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Research Article

Soil Erosion Spatial Prediction Using RUSLE and Geospatial Technologies in Gwang Khola Watershed of the Chure Region, Nepal

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ABSTRACT

Soil loss due to human activities as well as natural processes has been a major issue in the Chure region in Nepal. Significant tons of soil loss every year affects farmer's agricultural output and productivity. In this regard, for effective management of the sediments, soil loss estimation is extremely important. This research was meant to evaluate soil losses using Revised Universal Soil Loss Equation (RUSLE) model. The findings revealed that an estimated 547992.9 tons of soil were lost from the Gwang Khola watershed and the total annual erosion of soil of the study region amounts to 5.46 tons. In the gentle slope area, the marginal soil loss was noticed while in the steep slope the high loss was observed. In Gwang Khola watershed, 84.88% of its area is under negligible risk class, 13.13% in moderately risk, and only 1.99% area is under extremely high-risk class. The soil loss rate varies upon Land Use and Land Cover (LULC) and all land use types contain all categories of risk, albeit in different proportions. The results are useful for basin sediment control and associated policies.

Keywords: Revised universal soil loss equation; Soil loss; Land cover; Soil sediments

INTRODUCTION

Soil loss due to anthropogenic and non-anthropogenic activities is a global phenomenon that contributes to soil degradation. It plays a key role in the nutrients loss of topsoil and its effects impacts the natural resources and agricultural production. Soil erosion especially occurs in high slopes. It detaches the organic as well as inorganic soil particles from one place to another by wind and water. It is one of the important issues on the earth surface and is rising worldwide. Several investigations have found that 60% of the world's soil is deemed to be degraded. Every year 35.9 Pg of soil in the world is predicted to be depleted. Chaplot et al. from Laos reports that the gully erosion rates of sloping cropland system of northern Laos varied from 0.1 to 2.4 t. Similarly, a study conducted in Bangladesh showed that the soil loss rate of 30 t from the upland portion of a catchment was estimated to be only the regional average soil loss due to shifting cultivation. These facts show that the rates of soil loss vary significantly depending on the type of coverage of land use and topographical variation. In the high mountains of Nepal, the rate of erosion of soil is increasing. The topsoil is washed off from Nepal to Bay of Bengal every year 240 million cubic meters. Soil loss estimation in the Koshi Basin of Nepal has been studied by using RUSLE for assessment of priority areas for conservation. Likewise, RUSLE has been used effectively for estimating soil losses and for assessing the trend of spatial erosion in the watersheds of Mahesh Khola, the Basin of Bagmati and Kulekhani [1].

The Chure region covers four developing countries: Pakistan, India, Nepal, and Bhutan. The study area is case studies of the Chure region in Nepal, located between the Tarai plain and the middle of mountain regions, it covers 37 districts in Nepal. In the Chure region, intense monsoon-driven rainfall regime, higher local relief, and weak geological formation have led to the high amount of soil erosion. It has a distinct geographical and biophysical specificity lying on the foothill of the Himalaya. In comparison to other mountains, the Chure region is the youngest mountain in the world and it is not sustaining and also suffering from various problems of mass erosion, landslides, and other environmental externalities that make the region vulnerable. To assess the current situation is necessary for all development activities and it is also hard to assess the impacts of

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various soil factors under different cropping systems is a big challenge.

It faces the accelerated resource depletion, like, deforestation, due to natural as well as human induced factors in the region. Nowadays people are migrating here from the hilly region for livelihood opportunities and the Chure ecosystem as well as physical structure have been retreating. Consequently, the ecological, geographical, and biophysical conditions of the Chure region have rapidly degraded since the last 32 years. Soil erosion of the Chure region is not only the problem of this region, but also induced effects in the Tarai region, which includes the crop production storages of Nepal and downstream of the Chure region. In the Chure region, the land is affected by the flood, sifting river channels, sheet, rill, and gully erosion. It has faced a series of land degradation issues, however, not enough research activities have been carried out related to soil erosion. In the Chure, 1.7 mm topsoil is lost each year due to soil erosion. Land degradation is a critical problem of the Chure region. This type of study is better in small watersheds; it has been successfully done previously in Phewa watershedin Kaski and Kulekhani watershed. To predict the average annual soil erosion in the Gwang Khola watershed, used the RUSLE method [2].

