

Assessment of land cover on soil erosion in Lam Phra Phloeng watershed by USLE model

Jatuwat Wattanasetpong^{1,*}, Uma Seeboonruang², Uba Sirikaew³, Walter Chen⁴

¹Master's degree. Student, Civil Engineering Department, Faculty of Engineering, King Mongkut's Institute of Technology Ladkrabang, Bangkok, Thailand

²Associate Professor, Civil Engineering Department, Faculty of Engineering, King Mongkut's Institute of Technology Ladkrabang, Bangkok, Thailand

³Lecturer, Civil Engineering Department, Faculty of Engineering, King Mongkut's Institute of Technology Ladkrabang, Bangkok, Thailand

⁴Professor, Department of Civil Engineering, College of Engineering, National Taipei University of Technology, Taipei, Taiwan

Abstract. Soil loss due to surface erosion has been a global problem not just for developing countries but also for developed countries. One of the factors that have greatest impact on soil erosion is land cover. The purpose of this study is to estimate the long-term average annual soil erosion in the Lam Phra Phloeng watershed, Nakhon Ratchasima, Thailand with different source of land cover by using the Universal Soil Loss Equation (USLE) and GIS (30 m grid cells) to calculate the six erosion factors (R, K, L, S, C, and P) of USLE. Land use data are from Land Development Department (LDD) and ESA Climate Change Initiative (ESA/CCI) in 2015. The result of this study show that mean soil erosion by using land cover from ESA/CCI is less than LDD (29.16 and 64.29 ton/ha/year respectively) because soil erosion mostly occurred in the agricultural field and LDD is a local department that survey land use in Thailand thus land cover data from this department have more details than ESA/CCI.

1 Introduction

Nowadays many global problems are caused from climate change and human activities. Soil erosion problem is one of them. For example, the total soil loss to the European Union is estimated to be 970 million tons annually [1], which is a major threat to the ecosystem, crop production, and drinking water. Soil erosion is the displacement of the upper layer of soil, one form of soil degradation. There are several variables that affect soil erosion such as water, soil type, human activity and so on. A low rate of soil erosion has been occurring in every land on the earth and high rate of soil erosion is mostly happening on areas with high steepness slope and deforestation. The effect of soil erosion has led to sedimentation in streams and rivers; when sediment has delivered through the river into the bottom of reservoir. The sedimentation increases loads on the dams and gates, damages mechanical equipment and creates a wide range of environmental impacts [2]. In the past three decades, rapid increases in human developments have caused some significant environmental problems, such as deforestation and slope mass movement in every place in Thailand. There is a department in Thailand called Land Development Department (LDD) that studies about soil erosion [3]. They published a table and data for evaluating soil erosion with Universal Soil Loss Equation (USLE) [4] for every region of Thailand [3] because they recognized the importance of soil erosion.

Lam Phra Phloeng reservoir is currently being used for agriculture and irrigation in Thailand. Severe erosion of the areas becomes a big problem consequently [5] the reservoir is one of the most seriously affected by soil erosion related sedimentation in Thailand. Most of the area in upper watershed is cultivated by sugarcane and cassava. After the crop has been harvested the land is tilled and becomes sensitive to sheet erosion [6]. Due to this area has many high slope on the mountain near the boundary of watershed, agriculture area and urban, this area is facing with many problem about soil erosion.

As mentioned previously about LDD, there exists no update of overviews of spatial soil erosion. It's necessary to evaluate soil erosion in this specific area. Lam Phra Phloeng watershed has enough reason to be used in the study. One of the methods that has been used widely to evaluate soil erosion is Universal Soil Loss Equation (USLE)[4]. It is designed to evaluate long-term average annual soil loss from field slopes under a specific land use and management system, based on the product of rainfall-runoff erosivity (R), soil erodibility (K), slope length and steepness (LS), cover and management (C) and support practice factor (P). This model can work with geographic information system (GIS). One of the most important factors is the coverage and management (C) thus this study aims to evaluate soil erosion in Lam Phra Phloeng watershed by USLE with different sources of land cover data; one is from LDD and another one is from ESA Climate Change Initiative (ESA/CCI).

*.Corresponding author: 59601202@kmitl.ac.th

2 Study area

Lam Phra Phloeng watershed is located in northeast part of Thailand from 14°18'30" - 14°38'30"N, 101°30'00" - 101°54'00"E in WGS 84 coordinate system as shown in Fig. 1 with 815.2 km² (81,520 ha) of total area. Lam Phra Phloeng reservoir was constructed since 1963. Total capacity of reservoir is 155,000,000 m³ and average annual rainfall 1,135.8 mm/year. Lam Phra Phloeng River is a branch of Mun River in Nakhonratchasima province. Upper watershed area is close to Khao Yai National Park. This area has many high steep slope mountains. The land cover types in this area include paddy field, crop field, shrubland, residential area and forests. Normally this area has low rainfall rate but in rainy season it has too much rainfall. This causes flooding every year. To solve this problem Royal Irrigation Department has created the Lam Phra Phloeng reservoir to manage the flooding, irrigation and water supply. Construction of reservoir was completed in 1963, and reservoir has suffered from very high levels of sedimentation.

