INTEGRATION OF OF GEOGRAPHIC INFORMATION SYSTEMS AND UNIVERSAL SOIL LOSS EQUATION FOR SOIL EROSION ASSESSMENT IN DONG PHU DISTRICT, BINH PHUOC PROVINCE, VIETNAM

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ABSTRACT

The study evaluates soil erosion status in Dong Phu district, Binh Phuoc province, using the Universal Soil Loss Equation (USLE) and GIS methodologies. R (Rainfall erosivity factor), K (Soil erodibility factor), L x S (Slope length-gradient factor), C (Cropping management factor), and P (Pest management factor) were used in the calculation (Conservation practices factor). The generated maps depict soil erodibility and erosion condition, with potential erodibility estimated at 3,568.72 tons per hectare per year. Soil erosion is very low (; 50 tons/ha/year) with an area of 63,645.98 hectares (68.04 percent of the natural area), low (1-5 tons/ha/year) with an area of 20,878.57 (accounting for 22.32 percent of the natural area), moderate (5-10 tons/ha/year) with an area of 6,791,15 hectares (accounting for 7.26 percent of the natural area), soil erosion is low (1-5 tons/ha (accounting for 0.33 percent of the natural area).
Keywords: soil erosion, Dong Phu district, GIS, USLE

1. INTRODUCTION

In earth science, erosion is defined as incorporation and transportation of material by a mobile agent, such as water, wind, or ice (Lutgens, 2016). Thus, soil erosion is a natural process that occurs regularly and continuously, affecting the characteristics and properties of the soil. Erosion can occur in all different types of terrain. Agricultural scientists believe that soil erosion is the process in which topsoil is removed due to physical factors such as water and wind or factors related to farming activities. Thus, erosion is considered one of the causes of soil degradation, especially in sloping areas. Factors affecting soil erosion are mainly terrain slope, soil characteristics, rainfall, vegetation cover characteristics and farming techniques. In recent years, climate change is becoming more evident in Vietnam such as the increase in temperature, changes in rainfall and sea level rise. All of which can be potential causes for exacerbation of soil erosion.

Dong Phu is a district located in the southern major economic zone of Binh Phuoc province. It offers a lot of advantages in terms of territory, natural resources, people, and economic potential. Dong Phu district is an important location in Binh Phuoc province, with the National Highway 14 serving as an arterial artery connecting Dong Phu to the Central Highlands, Ho Chi Minh city and Cambodia. Soil deterioration is becoming more likely as a result of socioeconomic development, population growth, and changing farming circumstances. As a result, research to assess soil erosion is critical.

Researches on erosion and erosion protection measures to protect slopes in the world have been deployed by scientists from the 18th century. One of popular methods is universal soil loss equation (USLE) by Wischmeier and Smith (1978). USLE has been used in various case studies for tropical region (Ali and Hagos, 2016), (Lai, 2011), (Tung et al., 2018). Soil erosion assessment and its verification using the Universal Soil Loss Equation and Geographic Information System: a case study at Boun, Korea (Saro L., 2004). Rapid Assessment of Soil Erosion in Central America's Rio Lempa Basin The estimated erosion rates were compared to sediment delivery ratios utilizing the Universal Soil Loss Equation and geographic information systems and remote sensing technology. (John B. K., 2005). This study analyzed soil erosion changes in the Kondoa degraded area and investigated reasons of change using the Universal Soil Loss Equation, Geographic Information Systems, and a socioeconomic survey. To forecast soil erosion, researchers employed soil data, digital elevation models, rainfall, and land use/cover visually assessed from multitemporal satellite imageries. (Ligonja P.J., 2015). The goal of this study was to quantity and map mean annual soil erosion and sediment deposition using a geographic information system in Thailand (GIS). The revised universal soil loss equation (RUSLE) model was used to examine soil loss in each grid cell. (Prem Rangsiwanichpong, So Kazama, (Luminda G., 2018).

In Vietnam, after 1990s studies on soil erosion gradually shifted to using GIS and remote sensing methods, notably the studies by Mai (2007), Ho (2000), My (2005), Huong (2015). Thus, it can be seen that the integration of GIS and RS technology for soil erosion assessment research is currently of interest. GIS can support modeling and assessment of the current situation and using mathematical models to find areas of high soil erosion proneness to propose measures to minimize and prevent soil erosion.