This study was conducted based on the hypothesis that the erosion rate differs in LULC. Conversion of forest to cropland can degrade the soil structure and should increase soil erosion. Consequently, this study was carried out to assess the soil erosion at a watershed scale which is located within the Chure region. The specific goal of the study was to predict the soil loss based on LULC at the watershed using the geospatial technique and RUSLE model. Since the evaluation of soil loss is crucial for soil conservation. This study provides a baseline for the small watershed of the Chure region and provides data and also contributes to filling a shortage in data.

MATERIALS AND METHODS

Gwang Khola watershed located in the north eastern part of the Sindhuli district, Bagmati province, was selected as the study area. Geographically, it is located between 27° 13' to 27° 29' N and 85° 82' to 86° 13' E. The watershed covers 94 km area and ranges from 453 to 1651 masl. The Kamala River, originating from the Mahabharat region and flowing from the east to the west is the main river in this watershed. It is a perennial river where different tributaries including the Gaumati Khola and Phiting Khola flowing from the north to the south enters in different locations of the watershed [3].

This study area lies in the subtropical region and tropical deciduous forest found in this watershed. The Sal tree (Shorea robusta) dominates the forest. The lower part of the study area, is the valley type landscape and a built up area with a dense population. Similarly, most of the developmental activities prevails in this low land area. Sindhuli Madhi, Dhura Bazaar, Majhitar, Bhadrakali, Sindhuli Gadhi, BP Highway, Kamalamai Temple, Siddheshwor, and Jalakanya lie on the Gwang Khola region. They are old important settlements for economic activities for over 39,413 population and 9,304 households. The Gwang Khola watershed is humid with tropical climatic conditions, where the mean winter temperatures settle between 15° C to 22° C while the summer temperatures reach up to 36° C. Sindhuli is the second-highest rainy area of Nepal. The average annual rainfall of 1,963 mm, as measured at Sindhuli Gadhi meteorological station.

Data source and analysis

In this study, 30 m resolution NASA's Shuttle Radar Topography Mission (SRTM), Landsat Enhanced Thematic Mapper (ETM+), Thematic Mapper (TM) and Operational Land Imager (OLI) imagery were obtained from the US geological survey. 30 m SRTM, Digital Elevation Model (DEM) was used in this study. ArcGIS 10.3 (ESRI, USA) was used to generate slope, flow accumulation, and stream flow channels using the Spatial Analyst Tool. Rainfall data for 30 years used in this study were collected from the Department of Hydrology and Meteorology, Government of Nepal. The soil data were obtained from the Department of Survey, the Government of Nepal. Land use, land cover map was prepared from the high-resolution satellite image. ERDAS imagine for image processing and classification, and GIS analysis tool was used for this study. ERDAS Imagine was used for geo-reference and sub-setting of the image. Image extraction, rectification, restoration, atmospheric correction, classification, and radiometric correction were used for image analysis. In this study Landsat imageries of three bands of Landsat TM, and bands of Landsat-8 were used in image enhancement to identify changes in LULC features. All original images were exported to format in ERDAS Imagine 2015 software. The layer stack function was used for this work. All images were georeferenced into the World Geodetic System (WGS) 1984 zone 45 N.

Revised Universal Soil Loss Equation (RUSLE) model was used in this study for loss estimation. The (RUSLE) is a computerized version of the Universal Soil Loss Equation USLE. It incorporates improvements in many of the factor estimates including a new procedure to calculate cover factor, new algorithms to reflect rill to inter-rill erosion in slope length and steepness factors. Also, the climatic factors based on an extended database of rainfall-runoff in the United. Further-enhanced Windows version of the software, known as RUSLE2 is recently released for guiding conservation planning, inventory erosion rates and estimated sediment delivery. RUSLE2 supported by extensive databases maintained by the United States Department of Agriculture (USDA)-Natural Resources Conservation Service [4].

