Research Article

FOREST LAND PRONE TO MORE SOIL EROSION THAN CULTIVATED LAND IN THE CHURE HILL OF EASTERN CHITWAN, NEPAL

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ABSTRACT

This study was done at Lothar-Pampha Watershed, located in the Chure hill of eastern Chitwan, inside the boundary of Rapti Municipality covering 121.83 km^2 (12183.12 ha). The main objective of the study was to estimate the spatial distribution and the extent of soil erosion in the watershed using Geographic Information System (GIS) and Remote Sensing (RS) tool. Annual average soil loss was estimated by using the Revised Universal Loss Equation (RUSLE), RSdata using GIS platform, taking spatial variation of each factors. Data on Rainfall erosivity (R), Soil erodibility (K), slope length and steepness (LS), cover crops (C) and soil conservation practices (P) were calculated from laboratory analysis and also retrieved from Landsat image. Soil sample were taken to determine the K factor from the 71 different areas inside the research boundary of Rapti Municipality. Rainfall data of 21 years from 21 different nearby stations were taken from the Department of Hydrology and Meteorology, Nepal (DHM). The soil erosion was categorized into seven classes as, extremely severe (>190 t ha^{-1} $year^{-1}$), very severe (100-190 t ha^{-1} $year^{-1}$), severe (50-100 t ha^{-1} $year^{-1}$), high (10-50 t ha^{-1} $year^{-1}$), moderate (5-10 t ha^{-1} $year^{-1}$), slightly (2-5 t ha^{-1} $year^{-1}$), and very slightly (0-2 t ha^{-1} $year^{-1}$) that occurred in 0.0043 %, 0.0862 %,0.98 %,29.71 %,18.34 %,13.54 %, and 37.31 % of total area of Lothar-Pampha watershed, respectively. The total soil erosion estimated from the forest area (70.11 %) was 89537.29 t $year^{-1}$whereas from grasslands area (0.25 %) it was estimated as 81.03 t $year^{-1}$, and from the agricultural land (18.10 %) it was 1529.52 t $year^{-1}$. The maximum erosion rate (275.36 t ha^{-1} $year^{-1}$) was estimated in the forest area followed by grasslands (22.19 t ha^{-1} $year^{-1}$). Average soil erosion rate in settlement area was estimated as 0.27 t ha^{-1} year. Likewise, 8.87 % of total erosion was estimated from the agricultural land. Forested land is seemingly contributing to more soil erosion than agricultural land due to steep land topography, poor conservation program, deforestation, and unscientific forest management practices which seek for scientific forest management plan including soil conservation measures such as grass waterways, terracing, contouring, strip-cropping in Lothar-Pampha watershed of the Chure range.

Key words: ArcGIS, remote sensing, RUSLE, watershed

INTRODUCTION

Soil erosion is one of the key environmental issues of mountain ecosystems of Nepal, mainly caused by the landslide, and induced by the steep slope and the decline in forest areas (Nyssen et al., 2009; ICIMOD, 1994). 30% of the population across the country was affected by flood in 2008 along with 15% decline in winter crop production due to drought (FAO, 2016). Loss of forest cover, heavy monsoon rainfall pattern, fragile soil with low water retention capacity are the major influencing causes of soil loss in the Himalayan mountain (Rawat & Rawat, 1994). MoEST (2006) reported that water erosion has seriously affected 45.5% area of Nepal. Deforestation, overgrazing, over tilling, and other human activities have accelerated soil erosion further than the tolerance limit. In deed flood and landslide are the common natural phenomena for land degradation seen in Nepal.Deforestation, forest fire, overgrazing, poor soil conservation practices such as terracing, contouring, strip cropping, along with intensive agriculture have caused the accelerated erosion rate higher beyond the natural phenomena. Similarly, on an average 80% of the rainfall occurs only on the monsoon season. Continuous bombardments of the raindrop due to heavy monsoon rain, soil loss from the agriculture and sloping forest area seems to be beyond the normal condition.

