{i=1}^{6} Vi \quad (7)$$

Where ss_j is the soil erosion sensitivity of certain grid j. Vi is the sensitivity level of factor I .Evaluation result were divided into five classes.

4. Result and Discussion

4.1 Image classification

LULC maps of the study area were produced for each of the years 1995 and 2010. Kappa coefficient of overall classification was 0.86 and 0.87 for 1995 and 2010 (Table 3). The importance of the use of Kappa analysis for evaluating accuracy is significantly better than a randomly generated map (Pontius, 2000). The producer’s accuracy shows probability of pixel location of a land use class on the map (Story and Congalton, 1986) ranged between 0.71 and 1.00. The user’s accuracy shows that probability of a pixel location on the map of land use class location as in the field (Story and Congalton, 1986) ranged between 0.62 and 1.00 (Table 4).

Grassland and waste land are the lowest accuracies among other classes. Accuracy assessment showed overall classification accuracy 88 % and over all Kappa statistics of 0.87 for 2010 and 87.2% classification accuracy and over all kappa statistic of 0.86 for 1995 LULC map, which is feasible for further application. Possible reason for the misclassification of waste land is confusion between actual waste land, construction sites and cleared agricultural land. LULC classification was considered to be satisfactory based on the value of Kappa and overall accuracies 85% or more (Foody, 2002).

4.2 LULC change detection

LULC of the two periods (1995 and 2010) was generated from the satellite imageries using a supervised maximum likelihood classification. Land cover change rate and LULC conversion matrix were employed to study the land cover change in the study area. The land cover maps of the two periods were analyzed based on rate of change and trend of land use conversion. This comparison did not provide information about the contribution of each LULC class for the change in spatial extent of the other. Thus, comparison matrix was employed and analyzed for each period to understand LULC dynamics. LULC conversion matrix analysis was conducted and conversion comparison map prepared for 1995 and 2010 in such a way that the columns represented year of destination and the rows represented year of source. LULC change of the Phewa watershed is discussed below with cover change comparisons of each LULC type over the study years. LULC have undergone significant modifications and land use conversions over the study years (Figure 2).

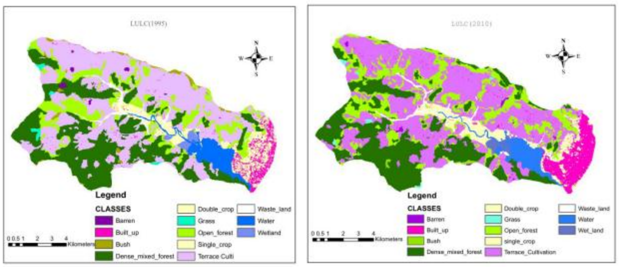
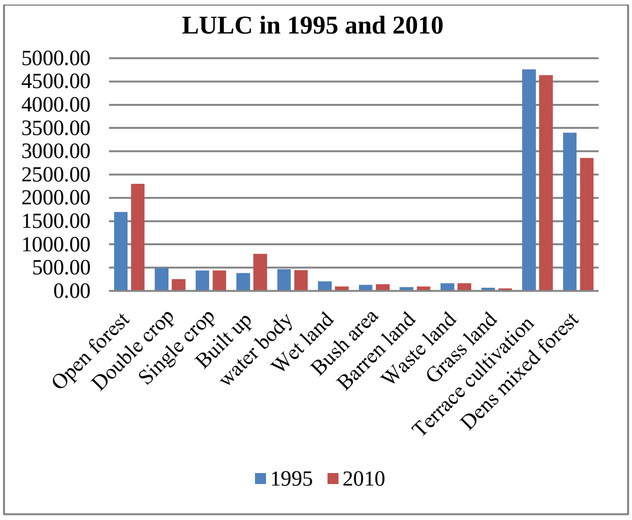


Figure 2 Land Use/Land cover Map of 1995 and 2010



In 1995, terrace cultivated land, dense forest and open forest constituted a relatively large proportion (38.7 %), (26.59 %) and (13.21%) of the area. These conditions were considered as a baseline for change detection over the study years. Dense forest declined from 27.64 % to 23.26 %, open forest increased 13.78% to 18.72% from 1995 to 2010. Double crop, grass land has shown a relatively small decline; while built up has experienced an increment from 3.13% to 6.48%. There was a continuous dynamics among LULC shown as in Figure 3. The major important changes were observed in the period considered as follows: Firstly, deforestation in all areas especially on the upper slopes has been occurred. Secondly, wetland has been converted to crop and grass land while terrace agricultural area has been converted to other land cover classes, particularly waste land and open forest. Thirdly, cultivated land such as double crop, single crop and terrace cultivated land changed into built up area. LULC changes and socioeconomic dynamics have a strong relationship; as population increases need for cultivated land, grazing land, fuel wood; settlement areas increase need to meet the growing demand for food and energy, and livestock population(Abate, 1994). The decrease in dense forest and the increase in population of watershed showed the transformations of the land cover into land use categories which are prone to accelerated erosion of the watershed.

