EVALUATING SOIL EROSION BY GIS AND UNIVERSAL SOIL LOSS EQUATION IN KON TUM PROVINCE

ĐÁNH GIÁ XÓI MÒN ĐẤT BẰNG MÔ HÌNH USLE TÍCH HỢP GIS TẠI TỈNH KON TUM

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ABSTRACT

Kon Tum, a mountainous province in central highland of Vietnam, is characterized by diversified and complex terrain. The change of land use/land cover in recent years has caused the phenomenon of soil erosion phenomenon. With the support of GIS technology, this research uses USLE model to evaluate potential soil erosion in Kon Tum area, including some factors: Rain fall (R), K factor map (K), Length Slope factor map (LS), Land cover (C) and cultivatural method map (P). The results make it possible to determine the level and location of soil erosion areas. Therefore, it can help decision-makers to make the best plans to reduce soil erosion. The research proves that the mountainous province Kon Tum has characteristics of highland climate with the annual average rainfall than 1.800m and thus, is potentially facing with strong and very strong erosion concentrating mainly at some highland districts.

Keywords: *Geographic Information System; Universal Soil Loss Equation; Soil erosion; Map; Kon Tum.*

TÓM TẮT

Kon Tum là một tỉnh miền núi, vùng cao của Tây Nguyên với địa hình đa dạng, gò đồi núi cao nguyên và vùng trũng xen kẽ nhau khá phức tạp. Việc thay đổi sử dụng đất trên địa bàn tỉnh trong những năm qua đã ảnh hưởng rất lớn đến tài nguyên đất đai gây ra hiện tượng xói mòn đất. Với sự trợ giúp của công nghệ GIS, nghiên cứu đã tiến hành đánh giá xói mòn đất trên địa bàn tỉnh Kon Tum bằng phương trình mất đất phổ dụng USLE gồm các bản đồ hệ số : bản đồ hệ số xói mòn do mưa (R); bản đồ hệ số kháng xói của đất (K); bản đồ hệ số xói mòn của địa hình (LS); bản đồ hệ số che phủ đất (C) và bản đồ hệ số do biện pháp canh tác (P). Kết quả nghiên cứu sẽ xác định được mức độ và vị trí của các khu vực xói mòn đất, từ đó giúp các nhà ra quyết định có kế hoạch áp dụng các biện pháp chống xói mòn đất một cách hiệu quả. Kết quả nghiên cứu cho thấy, Kon Tum là một tỉnh vùng cao với tính chất khí hậu cao nguyên, lượng mưa trung bình năm hơn 1.800m có mức độ xói mòn mạnh và rất mạnh tập trung phần lớn ở các huyện vùng núi cao.

Từ khóa: *Hệ thống thông tin địa lý (GIS); Phương trình mất đất phổ dụng (USLE); Xói mòn đất; Bản đồ; KonTum.*

1. INTRODUCTION

Land is a very precious resource, a special production supplies, and the most important component of the environment. Today, with the overexploitation of land resources make erosion increasingly, influence to crop yields, reduced income, and impacts on people's economic lives. According to the data about the soil erosion in Vietnam monitored systematically from 1960 till now, about 10-20% of the land area moderately to severely affect by the erosion.

Kon Tum is a mountainous province, border of the Central Highlands, have geographic coordinates from 13o55'10" - 15o27'15" North latitude, 107o20'15" - 108o32'30” longitude East, with its terrain descending from north to south and from east to west, steep slope at northern and lower about 2% - 5% at Southern. Landform is characterized by mountains, hills and plateaus alternate quite complex. Kon Tum's climate have common trait of monsoon tropical zone of South Vietnam, the annual average temperature of 220C - 230C. The rainfall is concentrated in the rainy season achieve 80-90% of annual rainfall, average annual rainfall of 2.500 to 3.000 mm. Concentrated rainfall in the rainy season combined with steep terrain lead to soil loss due to erosion is very high.