Rivers in Nepal carry 336 million t of soil down to India every year (Thapa, 2009). Study conducted by AED (2015) reported that more than 25,000 hectares of agricultural land was damaged due to flood and landslide during the year 2015. On the other hand due to insufficient rain, paddy plantation was delayed in 61,000 hectare of land. During the year of 2016, about USD 340.3 million rupees was lost by floods from agriculture and livestock sector (FAO, 2016). As reported by Burton et al. (1989) conversion of forestland into agriculture is major cause of soil erosion in context of Chitwan district of Nepal. Using the satellite image, timeline study conducted in Lothar watershed revealed that vegetative cover the upper catchment area is in rapid degradation, and has high risk of surface runoff and flood.Primary threats to the Chitwan valley are the aggradations of the streams including the changing catchment environment of the Rapti River.The eastern Chitwan valley has experienced a series of high flood events in the past recalling from 1954 AD, 1971 AD, 1975 AD, andduring the most damaging flood event in 1993 AD with loss ofmany lives and properties. Likewise, forest cover in eastern Chitwan, the then village development committees (VDCs) of Siddi, Piple, Lothar, Korak, Kabilas, Bhandara, and Birendra nagar was 42.8,28.9,49.1,42.4,16.6, 5.1 and 19.5Sq.Km, respectively in 1976 however, in 2010 forest cover was decreased to 24.3, 15.1, 32.9, 25.8, 9.2, 2.5 and 13.9 Sq.Km respectively (Singh, 2013). DHM (2002) reported that Runoff-rainfall ratio of the Lothar River is higher (0.97) among the river originating from middle mountains. In deed as per climate change vulnerability ranking, Chitwan district lies in High vulnerability zone with vulnerability index ranging from 0.061 to 0.78 (NAPA, 2010)

Due to complex factors such as climate, land cover/use, soil, topography and human activities the estimation of soil erosion is very difficult. The combined use of the Geographic Information System (GIS), remote Sensing (RS) and erosion models are effective methods which helps in estimation of the spatial distribution of erosion. GIS helps in efficient analysis and visualization of a large amount of geo-referenced data. GIS provide summary report with maps when data are geo-referenced which further helps in decision making process (Haralick, 1980)

The major factors for soil erosion includes rainfall intensity, soil particle size, organic matters content, slope length and steepness, vegetative cover and soil conservation management practices (Renard, 1997). Apart from this, farming practices without considering the conservation measures and steep slope have greater influence for the development of soil erosion in the study area. Under this context, this study was done with the objective to test the applicability of remote sensing and GIS in Lothar-Pampha watershed so that quantitative estimation of soil loss encompassing forestland, grassland, settlement and agricultural land inside the watershed boundary would possible to measure.

MATERIAL AND METHODS

Study area

The total area of Chure range in Chitwan district is 1888.58 km^2,i.e. 85.14% of total area (URL). The study was conducted at the Chure hill of Eastern Chitwancovering 121.83 km^{2}area of the watershed area of Lothar and Pamphariverduring April to September, 2018. Elevation inside the research boundary varies from 209.93 to 1646.70 meter which increases from south to north. Slope gradient varies from low to very steep slope, ranging from 0% to 63.33%.On the basis of slope, aspects, land cover/land use types,soil samples were collected randomly from 71 different parts of watershed areas using Google Earth Pro (GEP) and ArcGIS software. The study area of Lothar- Pampha watershed was digitized, and then categorized into six classes according to land use/cover such as- agricultural land, forest land, grassland, barren land, settlement, and river (Figure 3). Forest in the study area is most commonly covered with the semi-evergreen Saal tree (*Shorearobusta*), leaf dropss in February to March and grow green in April and May. During the time of the study, the cropped area was covered by maize. The major cropping pattern in the Korak, Siddhi and Parewakot are maize-fallow-maize, rice-fallow-maize and maize-fallow-buckwheat.