4.3 LULC change

Major LULC changes were discussed based on change comparison of each class. But this comparison did not provide information about which LULC class goes to where. Thus, change comparison matrix was employed and analyzed to understand the LULC dynamics for each period and whole study period. LULC conversion matrix used to analyze the source and destination of each cover type within the study period. The conversion matrix analysis was conducted in ERDAS 9.3 software and conversion comparison map prepared for (1995 and 2010) in such a way that the columns represented year of source and the rows represented year of destination. Finally, corresponding tables and figures were prepared using Microsoft excel sheet.

4.4 LULC change matrix for 1995 and 2010

LULC change matrix (1995 – 2010) for Phewa watershed showed that there was a significant LULC dynamics. A considerable amount (547.47 ha) of the dense forest cover has changed to different LULC class including open forest(518.41ha) and terrace cultivated land (9.2ha), bush area (15.72 ha) which has resulted in overall reduction in the amount of forest cover. The open forest area increases from 1693.5 ha (13.78%) of land to 2301.5ha (18.72%) in (1995–2010). The matrix result has shown the changes of LULC class in (1995-2010) as follows:

- Open forest has acquired additional land area from dense mixed forest (518.41ha), terrace cultivation (96.7ha), grassland (5.5ha), waste land (2.4ha) single crops (6.5ha) and bush area (4.4ha) during this period.
- Open forest has changed particularly to terrace cultivation (11.5ha), bush area (6.9ha), single crop (2.3ha) and dense mixed forest (2.7ha).
- Double crop land (286.91ha) has changed particularly to built-up (268.4ha), single crop (12.0ha) and waste land (4.1ha).
- Single crop (121.58ha) has been changed particularly to built-up (96.1ha), open forest (6.5ha), wasteland (7.9ha) and bush area (6.1ha).
- Wetland (125.14 ha) has been changed to single crop

Table 5 Soil erosion risk classes of 1995 and 2010

Erosion Classes	Average rate of soil loss(t/ha)	1995		2010	
		Area(ha)	Area (%)	Area(ha)	Area (%)
Very low	<5	6479.7	52.7	4205.3	34.2
Low	5 to 10	1107.4	9.0	1978. 5	16.1
Moderate	10 to 15	2058.3	16.7	1208.0	9.8
High	15 to 25	2050.7	16.7	4304.3	35.1
Severe	25 to 50	57.7	0.5	67.6	0.5
Very severe	>50	69.4	0. 6	84.6	0.7
Excluded area(river and stream)		469.2	469.2	3.8	444.2
Total		12292.3	12292.3	100	12292.3

(82.8ha) and double crop land (38.3ha) and grass land (2.3ha).

- Terrace cultivation (172.96ha) land has been changed into waste land (11.1ha), barren land (13.1), built up (46.6ha), open forest (96.7ha) and bush area (3.0ha).
- Waste land has changed into single crop land (22.31ha), terrace cultivation (4.0ha) and open forest (2.4ha) out of (30.2ha) waste land.
- Built up, water body, bush area, barren land, and grass land have relatively small change.

4.5 Soil erosion risk assessment

The soil erosion value estimated for 1995 and 2010 was reclassified based on degree of severity into six classes (Table 5).The spatial distribution patterns of the different erosion intensity classes for the different LULC class are shown in Figure 3.

Soil loss risk assessment in the study area by applying RUSLE model revealed that soil erosion risk category changes from 1995 to 2010 as below:

- High soil loss risk category (15 - 25 t/ha/yr) increased from 2050.65 ha to 4304.25 ha area
- Moderate soil loss (10-15t/ha/yr) decreased from 16.74% to 9.83% of the total area.
- Area of low class soil erosion risk (5-10 t/ha/yr) increased from 9.01% to 16.10 % of the total area.
- Very low soil loss class (<5t/ha/yr) decreased from 52.71% to 34.21% of the total area.

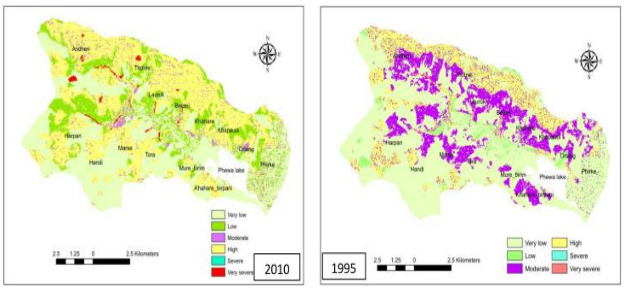


Figure 3 Level of Soil erosion risk in the Phewa watershed in 2010 and 1995

High rate of erosion were found along the steep slopes (mountainous) areas and south facing sub-watershed and its tributaries namely Andheri, Lauruk, Thotne, orlang, Khapaundi and Khahare. Rates of soil transport ranged between 0 and 206.7 t/ha/yr for across each land use. Two major sources of increased erosion are the barren and waste land classes. The erosion rate in the barren land area was increased from 136t/ha/yr to 206.78t/ha/yr in (1995 - 2010). Erosion risk in barren land was increased due to lack of protective soil cover. In the case of the waste land areas, erosion rate increased from 149t/ha/yr to 197t/ha/yr in 1995 to 2010. The construction activities and urbanization increases the waste land, barren land and deforestation which ultimately increase in soil erosion.

