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Erosion Predictions by Empirical Models in a Mountainous Watershed in Nepal

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Abstract:
Soil erosion is a crucial problem in Nepal where more than 80% of the land area is mountainous. In this study, two commonly used empirical soil erosion models, Revised Universal Soil Loss Equation (RUSLE) and Revised Morgan, Morgan and Finney (RMMF), were applied to the Kalchi Khola River Watershed of Nepal (drainage area approximately 58 hectares) to predict the soil loss rate and spatial erosion pattern. Models and field survey data were integrated using GIS tools. Several model runs were conducted to identify the most to least sensitive parameters of the models. On an annual basis, average soil loss rate predicted by the RMMF model for the watershed considered was found to be 3.76 tons per hectare (t/ha) over the agriculture land and 0.002 t/ha over the forested area. The RMMF model predictions are in close agreements with the available measured data of the region, whereas RUSLE predictions are far off, indicating that the RMMF model is a better choice to predict soil erosion rates in a steeply sloping mountainous region. It was also found that about 26% of the total watershed area is under high erosion risk (erosion rate > 5 t/ha per year). Moreover, about 60% of the area was found to be under high erosion risk if the entire watershed were converted into agricultural land. Accurate prediction of soil loss rates and erosion patterns will assist in the development of a robust soil conservation planning tool.

Keywords: Soil erosion, RUSLE, RMMF, Mountainous watershed of Nepal

1. INTRODUCTION

Over the past few decades, the environment in Nepal has been rapidly degrading. Resource degradation in the Himalayan region is mainly caused by landslides, mudslides, collapse of man-made terraces, soil loss from steep slopes, and decline of forest/pasture areas (ICIMOD 1994). Annually, nearly 24 million tons of soil is washed away from the country (ADB 1988). About 34 % of the agricultural land in Nepal suffers from water erosion and mostly through sheet and rill erosion (UNEP 1997). This leads to several other problems in Nepal such as reduction of reservoir capacity and threat to the sustainability of the hydropower and irrigation projects. Very few studies have been undertaken related to erosion issues in Nepal, perhaps due to the limited financial resources, to research, monitor and model sources and outcomes of environmental degradation due to erosion and sedimentation. The applicability of different soil erosion models has yet to be seen in a comprehensive manner. Soil erosion field plots study in Likhu Khola River Watershed in 1992 and 1993 registered following soil loss rates: 0.05 t/ha/y under grassland and slightly degraded secondary forest, 11 t/ha/y under no cultivation, and 2.7-8.2 t/ha/y under rain-fed cultivation (Shrestha 1997). Other studies in the Middle Mountain Region show the soil loss rates under conventional tillage as following:

- 14.39 t/ha/y – Kavre Watershed (Maskey and Joshi 1991)
- 3.01 t/ha/y – Kulekhani Watershed (Upadhyaya et al. 1991)
- 36.67 t/ha/y – Eastern Nepal (Sherchan et al. 1991)

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▪ 25- 40 t/ha/y (open degraded forest) and 3-25 t/ha/y (sloping terraces) – Jhiku Khola Watershed (ICIMOD 1998)

Soil erosion models can be divided into two main groups: empirical models and physically-based model. Many of the soil erosion models are based on the empirical models such as Universal Soil Loss Equation (USLE) (Wischmeier and Smith 1978), Chemical Runoff and Erosion from Agricultural Management Systems (CREAMS) (Knisel 1980), Agricultural Nonpoint Source model (AGNPS) (Young et al. 1989), Revised Universal Soil Loss Equation (RUSLE) (Renard et al. 1991), and Modified Universal Soil Loss Equation (MUSLE) (Williams 1975). Several physically-based erosion models include Water Erosion Prediction Project (WEPP) (Flanegan and Nearing 1995), Limburg Soil Erosion model (LISEN) (De Roo et al. 1996), European Soil Erosion Model (EUROSEM) (Morgan et al. 1998), and Revised Morgan, Morgan and Finney model (RMMF) (Morgan 2001). An advantage of physically-based models is the ease with which they can be combined with physically based hydrological models. Fully distributed modes such as WEPP and AGNPS perform better than the conceptual ones, but suffer from high computational expense and require much input with high spatial resolution. Complete listings and descriptions of the soil erosion models can be found in De Roo (1993). USLE was successfully applied to assess soil erosion in Trijuga Watershed (Sah 1996) and Kulekhani Watershed (Kharel 1999) of Nepal. The RMMF model was also applied to Pakhribas Watershed (Sherchan et al. 1991) and Hamsingha Khola Watershed (Dhungana 2002) of Nepal with satisfactory results.

