APPLYING UNIVERSAL SOIL LOSS EQUATION (USLE) TO ESTIMATING SOIL EROSION AT LAM SON HEADWATER CATCHMENT

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SUMMARY

Erosion is an environmental phenomenon, but due to human activities this phenomenon has led to many serious problems. With the aim of protecting soil resource, as well as circumscribe damages by erosion, so the study of applying USLE on assessing soil erosion at Lam Son headwater catchment was conducted. To reach the purposes, the content of the study focus on collecting data and using USLE, ArcGis software to form rainfall map, slope coefficient and slope length map, canopy cover coefficient map. From those maps, we can form the erosion potential map and current erosion map of the study site. The result of this study show that: (1) R factor in the study area is medium fluctuating from 950 – 1050 mm and decrease from the North to the South area; (2) Main soil type in the research area is yellow-red soil on sand (Fs) with K coefficient = 0.27; (3) In general, about 65% of the area is covered by plant, C factor was 0 - 1, averaged 0.2. This is the most important factor to determine the capable of erosion, so it is necessary to have a suitable plan for exploiting and planting forest; (4) The research area has total potential erosion (level 5) up to 90% and current erosion is 89% divided equally for 3 levels (level 1, level 4 and level 5). The area of erosion tends to decrease due to good farming method and conscious of local people; (6) The results of the study are trustful because it was verified in the research area. It can be used as document for plan of land using in the research area. In addition, the local community as well as local people should focus more on planning the bare land area and modifying the crop season.

Keywords: Headwater catchment, Lam Son commune, soil erosion, USLE model.

I. INTRODUCTION

Erosion is the phenomenon of soil transferred due to water drop and wind, under the impact of gravity of the Earth (Ellision, 1945). According to land use analyzed, Vietnam has about 25 million of steep land, with huge potential of erosion, about 10 tons/ha/year (Vinh and Minh, 2009). According to systematic monitoring from 1960 until now, there is 10 - 20% of area affected by erosion from moderate to strong (Xiem and Phien, 1999). Hence, each year, the mountainous area in Vietnam has lost a huge amount of soil due to erosion. Erosion makes soil loss, destroys the layer of surface soil, reduces the fertility of soil, make soil exhausted. In addition, depending on the characteristics of landform, erosion can be taken along the flow to make suspended solid then accumulate in appropriate location, usually in lying areas, this affect to the water quality and sediment. In the recent year, erosion has occurred seriously. Bui river belong to Lam Son headwater catchment is an important source of water for many activities of local people. So that it is necessary to estimate, evaluate about the erosion potential as a basis for planning and using resources sustainably at this location.

In the past to calculating the amount of soil loss due to erosion, researchers have to build reservoirs to monitor amount soil loss. However, this method is costly and time-consuming. There are many different approaches and methods in researching soil erosion. The common trend is to research oriented modeling by describing the dynamics of process of erosion. There are many models of evaluating soil erosion such as: MUSLE (William, 1975), ANSWERS (Beasley et al, 1980), SLEMSA (Elwell, 1981), SOILOSS model (Rosewell, 1993), RUSLE model (Renard, 1997). Those models have both pros and cons in calculating the amount of soil eroded. USLE model is an empirical technology that has been applied around the world to estimate soil erosion by raindrop impact and surface runoff. In Vietnam, there are some researches which apply USLE model such as Tu (2011) and Ha (2009). Those researches were success in point out the level of erosion at each research area and proposed very good solutions to limit erosion such as ground cover, ladder field or wetland method which has been successfully applied in the world. Those researches were appreciated and considered as dependability references, which contain high scientific content and can be use as references for the work of land use planning. Therefore, objective of this study is to use USLE to calculate the amount of soil erosion in Lam Son headwater catchment, Luong Son, Hoa Binh where has more than 70% of topography are mountain with huge potential of erosion. Up to the present, there is no research about soil erosion in this area, so the study on application of USLE to assess the soil erosion is necessary.

II. RESEARCH METHODOLOGY

2.1. Study site

Lam Son commune is located in the Northwest of Luong Son district, Hoa Binh province. It is about 46 km north from Hanoi center (Fig. 2.1). The terrain of Lam Son commune is mountainous and limestone alternating with absolute elevation is 500 m and relative elevation is 130 m (sources: Institute for Forest Ecology & Environment of VNUF). The mean annual temperature is 23.1^{0}C and the highest temperature is 28.2^{0}C in July while the lowest temperature is 16^{0}C in January. Average precipitation per year is 1913 mm. Rainy season is mainly in summer from June to October. December has the lowest amount of precipitation. The rainy season comprises above 70% of total rainfall so that lead to flood at headwater catchment in Bui River. However, dry seasons usually occurs lack of water for production and living. Lam Son commune has two main ethnics: Kinh people and Muong people. The economic depends much on agriculture, forestry and some services: golf, crafts. People in Lam Son commune planting rice, maize, fruit trees, woody trees and grazing cattle, poultry.