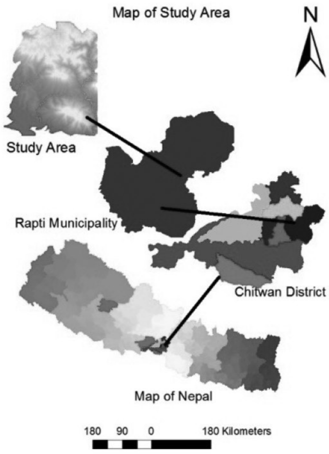

Figure 1. Map of study area

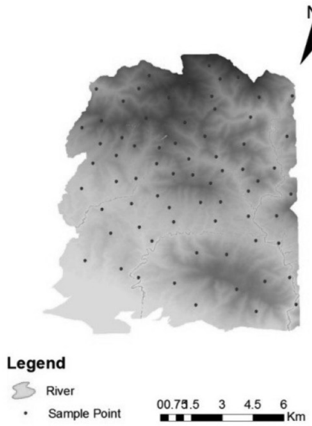

Figure 2. Soil sample pits

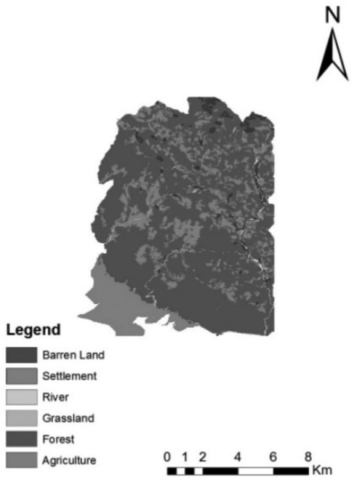

Figure 3. Land use map of the study area

Data sources

Data sources used in this research included the Digital Elevation Model (DEM), rainfall data, soil data, land use/cover, LANDSAT8 OLI 2018 images for C factor and table of support practices factor. A DEM was used to generate the LS factor. Analysis of the OM and texture of the soil sample was carried out in order to determine the K factor. Land cover/use value gives p value which is obtained from tabulated value, and by field observation. Based upon the visual estimation of soil permeability and soil structure chat in relation with soil physical behavior, colour, mottling, etc permeability, and structure code was given (Table 1).

Table 1. Visual indicators of permeability, texture, physical behaviour and colour of soil in FAO training series (Coche, 1985)

Permeability Class	Texture and profile	Physical behaviour	Colour and mottling
Very slow	Claypans, heavy clay or in presence of very slowly permeable substrum. Hardpan as distinguished from claypan	Soil cracks severely on drying with exception of hardpan or indurated layers which do not crack of fracture. The hardpan layers associated with this class often consist of highly indurated layers of sand or sand and gravel. These usually give out a ringing sound when struck with a spade	General to high degree mottling
Slow	Clay or silty clay, claypans, moderately indurated layers,silt and siltpan	Shrinkage and cracking are less pronounced than in the very slowly permeable class	Moderately strong mottling and greyish colour are indications in slit and siltpan type of structure
Moderately slow	Moderately fine textured horizons, showing a small amount of granulation or a slight dispersion of particles	Shrinkage is usually not very pronounced and cracks are neither large nor numerous.	Mottling is moderate, but the colour is brighter than for the slow permeability class
Moderate	Moderately fine textures, slightly plastic when wet and moderately hard when dry		Mottling is generally slight
Moderately rapid	Moderately fine to medium-textured soils		Occasional mottlings, colour is generally moderately bright yellow
Rapid	Medium or moderately coarse-textured soils		There are no mottlings unless water table is high. Colour is generally very bright. Organic matter content is usually moderate or low
Very rapid	Coarse-textured or gravelly soils		Colour is bright unless the water table is high.

Table 2. Analysis methods for various soil parameters

Parameters	Analysis methods
Soil texture	Hydrometer method (Gee et al., 1986).
Organic matter	Modified Walkley and Black method (Houba et al., 1989)

Data analysis

Rainfall erosivity factor (R)

Twenty-one years rainfall data were used from the 21 different closest stations on the watershed area to establish linear relationships between annual average rainfall and calculated EI_{30} values for the watershed area by using DEM. This average precipitation data was interpolated in ArcGIS using IDW tool for Clipped Lothar-Pampha watershed which further use to obtain the distribution of R factor. R factor was calculated by using the equation given by Singh et al., (1981).