In this study, the two commonly used soil erosion models, RUSLE and RMMF, are chosen to assess the soil erosion rates because (1) data requirements are not too complex or unattainable, within the context of a developing country like Nepal, (2) the models are compatible with Geographical Information System (GIS), and (3) they are easy to implement and understand from a functional perspective (Milward and Mersy 1999). The study aims to evaluate the magnitude of soil erosion with its spatial distribution in a small watershed located in the Middle Mountain Region of Nepal. The objectives of the study are to (1) compare the performance of RUSLE and RMMF in mountainous region with highly sloping lands, and (2) produce erosion risk maps for the prioritization of conservation planning and efforts. This paper provides an easier, faster, yet more reliable modelling approach for soil erosion risk assessment. Accurate representation of soil loss rates and erosion patterns will assist in the development of a land degradation monitoring and auditing technique to provide a robust soil conservation planning tool readily transferable and accessible to other land managers in similar environments.

2. MATERIALS AND METHOD

2.1 Description of the study area

The watershed chosen for this study is Kalchi Khola River Watershed (Figure 1). It is situated in the northwestern part of Bagmati Watershed of drainage area 3719 km^2 and has southwesterly aspect. It drains approximately 58 ha of mixed agricultural and forest area. The elevation ranges from about 1640 to 1859 m above the mean sea level; the “local relief” within the study area is 219 m. Kalchi Khola River drains the water to the Indra Sarowar (Kulekhani Reservoir). About 54% of the land is agriculture and the rest is forest (Figure 2). The soil texture is loamy skeletal (silt loam). The soil has very high silt content even up to 69 %, and some of the pocket area has rock fragments percent up to 53%. Most of the area is steep to very steep: 73% area have slope more than 25%, with an average slope of 50.62% (see Figure 3 and Table 1).

Table 1. Watershed areas under different slope classes.

Code	*Classes*	*Slope (%)*	*Area (%)*
1	Nearly level	0-3	10
2	Gently sloping or undulating	3-7	1
3	Strongly sloping or rolling	7-15	2
4	Moderately steep to hilly	15-25	15
5	Steep	25-55	52
6	Very steep	≥ 55	21

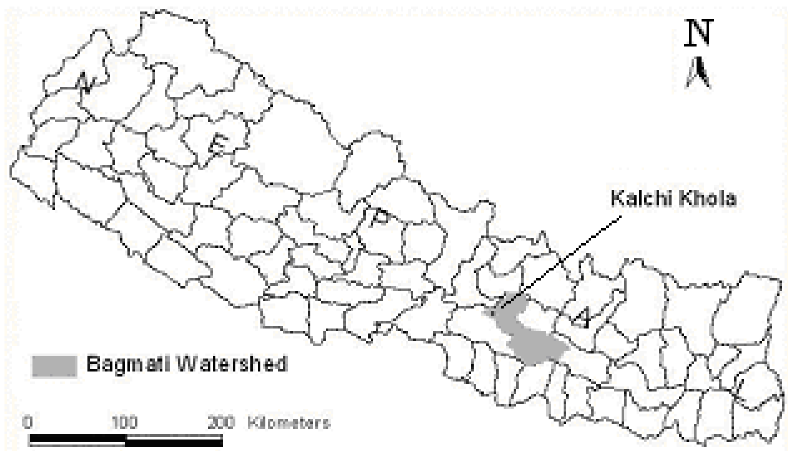

Figure 1. Location map of Kalchi Khola in Bagmati Watershed in Nepal.

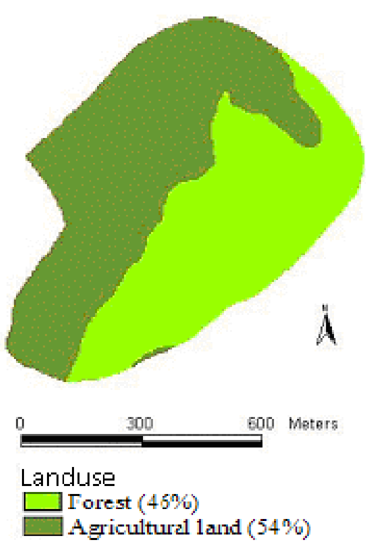

Figure 2. Land use map of Kalchi Khola River Watershed.

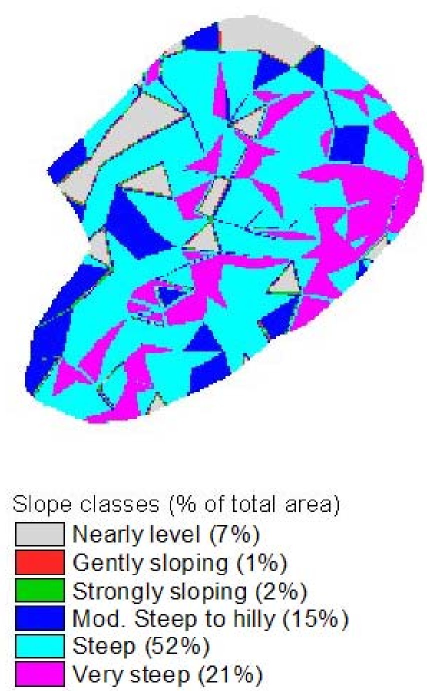

Figure 3. Slope map of Kalchi Khola River Watershed, derived from the DEM data.

