

## ASSESSMENT OF SOIL EROSION AND SEDIMENT DEPOSITION USING GIS TECHNIQUE IN THE YOM RIVER BASIN

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### ABSTRACT

Every year, greater than millions of tons of sediment are occurred around the world. One of major sources of sediment is soil erosion. Water erosion also delivers millions of tons of sediment to river, lake, reservoir, and ocean. Soil erosion and sediment are thoughtful problems in agricultural area of the Yom River Basin of Thailand. The purpose of this research aimed to assess the potential of soil erosion and sediment deposition in the Yom River Basin. Erosion model is necessary to develop land use planning. In this research, soil erosion hazard was analyzed by remote sensing data and GIS technique. The volume of soil erosion in each grid cell was estimated by the Revised Universal Soil Loss Equation (RUSLE). This method has been broadly used around the world in mountain, forest, including agriculture areas to estimate average annual soil loss. Moreover, new technique was developed to estimate the capacity of sediment yield or deposition in each sub catchment by modifying the original RUSLE method. It was assumed that the amount of sediment flow from one grid cell to another downstream grid cell depends on the sediment yield of the original grid cell compared to the average sediment yield capacity of the whole catchment. All catchments were considered, and average spatial parameters were calculated for each catchment.

*Keywords:* mapping, RUSLE, spatial analysis, Thailand

### 1. INTRODUCTION

Yom River basin, as an important river in the Northern Thailand. The Yom River is the only one river which has no reservoir or dam in large scale to control the sediment flow. Consequently, soil erosion and sediment deposition in this basin is a seriously problem for managing sediment resources. Due to soil erosion is a common sources of sediment yield around the world. Therefore, a technique for estimating soil erosion is necessary for assessing sediment yield. Empirical method, numerical model and field experiment have been used for analyzing soil erosion and sediment deposition from several researchers around the world. In 1978, Wischmeier and Smith suggested the Universal Soil Loss Equation (USLE) for estimating the erosion on a cultivated area. The USLE is a widely used mathematical model that assesses soil erosion processes. In 1997, Renard et al. offered the Revised Universal Soil loss Equation model for analyzing soil erosion based on the USLE. For the Past few decades, many researches have used the RUSLE for analyzing soil loss erosion (Zhang et al, 2013; Chadli K., 2016; Cunha et al., 2017). Soil erosion in Thailand, Pisit Sintuvanich, (2013) used the USLE method for estimating soil loss rate in the eastern part of Thailand. The results shown that high magnitude of soil erosion occurred in the upland crops with slope gradient greater than 5%. Furthermore, Sthiannopkao et al., (2007) assessed the impact of soil erosion on water treatment in the northeastern provinces of Thailand. They found that the operation costs of water treatment are increased in the wet period due to suspended load occurred in rainy season greater than dry season. In addition, Plangoen et al., (2013) evaluated the future climate and land use change impacts on soil erosion in the Mae Nam Nan Sub Catchment using the RUSLE method. The results indicated that soil erosion change are not vary depending on effect of green gas emission scenarios. Subsequently, future rates of soil erosion is normally projected to increasing by reason of the rising in rainfall and erosivity factor.

However, while researchers have focused on soil erosion areas, there are a few research efforts to estimate the sediment deposition areas. Recently, Rangsiwanichpong et al., (2018) developed a new method for estimating sediment deposition area in Thailand using GIS and remote sensing data. The new method modified from the original of the RUSLE method. The results shown good agreement between sediment yield from the modified RUSLE and observed data. Therefore, our research aimed to analyzing the potential of sediment yield and soil erosion in the Yom River Basin.