$R_{factor} = 79 + 0.363R_N$

Where R_N is average annual precipitation (mm)

Table 3. Average annual precipitation (mm) of different station from 1996 to 2016

Location	District	Average annual rainfall over 21 years
BahunTiplung	Sindhuli	1849.11
Hariharpur	Sindhuli	2441.00
Nepalthok	Sindhuli	846.10
Sindhulimadi	Sindhuli	2300.46
Beluwa	Nawalparasi	2682.16
Damkauli	Nawalparasi	2446.07
Dhumkibas	Nawalparasi	2517.87
Parasi	Nawalparasi	1609.24
Semari	Nawalparasi	1935.76
Beluwa	Makawanpur	1897.20
Chisapani	Makawanpur	1995.62
Daman	Makawanpur	1480.48
Hetauda	Makawanpur	2474.75
Makawanpurgadi	Makawanpuir	2316.12
MarkhuGadi	Sindhuli	1305.74
Bharatpur	Chitwan	1590.71
Rampur Chitwan	Chitwan	2017.50
Jhawani	Chitwan	2047.10
Dhading	Dhading	1641.78
Dhunibesi	Dhading	1604.90
Rajaiya	Chitwan	1966.45

Soil erodibility factor (K)

Soil erodibility factor K represents the susceptibility of soil to erosion. The soil erodibility factor was computed using the following equation (Wischmeier& Smith, 1978; Renard et al., 1997).

$K = 27.66 \times m^{1.14} \times 10^{-8} \times (12 - a) + 0.0043 \text{ x } (b - 2) + 0.0033 \times (c - 3)$

Where:

K = Soil erodibility factor (ton. hr. MJ^{-1} mm^{-1})

m = (Silt % + Sand %) × (100 − clay %)

a = % organic matter.

b = structure code: 1) very structured or particulate, 2) fairly structured, 3) slightly structured, and 4) solid.

c= profile permeability code: 1) rapid, 2) moderated to rapid, 3) moderate, 4) moderate to slow, 5) slow, 6) very slow.

Slope length and steepness factor (LS)

The topographic factor LS reflects the influence of length and steepness of slope on soil erosion. The LS factor was calculated using the modification of the empirical equation byWischmeier and Smith, (1978), Moore and Wilson (1992), using the ArcGIS Spatial Analyst tool of the equation:

$$LS = [\text{flow accumulation} \times \text{cell size} /22.13]^{0.4} \times [(\sin(\text{slope} \times 0.01745))/0.0896]^{1.4}$$

As the slope length L increase, the total soil loss and soil erosion per unit increase; as a result of progressive accumulation of runoff in the down slope. The power value for the calculation of slope length depends upon the slope steepness percentage. As slope inclination increases, soil erosion also increases as a result of increasing the speed and erosivity of runoff.

Crop management factor (C)

To calculate C value, method proposed by De Jong et al, (1998) was used relating NDVI value, calculated from Landsat8OLI image of April 22, 2018 in cloud free day. NDVI value was used to calculate the spectral ground based data, which shows the highest correlation with the above ground biomass (Lin et al., 2002). Landsat8OLI (Operational Land Imager) image of original resolution 30m was derived from- www.glovis.usgs.gov. This image was used to calculate Normalized Difference Vegetation Index (NDVI), and subsequent C factor values.

$$NDVI = (NIR - R) / (NIR + R)$$

$$C = 0.431 - 0.805 \times NDVI$$

Conservation practice factor (P)

Conservation practice factor (P) in the RUSLE model expresses the effect of conservation practices that reduce the amount and rate of water runoff. It is the ratio of soil loss with a specific support practice on croplands to the corresponding loss with slope-parallel tillage (Wischmeier & Smith, 1978). High resolution Google earth imagery were extracted from Google Earth Pro (GEP), and then geo-referenced to digitize the land use of the watershed area to delineate agricultural land of lower altitude of study area (plain area), forest, settlements, agricultural land of high altitude hill and water body area. P factor values were assigned (table 4)

Table 4. Land cover and control practices factors

Land cover/use types	P factor
Forest Hill	1.0
Plain Forest	1.0
Grassland	1.0
Cultivate land Hill	0.8
Cultivate land Terai	0.5
River	1.0

Source: (Jung et.al., 2004). AIM Korea team, Development of soil water erosion module using GIS and RUSLE

After all, with the use of interpolation krigging tool, the values of R-factor and K-factor were calculated over the boundary of study area. LS factor value was calculated using the hydrology tool of Arc GIS. The C factor value was calculated with the use of Landsat image retrieved from USGS site. The P factor value was given based on the table (2). For the identification of various land use to give the P values, path was drawn in the high resolution google earth image to delineate the boundary of forested land, grassland, river, settlement, agriculture and barren land which was then converted to raster data set in Arc GIS.