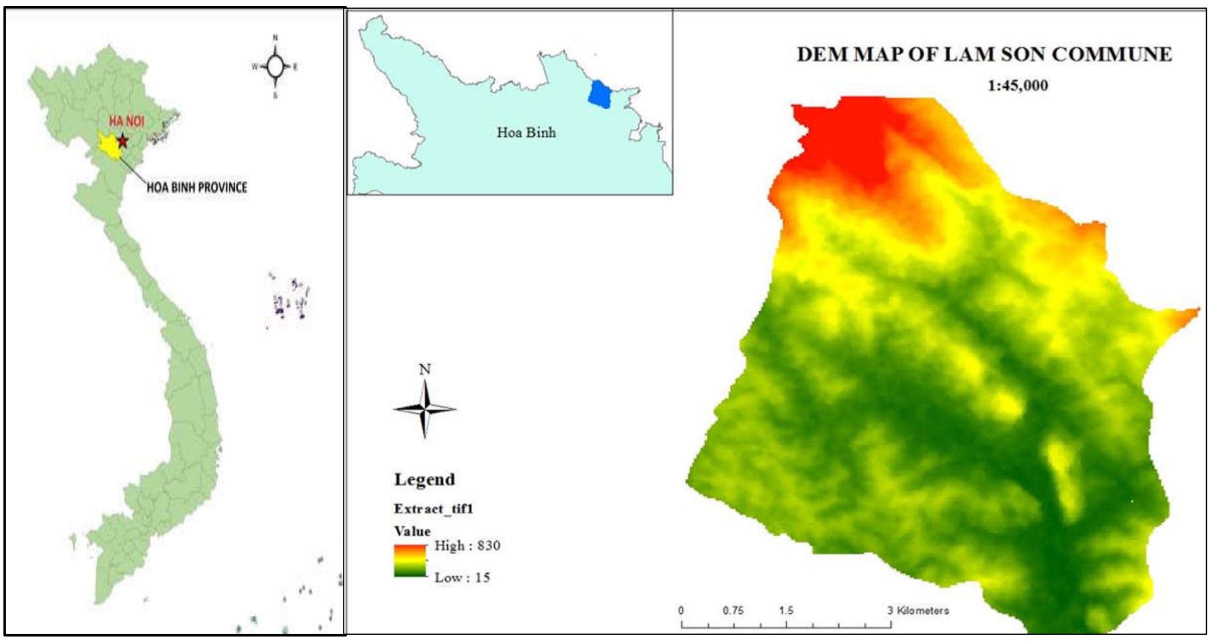


Figure 2.1. Location of study site in Lam Son commune

2.2. Methodology

2.2.1. About USLE model

The Universal Soil Loss Equation (USLE) was developed at the USDA National Runoff and Soil Loss Data Center at Purdue University in a national effort led by Walter H. Wischmeier and Dwight D. Smith in 1978. The USLE is based on extensive erosion data from studies throught out the USA, and provides a quick approach to estimating long-term average annual soil loss (A). In this model, erosion process is influenced by climate, topographic, component and structure of soil and human activities. Those factors are shown by 6 erosion coefficients included: rainfall (R), Slope length (L), Slope steepness (S), Cover and Management (C), support practice (P) with:

$$A = R \times K \times L \times S \times C \times P \qquad (2.1)$$

2.2.2. Soil erosion process using USLE model

To make a map of soil erosion for study site based on USLE and GIS, we made map of R index, K index, LS index, and C index. After that, gather those maps to form potential erosion map. Finally, gathering map of C index with potential erosion to form present condition erosion map (Fig. 2.2).