Soil erosion modeling is able to consider many of the complex interactions that influence rates of erosion by simulating erosion processes in a watershed. Several empirical and physically based erosion models, Revised USLE (RUSLE) using R*K*LS*C*P were used to estimate the soil loss in better options for soil erosion analysis. RUSLE model was used to predict the mean annual soil loss at the Gwang Khola watershed. The erosion model of the following factors were used to develop this equation: $A=R*K*LS*C*P$

where,

A=Annual average soil loss (t ha-1 yr -1),

R=Rainfall Erosivity factor (MJ mm ha-1 h -1 yr-1),

K=Soil Erodibility factor (t ha h ha-1 MJ-1 mm-1),

C=Cover-Management factor (dimensionless),

LS=Slope Length and Slope Steepness factor (dimensionless),

P=Support practices factor (dimensionless)

The equation was developed not only to take several erosion factors into considerations but also the effect of soil conservation practices. The RUSLE model applies climatic as well as soil data. Topographic variation and present land use pattern are important factors in the RUSLE model. They affect rill and inter-rill soil erosion caused by raindrop impacts.

RESULTS AND DISCUSSION

Assessment of soil loss in the study area

Seven major types of land use land cover were observed in the watershed. Cultivated land is found dominant in the middle part of study area and rest of all is covered by forest. In this watershed, 64.71% of the land was covered by forest and 29.19% by cultivated land. The built-up area represents nearly 4% of the study area, while the water body is 1.75% and barren land is 0.01%. Increasing soil loss in the Chure region is serious cause of land degradation and it is creating big challenge for nations. Soil erosion in the Chure region has multiple effects. Firstly it degraded the land in Chure region, increasing bed level of river in Tarai plains area and also contributed to increasing the flood also. To control the soil loss in the Chure region [5].

Rainfall runoff erosivity factor (R)

Rainfall is the driving force of erosion. It has a direct impact on detachment, breakdown, and transport of eroded soil particles via. Runoff. The R factor calculates kinetic energy and intensity of rainfall on sheet and rill erosion. EI30 is the most accepted and usable source for calculating the R factor. In this study, 30 years monthly rainfall data used from the different 10 meteorological stations around the study area. $R=587.8-1.219*P+0.005105*P$ when $P>850$ mm are normally accepted and most of the researchers who are working in the same climatic zone used this equation for the mountainous tropical and the Siwalic climate and used this formula for calculating R factor in this study. The spatial distribution of R factor showed that the R factor value ranges from 920 to 1445 MJ mm with the highest value occurred in the norther part of the region and the lowest in the southern part of study area. The researcher found good relation between R factor distribution and annual rainfall distribution in the study area and there is also similar relation between rainfall intensity and amount with soil loss has been reported.

Soil erodibility factor (K)

The soil erodibility factor K, as measured under the standard unit plot condition, represents both soil susceptibility to erosion and the amount and rate of runoff. Therefore, the best estimation of soil erodibility is to perform a direct measurement on field plots. K value is determinant by dominant texture. Soil erodibility is an important factor for calculating and estimating soil erosion, which is a measure of soil resistance capacity against the rainfall energy and runoff i.e. the reciprocal of soil opposition to erosion. In the Gwang Khola watershed, there are three types of dominant textures. Most of the area is covered by loamy skeletal while only one polygon is dominated by sandy soil. Soil erodibility is highly concerned with soil mechanical composition and organic matter content. The K factor of this study area starts from 0.35 to 0.41. The predicted K values ranged from 0.35 to 0.41 T ha MJ−1 mm−1 with the highest value occurred in the northern and southern part and the lowest in the middle part of the study area. The northern and southern part has a high K value, that was observed in the Gwang Khola watershed, are classified high. This area of the watershed is much susceptible to erosion because of their higher values of K factor. In comparison to this location, the middle part of the study area is less susceptible to erosion. There is a proportional relationship between the K factor and land use type. In this study area, the K factor is high in the south and north part, these are the cropland area and the K factor is less in the middle part, which is forest and urban area. Soil Organic Matter (SOM) content is usually larger in the forest and well manages in the urban area. In the cropland, there is fine soil and people are practice traditional cropping farming [6].