## 2. STUDY AREA & DATA

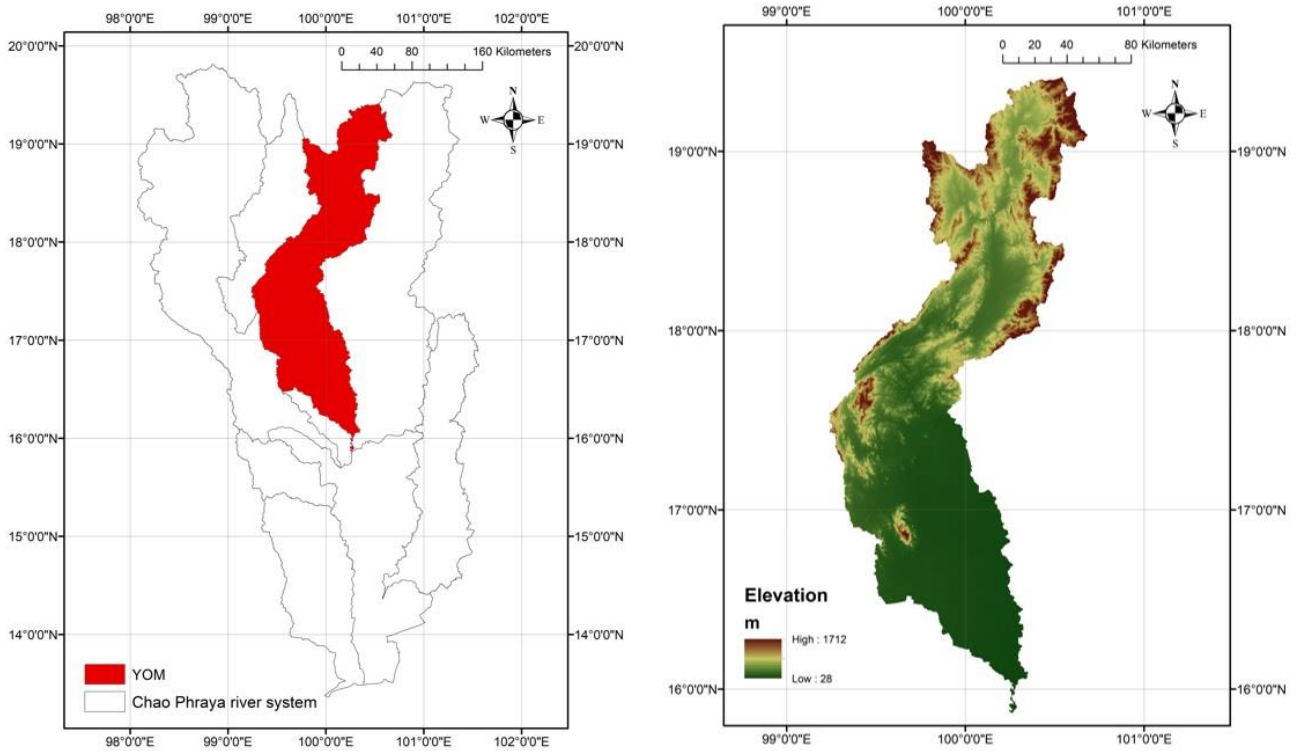


Figure 1. The Yom River Basin and topography

The Yom River is one of four main tributaries of upper Chao Phraya River basin, between latitudes  $14^{\circ}50'N$  to  $18^{\circ}25'N$  and longitudes  $99^{\circ}16'E$  to  $100^{\circ}16'E$ . The Yom River Basin covers approximately 15 percent of the Chao Phraya network, which area of the basin is  $24,046 \text{ km}^2$ . The topography of Yom River Basin can be classified into 3 categories consisting of mountainous in the upper basin, flat plain in the middle basin, and low lying area in the lower basin (Figure 1). The average annual rainfall of the Yom River Basin is  $1,113 \text{ mm}$ , which the upper basin having greater rainfall than the lower basin.