The agriculture is mainly rain-fed. The cultivation is mainly through terraces, which are outward sloping. Two crops per year namely maize and wheat is the dominant cropping pattern. Conventional tillage forms the dominant agricultural management practice. The quantity of crops residue is very minimal due to its alternative value as livestock forage during the dry season. Mulching is not excessively used in cultivation practices. Most of the population depends on farming for their livelihood. The human settlements are mainly located in the watershed boundary. No events of landslides were noted in recent years. Channel and gully erosion also are not the remarkable erosion features in the area. The forest is secondary forest (newly grown). At higher elevations forest consists of Chir pine (*Pinus roxburghii*) and broad-leaf trees (*Schima wallichii,* local name Chilaune), while at lower elevations the forest consists of Quercus-Rhododendron mixed with broad-leaf trees. The rainfall pattern for the watershed is shown in Figure 4. Mean annual precipitation for the period 1991 though 2000 is 1534 mm. Discharge records are not available. Within the 12- month range, temperature averages for the four seasons are 8ºC (Dec-Feb), 16ºC (Mar-May), 23ºC (Jun-Aug), and 17ºC (Sept-Nov) (Perino 1993).

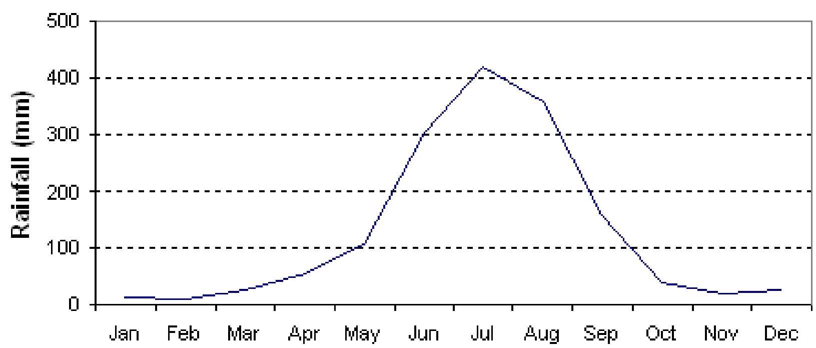

Figure 4. Seasonal rainfall distribution in Kalchi Khola River Watershed.

The measured sediment yield values in two experimental subwatersheds within Kalchi Khola River Watershed are found reported in Perino (1993) as follows: the sediment yield for the subwatershed 1 (area 2.68 ha, agriculture 94%, forest 4%, and annual rainfall 1106 mm) was estimated as 0.72 t/ha/y, and for the subwatershed 2 (area 1.88 ha, agriculture 83.5%, forest 16.5%, and annual rainfall 1106 mm) as 0.89 t/ha/y. Applying the sediment delivery ratio (SDR), soil loss rate for this region was estimated to be 1.02 t/ha/y.

2.2. Erosion models

Two erosion models, RUSLE and RMMF, were applied to the Kalchi Khola River Watershed. The RUSLE is an empirical model based on experimental data that uses a unique set of definitions to estimate average annual soil loss. The RUSLE model calculates average annual soil loss using five factors, including rainfall erosivity factor, soil erodibility factor, slope length-steepness factor, crop cover factor, and crop management practice factor. The RMMF is more physically-based than the RUSLE. It predicts annual soil loss from field-sized area on hillslopes. The model consists of a water phase and a sediment phase. Annual rainfall is used to determine the energy of rainfall for splash detachment. Runoff is assumed to occur when a critical amount of (daily) precipitation is exceeded and the corresponding volume is calculated on the basis of annual precipitation. Transport capacity is determined using the runoff volume, slope steepness and crop cover. This approach differs somewhat from RUSLE, in that it allows entry of variable vegetative coverage throughout the year as well as more soil physical data.

Both models chosen are basically lumped models and estimate soil erosion of sheet and rill types. These models should not be used to calculate the sediment yield in regional scale, where deposition is significant. These models estimate soil erosion rates on annual basis and are not capable of predicting the erosion from an individual storm.