RESULTS

Rainfall erosivity factor (R)

. The highest precipitation (1955.46 mm) was along the South East part while lowest precipitation (1856.43 mm) was along the North West part of the study area (Figure 2). The data shows highest rainfall around the area of Pampha river and lowest on the Lothar river. The R value varied with highest (788.831 MJ mm ha^{-1} hr^{-1} $Year^{-1}$) along the South East region to lowest (752.883 MJ mm ha^{-1} hr^{-1} $Year^{-1}$) North West region of study area respectively (Figure 5)

Figure 4.Spatial variation of rainfall Area **Figure 5. R-factor map of study area**

Soil erodibility factor (K)

Soil erodibility factor map of the study area was prepared based on the texture and organic matter value (Figure 8). The K value varied with highest (0.088 thr MJ^{-1} mm^{-1}) to lowest (0.070 thr MJ^{-1} mm^{-1}) respectively. Moreover, the K value was higher in forest areas and agricultural land.

Slope length and steepness factor (LS)

The LS value was varied with lowest (Zero) to highest (15.4854) in plain and sloppy area across the watershed respectively (Figure 7). Similar trend in slope degree value was obtained which ranges from 0 to 63.33 degree in plain and sloppy area of the watershed respectively (Figure 6).

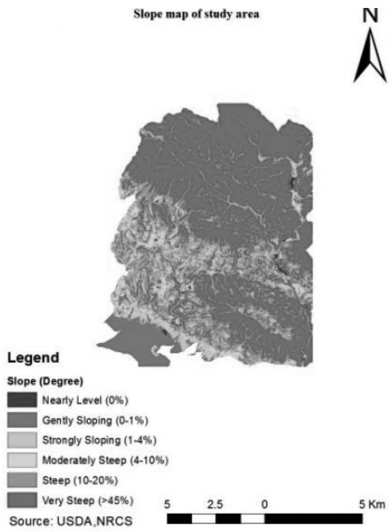

Figure 6. Slope (degree) map of study area

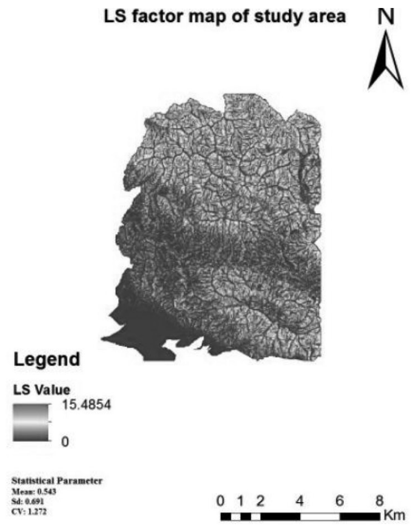

Figure 7. LS factor map of study area

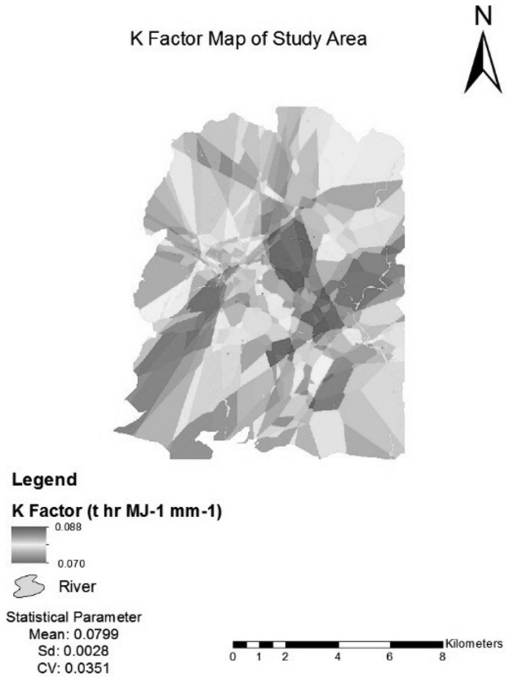

Figure 8. Spatial distribution of soil erodibility factor (K)

As shown below in the table (5), highest mean slope degree in the study area was in forest (25.60) followed by barren land (24.47), agriculture land (19.97) and grassland (15.27).