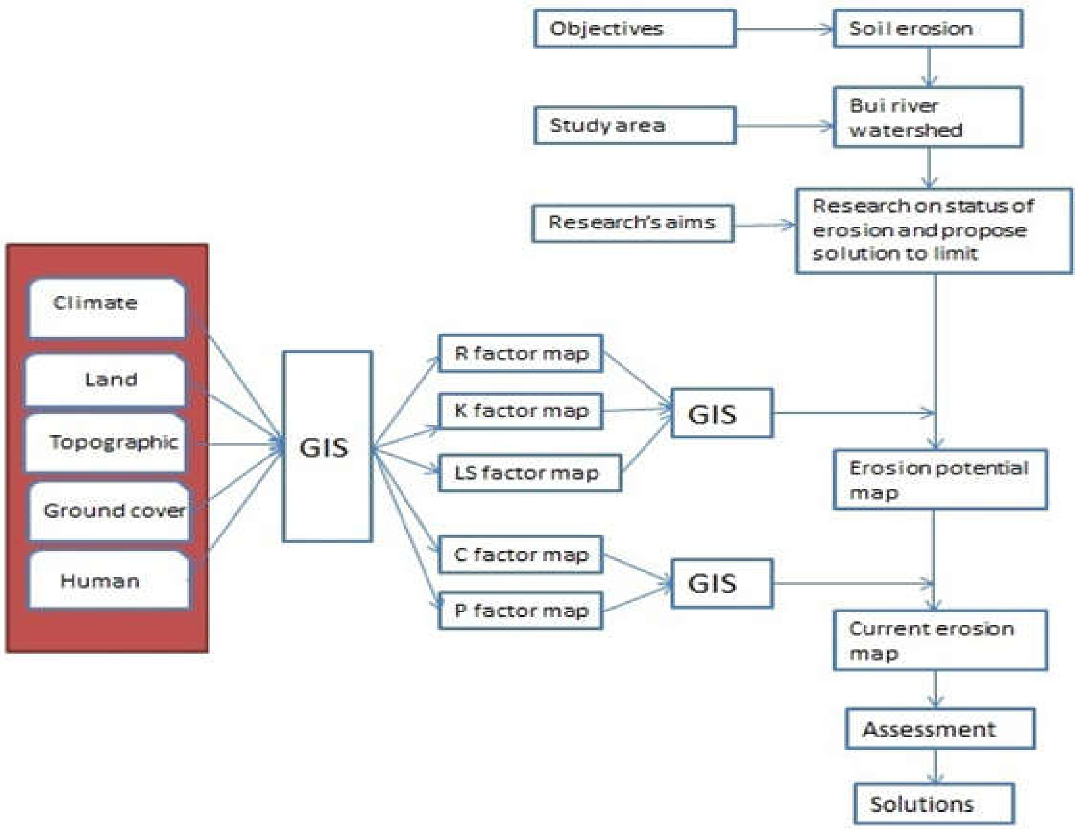


Figure 2.2. Illustrated graph for soil assessment process based on USLE model

a. R factor

R factor represents for *Rainfall and runoff erosivity*. It is the key to calculate the strength of rain erosion and the surface runoff. R is not only precipitation, it is calculate by sum of precipitation and rainfall intensity.

R factor map show the distribution of rain and flow in Lam son headwater catchment. Forming equation to calculate R factor require the annual precipitation and the rainfall intensity in 30 minutes (I30) of Wishmeier (1985). But due to lack of data of rainfall intensity in 30 so R factor in this study site will be calculated according to average precipitation and applied equation of Ha (1996): $R = 0.548257 \times P - 59.9$ (2.2)

In which: R is erosion coefficients of rain and flow and P is Average precipitation/year. Annual precipiation was collected at Lam Son weather station.

b. K factor

K factor represents for soil erodibility. The higher value of K makes higher potential of erosion. K depends on soil characteristics and the stable of soil structure, components. For more easily in calculating K factor, we based on equation of Wischmeier and Smith (1987) to look up for K factor. To form K index map in Arcgis 10.0, algorithm was used to query any types of soil in soil map to fill value of K index based on table 2.1. After fulfill K index, we turn to transform data from vector to raster by Feature to Raster tool based on K fields.

Table 2.1. K index of some types of soil in Lam Son headwater catchment

Symbol	K index	Total area (km^2)	Percentage of K factor (%)
D	0.28	2.24	6
Fk	0.2	1.58	4
Fl	0.28	1.42	4
Fq	0.26	3.75	11
Fs	0.31	25.15	71
Nui da	1	1.26	4

c. LS factor

LS factor represents for the effect of slope steepness factor (S) and length (L) to the process of erosion. We based on Wischmeier and Smith (1978)'s formula to calculate LS factor as follow:

$$LS = (x/22.13)^n * (0.065 + 0,045 * s + 0.0065 * s) \quad (2.3)$$

In which: x: the length of the slope (m); s: percent of slope; n: actual parameter (n = 0.5 when S > 5%; n = 0.4 when 3.5 < S< 4.5%; n = 0.3 when 1% < S < 3.5%; n = 0.2 when S < 1%). Slope in the study area is almost from 80 – 25^0 so n = 0.5 was used for the study site (Table 2.2).