2.2.1. The Revised Universal Soil Loss Equation (RUSLE) model

The RUSLE (Renard et al. 1991) is an erosion prediction model designed to predict the long-term average annual soil loss from specific field slopes in specified land use and management systems. The model is the extended version of Universal Soil Loss Equation (USLE). RUSLE refines USLE by assigning new equations based on the ratio of rill to interrill erosion, and accommodates complex slopes while calculating LS-factor. The RUSLE quantifies the soil erosion as the product of five factors:

$$A = R \times K \times L \times S \times C \times P_S \qquad (1)$$

where *A* is the average soil loss per unit area, *R* is rainfall-runoff erosivity factor, *K* is soil erodibility factor, *L* is slope length factor, *S* is slope steepness factor, *C* is cover-management factor, and P_S is the support practice factor. *LS* combines both the *L*- and *S*-factors to give the topographic factor *LS*, and is best represented by the upslope drainage area per unit contour length.
Calculation of the *R*-factor depends on rainfall intensity. On average, 20 years of rainfall intensity data are recommended to be used to calculate R factor to incorporate natural climatic variations. In the absence of long-term (>20 years) rainfall intensity data, the R- factor estimation relation using mean annual rainfall could be used for at least assessing relative erosion rates for different management, crop, and soil condition (Renard and Freimund 1994). Equations proposed by Morgan (2001) (Equation 2) and Renard and Freimund (1994) (Equation 3) are generally accepted equations for the mountainous tropical climate.

$$R = (9.28 \times P - 8.8838) \times 0.102 \times I_{30} / 173.6 \qquad (2)$$

$$\left.\begin{array}{ll} R = 0.0483 \times P^{1.61} & \text{for } P < 850 \text{ mm} \\ R = 587.8 - 1.219 \times P + 0.004105 \times P & \text{for } P > 850 \text{ mm} \end{array}\right\} \qquad (3)$$

where *R* is R-factor in RUSLE equation, *P* is average annual precipitation, and I_{30} is the maximum 30-hr rainfall intensity.

Soil erodibility factor (*K*-factor) can be estimated using U.S. Department of Agriculture (USDA) nomograph. The nomograph can be found in Schwab et al. (1993). An algebraic approximation of the nomograph for those cases where the silt fraction does not exceed 70% is given as (Wischmeier and Smith 1978):

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

where, *M* is particle size parameter and equal to [(%silt + %sand)×(100 - %clay)], *OM* is percent of organic matter, *s* is soil structure code (1 - very fine granular; 2 - fine granular; 3 - medium or coarse granular; and 4 - blocky, platy, or massive), and *p* is profile permeability class (1 - rapid; 2 - moderate to rapid; 3 - moderate; 4 - slow to moderate; 5 - slow; and 6 - very slow).

LS factor can be derived from the topography data, and *C*- and P_S-factors can be selected from the literature.

2.2.2. The Revised Morgan-Morgan-Finney (RMMF) model

The RMMF model (Morgan 2001) is the extension of original MMF model. The original MMF model ignores the ability of rainfall to transport soil particle downslope and of runoff to detach soil particles. While the transport of soil particles by raindrop impact may be negligible, neglecting the detaching power of runoff does not seem reasonable, particularly on steep slopes where runoff becomes channelled into rills.

The model separates the soil erosion process into two phases, water phase and sediment phase. The water phase determines the energy of the rainfall available to detach soil particles from the soil mass and the volume of runoff. The sediment phase determines the soil particle detachment by both the raindrop impact and by the runoff. It also estimates the transport capacity of runoff. The total detachment of the soil particles is compared with the transport capacity. The minimum of the two becomes the rate of soil erosion.

The soil particle detachment by raindrop impact:

$$F = K_i \times KE_T \times 10^{-3} \quad (5)$$

where F is soil detachment rate by rainfall (kg/m^2), K_i is detachability index (g/J), KE_T is the total energy of the effective rainfall (J/m^2). The detachability index can be determined by the textural class. Total energy of the effective rainfall is the sum of the kinetic energy of the rainfall that reaches the ground surface as direct though fall (depends on intensity) and the kinetic energy of the rainfall that reaches the ground as leaf drainage (depends on height of the plant canopy).

The soil particle detachment by runoff:

$$H = Z \times Q^{1.5} \sin S(1 - GC) \times 10^{-3} \quad (6)$$

where H is soil detachment rate by runoff (kg/m^2), Z is a coefficient (function of the soil cohesion), Q is the runoff volume (mm), S is the slope steepness (degree), and GC is percentage ground cover fraction (0 to 1).

Transport capacity of the runoff:

$$TC = C_f \times Q^2 \sin S \times 10^{-3} \quad (7)$$

where TC is the transport capacity of the runoff (kg/m^2) and C_f is a factor that depends on different tillage practices.