Table 5. Zonal statistics of slope with land use

Land use	Slope degree (min.)	Slope degree (max.)	Standard deviation	Mean slope degree
Grassland	0.04	49.52	11.96	15.27
Forest	0.00	63.33	12.50	25.60
River	0.00	57.58	9.75	8.73
Settlement	0.00	46.87	2.85	1.51
Barren land	0.00	59.78	17.27	24.47
Agriculture land	0.00	55.27	11.25	19.79

Cover management factor (C factor)

The C value of the study area ranged from 0.495 to 0.0089. The highest C value was obtained in the areas adjoining the river, forest, barren land, and in settlements areas while the lowest value was obtained in the area covered by the grassland and agriculture land (Figure 9; Table 6). Higher the C value, lower the crop cover. Highest C value in the forest land was obtained in the study area due to the degraded forest condition being poor vegetation/ crop cover.

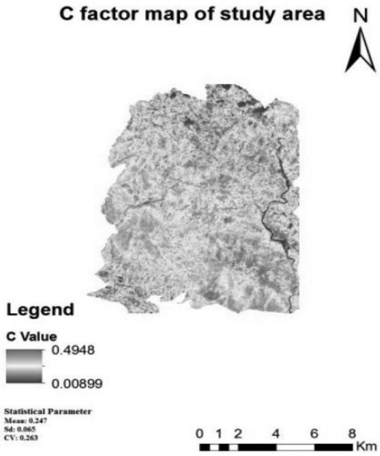

Figure 9. C factor map of study area

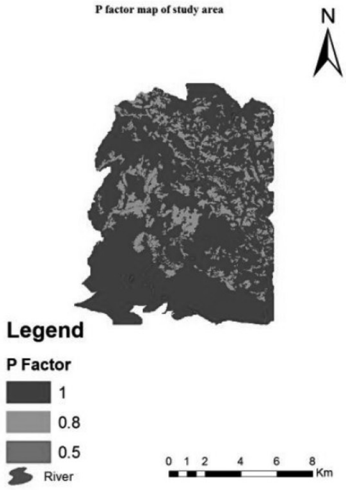

Figure 10. P factor map of study area

Table 6. Zonal statistics of C-factor with land use

Land use	C value (min.)	C value (max.)	Standard Deviation	Mean C value
Grassland	0.0200	0.4022	0.068	0.169
Forest	0.0262	0.463	0.058	0.264
River	0.0200	0.3845	0.069	0.144
Settlement	0.0089	0.4948	0.068	0.238
Barren land	0.116	0.4000	0.051	0.267
Agriculture Land	0.0269	0.4287	0.046	0.197

Conservation practice factor (P)

The P value was assigned based on the land use pattern inside the watershed boundaries. The P value varied from 0.5 to 1.0. With reference to table (4), P value 1.0 was given to the area covered by forest and dense vegetation in hill as well as in lower plain land while the lowest 0.5 was given to the grassland areas. However, intermediate P value (0.8) was given to the agricultural land of the study area (Figure 10). Higher the P value, there is lower the conservation practices so more is the erosion potential. Lower the P value there is very good human made erosion resistance facility such as contouring, terracing, strip cropping, etc. that helps to prevent erosion by reducing the rate and amount of water runoff.