## 3. METHODOLOGY

### 3.1 The RUSLE

The aimed to estimate the potential of soil erosion and sediment deposition in the Yom River Basin using the RUSLE and Geographic Information System (GIS) data. The GIS is a system to analyze, manage, and present all types of geographical data. GIS can be used as tool for decision making, problem solving, and visualization of data in a spatial environment. Furthermore, the RUSLE is the most popular model for assessing average annual soil erosion by water. The RUSLE is an empirical soil loss model, which based on the universal soil loss erosion model (USLE). The average annual soil erosion by RUSLE was computed using Equation (1).

$$A = R \times K \times LS \times C \times P \quad (1)$$

Where

$A$  is the mean annual soil loss per unit area ( $T \cdot ha^{-1} \cdot y^{-1}$ )

$R$  is the rainfall erosivity factor ( $MJ \cdot mm \cdot ha^{-1} \cdot hr^{-1} \cdot y^{-1}$ )

$K$  is the soil erodibility factor ( $T \cdot hr \cdot MJ^{-1} \cdot mm^{-1}$ )

$LS$  is the topographic factor

$C$  is the cover-management factor

$P$  is the conservation practice factor

### 3.2 Erosivity Factor

Rainfall is an important factor in the process of soil erosion and sediment deposition. Therefore, the potential of soil erosion can be analyzed by rainfall intensity and storm duration. Generally, relationship of storm energy and maximum 30 min intensity can be considered as the  $R$  factor. The  $R$  factor was used on the recommended equation by the Land Development of Thailand:

$$R = 0.4669X - 12.141559 \quad (2)$$

Where:

$R$  is the erosivity factor ( $MJ \cdot mm \cdot ha^{-1} \cdot hr^{-1} \cdot y^{-1}$ )

$X$  is the average annual rainfall (mm)

### 3.3 Topographic Factor

The slope of basin or watershed has a major effect on soil erosion process. Owing to a greater slope results in a higher velocity of water flow and amplified shear stress on surface soil. Therefore, calculation of the topographic factor ( $LS$ ) was estimated by GIS technique based on principle of the RUSLE. The  $LS$  factor can be described using Equation (3) to (6).

$$L_f = \left(\frac{\lambda}{22.12}\right) \times \left(\frac{\frac{\sin \theta}{0.0896}}{3 \sin \theta \times 0.8 + 0.56}\right) \quad (3)$$

$$\text{Slope gradient} < 9 \text{ percent}; S_f = 10.8 \sin \theta + 0.03 \quad (4)$$

$$\text{Slope gradient} > 9 \text{ percent}; S_f = 16.8 \sin \theta + 0.5 \quad (5)$$

$$LS = L_{\text{factor}} \times S_{\text{factor}} \quad (6)$$

where:

$\lambda$  is the length of slope

$L_f$  is the slope length factor

$S_f$  is the steepness factor

### 3.4 Cover Management Factor

The cover management factor ( $C$ ) expresses the effect of vegetation cover on the erosion process. Due to vegetation on soil surface can protect or reduce the process of splash erosion. The splash erosion or raindrop impact represents the first step in process of soil erosion. Splash erosion results from the bombardment of soil surface by rain drops. Normally, the  $C$  factor is analyzed by the relationship between the Normalized Difference Vegetation Index ( $NDVI$ ). The  $C$  factor can be expressed as Equation (8) and based on Farhan et al., (2013)

$$NDVI = \frac{NIR - RED}{NIR + RED} \quad (7)$$

$$C = (-0.7388 \times NDVI + 0.4948) \quad (8)$$

Where:

$NIR$  is the near infrared band

$RED$  is the red band

### 3.5 Erodibility Factor & Conservation Practices Factor

The erodibility factor ( $k$ ) explains the effect of water flow on soil resistance. The  $k$  factor were collected from the Land Development Department of Thailand (0.05, 0.19, and 0.3 for clay, silt, and sand, respectively). The conservation practices factor ( $p$ ) is a soil loss ratio with particular support practices answering to the loss of down and up slope in agricultural area. In this research, the  $p$  factor collected from the experiment of Wischmeier and Smith (1978) as shown in Table 1.

