SOIL EROSION ASSESSMENT IN LAK DISTRICT, DAK LAK PROVINCE, VIETNAM

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ABTRACT: The Research Systematically assessed the extent of soil erosion in Lak district, Dak Lak province, using the interconnection of the Universal Soil Loss Equation (USLE) and GIS methods. As a result, Experiment has incorporated the following criteria: The Rain Erosion Ratio (R), the Capacity of the Soil Erosion Coefficient (K), the coefficients showing the effect of slope and slope length (LS), the coefficient of erosion restriction by vegetative cover (C), and the graph showing the efficacy of agricultural practices (P) research findings indicate that the erosion status in the town of Lak is predominantly level I (less than 2 tons/ha/year). Level I (25 tons/ha/yr) has an area of 1.316 ha, accounting for 10,66 percent, while level III (510 tons/ha/yr) has an area of 923,9 ha, accounting for 7,48 percent.

1. INTRODUCTION

Erosion is described as the assimilation and movement of material by a mobile agent such as water, wind, or ice in earth science (Lutgens, 2016). As a result, soil erosion is a natural process that occurs on a regular and ongoing basis, altering the soil's features and qualities. Erosion may occur in a variety of terrain types. Soil erosion, according to agricultural experts, is the removal of topsoil owing to physical forces such as water and wind, as well as variables connected to farming activities. As a result, erosion is one of the leading causes of soil deterioration, particularly in sloping regions. As a result, erosion is one of the leading causes of soil deterioration, particularly in sloping regions. Terrain slope, soil properties, rainfall, plant cover features, and agricultural practices are all factors that influence soil erosion. Climate change, such as rising temperatures, changing rainfall patterns, and rising sea levels, has been more visible in Vietnam in recent years. All of these factors have the potential to exacerbate soil erosion.

Lak District is surrounded by the stretching Chu Yang Sin mountain from the northeast to the southwest. The average altitude is from 800 to 1,000 meters above sea level while the average slope is 20 – 25º, gradually decreasing from East to West. The peaks higher than 1,000m are concentrated mostly in the East such as Chu Pan Phan peak at 1,928 m high, Chu Drung Yang peak at 1,802 m high. Currently, due to climate change, cultivation conditions are increasing the risk of soil degradation. As a result, a study to assess soil erosion in this area is necessary (Dak Lak People Committee, 2016).

Since the 18th century, scientists have been studying erosion and erosion control strategies to protect slopes all over the world.Wischmeier and Smith's universal soil loss equation (USLE) is one of the most widely used techniques (1978). Ali and Hagos (2016), Lai (2011), (Tung et al., 2018). An evaluation of soil erosion and its verification using the Universal Soil Loss Equation and a Geographic Information System in Boun, Korea (Saro L., 2004). The Universal Soil Loss Equation, as well as geographic information systems and remote sensing technology, were used to compare predicted erosion rates to sediment supply ratios in Central America's Rio Lempa Basin. (2005, John B. K.) Using the Universal Soil Loss Equation, Geographic Information Systems, and a socioeconomic survey, this study examined soil erosion trends in the Kondoa degraded region and studied reasons for change. To estimate soil erosion, researchers employed soil data, digital elevation models, rainfall, and land use/cover visually assessed from multitemporal satellite imageries. (2015, P.J. Ligonja). The goal of this work was to measure and map mean annual soil erosion and sediment deposition across Thailand using a geographic information system (GIS). The revised universal soil loss equation (RUSLE) model was used to evaluate soil loss in each grid cell.

Research on soil erosion in Vietnam began to use GIS and remote sensing technology after the 1990s, with studies by Mai (2007), Ho (2000), My (2005), and Huong (2005) being significant examples (2015). Combining GIS and RS technology for soil erosion assessment is a prominent issue right now, as can be shown. GIS can aid in the modeling and assessment of current conditions, as well as the identification of areas prone to soil erosion and the development of ways to decrease and prevent soil erosion using mathematical models.

2. RESEARCH AREA AND METHOD

2.1. Research area

2.1.1. Location

Lak District is a mountainous area, located south of the Truong Son range, southeast of Dak Lak Province, 54 km from Buon Ma Thuot City along Highway 27. Its total natural area is about 1,256 km^2 with a population of 61,599 people (49 people/km^2 as of 2018) includes 11 administrative units (Lien Son town and 10 communes, namely Yang Tao, Bong Krang, Dak Lieng, Dak Phoi, Dak Nue, Buon Tria, Krong Knô, Nam Ka and Ea Rbin) (Dak Lak People Committee, 2016). Administrative boundaries are as follows:

- to the North: Krong Ana and Krong Bong districts, Dak Lak Province.
- to the West: Krong No District, Dak Nong Province.
- to the South: Dam Rong and Lac Duong districts, Lam Dong Province.
- to the East: Krong Bong District, Dak Lak Province.