Table 2.2. Slope analysis in Lam son headwater catchment

Steep (^{0})	Total area (km^2)	Percentage of steep (%)
< 3	0.96	3
3 - 8	4.67	13
8 - 15	9.59	27
15 - 25	12.01	34
> 25	8.07	23

d. C factor

According to Wischmeier and Smith (1978), C factor is a simple relation between erosion on bare soil and erosion observed under a cropping system. The C factor combines plant cover, its production level and the associated cropping techniques. It varies from 1 on bare soil to 0.001 under forest, 0.01 under grasslands and cover plants, and 1 to 0.9 under root and tuber crops. To define C factor for the study area, it is necessary to have long-time observations. There are two methods to calculate C factor, including Surveying method Wischmeier and Smith (1978) and Using current land use status map or satellite figures to forming plant cover, after that collecting C factor of each status from other documents. In this study, C is considered as the cover of surface vegetation. However, due to lack of data of satellite figures, C index will be divided based on land use map and consulted from other resources. From the land use map, we divided and distributed coating the surface of the study area with the government of the types of values corresponding C index (Table 2.3)

Table 2.3. C index of Lam Son headwater catchment

Soil Type	C index	Total area (km^2)
Mountain, river	0	8.46
Protective forest land	0,001	2.9
Productive forest land	0,008	17.3
Rice field land	0,06	0,04
Perennial crop land	0,08	0,8
Annual crop land	0,2	2.1
Bare land	1	4.37

e. P factor

In USLE equation, P factor assess the effectiveness of farming methods, it reflect the effect of practices to protect and limit soil erosion. P factor is formed of three sup-factors:

$P = Pc*Pst*Pter$ (2.4)

In which: Pc: Contour tillage sub-factor; Pst: Contour plant sub-factor; Pter: sub-factor of embankment to prevent erosion. It required long time and money to survey to calculate P factor. Due to the limit of the research, P factor in the thesis is considered equal to 1.

f. Potential erosion map

Potential erosion map show the impact of natural factors on erosion. In USLE model the map is formed from maps of R, K and LS factors. We use GIS software to join those maps together.

g. Current erosion map

Beside natural factors, the current erosion is affected by social economic factors such as: land use, farming methods. To determine the soil loss at defined moment, we gather C factor map with potential erosion map to form current erosion map. According to regulation of classifying current erosion follow Vietnamese standard (TCVN 5299-1995) in the study area, we can divide into 5 level of erosion as level 1 (< 1 ton/ha/year), level (1 - 5 ton/ha/year), level 3 (5 - 10 ton/ha/year), level 4 (10 - 50 tons/ha/year) and level 5 (> 50 tons/ha/year).