4.6 Impact of land use changes on soil loss

Deforestation and substitution of forest by crop or decreasing the protective function of the land have led to a dramatic increase in soil loss (Cebecauer and Hofierka, 2008; García-Ruiz, 2010). Land use types affects on runoff and soil loss (Gosavi and Tamilmani, 2009; Wei et al.,2007). Significant increase from 1693.51ha to 2301.50ha of open forest area in 1995 and 2010, decreased in dense forest area from 3397.29 ha to 2859.11ha in 1995 and 2010 showed the assessment of soil loss risk by applying RUSLE model, high soil loss risk category significantly increased from 2050.65ha to 4304.25ha from 1995 to 2010. The built up area increased from 384.34 ha to 797.14 ha and wasteland, barren land slightly increased from 1995 to 2010 which accelerate soil loss. The soil loss risk changes corresponded to the land use changes over 1995-2010 periods. Since, C factor in RUSLE directly depend on LULC and land use had a significant influence on soil loss risk. Therefore, the decrease of the dense forest from 1995 to 2010 decrease protective function of the land and led to an increase of soil loss risk.

4.7 Sensitivity pattern of integration of soil erosion

Sensitivity pattern of the integrated soil erosion increases significantly from 1995 to 2010.The area covered by sensitivity of soil erosion was located in Andheri and Harpan tributaries and Northern part of the watershed. This was due to human activities for settlement, agriculture and road construction. Other part of watershed is mixing pattern of sensitivity of the soil erosion .The extreme sensitivity area was distributed over the Andheri Khola and Harpan Khola tributaries. The sensitivity level of the area was changed in two years.

4.8 Selection of indicator for sensitivity assessment of soil erosion

This study based on RUSLE model with six selected characteristic rainfall erossivity, soil texture, slope, cover, conservation practice and population density. There are several reasons for selection of RUSLE model. This model tries to cover the socioeconomic factor then the previous methods. Human activities are the major factor for the soil erosion so here trying to introduce the population density effect on soil erosion and sensitivity.

4.9 Comparison between soil erosion sensitivity and soil erosion risk

Soil erosion had consistent with the pattern of soil erosion sensitivity. The serious soil erosion areas are the extreme and high sensitive area. Some area had high soil erosion but moderate sensitivity such as Tora and Lauruk area. However, the relative little human disturbances and high vegetation cover made less soil erosion due to topographic situation for difficulty on exploitation. Some areas have high sensitivity and high risk area. The erosion is due to high population, poor vegetation coverage and construction of road and building. Therefore the more environmental factors data could find the detail soil erosion area with different region of the watershed to support the future research. Soil erosion sensitivity in 1995 and 2010 is as shown in figure 4.

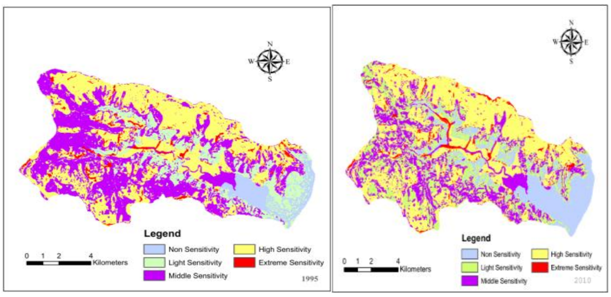


Figure4 Level of soil erosion sensitivity in the Phewa watershed in 1995 and 2010

Conclusion

Knowledge of LULC features and their relative environmental risks is important for effective and sustainable land resource management. Phewa Watershed has sufficient natural resources; it is at severe risk due to land degradation caused by inappropriate LULC practices aggravated by local people. Knowledge of LULC trends and dynamics, process of soil erosion and the impacts on fragile environments made a priority issue in order to devise effective control mechanisms and suitable land management practices. The finding of the LULC in Phewa Watershed over the past 15 years showed that dense forest decreased and shifted into open forest and bush area. Furthermore, urbanized settlements were found to have expanded and intensified at the expense of terrace cultivation, single crop land and double crop land. Rapid population growth demands for additional land for farming, wood for fuel, and construction which result deforestation and reduction of the wetland areas. Furthermore, the result of the study revealed that the area is potentially prone to soil erosion. The mean annual rate of soil loss in the Phewa watershed is 14.71t ha^{-1} yr^{-1}, which identifies a severe rate of degradation. The highest degree of soil loss (above 50 t ha^{-1} yr^{-1}) was found to occur in the upstream and riverbank areas. This paper identified that increasing human pressure on the environment exacerbates soil erosion and that soil erosion can be attributed to LULC change. From 1995 to 2010 soil erosion sensitivity increased significantly. The increase in soil erosion sensitivity means the degradation of environment. The most of the study area covered with high, moderate in agriculture and road construction and extension of settlement area. The area with high erosivity is due to intensive human activities in the watershed due to topography and hill side farm land agriculture. Light area is covered with dense forest area. Thus, knowledge of LULC and soil erosion sensitivity provides an unambiguous opportunity to improve soil erosion management and benefit the myriad of stakeholders in Pokhara, Nepal.

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