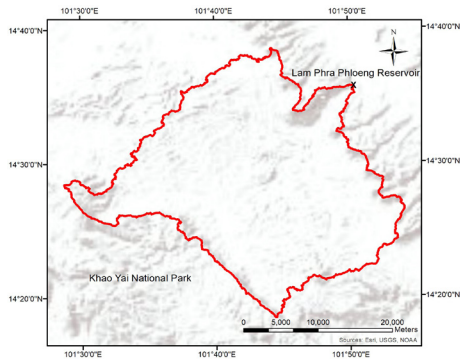


Fig. 1 The geographical map of Lam Phra Phloeng watershed

3 Methodology

3.1 Universal Soil Loss Equation

The Universal Soil Loss Equation (USLE) can evaluate an average rate of soil erosion for each feasible alternative combination of crop system and management practices in association with a specified soil type, rainfall pattern, and topography [4]. The equation of USLE is as follows [7].

$$A_m = R_m \times K_m \times L \times S \times C \times P \quad (1)$$

A_m : soil loss (ton/ha/year)

R_m : rainfall factor (ton/ha/year)

K_m : soil erodibility factor (ton-hour/106joule/mm)

L : slope length factor

S : steepness factor

C : vegetation cover factor

P : conservation practice factor

This equation is widely accepted worldwide for erosion prediction. Each variable is considered as a layer in the GIS database to be used in the modeling process.

3.1.1 R_m : rainfall factor layer

$$R_m = 0.4669X - 12.1415 \quad (2)$$

where:

R_m – rainfall and runoff erosivity (Mg/ha/year)

X – average annual rainfall (mm/year)

The average annual rainfall of the study area was calculated based on the 10-year period

(from 2005 to 2015) rainfall by 9 stations in the watershed from Royal Irrigation Department (RID). Thiessen Polygons method was applied to create R_m factor layer.

3.1.2 K_m : soil erodibility factor layer

K_m factor layer was based on soil group map from LDD which the value identified by LDD [8]. Soil group map was provided by LDD at a scale of 1:50000

3.1.3 L, S -factor layer

These layers were topographic factors which were extracted from 30 m × 30 m digital elevation model (DEM) by using spatial analysis on ArcGIS 10.5. This DEM derived from Global Land Cover (USGS).

(a) L factor was calculated by following equations.

$$L = (\lambda/22.13)^m \quad (3)$$

where, λ is field slope length(m); m is a variable slope-length exponent that depends on slope described by [3], [4], [8], and [9].

$m = 0.2$ for gradients 0-1.0%

$m = 0.3$ for gradients 1.1-3.0%

$m = 0.4$ for gradients 3.1-5.0%

$m = 0.5$ for gradients >5.0

(b) S factor is the ratio of soil loss from the field slope gradient to a 9 percent slope. It was calculated by following equations.

$$S = 0.065 + 0.045s + 0.0065s^2 \quad (4)$$

where: s – slope (%) [4]

3.1.4 C vegetation cover factor layer

The cover and management factor, is the ratio of soil loss from an area with specified cover and management to that from an identical area in tilled continuous fallow [4]. To evaluate the C -factor layer, the value for each class of the land cover was assigned as identified by LDD [3] in Table. 1. In this study use 2015 land cover map from LDD and ESA/CCI to compare soil loss with different C value as shown in Fig. 2.

3.1.5 P conservation practice factor layer

In this study use land cover map from LDD and ESA/CCI to evaluate P factor layer. This P factor layer was established by LDD [3] in Table. 1.

Table. 1 Vegetation cover factor (C) and Conservation practice factor (P) for land use land cover classes (LULC) [3].

LULC Class	C Value	P Value
Mixed crops	0.255	1
Paddy field	0.280	0.10
Field crops	0.525	1
Perennial trees	0.150	1
Orchards	0.300	1
Horticulture crops	0.600	1
Grassland	0.100	1
Shifting cultivation	0.250	1
Evergreen forest	0.003	1
Deciduous forest	0.048	1
Forest plantation	0.088	1
Agro forestry	0.088	1
Natural grassland	0.015	1
Water body	0	0
Urban	0	0