Erosion research and evaluation was implemented very soon by many scientists in the world and Vietnam with many different methods such as experimental methods (simulation models ...) or the mathematical model (USLE, RUSLE ...) [1].One of the most widely applied empirical models for assessing erosion is the Universal Soil Loss Equation (USLE), developed by Wischmeier and Smith in 1978. This model takes into consideration several determining factors, such as the soil erosibility factor, rainfall intensity factor, slope length and steepness factor, cover and management factor and support practice factor. USLE was developed mainly for soil erosion estimation in croplands or sloping topography caused by raindrop impact and overland flow [2]. The application of geography information system integrated with USLE is strongly supported tools in spatial analysis.

Pham Ngoc Dung (1991) has conducted research and application of universal soil loss equation to predict potential soil erosion and provide anti-erosion measures for the Central Highlands provinces. Cam Vinh Lai [3] using USLE to assess the potential and current erosion level of each basin, indicate the hazard erosion areas, as a basis for proposing effective preventive measures. Dinh Van Hung's research, 2009 with soil erosion prediction Yen Chau area was tested in the real with results consistent with the results calculated by GIS and USLE. This study was conducted in Kon Tum province, aims to evaluate the erosion by USLE model integrated with GIS.

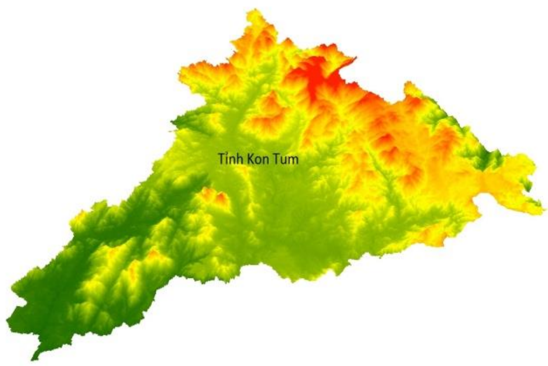

Figure 1. *Kon Tum 2D terrain model.*

2. METHODS

USLE model was displayed by the following empirical equation (Wischmeier and Smith 1978) [4]:

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

Where A is average annual soil erosion per unit area (t hm-2 year-1), R is rainfall and runoff erosivity index, K is soil-erodibility factor (t hm2 h hm-2 MJ-1 mm-1), L is slope length factor, S is slope steepness factor, C is cover and management factor, and P is conservation supporting practice factor. S, C, and P are all dimensionless.

To implement equation (1), GIS was applied to make component maps and factor maps. Quantity of potential erosion and reality is assessed on the basis of calculate the factor maps (Figure 2).

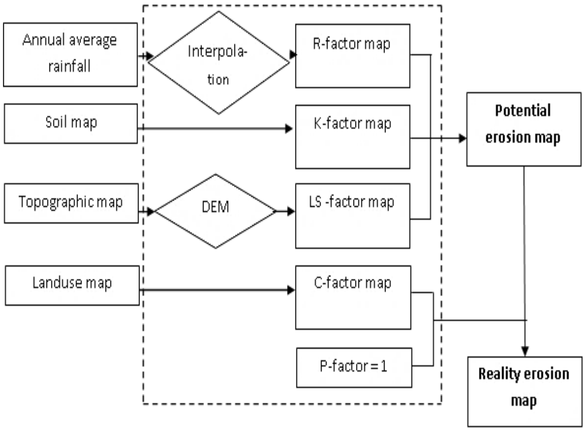

Figure 2. *The chart of methodological approach*

R-factor calculation: R-factor shows the distribution of the value of the rain and flow elements in the study area, based on a formula of Nguyen Trong Ha (1996):

$$R = 0.548257 * P - 59.9 \quad (2)$$

With R: rainfall erosivity factor (J / m^2); P: annual average rainfall (mm / year). Annual average rainfall is calculated in ArcGIS 10.1 software using interpolation method with IDW tool.

K-factor calculation: The soil-erodibility factor depends on the following soil parameters in combination: Percentage of silt, very fine sand, clay and organic matter. Structure (codes between 1 and 4 are given to different common structures) and drainage (codes between 1 and 6 are given from fast to very slow drainage respectively). Wischmeier and Smith (1978) proposed the following formula for *k*-erodibility factor calculation:

$$100K = 2,1*10^{-4}M^{1,14}(12-a) + 3,25(b-2)+ 2,5(c-3) \quad (3)$$

Where *M* is the size of soil particles (% silt + % very fine sand)·(100 - % clay), *a* is the percentage of organic matter, *b* is the code number defining the soil structure (very fine granular = 1, fine granular =2, coarse granular = 3, lattice or massive = 4), and *c* is the soil drainage class (fast = 1, fast to moderately fast = 2, moderately fast= 3, moderately fast to slow = 4, slow = 5, very slow = 6). In this work, the *k*-factor was derived from the soil map with scale of 1:50.000.