2.1.2. Landscape:

The district can be divided in four areas in term of landscape feature:

High mountains: Formed by the Chu Yang Sin mountain range stretching from the Northeast to the South West, the average altitude is from 800 to 1,000 meters above sea level, the average slope is 20 - 250, gradually decreasing from the East. In the West, the peaks higher than 1,000m are mostly in the East such as Chu Pan Phan peak at 1,928 m high, Chu Drung Yang peak at 1,802 m high (Dak Lak People Committee, 2016). This type of terrain is distributed in most of the communes creating a roof across the district sloping to the North (Krong Ana basin) and South (Krong Kno river basin). This landscape is dominated by forests. It is difficult for gravity irrigation, but easy to arrange reservoirs as sources of water supply.

Riverside low lying area: It is created by alluvial from the weathering of mountain and alluvial area of Krong Kno and Krong Ana rivers. This low lying terrain is mainly in the Northwest in the communes of Buon Triet, Buon Tria, Dak Lieng and Ea Rbin. Average slope is from 3 to 8^o, average elevation is 400-500 m and is often innindated in flood seasons. The main crop is rice, providing the main rice area of the district as well as of Dak Lak Province.

Low lying areas along streams: Formed by alluvial from streams, concentrated mainly in the end of Dak Phoi stream and Dak Lak stream in the communes of Yang Tao, Bong Krang, TT. Lien Son, Dak Phoi and Dak Nue.

Low hill plateau: Distributed along Krong Kno river in Nam Ka and Krong Kno communes.

Lak District is located in the east of Truong Son Range, between the Buon Ma Thuot Plateau and the Chu Jang Sin mountain. It is influenced by the southwest monsoon climate and characterized by humid and tropical highland valley climate. There are two distinct seasons: the rainy season starts from May to the end of October with over 94% of annual rainfall, the dry season from November to May of the following year where rainfall is negligible and almost none in February. The average rainfall is lower than the surrounding areas with rainfall from 1,800-1,900mm because the area was shaded by the Chu Jang Sin mountain range in the southeast. The rainfall regime in southwestern communes of the district is from 1,900mm - 2,100mm, which is above average (Dak Lak People Committee, 2016).

2.2. Research method

In addition to traditional research methods like collecting and analyzing secondary data from available documents and literature in conjunction with field surveys, the study uses cutting-edge techniques like remote sensing technology to determine plant cover characteristics and a geographic information system (GIS) to integrate various elements into the USLE mound.

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):

$$A = R \times K \times (L \times S) \times (C \times P)$$

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
C: Cropping management factor
P: Conservation practices factor

3. RESULT AND DISCUSSION

3.1. Factors for erosion

3.1.1. Rainfall erosivity factor

Rain instantly hits the soil surface, causing surface runoff, which transfers that soil layer to a new place when combined with topographic conditions. For each downpour, the rainfall erosivity is determined by multiplying the kinetic energy by the highest rainfall intensity over a 30-minute period. The R-factor takes the erosivity of various rainy events across multiple years and averages it (equation 2).

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

In which: E: total kinetic energy of precipitation (J/m2); I30: maximum rainfall intensity during a period of 30 minutes for each rainstorm (mm/h); R: rainfall erosivity factor (MJ/ha.mm/h).

Due to the lack of complete rainfall data, especially the maximum rainfall within 30 minutes (I). Therefore, the rain erosion coefficient (R) in this study is calculated according to the average annual rainfall, this is the solution to calculate the rain erosion coefficient (R) in the absence of rain data. 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.