Slope length and slope steepness factor (LS)

The topography is the main and leading cause of soil loss and LS factors help us to calculate its value. It describes the effects of topographic variation on soil erosion. The combined slope length and slope angle (LS-factor) has the greatest and noticeable influence on soil loss. There are different roles of L and S factors. The S-factor calculates the effect of slope steepness, and the L-factor calculates the impact of slope length in the RUSLE model.

The landscape of the Gwang Khola watershed has very diverse geomorphology. The spatial distribution of the LS factor values ranged from 0 to 20.467 across the study area. Some northeast parts of the study area found high value and the middle part of the study area found a low-value range. The southwest part has also a high-value range of LS factor. Most of the study area has low and moderate LS factor values. Only limited areas (less than 15%) mainly located in the northeast and south parts had high values of LS factor. Slope length and steepness contribute to soil loss. The LS factor and Slope length and steepness have a positive relationship. Increase in Slope length and steepness, soil loss automatically increases in this spatial phenomenon. This study found there is an increasing trend in soil erosion with LS-factor [7].

Cover management factor (C)

The cover management factor, C depends upon the topography and people's awareness. It plays a leading role in controlling soil erosion on farmland. The C-factor depends upon the land cover and it is also related to crops and crop management practices, affect soil loss to vary from that of the fallow areas. The bare plot (no vegetation) with till up and down the slope is taken as a reference condition. In this model, put the C value 0 to 1: when the land has no coverage and we put the C valve higher: when there is more coverage of a crop assigned lower value. For the built-up, and the cultivation areas C factors were assigned 0.13 and 0.21 respective. In this study area, there is no noticeable vulnerability to soil erosion due to the high C factor value. Due to the forest cover, most of the area is less vulnerable. The zero and near-zero values of C for most of the parts indicate very well-protected soils which are mainly corresponded to the grassland and forest [8].

Support practice factor (P)

The P-factor reflects the impact of support practices on the average annual erosion rate. Derived the P-values either from image classifications using high resolutions data or from previous research and researcher knowledge. For image classification, need high resolutions images or datasets. In our research purpose, cannot get high resolutions remote sensing datasets. Therefore, assigned 0.2 to 1 P value according to land use type for this research. In the RUSLE model, support practice factor (P) is define as the proportion of soil loss with certain support practices to the corresponding soil loss with farmland or a specific place. The supporting mechanical practices are included in effects of contouring, strip cropping, or terracing. The support practice factor (P) was calculated according to the cultivation method and slope was found to range from 0.55 to 1 in this study area [9].

Soil losses according to land use land cover (LULC)

Satellite images were pre-processing before the detection of changes, it is a primary procedure and has a unique aim of building a more direct association between the biophysical phenomena on the ground and the acquired data. Different grid-based layers are associated with the RUSLE factors. They are integrated with ArcGIS to produce the final soil erosion map in the study area. The spatial distribution of soil erosion in the Gwang Khola watershed. The Northeast part of the study area is a more susceptible in this study area. The spatial patterns of soil erosion are similar in the middle part and west part of the study area. The northern part of the study area tended to have the highest and the western parts tended to have the lowest soil erosion. The results showed an estimated 547992.9 ton soil annually is lost from the watershed with average annual soil erosion of 5.46 t ha-1. Maximum parts of the study area experienced a low risk of soil erosion and very few parts have suffered from a high risk of erosion. The soil loss rate varied upon LULC and all land use types contained all categories of risk, albeit in different proportions. Out of the 9032 ha of the total land, around 73% represents a low risk, 24% moderate risk, and around 3% of the high risk. Our data indicated that erosion from most of the land used land cover except cultivation, barren, and rock and generally varied low erosion. In contrast to this, the erosion of the cultivation, barren, and rock land was much higher. This data showed that there was a strong relationship between land cover and soil erosion.