LS-factor calculation: Topography influences runoff characteristics and transport processes of sediment. Digital elevation models (DEM) have been commonly used to collect topographic characteristics. A DEM map was derived by digitizing 30-m contour lines from a 1:50,000 topographic map. The LS-factor was inferred from the DEM which is calculated based on the formula of Bruch (1986) as follows:

$$LS = (FlowAccumulation * cellsize / 22,13)^n * ((Sin [Slope] * 0.01745)/0.0896)^{1.3} \quad (4)$$

Where LS: coefficient shows the influence of the terrain to erosion; Flow Accumulation: accumulated stream value; Cellsize: pixel size of the DEM; Slope: slope map on percentage; n: empirical parameters with n = 0.2 when S <1%; n = 0.3 to 1% <S <3.5%; n = 0.4 to 3.5% <S <4.5%; n = 0.5 when S> 5%.

C-factor calculation: The C-factor is defined as the ratio of soil loss from crop land under specified conditions to the corresponding clean-tilled continuous fallow (Wischmeier and Smith 1978). For this study, the C value was determined using land use map combines with satellite images to build the land cover, refer the research result of C-factor of Nguyen Ngoc Lung and Vo Dai Hai to determine the value of C-factor in the study area.

P-factor calculation: The support practice factor *P* represents the effects of those practices that help preventing soil from eroding by reducing the rate of water runoff. The values of *P* are calculated as rates of soil loss caused by a specific support practice divided by the soil loss caused by row farming up and down the slope. In this study, however, the *P*-factor was not taken into account, because it was not possible to obtain data regarding the support farming practices. The maximum value of P = 1 if no measures, anti-erosion works.

Potential erosion map presents the impact of natural factors on erosion, was built from multiply method R-factor map, K-factor map and LS-factor map under the supported by ArcGIS. Actual erosion map is calculated by multiplication of the C-factor map, P-factor map (P = 1) with the map of potential erosion. The necessary database for the calculation according to the equation USLE erosion include meteorological data, topographic map, soil map, land use map in 2010 and statistics data on economic and social with support of ArcGIS 10.1 software.

3. RESULTS AND DISCUSSION

3.1 R-factor

The R-factor in the study area were calculated according to annual average rainfall and collected from eight rainfall stations in the region and three rain gauge stations worldwide. Based on meteorological data, the annual average rainfall distributed over the region is high > 1885mm.