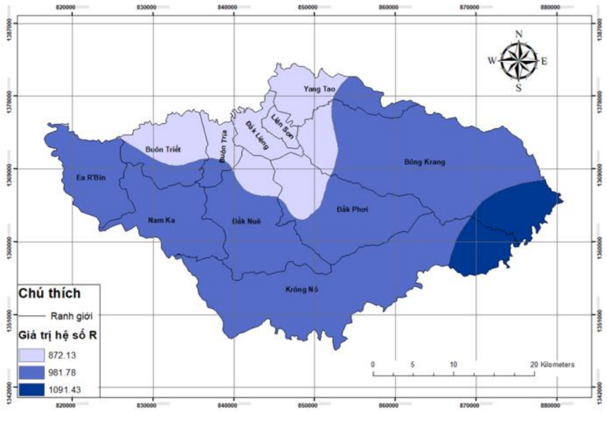

Figure 1. R factor distribution

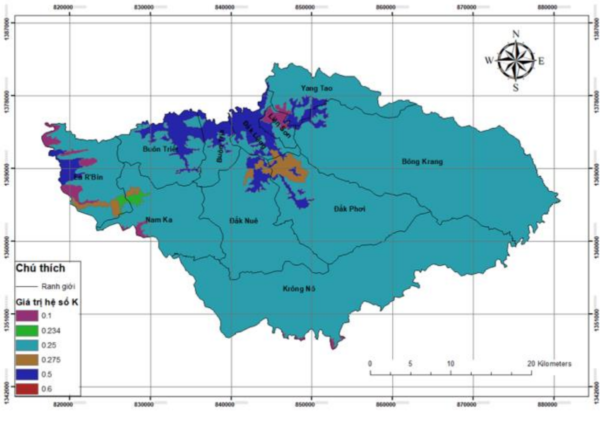

Figure 2. K factor distribution

The communes of Bong Kran and Krong No in the east have the highest R factor. Ea R'Bin, Nam Ka, Dak Nue, Dak Phoi, Bong Krang, Krong No, Yang Tao, and a tiny portion of two communes Buon Triet, Buon Tria have an average R factor and cover up to 73.28 percent of the district area. The northern section of the district, as well as a portion of the center part, have the lowest R factor.

Table 1. R factor distribution

R	Area (ha)	Ratio (%)
872.13	25,078.74	19.97
981.78	92,041.64	73.28
1091.43	8,479.62	6.75
Total	125,600.00	100.00

3.1.2. Soil erodibility (K)

From map of soil type in Lak District, Figure 2 was developed. The result shows that in Lak District, K factor is from 0.1 to 0.6, in which K at 0.25 accounts for most of the area (89.61%). K factor shows small difference, indicating that that the erosion resistance of the above soils is not much different (except for the two soils type GL.c and E which have different values but occupy the relatively small area at 8,767.38 ha) (Figure 2). According to Nguyen Trong Ha (1996), K factor for different soil type is as follow (Table 2).

Table 2. K factor of different soil types in Lak District

	Type	K factor
1	R	0.23
2	Fđ.c	0.27
3	GL.c	0.50
4	CM	0.25
5	P.c	0.10
6	X	0.25
7	E	0.60
8	Water surface	0.10

3.1.3. Slope-length and steepness

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

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

Trong đó: (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 3. LS distribution

LS	Area (ha)	Ratio (%)
0 – 0.68	113,758.79	90.57
0.68 – 2.23	5,404.46	4.30
2.23 – 4.07	3,516.44	2.80
4.07 – 6.21	1,856.37	1.48
6.27 – 9.48	898.19	0.72
9.48 – 35.67	165.75	0.13
Total	125,600.00	100.00

Table 3 shows the LS values of the region in the range 0 - 35.67 and divided into 6 levels. Out of the total area of 125,600 ha, 90.57% of area has LS value <0.68 and 9.43% has LS value> 0.68.

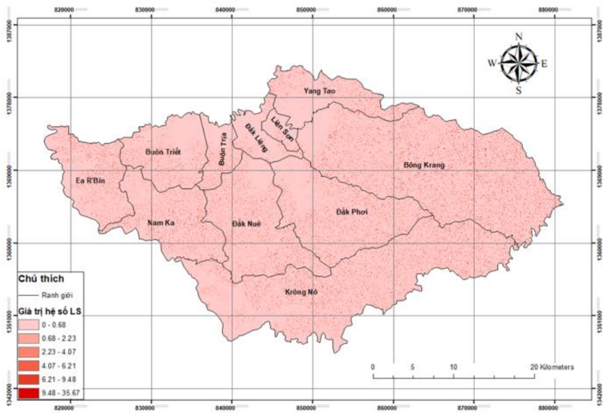

Figure 3. LS distribution map

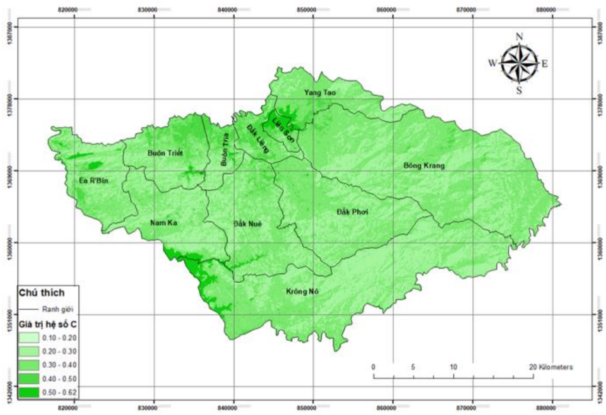

Figure 4. C distribution map

3.1.4. Crop management factor

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

$$C = \frac{-NDVI + 1}{2} \quad \text{in which} \quad NDVI = \frac{NIR - RED}{NIR + RED}$$

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

The data for this study was gathered from a Landsat 8 picture obtained from https://earthexplorer.usgs.gov/.
C 0.4 was found in more than 90% of the region (Table 4). C contributes for 39.77 percent of total area when it is between 0.1 and 0.3, and 52.17 percent when it is between 0.3 and 0.4. The remainder ranges from 0.4 to 0.62. The geographical distribution of present soil erodibility is a multiplication of all variables, indicating that soil erodibility in more than 90% of the region could have been half as a result of plant cover vs no vegetation cover.