Table 1. P factor values (Wischmeier and Smith, 1978)

| Land use type | Slope (%) | P factor |
|---------------|-----------|----------|
| Crop areas    | 0-5       | 0.1      |
|               | 5-10      | 0.12     |
|               | 10-20     | 0.14     |
|               | 20-30     | 0.19     |
|               | 30-50     | 0.25     |
|               | 50-100    | 0.33     |
| Other         | All       | 1.00     |

### 3.6 Estimation of sediment yield and sediment deposition area

In this research, sediment yield and sediment deposition area were assessed using modified the RUSLE model. The new solution for estimating sediment yield and sediment deposition area was developed by Rangsiwanichpong et al. (2018). They analyzed the suspended load flow from one grid cell to downstream grid cells, which it depends on the average sediment yield capacity in each sub basin ( $S_C$ ) and the sediment yield of

the original grid cell ( $S_y$ ). Therefore, the new solution for analyzing sediment yield and sediment deposition can be explained by Equation (9)-(12).

$$S_y = f(I_1, I_2, \dots, I_5) \quad (9)$$

$$S_c = f\left(\frac{\sum_{i=1}^n I_1}{A}, \frac{\sum_{i=1}^n I_2}{A}, \dots, \frac{\sum_{i=1}^n I_5}{A}\right) \quad (10)$$

$$D_i \text{ if } S_y < S_c \quad (11)$$

$$T_i \text{ if } S_y > S_c \quad (12)$$

where:

$S_y$  is the sediment yield

$S_c$  is the sediment capacity

$I_i$  represents the parameters in the RUSLE model

$A$  is the area of the sub-basin

$n$  is number of datapoints in each sub-basin

$D_i$  is the deposition in cell  $i$

$T_i$  is the transportation in cell  $i$

#### 4. RESULTS & DISCUSSION

The potential of annual soil erosion was estimated by the RUSLE method and remote sensing data. The annual soil loss was calculated on the five parameters using spatial analysis by GIS techniques. Erosivity Factor, this factor determined to each grid with resolution 1 km<sup>2</sup> as referred in Equation (2). The  $R$  factor was in the range from 489 to 652 (Figure 2L), which higher values occurring in the upstream of the Yom River Basin. The erodibility factor ( $K$ ) was analyzed by soil type data that obtained from the Land Development of Thailand (LDD). The standard of  $K$  values suggested by the LDD for sand and silt were 0.3 and 0.19 (Figure 2R). Furthermore, topographic factor ( $LS$ ) was analyzed from the topographic map of the Yom River Basin and estimations of Equation (3)-(6). Consequently, the  $LS$  factor generated to map as shown in Figure (3L). The cover-management factor ( $C$ ) was assessed using the relationship between  $C$  factor and NDVI based on Farhan et al., (2013) (Equation 8). Relatively, greater value for  $C$  factor were located on the downstream area of the Yom River Basin. The results indicated that the  $C$  factor with lower values mostly covered in the forest areas. Due to the high density of vegetation in forest areas can be protected or reduced the process of soil erosion better than vegetation covers in agriculture areas. The results of the  $C$  factor were in range of 0.01-0.61 (Figure 3R). Conservation practice factor ( $P$ ), the factor map were generated following the experiment of Wischmeier and Smith (1978). The  $P$  factor values were 0.1, 0.12, 0.14, 0.25 and 1 as shown in Figure (4L).