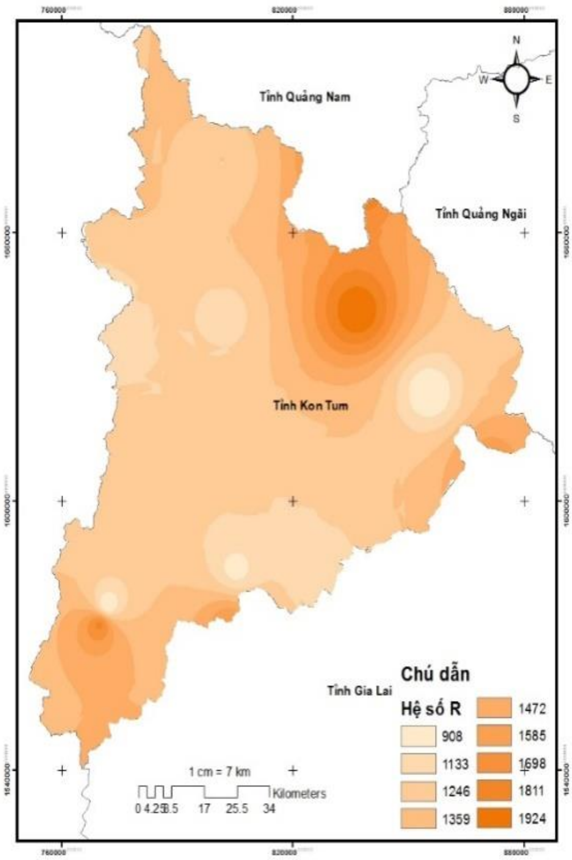

Figure 3. *R-factor map.*

Result shows that the erosion was caused by rainfall in Kon Tum is quite high, especially in the east, however, the R-factor according to the annual average precipitation does not fully reflect the impact elements of rain and flow to the erosion, it also depends on other factors such as slope, soil type, land cover... Due to the characteristics of the topographic and the rainfall is quite complex, making the difference in the value of the R-factor is shown in Figure 3. From the above results, we can see that, the erosion resistance of the region is relatively low, a 0.41 K value is concentrated in Kon Tum downtown, occupies a very low rate of 0.33% (3.182ha), the K value from 0.19 to 0.25 K accounted for nearly two-thirds of the area, approximately 63% (608.234ha), mainly ferralic acrisols, distributed in the west of Sa Thay, Ngoc Hoi and Dak Ha district. The K value is less than 0.19 which is equivalent to 355.739 ha (reached 36.6%), mainly humic acrisols, distributed in the east and southeastern of province.

3.2 K-factor

K-factor map reflects the erosion ability of each type of soil. According to the classification of soil in Kon tum have major soil groups, such as ferralic acrisols, humic acrisols, humic ferrasols, umbric gleusols, rhodic ferrasols... Among those, ferralic acrisols and humic acrisols have the large area, almost all of the area total of the study area (Figure 4).

3.3 LS factor

LS factor in Kon Tum is calculated from DEM model and GIS with the equation (4), was divided 6 classifies. Results table 3 shows that almost of slope in the region bigger than 5%, reached 95% of the area total, distributed at high terrain place like Dac Glei, TuMoRong and Kon Plong and Kon Ray ... be a risk of erosion in the area. LS factor and LS map were shown in table 1 and figure 5. From the results of figure 5, we can realize that the LS value from 0 to 723, was classified into 6 levels. LS values less than 5, used 53.2% area(50496ha) focused almost at Sa Thay, Kon Dak district and Kon Tum downtown, LS values from 5-20, accounted 34.4% area (325.522ha) distribute scattered in the region and the value more than 20, got 12.5% area (136.637ha), located over the high mountainous terrain which are highly sensitive position to eroding. According to the study of C.P. Devatha et al [5], the topographic factors are in large influence soil erosion, so it can be found that slope factors and slope length would affect much amount of soil loss caused erosion in the study area.

Table 1. *LS factor*

LS factor	Area (ha)	Ratio (%)
0-0,5	374.545	39,5
0,5-1	7.548	0,8
1-5	122.903	12,9
5-10	160.429	16,9
10-20	165.093	17,4
>20	136.637	12,5