The study found the maximum erosion risk in the northeast parts could be attributed to the higher values of R, K, LS, C, and P factors in these areas. The positive relationship found in the study between RUSLE factors and soil loss has been reported in several studies. The land-use types included forest area, agricultural land, built up, grassland, water bodies, rock, and barren land. The forest was a higher and dominant land use land cover. The agricultural land covers the second-highest area after the forest. The barren land is only 0.08% cover out of the study area. The soil loss rate varies upon LULC and all land use types contain all categories of risk, albeit in different proportions. Of the total 9032 ha of total land, around 73% represented a low risk, 24% moderate risk, and only around 3% of the high risk (Figure 1) (Table 1) [10].

Level / LULC	Water bodies	Built up	Rock	Forest	Barren land	Grass land	Cultivation land	Total
Very low	173.16	363.87	7.02	4477.5	4.32	32.4	1556.01	6614.28
Low			0.09	782.37	1.17	0.09	269.82	1053.54
Moderate			2.25	317.79	1.44	0.09	863.55	1185.12
High			4.59	10.8	0.09		120.33	135.81
Very high			2.34	2.79			38.97	44.1
Total	173.16	363.87	16.29	5591.25	7.02	32.58	2848.68	9032.85

Table 1: Risk level of LULC as observed in the Gwang Khola watershed, 2020.

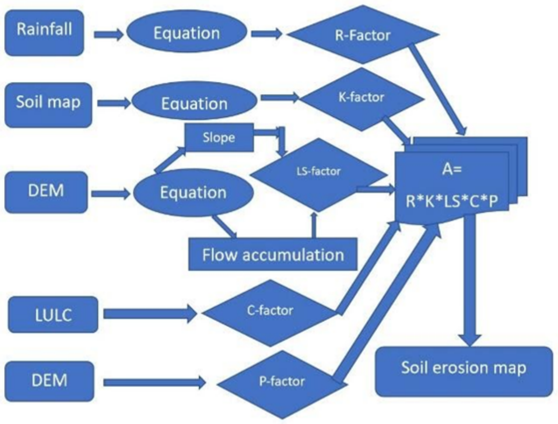

Figure 1: the methodological framework of implementing the RUSLE.

The high-risk characteristics of these areas were attributed both to their importance in providing ecosystem services and to their locations at higher elevations and steep slopes, especially for the forest reserves. Out of total cultivation land i.e. 2849 ha area, of which 31.54% was covered in the study area, where more than 50% area was under very low risk for soil erosion. The forest was widely distributed in the watershed, but only a few areas around

13.59 ha of its area was in high-risk zones, mostly around the forest as well as in the buffer zones of the river. Additionally, one-fourth of the cultivated farmlands were at high risk mainly along the road network and river buffer zones (Table 2) [11].

Land use land cover	Area (Ha)	Area (%)	Soil Loss(t/h/yr)
Water bodies	173.16	1.92	10505.04
Built up	363.87	4.03	22074.78
Rock	16.29	0.18	988.26
Forest	5591.25	61.89	339202.5
Barren land	7.02	0.08	425.88
Grass land	32.58	0.36	1976.52
Cultivation land	2848.68	31.54	172819.9
Total	9032.85	100	547992.9

Table 2: Soil loss estimation according to land use land cover in the Gwang Khola watershed, 2020.

Soil loss in the Gwang Khola watershed was estimated by land use and cover types to understand its role in determining erosion rate. The soil loss by land use and land cover types and its descriptive statistics. Soil erosion rates were found highly correlated with the increasing exposure of land surface. It was supported by the fact that agriculture land-sharing 31.54% of total land use land cover in the watershed, was contributing almost 75% of the total soil loss in the watershed. Similarly, barren land, rock, and river sand areas were also considered as the most influencing factor of soil erosion that contributed to higher levels of soil erosion.