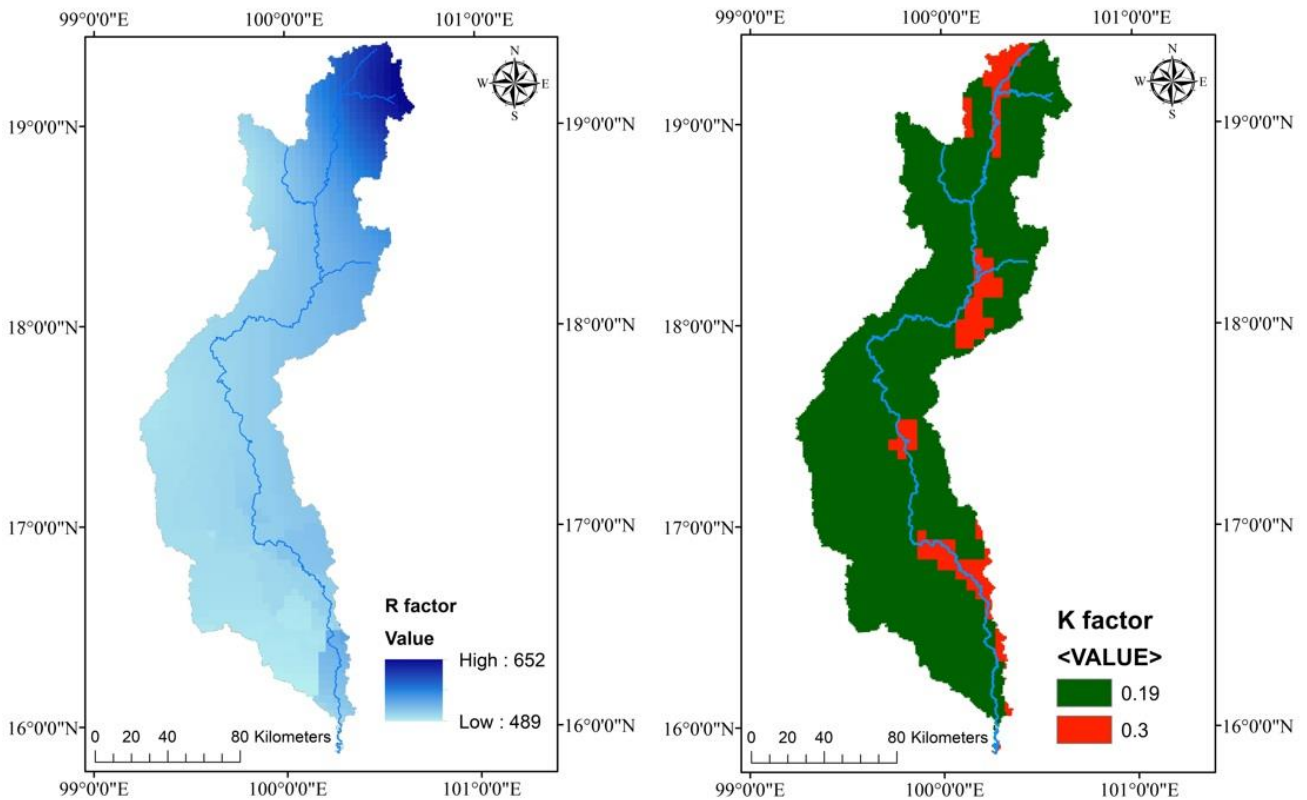


Figure 2. The erosivity factor (L) and the erodibility factor (R)