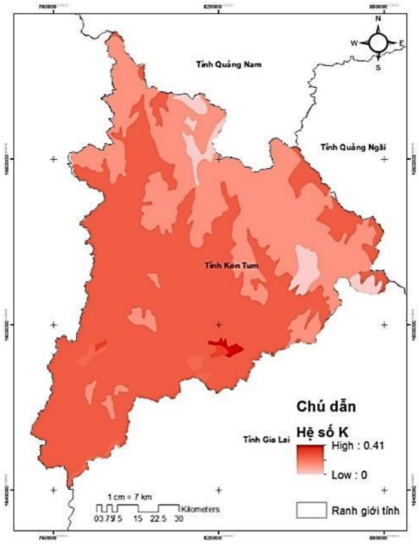

Figure 4. *K-factor map.*

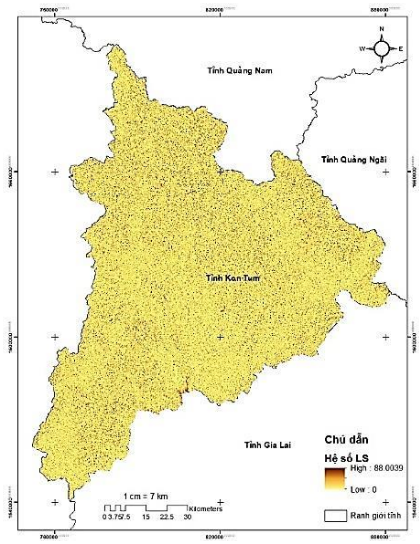

Figure 5. *LS factor map.*

3.4 C factor

In this research, the *C*-factor represents how management affects soil loss. It is mainly related to the specified cover percentage. The value of *C* depends on vegetation type, stage of growth and coverage percentage. C factor map built from land use/ land cover map (2010) and a link with the Tay Nguyen land cover database by means of a lookup-table is suggested by Nguyen Manh Ha [6]. The *C*-factor of USLE ranges from 0 (full cover) to 1 (bare land). According to Nguyen Manh Ha, C factor characterized limited erosion extent of vegetation cover, an area without vegetation cover occurs then the C factor will be equal to 1. The results show that C factor for each type of land use in the study area has small value margin. C factor more than 0.2 accounted 12% of the area (120.508ha), which more or less affects the amount of soil erosion in the area.

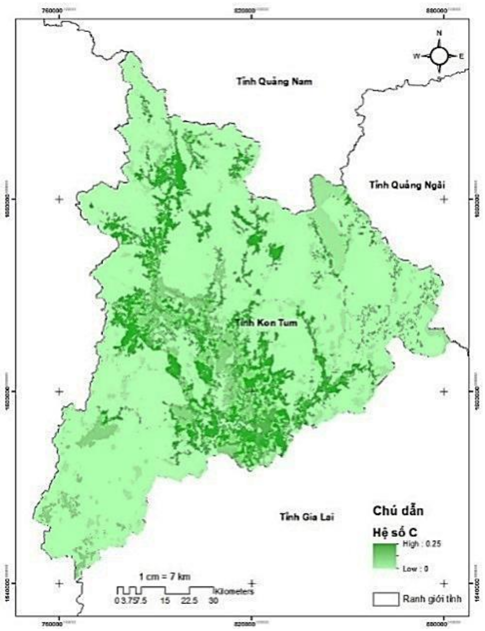

Figure 6. *C factor map.*

3.5 P factor

P factor displays the degree of erosion mitigation measures through cultivation. The determination of P requires the calculation, the long-term survey. In the study area, however, practical cultivation is uneven and limited of the data, P has value of 1. With P = 1, the total amount of soil loss in the formula A (1) will not affected by this factor.

3.6 Potential erosion

Potential erosion is assessed based on three main factors are coefficient soil erosion by rainfall (R), soil erosion coefficient (K) and the coefficient of erosion by topography (LS), not including factors vegetation cover. Results potential erosion maps built in Figure 7. Based on the potential erosion map and the provisions on decentralization of potential erosion following Vietnam standards (TCVN5299-2009), implement classify the potential eroding in the study area (Table 2).

From potential erosion map and table 5, we can see that eroding took place nearly 60% of the study area, erosion at the level IV (1000-5000 tons/ha/year) occupies volume 26.5% (256.438ha) total area of the region, erosion at the level V (> 5,000 tons/ha/year) increased with 286.709ha area, achieved for 29.7% of total area. Overall, the levels of potential erosion distributed alternating together from the highlands to the valley. The total amount of the potential soil loss is up to 364 204 tons/ha/year. Erosion at the level I (level not eroded) had a high proportion of 40.4% of the area, concentrated mainly in the area of Kon Tum town. Both erosion levels IV and V are distributed over the highland districts in steep terrain, high rainfall such as KonPlong, Kon Ray, DakGlei and Dak Ha, SaThay and TuMo Rong. However, the potential erosion just say eroding risk when no the vegetation cover.

Table 2. *Classify potential eroding in KonTum*

No.	Classify	Soil loss(ton)	Area (ha)	Ratio (%)
1	Level I	0-100	391.103	40,4
2	Level II	100-500	9.597	1,0
3	Level III	500-1.000	23.308	2,4
4	Level IV	1.000-5.000	256.438	26,5
5	Level V	> 5.000	286.709	29,7

3.7 Practical erosion

Current erosion map shows erosion levels while taking into account factors C and P. Table 3 and Figure 8 show the actual erosion hierarchy in the study area as follows