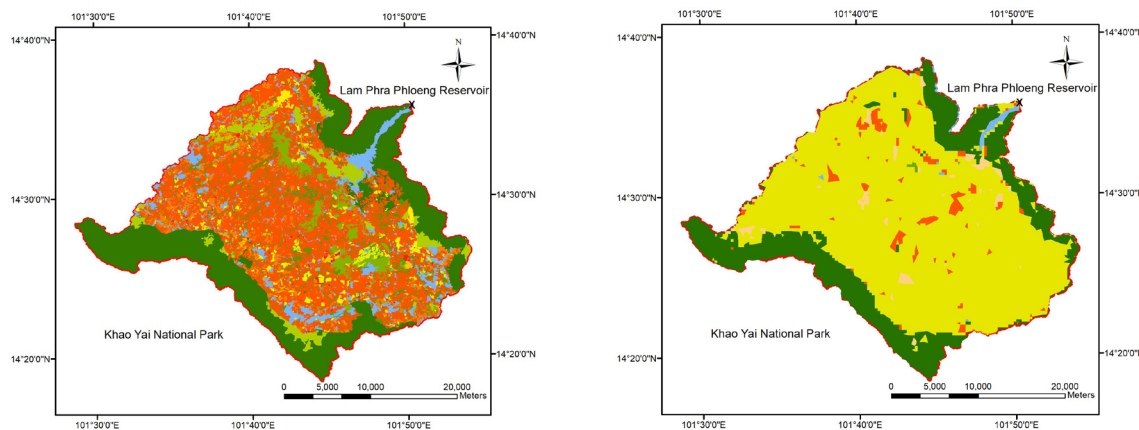


Fig. 2 Vegetation cover factor map (a) Land cover from LDD (b) Land cover from ESA/CCI

4 Results and discussion

4.1 Assessment of land use on soil erosion in Lam Phra Phloeng watershed by USLE model

The soil erosion map resulting from spatial overlay of the factor layers with the USLE model in Lam Phra Phloeng watershed is presented in Fig. 3 and Table. 2.

As mentioned before, this study evaluated soil erosion with USLE model by using land cover from different sources, (a) land cover data from LDD has 6.96% high risk soil erosion, 16.90% very high risk soil erosion and the average of soil erosion was 64.29 ton/ha/year as shown in Table.2.

In Fig. 3(a) show a high risk of soil erosion in the central of watershed and near Khao Yai National Park because the most agriculture in this area is field crop, paddy field and high steepness slope that affect high value of soil erosion.

(b) land cover data from ESA/CCI has 2.05% high risk soil erosion, 3.30% very high risk soil erosion and the average of soil erosion was 29.16 ton/ha/year as shown in Table.2

In Fig. 3(b) show a small risk of soil erosion because land use data from ESA/CCI is a global land cover data then it has less detailed than LDD.

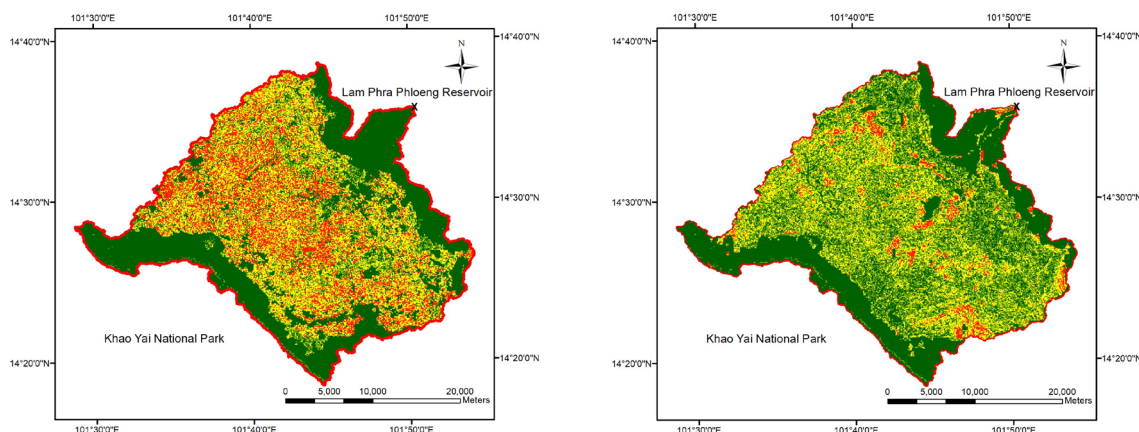


Fig. 3 Soil erosion map (a) Land cover from LDD (b) Land cover from ESA/CCI

Table. 2 Soil erosion risk categories

Category	Land cover data from LDD		Land cover data from ESA/CCI	
	Area(ha)	%	Area(ha)	%
Low risk (0-12.5 ton/ha/year)	32134	39.42	34181	41.93
Slightly low risk (12.5-31.25 ton/ha/year)	9354	11.47	25146	30.85
Moderately risk (31.25-93.75 ton/ha/year)	20582	25.25	17827	21.87
High risk (93.75-125 ton/ha/year)	5674	6.96	1676	2.05
Very high risk (>125 ton/ha/year)	13776	16.90	2690	3.30

5 Conclusions

This research has evaluated a soil erosion value by using USLE model. This model is widely acceptable for land cover management and organization that work about environment. In this study focus on different land cover sources to see an effect of soil loss with different land covers. Land cover data from LDD mostly has field crops, horticulture crops and paddy field. These land cover has huge impact to soil erosion as shown in Table. 1 but Land cover data from ESA/CCI mostly has grassland that has less impact than land cover from LDD. Therefore, the land cover management should emphasize on agriculture area to prevent and reduce a soil erosion rate.

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