III. RESULTS AND DISCUSSION

3.1. Mapping factors of USLE model

3.1.1. R factor map

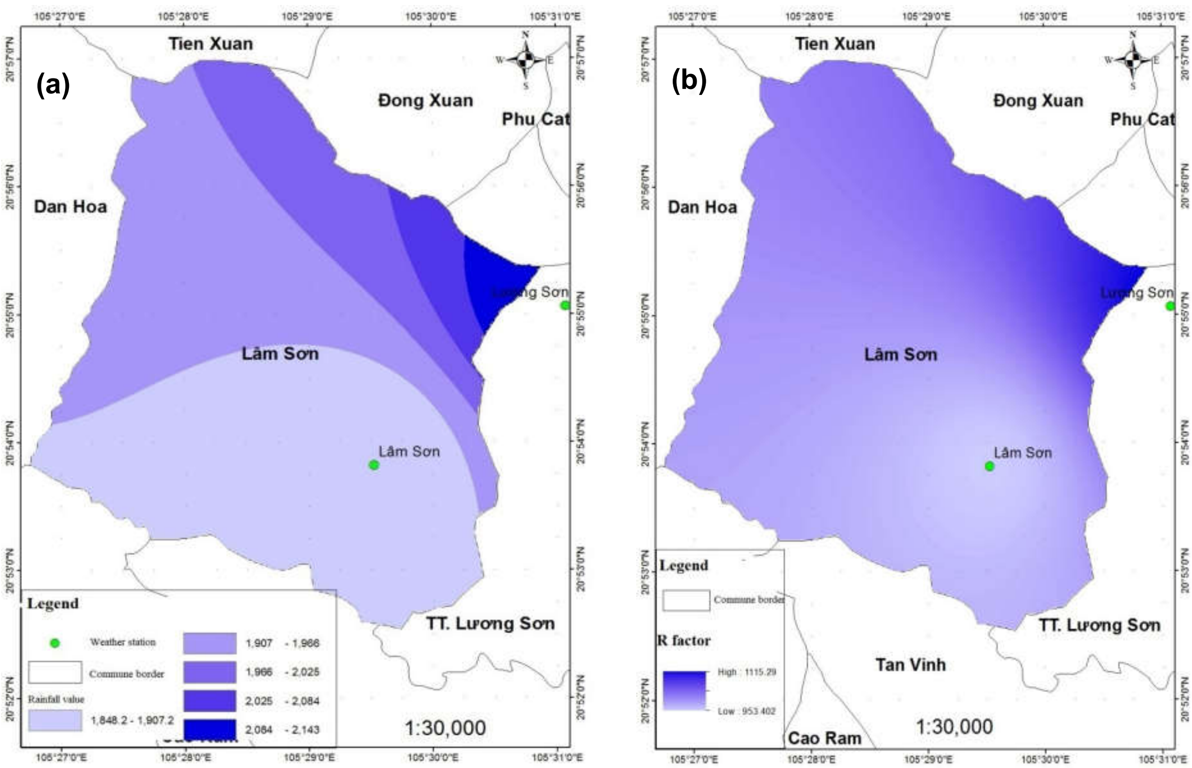


Figure 3.1. a - Annual Precipitation Interpolation map and b - R factor map of Lam Son commune

R factor in the whole commune from 953 to 1115 mm. R factor in the study area is medium and decreases from the North to the South. Total area for R < 1000 is largest with 21.5 km^2 (corresponding to 61%), for R = 1000 - 1050 with 11.6 km^2 (occupied 33%) and for R > 1050 with 2.3 km^2 (6%).

3.1.2. K factor map

The result shows that, in Lam Son commune, K coefficient value is from 0.2 – 0.3. K coefficient value of soil types in the study area is not much different so that the soil erosion resistance coefficients are not much different.