These three land-use types were also characterized as land-use types of maximum soil losses. The Likhu Khola and The Gwang Khola watershed lie in the same geographical phenomena. Therefore, we compared with experimentally measured rates of the Likhu Khola watershed having similar mountainous characteristics and these rates were also the same. The modeled annual erosion rate in cultivated land confirmed the experimentally measured rate of rainfed terraces but it was quite different in contrast to the erosion rate for cultivation estimated by using the same model, RUSLE in Ratanchura VDC of similar biophysical condition. In the case of forest land, the modeled rate was slightly less than the experimental value but quite different from that of Ratanchura VDC of same land use whereas, in the case of grassland and barren land, it was significantly less in comparison to the experimental value [12].

Soil losses according to topographic variation

The Gwang Khola watershed is small with dynamic physiographic characters. In this watershed, the slope ranges from 0° to 62°. There are lowland valleys, and also high levels of the mountain. The slope gradient was divided into five classes, 0°–10°, 10°–620°, 20°–30°, 30°–40°, and>40°, respectively which represented flat, slowly, oblique, steep and very steep slope conditions respectively. The erosion was low on a gentle slope and high in the steep slope area. The erosion rate was high on steep and very steep slope regions of this watershed. The erosion found to be increasing with slope. This study revealed that soil erosion was bound up with the sloppy area and the main erosion degree increased with the slope gradient increasing under all types of land. This study speculated that soil erosion increased rapidly with increasing slope gradient but it was not related to slope only as affected by numerous factors, landforms, soil types (Table 3) [13].

Erosion level/ Slope	0°-10°	10°-20°	20°-30°	30°-40°	>40°	Total (Ha)
Very low	1486.44	1672.29	2052.72	1156.32	244.89	6612.66
Low	78.39	220.5	270.54	324.36	159.66	1053.45
Moderate	86.85	236.79	435.96	319.68	105.84	1185.12
High	9.63	24.84	37.08	43.74	20.52	135.81
Very high	3.51	13.5	14.76	9.18	3.15	44.1
Total (Ha)	1664.82	2167.92	2811.06	1853.28	534.06	9031.14

Table 3: Erosion level based on slope in the Gwang Khola watershed, 2020.

At the Gwang Khola watershed, there were different types of landforms. There was correlation between slope gradient and soil erosion. In the steep sloppy area, there were very high soil erosion levels and valleys, there was less soil erosion. It had a dense urban area and limited cultivation land, most of the area was flat land (0°–10°), which covered 4203.72 ha land. In this watershed, there was a high mountain on the eastern side and they were up to 1500 m high. But this type of landform was small and limited with steep sloppy and high levels of soil erosion.

In the study area, there were different types of land use and all these contained the categories of risk, but they had different proportions. Most of the watershed covered by forest. Of the total 9032 ha of forest, 5259.87 ha were at low risk, 317.79 ha at moderate risk, and 6.93 ha at high risk. Cultivation land occupies 2848.68 ha, of which 1825.56 ha is at low risk, 863.55 ha land at moderate risk and 159.3 ha land are in high risk. There we noticed that cultivation land was at a high risk for soil erosion. Around 36% of cultivation land was in the risk zone. The barren land was only 0.08% of the total land of the Gwang Khola watershed and it is in high-level risk for soil erosion. Additionally, more than one-fourth of the cultivated farm lands were at high risk mainly along the road network and river buffer zones.

The soil erosion level also closely correlated with altitude: high and very high levels of soil erosion were mostly distributed in areas with an elevation above 1250 m. The extreme level of soil erosion was distributed entirely above the elevation of 1250 m, whereas the moderate and low levels of soil erosion were mostly distributed in the lower elevation range of 950 m to 1250 m and 650 to 950 m. It is interesting to note that elevation below 650 m has very low soil erosion. The high soil loss rates under rainfed agriculture are directly related to the sloping nature of the terraces. Farmers would likely to invest more in growing a cash crop like rice if the water supply and temperature conditions are favorable. Rainfed crops are usually grown in a relatively drier environment, in soils with lower organic matter content and reduced structural stability.