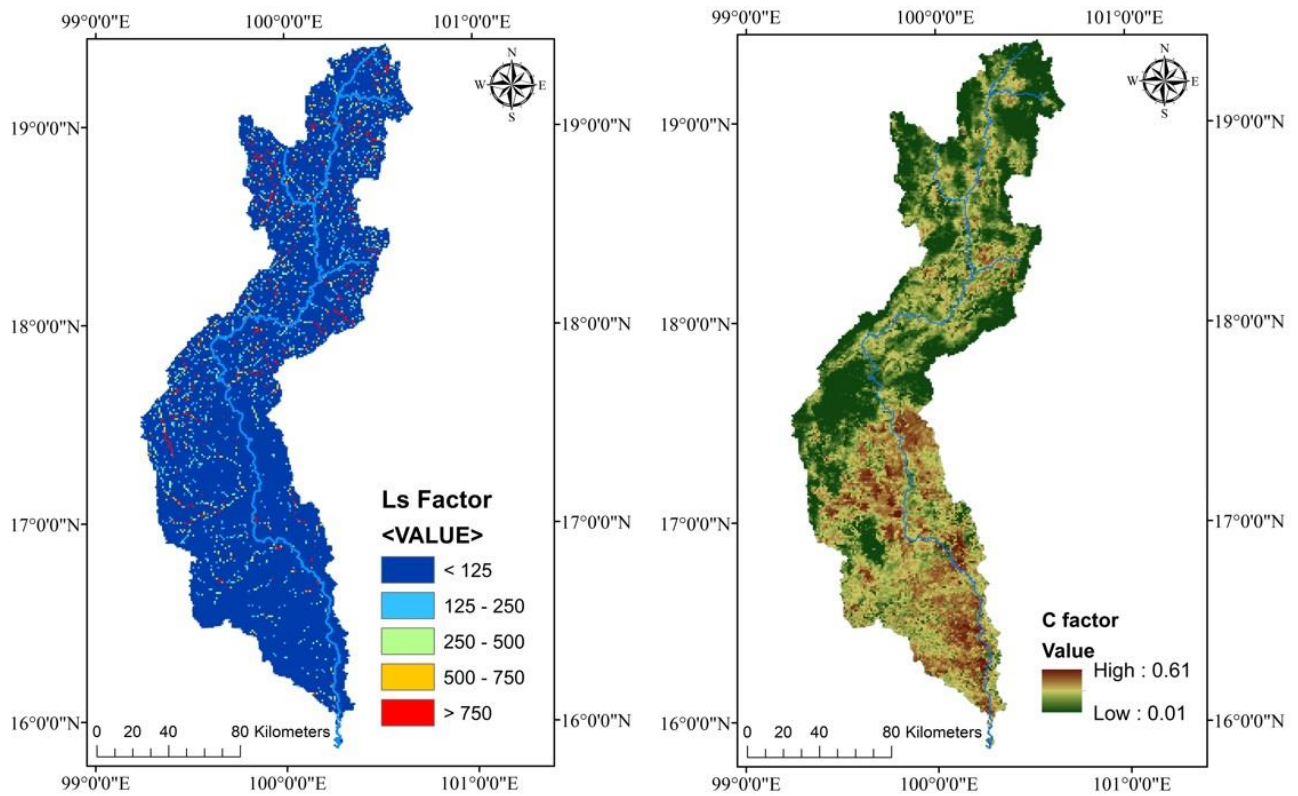


Figure 3. The topographic Factor (L) and the cover-management factor (R)