2.3. Input data preparation

Basic input data needed to run the models are topography, land use, soil and climate data (Figure 5). Topography and land use data were collected for the selected watershed (personal communication, Bagmati Integrated Watershed Management Project, HMG/CEC Project # ALA/96/17, Babarmahal, Kathmandu, Nepal). Soil information was collected from ICIMOD (personal communication, ICIMOD, Kathmandu, Nepal). Soil properties were determined by conducting field survey. A total of 12 soil samples were collected and analyzed to determine the soil parameters such as soil types and textures. Rainfall data were obtained from the Department of Soil Conservation and Watershed Management (personal communication, Ministry of Forests and Soil Conservation, HMG, Kathmandu, Nepal).

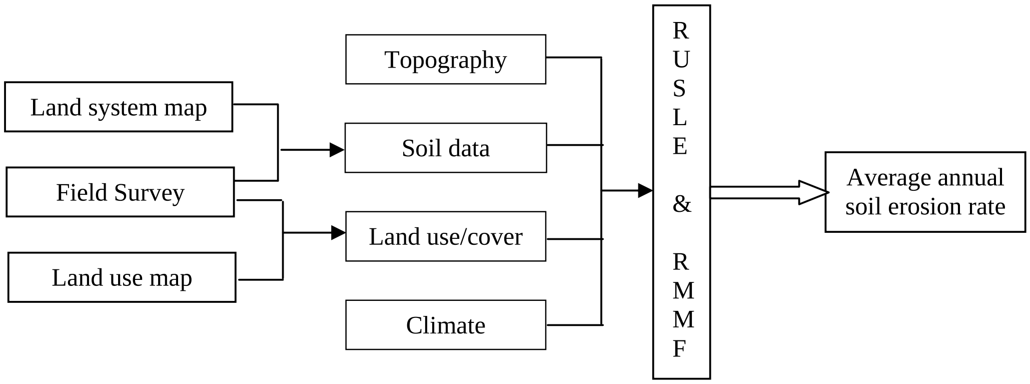

Figure 5. Soil erosion assessment using RUSLE and RMMF models.

Both the RUSLE and RMMF models were executed within ArcInfo GIS environment. The *R*-factor of RUSLE equation (see Equation 1) was determined by averaging *R*-factor values calculated from two different empirical equations (Equations 2 and 3) using annual precipitation. The soil erodibility factor *K* was calculated using Equation 4. The topographic factor (*LS*-factor) was calculated using the method suggested by Remortel et al. (1991). A digital elevation model (DEM) of 5 m spatial resolution was created in ArcInfo using an iterative finite difference interpolation of a 10 m contour map available at 1:3000 scale. A series of DEM-derived grids were produced using AML program within ArcInfo. The *C*- and P_S-factors of RUSLE equation were obtained from Morgan (2001).

For the RMMF model, vegetation and crop cover parameters such as rainfall interception (*A*), rainfall intensity (*I*), ratio of actual evapotranspiration to potential evapotranspiration (E_t/E_0), plant canopy height (*PH*), percentage canopy cover (*CC*), percentage ground cover (*GC*), and effective hydraulic depth of soil (*EHD*) were determined. The detachability index (K_i) was estimated from Morgan (2001) based on the information on soil textural class. Slope gradient map was derived from the DEM data. The rainfall parameters used in RMMF model are the annual rainfall (*P*), the no of the rain days (*Rn*) per year, and rainfall intensity (*I*). A typical value of *I* as 30 mm/hr was taken, as suggested by Morgan (2001) for strongly seasonal climate. After generating all the attribute maps indicating rain, topography, soil and plant parameters, the model was applied in a GIS environment using map calculation procedures. The prediction of the detachment was compared with the transport capacity of the runoff and the lower of two was assigned as the annual rate of soil loss, denoting whether the detachment or the transport was the limiting factor.

3. RESULTS AND DISCUSSION

3.1. Sensitivity analysis

Sensitivity analysis is a methodical study of the response of selected output variables to variations in parameters and/or driving variables. This provides valuable information and insight to modellers and model users. Model users refer to sensitivity analysis results to guide their parameterization efforts, using more resources to quantify those parameters to which the model is most sensitive. Several runs of the RUSLE and RMMF model were conducted with varying input parameters to assess their effects on model output. RUSLE parameters used in the sensitivity analysis are *P*, *K*-factor, *L*-factor, *S*-factor, *C*-factor, P_S-factor, and percent of organic matter (*OM*). Similarly, sensitivity analysis was conducted for the RMMF model for each module: raindrop detachment, runoff detachment, and transport capacity of runoff. RMMF parameters of the raindrop detachment module used in the sensitivity analysis are K_i, *PH*, *A*, *I*, P, and *CC*. RMMF parameters of the runoff detachment module used in the sensitivity analysis are *GC*, E_t/E_0, *P*, E*HD*, slope steepness (*s*), cohesion of soil (*COH*), soil moisture content at field capacity (*MS*), and bulk density of the top soil layer (*BD*). And, RMMF parameters of the transport capacity of the runoff module used in the sensitivity analysis are *s*, *BD*, *Rn*, *P*, *MS*, *EHD*, C_f, and E_t/E_0.