Table 4. Crop management factor (C)

C	Area (ha)	Ratio (%)
0.1 – 0.2	1.03	(0.01)
0.2 – 0.3	49,953.00	39.77
0.3 -0.4	65,521.10	52.17
0.4 – 0.5	6,985.20	5.56
0.5 – 0.62	3,139.67	2.50
Total	125,600.00	100.00

3.1.5. Farming conservation practice (P)

The P is only a reflection of the effect of the farming practices used on reducing the amount of soil that is eroded. The P map is built based on the slope map and the current land use map. From the slope ranges, the P corresponding to that slope range will be known. 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 5. P by steepness

Slope (%)	P	Area (ha)	Ratio (%)
0 - 8	0.5	24,464.27	19.48
9 - 12	0.6	18,853.41	15.01
13 - 16	0.7	15,684.94	12.49
17 – 20	0.8	17,699.71	14.09
21 - 25	0.9	48,897.67	38.93

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.

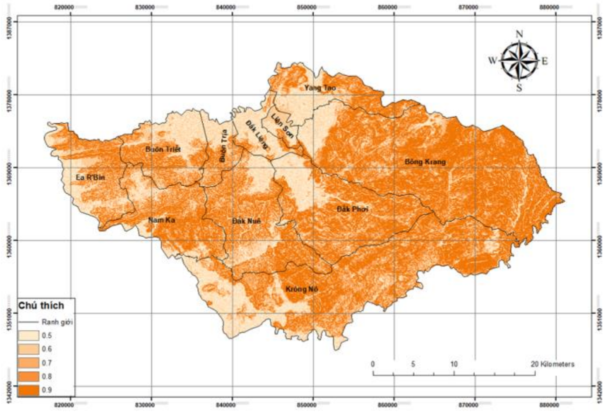

Figure 5. P distribution map

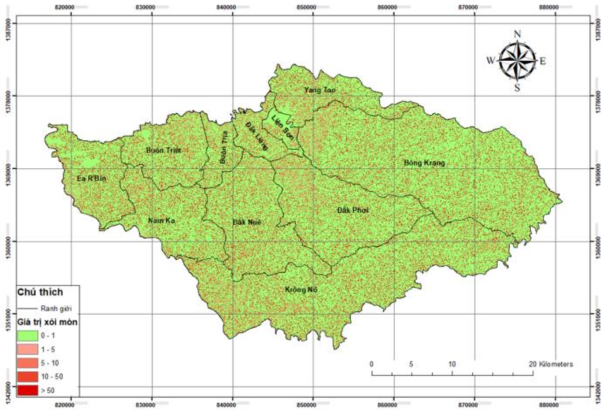

Figure 6. Soil erosion status

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 6).

Table 6. Distribution of soil erosion status in Lak District

	Level	Soil loss (ton/ha)	Area (ha)	Ratio (%)
1	I	0 - 1	106,333.16	84,66
2	II	1 – 5	472.38	0,38
3	III	5 – 10	1,782.00	1,42
4	IV	10 - 50	7,063.89	5,62
5	V	> 50	9,948,57	7,92
Total			125.600,00	100.00

It can be seen that the current erosion status in Lak District is divided to the following levels: Level I (no or negligible erosion): accounting for 106,333.16 ha (84.66% of the entire area), distributed throughout the area, and with low terrain factors (LS). Level II (mild erosion): accounting for 472.38 ha (0.38%), 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 1,782.00 ha (1.42%). Level IV (high erosion): distributed in the entire district, accounting for 7,063.89 ha (5.62%). Level V (extreme erosion): accounting for 9,948.57 ha (7.92%), mainly in 8 - 76% slope area.

4. CONCLUSION

The erosion map of Lak District indicates that erosion is minimal in regions with high plant cover (high NDVI index). In the Lak District, erosion is unevenly distributed. The area of negligible erodibility (from 0 to 1 ton/ha/year) in most of the district is around 106,333.16ha, accounting for 84.66 percent of the total land area. Only 7.92 percent of the whole area is subject to extreme erodibility. The average annual land loss is around 3,244 tons/ha, despite the fact that the region with significant erosion is not big. As a result, steps must be taken to avoid erosion, particularly on sloping ground.

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