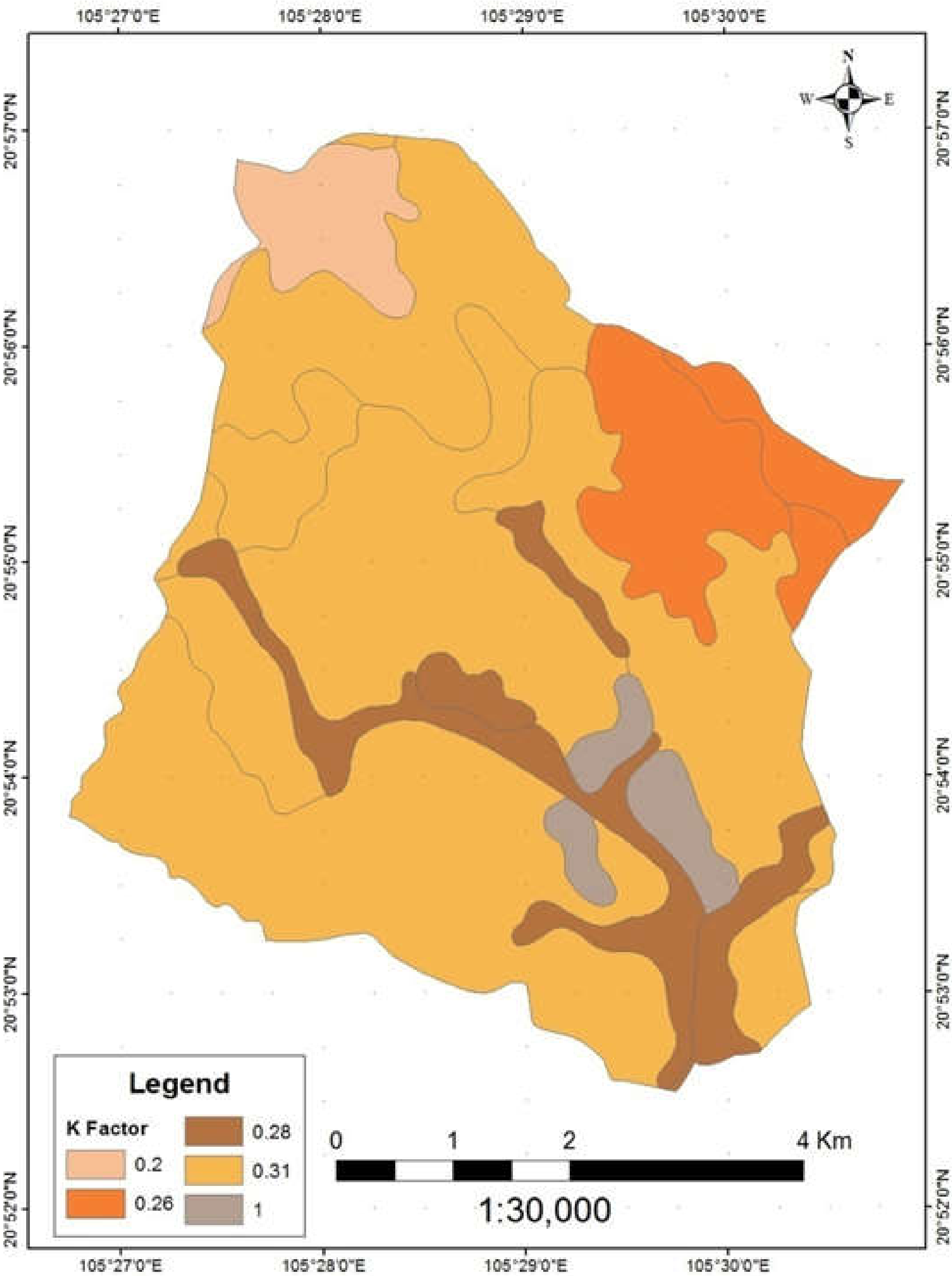


Figure 3.2. K factor map of Lam Son commune

3.1.3. LS factor map

Slope in the study area is almost from 8^0 to > 25^0 (occupied 98%). This suggests high potential erosion at this location (Fig 3.3a). LS coefficient in Lam Son commune was 0 - 258. LS coefficient in the research area is quite big, this reflects the huge influence on the amount of soil eroded. Total area with LS = 11 - 34 is 14 km^2 (corresponding to 52%), with LS < 11 is 13 km^2 (corresponding to 47%) and 1% for other LS.