Estimated soil erosion

The five factors R, K, LS, C and P were multiplied in raster calculator tool and erosion rate was estimated. The erosion rate ranged from less than 2 t ha^{-1} $year^{-1}$to 275.36 t ha^{-1} $year^{-1}$(Figure 11). The erosion rate was less than 2 t ha^{-1} $year^{-1}$ in 6196.69 (37.32 %)ha. area; 2 - 5 t ha^{-1} $year^{-1}$in 1650.16 (13.54 %) ha. area; 5 – 10 t ha^{-1} $year^{-1}$ in 2235.4 (18.35 %) ha. area; 10 – 50 t ha^{-1} $year^{-1}$ in 3620.32 (29.72 %) ha. area; 50 – 100 t ha^{-1} $year^{-1}$ in 119.7 (0.98 %) ha. area; 100 - 190 t ha^{-1} $year^{-1}$ in 10.5 (0.086 %) ha. area, and 190 – 275.35 t ha^{-1} $year^{-1}$ in 0.52 (0.0043 %) ha. area of total area of Lothar-Pampha watershed. The total erosion amount from total forest area (8541.96 ha) was 89537.29 t $year^{-1}$, from agricultural land (2205.6 ha) it was 8901.94 t yr^{-1}, and from grassland (30.32 ha), it was 81.03 t $year^{-1}$ (Table 7). The rate of soil erosion was 89.23 % in the forest area, and 8.87 % in the agricultural land. Likewise, it was 1.52 % in the barren land, and 0.29% in the settlement areas. The rate of soil erosion was 0.08% in the grassland area inside the watershed boundary.The average soil erosion rate from grassland area was estimated

2.67 t ha^{-1} year^{-1} whereas it was estimated as 10.48 t ha^{-1} year^{-1} from forest area; 0.27 t ha^{-1} year^{-1} from settlement; 7.50 t ha^{-1} year^{-1} from barren land, and 4.04 t ha^{-1} year^{-1} from agricultural land (Table 7).

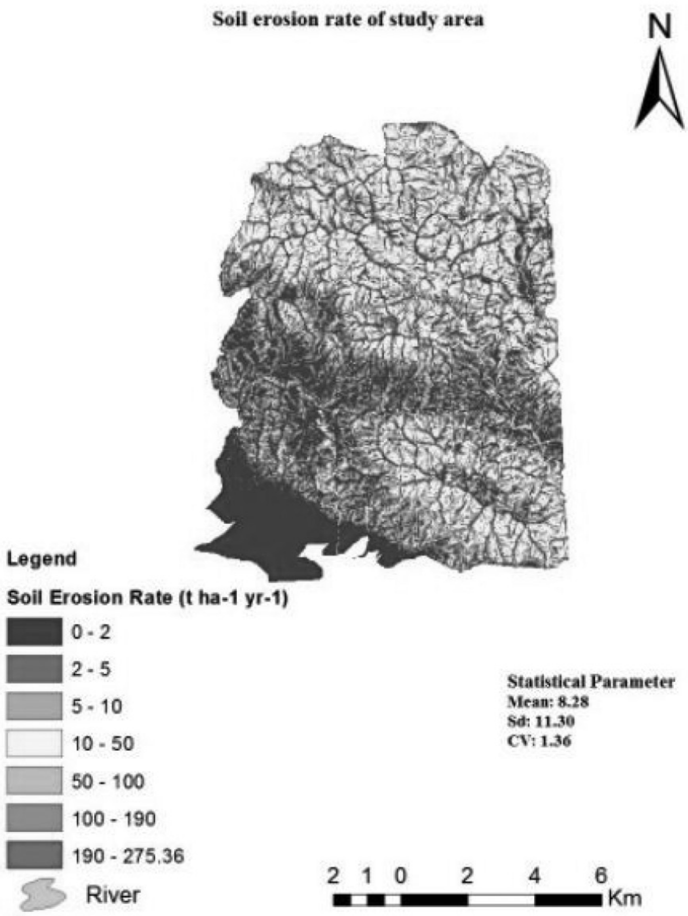

Table 7. Soil erosion level/amount according to land use, or land cover

Class	Maximum erosion rate (t ha^{-1} year^{-1})	Average erosion rate (t ha^{-1} year^{-1})	Area(ha)	Total erosion (t year^{-1})	Erosion (%)
Grassland	22.19	2.67	30.32	81.03	0.08
Forest	275.36	10.48	8541.96	89537.29	89.23
Settlement	60.26	0.27	1073.96	295.30	0.29
Barren land	124.88	7.50	204.00	1529.52	1.52
Agricultural land	125.09	4.04	2205.60	8901.94	8.87
River	-	-	127.28	-	-