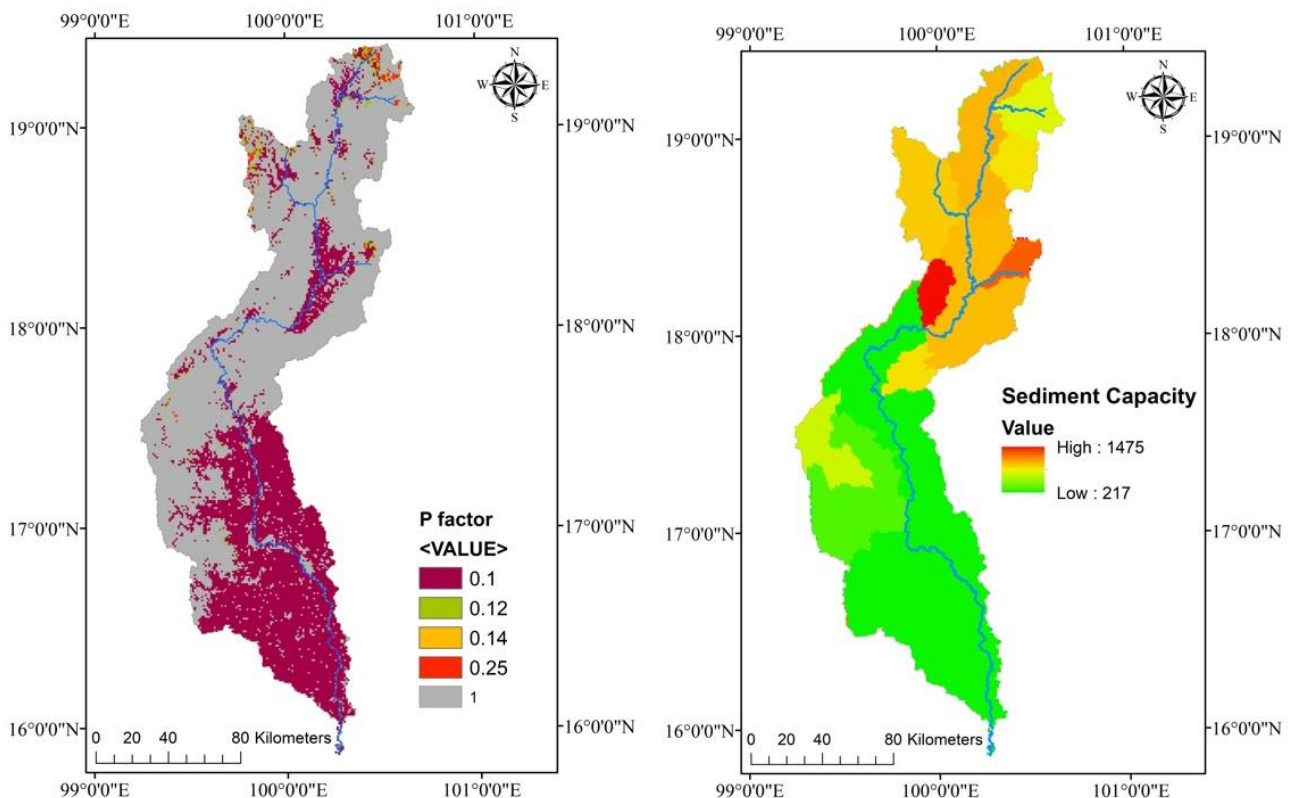


Figure 4. The conservation practice factor (L) and sediment capacity (R)

The five parameters based on the RUSLE model were calculated using the spatial analysis of ArcGIS software for analyzing annual soil loss in the Yom River Basin. The results shown that average annual soil erosion in the Yom River Basin was approximately  $225 \text{ m}^3/\text{km}^2/\text{y}$ . High rate of soil erosion ( $> 1,000 \text{ m}^3/\text{km}^2/\text{y}$ ) occurred in the mountainous areas of the Yom River Basin (Figure 5L). In this research, we applied a new method for assessing sediment deposition area, that method was developed by Rangsiwanichpong et al. (2018). The results shown that the average catchment sediment yield capacity in the Yom River Basin was  $495 \text{ m}^3/\text{km}^2/\text{y}$ . Greater sediment yield capacity located on the upstream area especially Maekammee River and Tha River areas (Figure 4R). Furthermore, the averaged potential of sediment deposition in the



Yom River Basin was  $230 \text{ m}^3/\text{km}^2/\text{y}$  (Figure 5R). The results shown that deposition areas located in the upstream area of The Yom River. Due to sediment yield of the Yom River occurred in the upstream areas, mostly along the Yom River margins where the elevation is flat and low lining areas.