Figure 6 shows the sensitivity of RUSLE input parameters in model predictions when input parameters are changed by ± 10% and ± 20% from their base values. Soil erosion calculation of the RUSLE model was found to be the most sensitive for the changes of *P*- and *S*-parameters. Similarly, Figures 7-9 show the sensitivity of RMMF input parameters for predicting soil erosion by raindrop detachment, runoff detachment and transport capacity of runoff, respectively. The soil erosion detachment due to raindrop impact was found to be the most sensitive for changes of K_i and *CC*. The soil erosion detachment due to runoff was found to be the most sensitive for changes of *P*, *MS*, *BD*, *EHD*, and *Rn*. Transport capacity calculation module of the RMMF model was found to have the same sensitive parameters as that of runoff detachment module of the RMMF model.

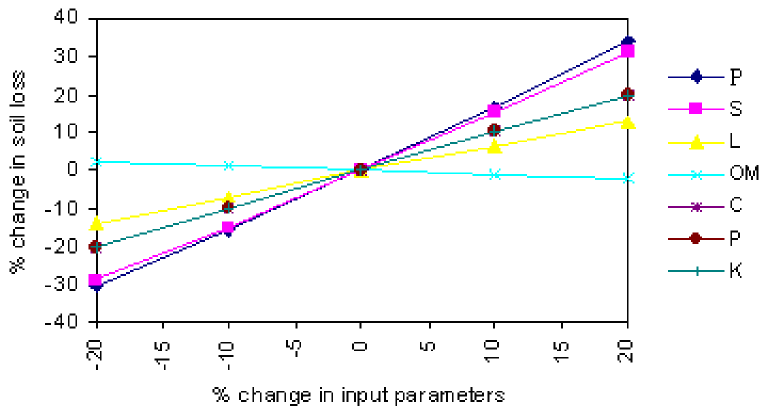

Figure 6. Sensitivity of RUSLE parameters.

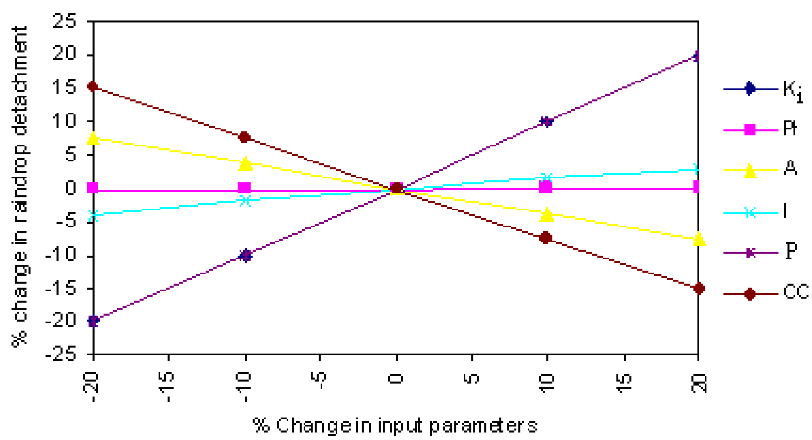

Figure 7. Sensitivity of RMMF raindrop detachment module parameters.

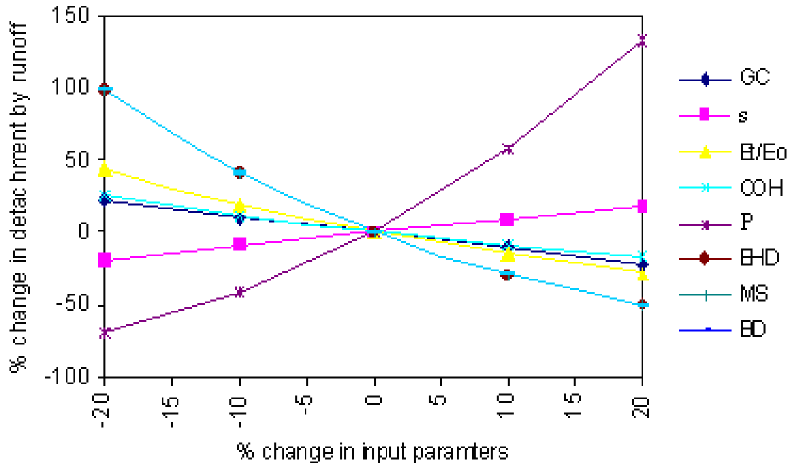

Figure 8. Sensitivity of RMMF runoff detachment module parameters.