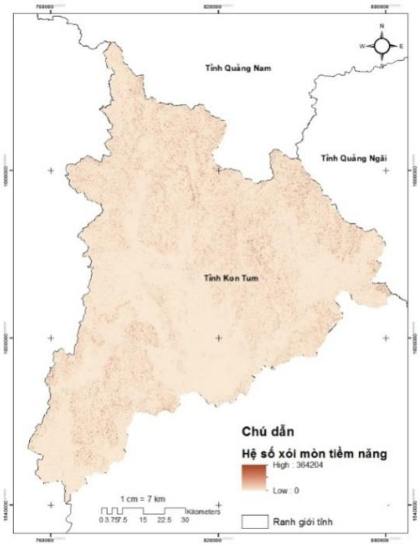

***Figure 7**. Potential erosion map.*

The statistical results shows that the effect of coverage in limiting eroding from 364.204 tons/ha/year to 72.841 tons/ha/year. Potential erosion value and the actual erosion value are constantly changingvalues at the same location. Based on the above hierarchy table, we possible commented that: Level 1 (<1 ton/ha/year): scattered many places of the region, focusing almost at KonTum town with 407.286ha area (get 41.2% of the area total), the types of soil are mainly water body and non-agricultural land. Level 2 (1-5 tons/ha/year): scattered some districts in the west, northwest and northeast of the province like Ngoc Hoi, KonPlong and DakGlei, with the main soil types like level 1, used 10.3% of the area (99.737ha) at the region area. Level 3 (5-10 tons/ha/year): having area is 119.146 hectares (achieved 12.3%), distributed at areas which have slopes between 3-8%, is primarily forest land, concentrated at all districts. Level 4 (10-50 tons/ha/year): distributed over the region with area 168.311ha (means 17.4% of the total area), focusing more at SaThay, DakGlei, KonPlong and Kon Ray, TuMoRong districts, mainly planting forests, hills and unused land. Level 5 (> 50 tons/ha/year): distributed everywhere in the region with area 172.675 ha, achieved 17.9% of the area total, concentrated most districts as KonTum, DakHa, DakTo and NgocHoi, mainly perennial crops like coffee all, rubber, pepper, cashew and fruit trees annually.

Overall, the current erosion status of study area has unequal area between erosion levels with the total soil loss up to 72.841tons/ha/year. Although the total soil loss in level IV and V do not high, only 22.6% of the total area, if having no measures to protect coverage, it will grow up quickly.

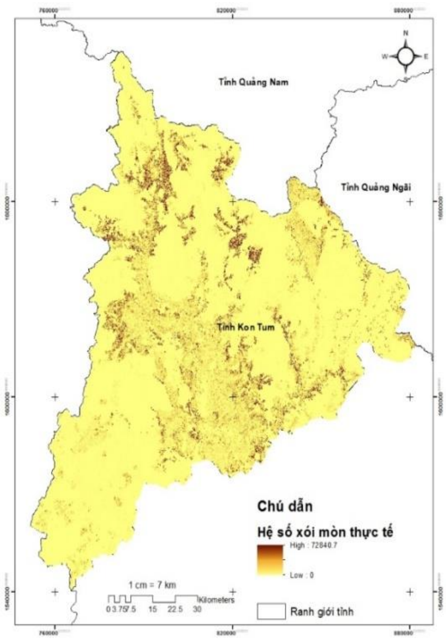

***Figure 8.** Practical erosion map.*

***Table 3.** The actual erosion hierarchy*

No.	Classify	Soil loss (ton)	Area (ha)	Ratio (%)
1	Level 1	0-1	407.286	42,1
2	Level 2	1-5	99.737	10,3
3	Level 3	5-10	119.146	12,3
4	Level 4	10-50	168.311	17,4
5	Level 5	> 50	172.675	17,9

4. CONCLUSSION

This research was a technological application of geographic information systems (GIS) combining with universal soil loss equation of Wischmeier and Smith to assess the status of the annual soil loss due to erosion about 72.841 tons/ha/year on KonTum province.

The study helps build up the potential map and practical erosion map at research area, which is also the basis for rational land use planning for the region to ensure its sustainability.

Further research on soil erosion is suggested to combine the use of GIS technology with erosion identified measures in the field to verify and enhance the practical value of the research problem locally.

The soil erosion investigation by using GIS with the larger scope (national level) is really essential to synchronize the process of analysis, evaluation and selection of measures impacting on aggregation and systems in the near future.

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