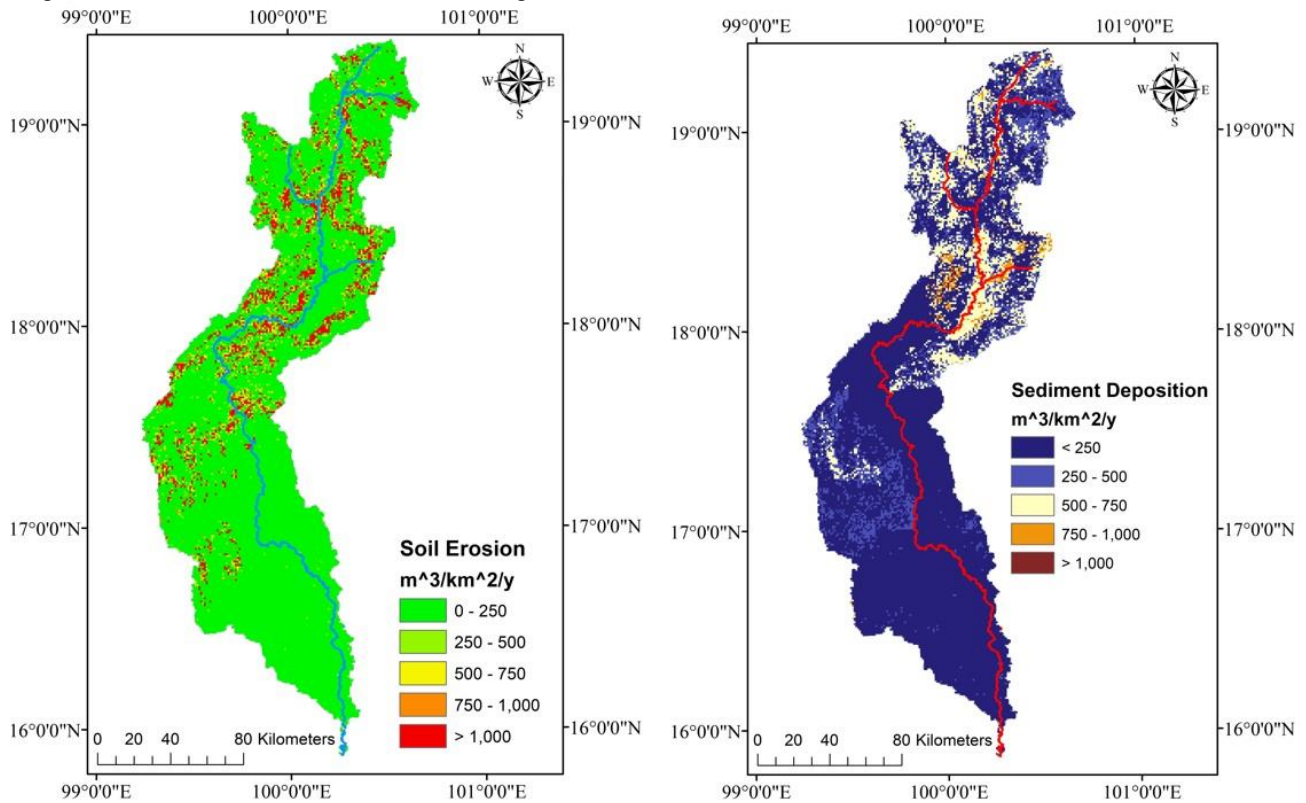


Figure 5. Average annual soil erosion (L) and sediment deposition (R)

## 5. CONCLUSIONS

This research assessed the potential of soil erosion and sediment deposition by remote sensing and GIS technique. The results indicated that soil erosion mostly occurred in the mountain and hill areas of the Yom River Basin. The potential of average annual soil erosion rate in the Yom River Basin was  $225 \text{ m}^3/\text{km}^2/\text{y}$ . Conversely, the potential of annual sediment deposition in the Yom River Basin was  $230 \text{ m}^3/\text{km}^2/\text{y}$ . This research found that deposition areas of the Yom River Basin was located in the upstream area mostly along the Yom River margins and low elevation areas. However, this research can help policymakers to control and management sediment yields in this region.

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