In this study area, most of the area was under a very low level of soil erosion. 4203.72 ha land was under 650 m and covered around 46% area of the taken area. The study explored the massive diversity of erosion rates even within the narrow span of a landscape in the Chure range of the Himalayan foothills. Massive diversity of erosion rates even within the narrow span of a landscape in the Chure range of the Himalayan foothills [14].

Rainfall erosivity was calculated by the prescribed method for meteorological stations in the study area with a continuous record of annual rainfall ranging from 784.50 to 2401.72 mm. A relation was established between the calculated R-values and the more readily available type of precipitation data. The mean R-factor of the study area was 554.16 MJ mm. The natural advantages of the Gwang Khola watershed, fertile soil, and a favorable climate facilitate the development of agriculture. Land use for agriculture in the form of cropland is substantial in Kamalamai Municipality, Sindhuli where the total agricultural area covers about 2,993 hectares. While field crops like wheat, rice, and maize are grown extensively and occupy a large percentage of the total cropland.

A soil loss of annually 52.54 t is considered in the Chure region of the same study area (The Kulekhani reservoir catchment, Nepal). The mean potential soil erosion rate for Nepal is estimated to be 25 t, with an annual loss of 369 mt. In another study conducted in Nepal. About the soil erosion by physiographic region, it was found that, middle mountains have the maximum mean annual erosion with 38.39 t. But the high mountains (32.46 t) with Chure having the low erosion potential (6.9 t) have less soil erosion. As compared to this threshold, the average yearly soil erosion of the study area was 5.46 t, which was quite low. A total of 547992.9-ton soil, using RUSLE is estimated to be lost annually from the watershed. Dense vegetation cover, well cover management practice and urban area were the reasons for low soil erosion in this study area. In erosive areas where vegetation was less, it was a wise recommendation to raise and maintain the protective forest belts [15].

The Chure region has a high intensity of soil erosion processes. Among the natural factors mentioned above, topography has great importance. Soil erosion rate is quite low on gentle slopes or flats, while the opposite is on terrain with high slopes. In this study area, the soil loss rate was high on a steep slope and high mountain area. This study showed that nearly 15% of the area needs conservation attention to reduce the risk of soil erosion. We analyzed our study based on land use land cover and the mean erosion rate were higher in barren lands, followed by agricultural lands, grasslands, and forests. The highest erosion rates were observed in steep slopes>20%. In a study area, which lacked continuous and long-term monitoring of erosion hazards, RUSLE erosion modeling to develop a detailed spatial assessment of erosion hazards using remotely sensed data and automated analysis of land cover and slope gradient could be a good alternative (Figure 2) (Table 4) [16].

S. No.	Soil loss class (t/ha/yr)	Erosion Intensity type
1	0-5	Very less erosion
2	5-10	less erosion
3	10-50	Moderately erosion
4	50-100	High erosion
5	>100	Very high erosion

Table 4: Soil erosion type.

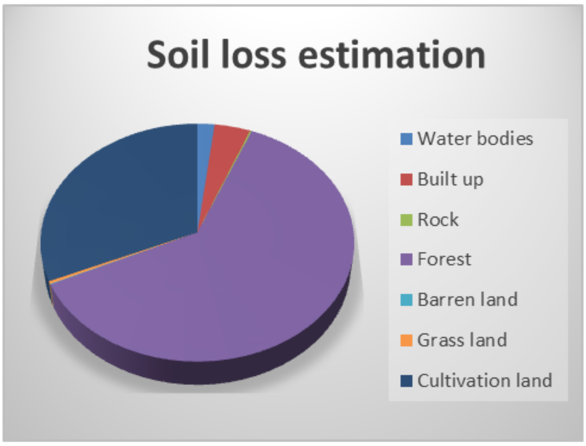

Figure 2: Soil loss estimation.