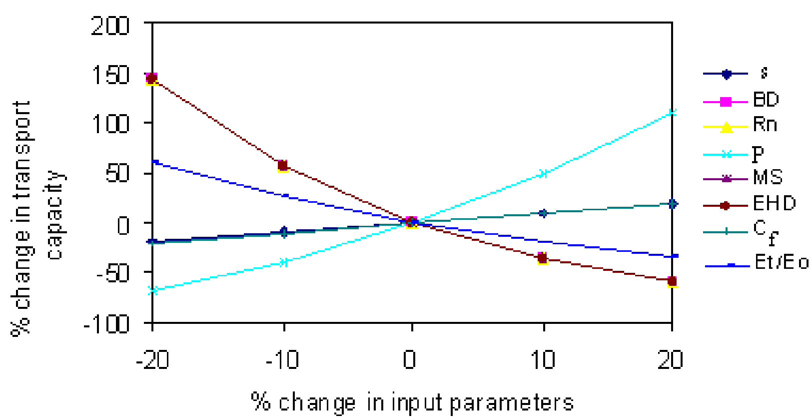

Figure 9. Sensitivity of RMMF transport capacity module parameters.

3.2. Erosion predictions

The RUSLE model predicted erosion rates from 0 to 2042 t/ha/y, with an average value of 315 t/ha/y for the agriculture area and 8 t/ha/y for the forest area. These rates were found unacceptable when compared with the erosion rates found in Shrestha (1997) for the similar watershed conditions, which estimated an average soil erosion rate of 2.7-8.2 t/ha/y for the agricultural area and 0.05 t/ha/y for the forested area. This erroneous prediction by the RUSLE model can be attributed to the assumptions on which the model was originally developed and uncertainties associated with the input data. Vigiak and Sterk (2001) indicated that RUSLE tends to overestimate erosion rates, especially when the model is applied to areas larger than the field size, such as geomorphologic units or hill slopes. Moreover, Renard et al. (1991) indicated that the contour digitizing (the method we used in this study) overestimates *LS*-factors. The distribution of RUSLE results reflects directly the distribution of the *LS*-factor. These results, therefore, indicated that the RUSLE model is not suitable to estimate soil erosion rates in a steeply sloping mountainous region.

The RMMF model predictions found that the erosion is transport-limited for this study area. The average soil erosion rate was found to be 3.76 t/ha/y for the agricultural area and 0.002 t/ha/y for the forested area of the watershed. The results are in close agreement with the predictions by Shrestha (1997). The probable reason for RMMF model prediction being more accurate is that most of the model parameters can be determined through field survey, which is not the case for RUSLE model. These results indicated that the RMMF model could be considered suitable for the prediction of soil erosion rates in a steeply sloping mountainous region.

Spatial soil erosion risk map was prepared (Figure 10) based on the erosion rate prediction of the RMMF model. Table 2 shows the different erosion risk classifications as well as the percentage area of the watershed under different erosion classifications. Erosion risk classes were defined from "very low" to "very high." It was found that about 26% of the total watershed area, which is found to exist within the agricultural land use, is under high erosion risk (> 5 t/ha/y). Very low erosion risk (< 1 t/ha/y) was found for the forest area.

Table 2. Watershed area under different soil erosion classification - RMMF.

Erosion risk class	*Typical annual soil loss rate (t/ha)*	*Percentage area of total watershed*	
		For existing condition	*When all land use were agriculture*
Very low (none to slight)	< 1	54.7	10.6
Low (slight to moderate)	1 < and < 2	1.1	1.6
Moderate (moderate to severe)	2 < and < 5	18.1	27.8
High (severe)	5 < and < 10	17.7	31.8
Very high (very severe)	≥ 10	8.3	28.2

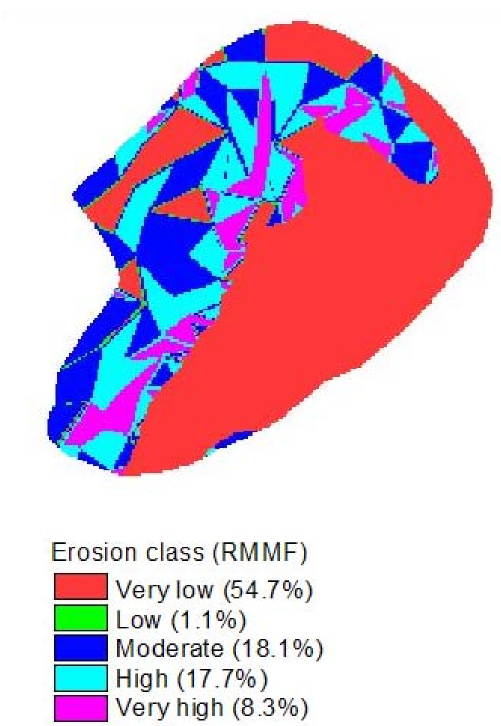

Figure 10. Erosion risk map using RMMF for the existing condition.