2. RESEARCH METHOD

2.1 An overview of the field of study

Topographic: The district of Dong Phu is situated at a height of roughly 100 to 120 meters above sea level. Red soil grows on basalt soil and gray soil develops on ancient alluvium in this low undulating terrain, which is generally found in the district. The landscape is low-lying, with undulating low-hill terrain intermingled; the common soil is mostly sloping ground.

Soil resources: With a total natural area of 93,542 ha, red-yellow shale soil accounts for 42.53 percent, red-brown basalt soil accounts for 23.90 percent, yellow-brown basalt soil accounts for 9.13 percent, and soil on basalt accounts for 9.13 percent. Gray on ancient alluvium makes up 14.47 percent of the total, with yellow-brown soil on ancient alluvium and sloping soil accounting for the remainder.

Climate: The climate is mild, with two distinct seasons each year; the average annual temperature is around 27.8^0 C; high air humidity, rarely influenced by storms; and ideal growing conditions for plants and animals. The temperature is typically cold at night in the latter months of the rainy season and the beginning of the dry season. The daytime temperature is generally the greatest in the country during the dry season, although the high temperature only lasts approximately a month before progressively decreasing.

2. Research method

In addition to traditional research methods such as collecting and analyzing secondary data from available documents and literature in combinatin with field survey, the research also uses modern methods such as the application of remote sensing technology to determine the characteristics of plant cover, geographic information system (GIS) to integrate various elements into USLE model to assess soil erosion in Dong Phu district, Binh Phuoc province, Vietnam. The method used in this study is presented in Figure 1.

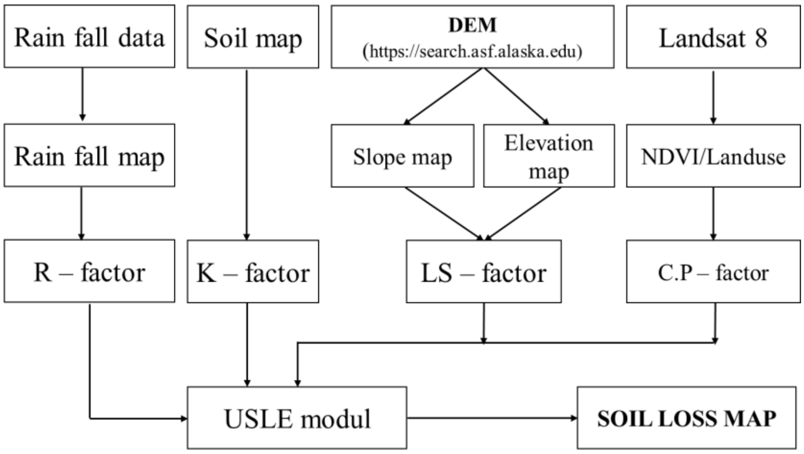

Figure 1. Flowchart of the methodology.

To prepare a soil erosion map, the study used USLE and GIS models. Factors affecting soil erosion are performed according to USLE developed by Wischmeier and Smith in 1978 (equation 1):

$$A = \mathrm{R} \times \mathrm{K} \times (\mathrm{L} \times \mathrm{S}) \times (\mathrm{C} \times \mathrm{P}) \quad (1)$$

In which:
A: Average annual soil loss (ton/ha/year)
R: Rainfall erosivity factor
K: Soil erodibility factor
L x S: Slope length-gradient factor (m)
C: Cropping management factor
P: Conservation practices factor

3. RESULT AND DISCUSSION

3.1. Factors for erosion

3.1.1 Rainfall erosivity factor

Rain immediately impacts the soil surface, which, when coupled with topographic circumstances, creates surface runoff, which transports that soil layer to another location. The rainfall erosivity is calculated by multiplying the kinetic energy by the maximum rainfall intensity during a period of 30-minutes for each rainstorm. The R-factor averages the erosivity of individual rainy occurrences across several years (equation 2).

$$R = \frac{E * I_{30}}{1.000} \qquad (2)$$

In which: E: total kinetic energy of precipitation (J/m^2); I$_{30}$: maximum rainfall intensity during a period of 30 minutes for each rainstorm (mm/h); R: rainfall erosivity factor (MJ/ha.mm/h).