Vast deforestation and indiscriminate land clearing in the Chure range for agricultural, urbanization, and infrastructure development have resulted in widespread soil erosions over the land surface. In this study area, soil erosion was a big problem and was still not under control. The slowly increasing soil erosion is a problematic issue for this landscape. We predicted the soil erosion for the Gwang Khola watershed The RUSLE model is a better option for calculation and estimation of soil loss in the watershed level. It is high accuracy and predictable with geospatial tools and techniques. It has been shown to be an efficient and usable method for estimating soil losses in the watersheds level.

The result showed that the study area had a high slope, therefore the erosion loss was obtained at a high rate compared to other research. In a study done in the Mekong river basin, a predicted average annual soil loss had been classified into six erosion intensity classes to assess erosion potential severity. We also adopted the same classes in this study but the class values were considered according to the result. Negligible soil erosion was found at the lower steep area and the high soil loss at the steep slope area. According to the study, it was observed that 84.88% area was under negligible risk class, 13.13% or area is in moderately risk class and only 1.99% area is under extremely high-risk class (Table 5) [17].

Erosion Level	Area (Ha)	Soil erosion(t/h/y)	Percentage
Very low	6614.28	401266.3	73.22
Low	1053.54	63914.76	11.66
Moderate	1185.12	71897.28	13.13
High	135.81	8239.14	1.5
Very high	44.1	2675.4	0.49
Total	9032.85	547992.9	100

Table 5: Erosion level on study area at the Gwang Khola watershed, 2020.

The spatial distribution of soil erosion of the Gwang Khola watershed was calculated, using the level of calculated soil erosion at each grid number multiplied by the grid area. An area of 9032 ha, accounting for 0.49% of the total Gwang Khola basin, belongs to the high level of risk for soil erosion. Approximately 1185 ha (13.12%) and 135.31 ha (1.5%) belong to moderately high soil erosion and high level of soil erosion respectively while nearly 2% of the total basin area was highly risky for soil erosion. The low and moderate zones accounted for 24.78% (2,238 ha) and 73.22% (6,614 ha) respectively. A high level of soil erosion occurs mostly in the north and northwest, but appears in patches in the south as well, whereas the level of moderate risk is concentrated in the southern parts of the watershed area. In this watershed lower levels of risk were scattered and a high level of risk was concerned with a high mountain of the watershed [18].

CONCLUSION

This study estimated a loss of soil from soil erosion and explored spatial distribution of soil erosion in detail in the Gwang Khola watershed located at the Chure-Shiwalik region of eastern Nepal. Steep topography, farming on sloped areas, unmanaged cultivation, traditional farming practices and changing lifestyles of farmers were correlated to the soil erosion and loss of soil from the watershed. The results of this study are important in implementation of soil conservation and management planning processes, at the policy level, by land-use planners, local governments, policymakers, and other stakeholders. The predicted amount of soil loss and its spatial distribution could facilitate sustainable land use management in the catchment area and hence helps to preserve the healthy water and soil in the Gwang Khola watershed. Also, we can apply this method to the different watersheds of the Chure-Siwalik region and country. For the conservation of watersheds first, we need to map and find out the erosion-prone area. It can give very good demarcation for the erosion-prone area prioritization and find out the soil erosion rate and ratio.

In a developing country, like Nepal, we lack continuous efforts on long term monitoring of soil erosion, The RUSLE model, is helpful for developing a detailed spatial assessment of soil erosion using remotely sensed data and automated analysis of LULC. The findings from this study were reliable and it could help during planning the strategies and management of soil loss in this area. This result emphasizes a better understanding of the current situation and soil loss relationships according to LULC in the Gwang Khola watershed of the Chure region. These results are useful to control erosion in this area, to create and implement conservation programs in this study area. It is potentially helpful to local government, development agencies, activists, and other relative groups and organizations for upscaling their activities to control soil loss.

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