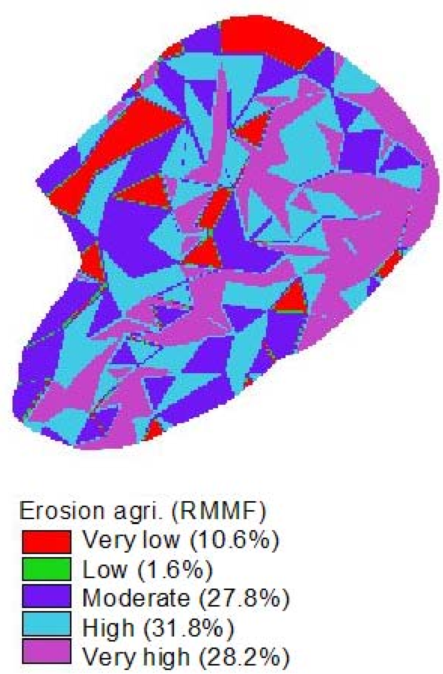

Figure 11. Erosion risk map using RMMF if all land use changed to agriculture.

Impacts on erosion rates due to changes in land use were assessed performing scenario analysis. The first scenario considered that all lands were converted into agricultural lands. Figure 11 shows the erosion risk map produced by the RMMF model for this scenario. About 60% of the land was found to be under high erosion risk (> 5 t/ha/y) under this scenario (see Table 2). Comparison of slope map of the watershed (figure 2) with soil erosion risk map for the case when all lands were agricultural lands (Figure 11) indicates a relationship between the slope of the watershed and the erosion rate; the higher the slope, the higher the erosion risk. The second scenario, which assumed that all lands were forests, found very low erosion risk (< 1 t/ha/y) for the entire watershed. Development of erosion pattern in the watershed is useful for the soil conservation planning. Decreased agricultural activities and increased plantation may be encouraged in the higher erosion risk areas.

4. CONCLUSION

Soil erosion predictions by the models being based on the modest data requirements overcome the general limitations of the developing nations in their soil conservation research and planning efforts. Empirical soil erosion models, though relatively simple, are easy to interpret physically, require minimal resources and can be worked out with readily available input values to pinpoint the areas exposed to high erosion risk. This paper demonstrates the application of empirical soil erosion models integrated with GIS to model soil erosion potential in a steeply sloping mountainous region.

Two soil erosion models RUSLE and RMMF were applied to Kalchi Khola River Watershed located in the Middle Mountain Region of Nepal to predict the soil loss rate and spatial erosion pattern. Several model runs were conducted to identify the most to least sensitive parameters of both models. This will give the valuable insights to the modellers about the sensitive parameters when applying the models to the region having similar characteristics. The RMMF model predictions are in close agreement with the available measured data, whereas RUSLE predictions are far off, indicating that the RMMF model is a better choice to predict soil erosion rates in a steeply sloping mountainous region.

On an annual basis, average soil loss rate predicted by the RMMF model for the Kalchi Khola River Watershed was found to be 3.76 t/ha for the agriculture area and 0.002 t/ha for the forested area. Spatial soil erosion risk map for the watershed was created based on the erosion rates predicted by the RMMF model. It was found that about 26% of the total watershed area is under high erosion risk (erosion rate > 5 t/ha/y).

Scenario analysis was performed to examine the impacts of land use in the model results. About 60% of the area was found to be under high erosion risk if the entire watershed were converted into agricultural land. The soil erosion risk maps provide valuable information about the possible erosion pattern in the watershed for the existing condition and scenarios, and thus establish a basis for the soil conservation planning.

List of Symbols

A	Soil loss per unit area
BD	Bulk density of the top soil layer
C	Cover management factor
CC	Canopy cover fraction
C_f	Coefficient that depends on tillage practices
COH	Cohesion of soil
EHD	Effective hydraulic depth
E_t/E_0	Ratio of actual to potential evapotranspiration
F	Soil detachment rate by rainfall
GC	Ground cover fraction
H	Soil detachment by runoff
I	Rainfall intensity
I_{30}	Maximum 30-hr rainfall intensity
K	Soil erodibility factor
KE_T	Total energy of the effective rainfall
K_i	Detachability index
LS	Slope length factor
M	Particle size parameter
MS	Soil moisture content at field capacity
OM	Organic matter
p	Profile permeability class
P	Precipitation
PH	Plant canopy height
P_S	Support practice factor
Q	Runoff
R	Rainfall-runoff erosivity factor
Rn	Number of rain days per year
s	Soil structure code
S	Slope steepness
TC	Transport capacity of the runoff
Z	Coefficient function of soil cohesion

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