Without 30-minute rainfall data, the authors employed annual average rainfall to calculate R using the method in Ha N.T. in 1996 (equation 3).

$$R = 0.548257 \times M_{TB} - 59.9 \qquad (3)$$

In which: (R) rainfall erosivity (J/m2); (P) annual average rainfall (mm/year); From equation (1), a map of R was developed for the district, showing value in range of 872.13 – 1091.43.

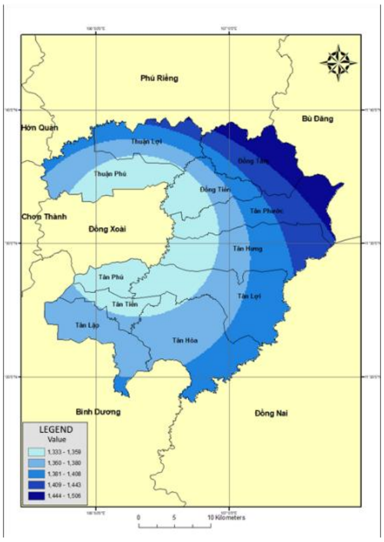

Figure 2. R factor.

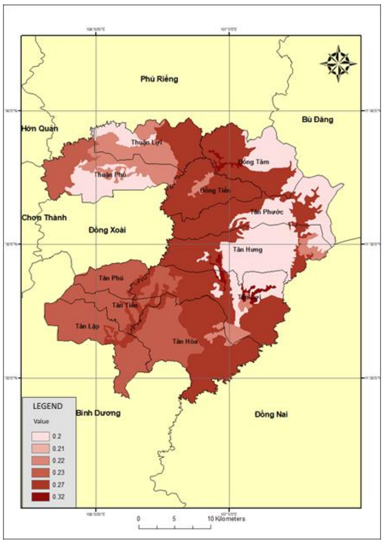

Figure 3. K factor.

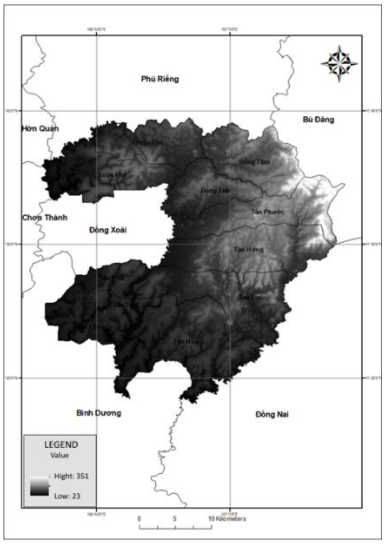

Figure 4. DEM.

R factor is highest in the east in the communes of Dong Tam, Tan Phuoc, Tan Hung, Thuan Loi. Communes of Dong Tien, Tan Hoa, Tan Lap have an average R factor and account for up to 30% of the district area. The lowest R factor is in the west area and a part of the central area of the district (Figure 2).

3.1.2 Soil erodibility (K)

K is depended on both soil physics and chemistry, namely soil structure, permeability and chemical composition.

According to Ha, N.T. in 1996, K factor for different soil type is as follow (Table 1).

Table 1. K factor of different soil types in Dong Phu District

N₀	**Type**	**WRB *(World Reference Base for Soil Resources)***	**K – factor**	**Area (ha)**	**Ratio (%)**
1	D	Umbric Gleysols	0.32	1,000.90	1.07
2	Fk	Acric Ferralsols	0.20	22,356.54	23.9
3	Fp	Haplic Acrisols	0.23	8,315.88	8.89
4	Fs	Haplic Acrisols	0.27	39,783.41	42.53
5	Fu	Acric Ferralsols	0.21	8,549.74	9.14
6	X	Haplic Acrisols	0.22	13,535.53	14.47
	Total			*93,542.00*	*100.00*

From map of soil type in Dong Phu District, Figure 3 was developed. The result shows that in Dong Phu District, K factor is from 0.2 to 0.32, in which K at 0.27 accounts for most of the area (42.53%). K factor shows small difference, indicating that that the erosion resistance of the above soils is not much different (Figure 3).