DISCUSSION

The average annual soil loss rate was grouped into different classes from very slight, i.e. less than 2.0 t ha^{-1} year^{-1}, to extremely severe areas, with > 190 t ha^{-1} year^{-1}. The estimated erosion was less than 2 t ha^{-1} year^{-1}forthe most of the lower slope regions of the study area which is within tolerable limit. Various findings estimated that acceptable soil loss tolerances range from 2.5-12 t ha^{-1}year^{-1} (Wijesekera, & Samarakoon, 2001). 2.5-10 t ha^{-1}year^{-1} of soil loss tolerable limit (SLTL) has been estimated by Sudhishri et al., (2015). In the study area, less than 2 t ha^{-1} year^{-1}of soil erosion was estimated in 37.32 % area; 2 – 10 t ha^{-1} year^{-1} soil erosion was estimated in 31.89 % area; 10 – 50 t ha^{-1} year^{-1} soil erosion in 29.72 % area, and is categorized to high erosion risk zone. Likewise, 50 - 190t ha^{-1} yr^{-1} erosion was estimated in 1.066 % area of land and is categorized into severe to very severe erosion risk zone whereas greater than 190 t ha^{-1} year^{-1} soil erosion was estimated in 0.52 % area, and is categorized as extremely severe erosion risk zone of Lothar-Pampha watershed. The highest amount of soil erosion was estimated in forest area (70.11 %) i.e. 89537.29 t year^{-1} (89.23 %) followed by 8901.94 t year^{-1} (8.87 %) in agricultural land(18.10%). Lowest soil erosion was estimated in the grassland area (0.25 %), i.e. 81.03 t year^{-1}(0.08 %).Forest covered 70.11 % in the research boundary area. About 89.23% of erosion was estimated in forests. Most of it is categorized into severe to very severe erosion risk zone. Yadav et al. (2005) reported that though Shivalik hill is under forest cover experience, higher soil erosion rate exist due to the steep slope category of the land. Study conducted in Shivalik hill of Haridwar, India shows higher average soil loss in open forest (134.9 t ha^{-} year^{-}) followed by moderately dense forest (106.47 t ha^{-1} year^{-1}). However, average soil loss was minimum in forest plantation (3.15 t ha^{-1} year^{-1}). The findings of the research also confirmed that LS factor was the most dominant in contribution of soil erosion in the Shivalik hills (Kumar, 2013).

The research on soil loss estimation in the mountainous sub-watershed in Kerala, India revealed that the mean soil erosion loss was higher in the deciduous forest (11.65 t ha^{-1} year^{-1}) followed by degraded plantation (10.09 t ha^{-1} year^{-1}) (Prasannakumar et al., 2012). Also, soil erosion risk assessed in Nuwakot district, Nepal also have similar results where the lowest soil losses (< 1 t ha^{-1} year^{-1}) was recorded in rice field and under the dense forest whereas soil losses vared from 1-9 t ha^{-1} year^{-1} (in degraded forest areas) to 8 t ha^{-1} year^{-1} (in the grazing land) (Shrestha, 1997). Patric, (1976) in his paper soil erosion in the eastern forest reported that irresponsible harvest of timber from the forest land could increase the erosion to an unacceptable level.

It is to note that, the higher erosion rate was estimated in the area of higher degree of slope and poor cover crop management. As shown in table (5) and (6), forest areas are in higher mean slope degree (25.6) and also have poor vegetation cover, showing greater C factor value. Furthermore, deforestation, forest fire and encroachment of the community forest are also a serious issue for the higher erosion rate from the forested land among other land use. Settlement area have lower erosion rate being nearly plain area. Thus soil erosion risk highly co-related with LS factor and C factor. Such area needs immediate attention for its conservation.

CONCLUSION

A soil erosion model at Lothar-Pampha watershed with the integration of RUSLE and GIS tools has been developed so as to estimate the annual soil loss. The different components of RUSLE were modelled using various formulae to assess the soil erosion in different land use of study area. The erosion map prepared was then categorised into different erosion risk classes. According to this model, approximately 69.21% of area has low erosion risk and 30.79 % area is under the erosion risk which requires soil conservation practices immediately.

High to extremely severe erosion was found to be distributed mainly within the area of steep slope gradient and degraded forest class. The results indicated that areas with degraded forests have a high erosion risk along with the integration of steep gradient and poor soil physical condition, i.e. fragile hill. It is therefore, in the areas having high LS factor and degraded forest- need immediate conservation and management practices. An additional study regarding the validation of the soil erosion from the field to estimate the approximate data is also necessary.

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