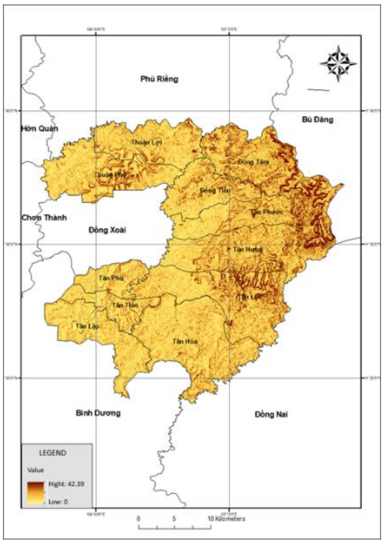

Figure 5. Slope

Figure 6. LS factor

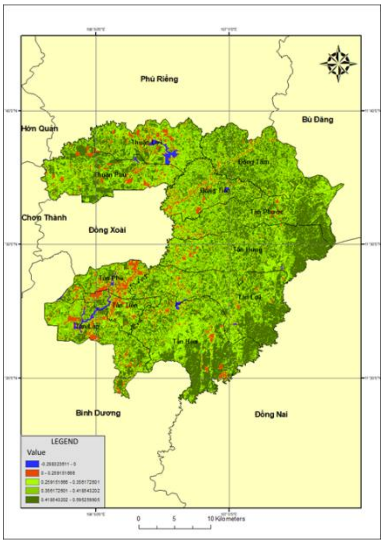

Figure 7. NDVI

3.1.3 Slope-length and steepness

LS factor distribution map is developed from digital elevation model (DEM) and Wischmeier and Smith (1978) equation. DEM (Figure 4) is acquired from https://search.asf.alaska.edu/ (equation 4).

$$LS = \left(\frac{X}{22.13}\right)^n * (0.065 + 0.045 * S + 0.0065 * S^2) \qquad (4)$$

In which: (X) slope length in m, (S) steepness in %; (n) experiment coefficient, n = 0.5 if S > 5%; n = 0.4 if 3.5% < S < 4.5%; n = 0.3 if 1% < S < 3.5%; n = 0.2 if S < 1%.

Table 2. LS distribution

No	LS factor	Area (ha)	Ratio (%)
1	0 – 0.2	56,134.55	60.01
2	0.2 – 0.5	9,840.62	10.52
3	0.5 - 1	16,762.73	17.92
4	1 – 1.5	7,240.15	7.74
5	>1.5	3,563.95	3.81
Total		*93,542.00*	*100.00*

Table 2 shows the LS values of the region in the range 0 – 1.5 and divided into 5 levels. Out of the total area of 10,809.1 ha, 11.55% of area has LS value < 1.0 and 88.45% has LS value > 1.0 (Figure 6).

3.1.4 Crop management factor

Map of crop management factor (C) is developed from normalized difference vegetation index (NDVI – Figure 7) based on equation of Durigon (2014) as follow (equation 5):

$$C = \frac{-NDVI + 1}{2} \qquad (5) \qquad \textit{in which} \quad NDVI = \frac{NIR - RED}{NIR + RED}$$

In which:

NIR and RED: reflection on near-infrared and red channels

In this study, data was collected from Landsat 8 image downloaded from: https://earthexplorer.usgs.gov/.

More than 85% of the area had a C ≤ 0.3 (Table 3). Specifically, C at 0 - 0.2 accounts for 22.16% of total area, at 0.2 accounts for 63.16%. The spatial distribution of current soil erodibility is a multiplication of all factors, which shows that soil erodibility of more than 90% of the area might have been halved thanks to existence of vegetation cover compared with non-existence of vegetation cover (Figure 8).

Table 3. Crop management factor (C)

No	C factor	Type	Area (ha)	Ratio (%)
1	0.0	Water (lake)	1,159.92	1.24
2	0.08	Forest, perennial plant	19,662.52	21.02
3	0.2	Rubber plant	59,081.13	63.16
4	0.3	Fruit plant	5,893.15	6.30
5	1.0	Other land	7,745.28	8.28
Total			*93,542.00*	*100.00*

3.1.5 Farming conservation practice (P)

P value is calculated according to Wischmeier and Smith (1978) from slope map using ArcGIS 10.3 software. As a result, P value map is developed (Table 4, Figure 9).

Table 4. P by steepness

No	P factor	Slope	Area (ha)	Ratio (%)
1	0.5	< 8	60,699.40	64.89
2	0.6	9-12	26,799.78	28.65
3	0.7	13-16	4,031.66	4.31
4	0.8	17-20	1,328.30	1.42
5	0.9	> 20	682.86	0.73
Total			93,542.00	100.00

3.2 Assessment of soil erosion status

Soil erosion status is developed from the integration of R, K, LS, C and P by using Raster Calculator in ArcGIS 10.3.

Table 5. Distribution of soil erosion status in Dong Phu District

STT	Level	Soil loss (ton/ha/year)	Area (ha)	Ratio (%)
1	No or negligible erosion	0 - 1	63,645.98	68.04
2	Mild erosion	1 – 5	20,878.57	22.32
3	Medium erosion	5 – 10	6.791.15	7.26
4	High erosion	10 - 50	1,917.61	2.05
5	Extreme erosion	> 50	308.86	0.33
Total			*93,542.00*	*100.00*

Erosion level is divided into 5 level: Level I (no or negligible erosion); Level II (mild erosion); Level III (medium erosion); Level IV (high erosion); Level V (extreme erosion) (Table 5).

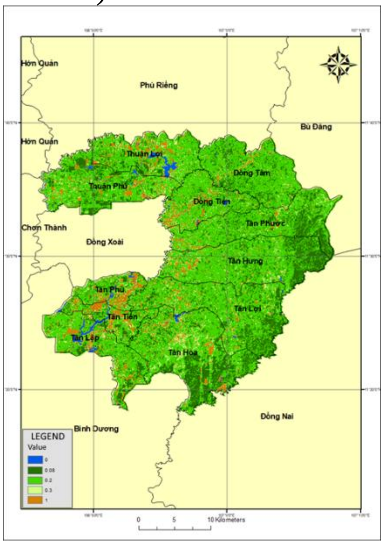

Figure 8: C factor

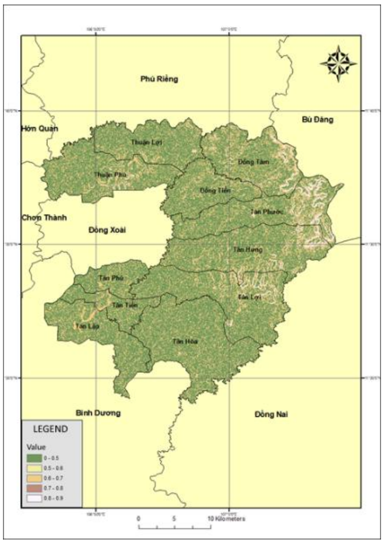

Figure 9. P factor

Figure 10. Soil erosion status map

It can be seen that the current erosion status in Dong Phu District is divided to the following levels (Table 5 and Figure 10):

- Level I (no or negligible erosion): accounting for 63,645.98 ha (68.04% of the entire area), distributed throughout the area, and with low terrain factors (LS).
- Level II (mild erosion): accounting for 20,878.57 ha (22.32%), sandwiched between Level I, Level III and Level IV land.
- Level III (medium erosion): most concentrated in the North, the central region and the South with an area of 6,791.15ha (7.26%).
- Level IV (high erosion): distributed in the entire district, accounting for 1,917.61ha (2.05%).
- Level V (extreme erosion): accounting for 308.86ha (0.33%).

4. CONCLUSION

The erosion map of Dong Phu district shows that in areas with high vegetation cover (high NDVI index), erosion value is low. Erosion in Dong Phu District is uneven among areas. In most of the district, area of negligible erodibility (from 0 to 5 ton/ha/year) is about 84,524.55 ha, accounting for 90.36% of the total land area. Extreme erodibility only accounts for 0.33% of the entire area. Therefore, it is necessary to take measures to prevent erosion especially on sloping land.

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