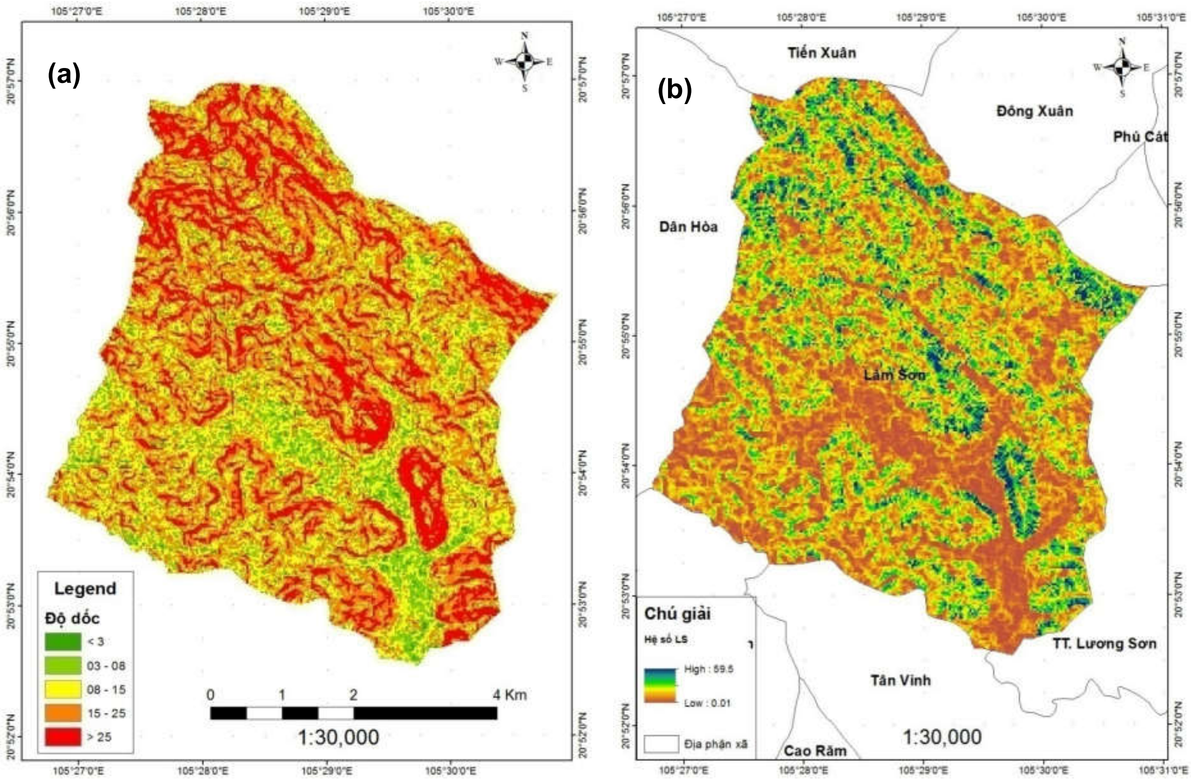


Figure 3.3. a - Steep map and LS map of Lam Son headwater catchment

3.1.4. C factor map

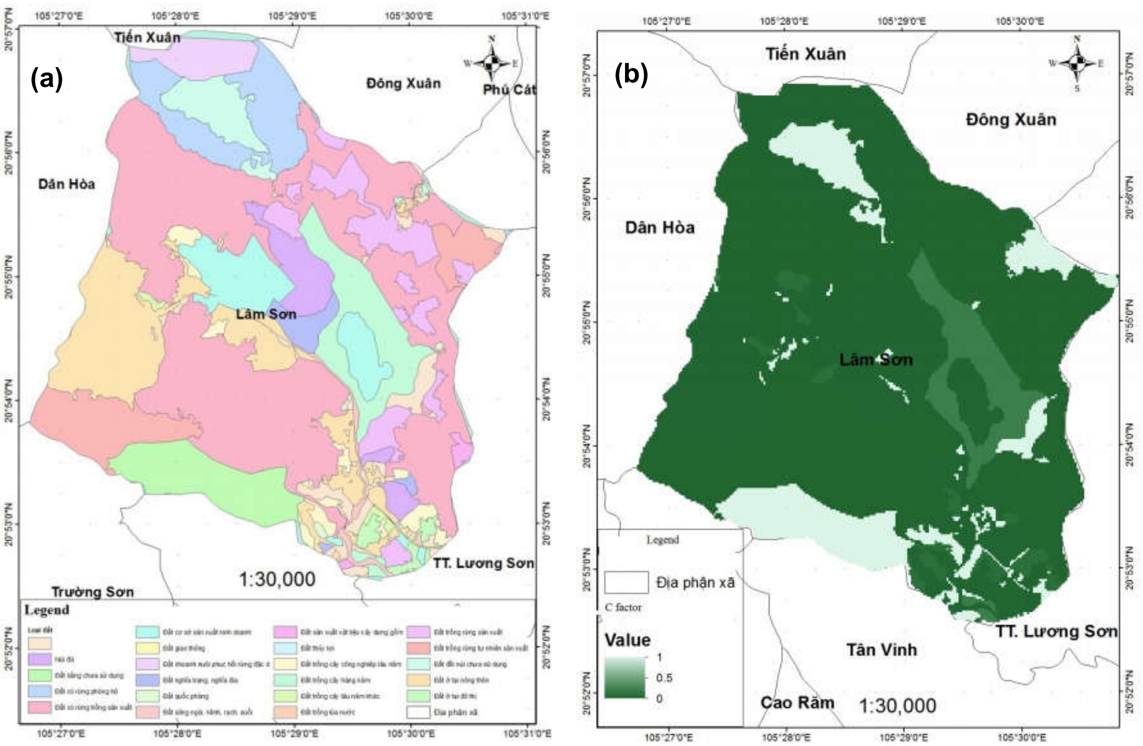


Figure 3.4. a - Land use map and b - C factor map of Lam son headwater catchment

There are many type of land use at Lam son headwater catchment. However, main type of land use at the study site is forest and crop land (65%) (Fig. 3.4a). Almost Lam Son commune is covered by plants. C coefficient map of each plant aren't much different. C coefficient in Lam son commune is almost equal to 0.01. This help to reduce the amount of erosion at study area (Fig. 3.4b).

3.2. Erosion map of Lam Son headwater catchment

3.2.1. Potential erosion map based on R, K LS factor

Potential erosion map is formed by gathering R, K, LS map together. After calculating and using Arcgis 10.1 to integrated maps of factor by Raster Calculator tool.

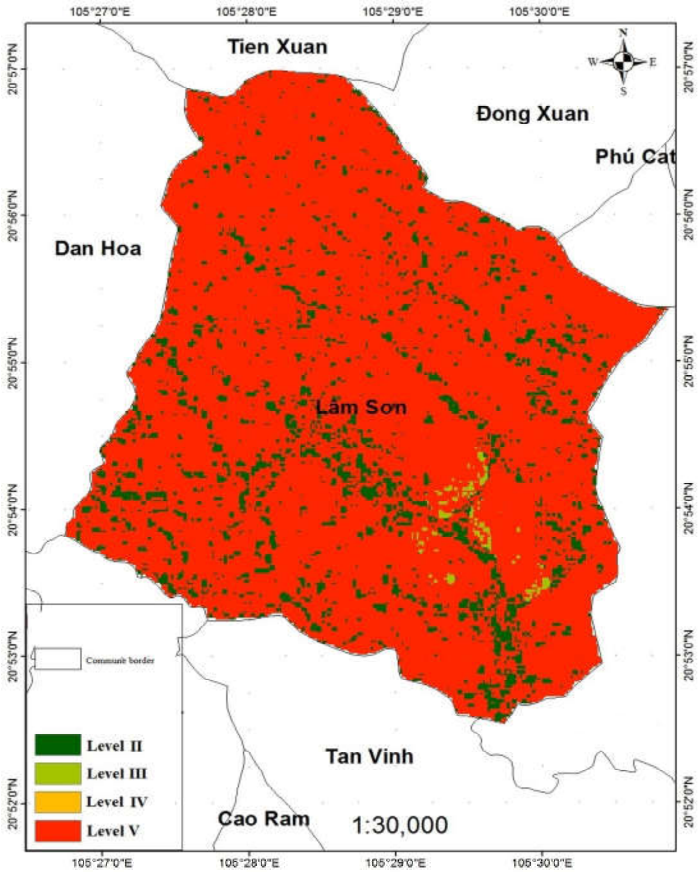


Figure 3.5. Potential erosion map based on R, K, LS factor at the study site

Based on the potential erosion map and the regulation of classifying potential erosion follow the Vietnam standard (TCVN 5299-1995), conduct potential erosion classification at the study site as in Table 3.1. As can be seen from the potential erosion map, almost area are eroded seriously, there are three main type of potential erosion as follow:

Level 2: 1 - 5 tons/year: In the research area, the potential erosion area count for 9.6% of the whole region, erosion area concentrate mainly from the North to the Northwest. This area has low rate of erosion thanks to the low of slope, main type of soil is valley land by slope (D) (Fig. 3.5 and Table 3.1).

Level 3 (5 - 10 tons/year): Count for 0.02 km^2 (0.05%), this area has low potential of erosion due to the not steep of slope and high density of ground cover (Fig. 3.5 and Table 3.1).

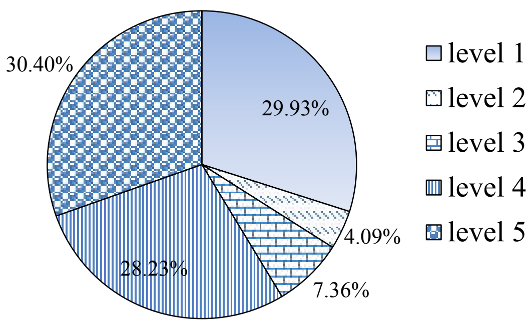
Level 5 (> 50 tons/year): Count for 90.33%, in general, almost the region is eroded seriously. Lam Son is a small commune with main soil type is yellow-red soil on clay with K index = 0.31, high of average precipitation per year and steep of slope, so the potential erosion is very high (Fig. 3.5 and Table 3.1).

Table 3.1. Classifying potential erosion in Lam son headwater catchment

Level of potential erosion	Assessment	The amount of soil loss (tons/ha/year)	Total area (km^2)	Percentage of potential erosion area (%)
I	No erosion	< 1	0,00	0.00
II	Slight	1 – 5	3.36	9.6
III	Medium	5 – 10	0.017	0.05
IV	Strong	10 – 50	0,00	0.00
V	Very strong	> 50	31.56	90.33

3.2.2. Current erosion map at the study site

Assessment	Amount of soil loss (tons/ha)	Total area (Km^2)	%
No erosion	<1	10.4	29.9
Slight	1- 5	1.4	4.1
Medium	5-10	2.5	7.4
Strong	10 - 50	9.8	28.2
Very strong	>50	10.6	30.4



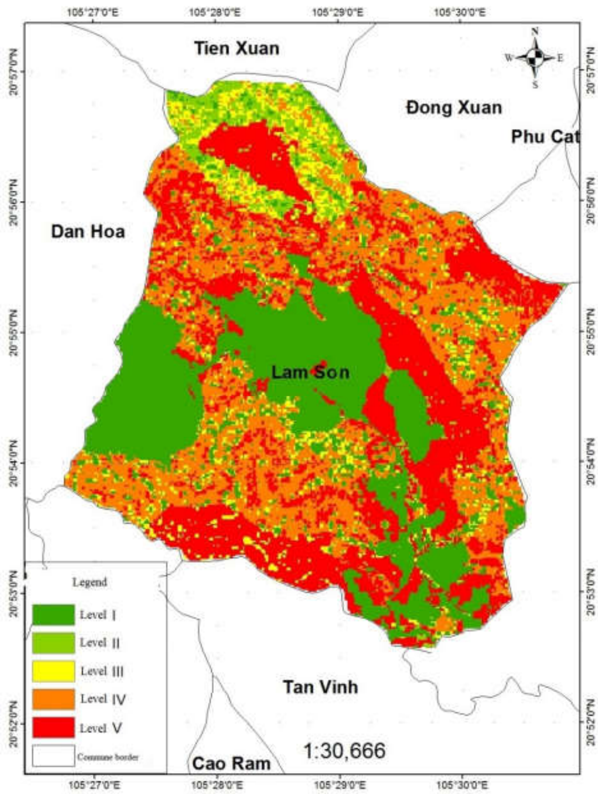


Figure 3.6. Classifying and current erosion map of Lam Son headwater catchment

According to the statistic, the result shows the effectiveness of ground cover in limiting soil erosion. Value of potential erosion and current erosion are changeable. Based on table 3.1 and the current erosion map, we can see that in Lam Son, there are three main level of current erosion (level 1, level 4 and level 5) (Fig. 3.6).

Level 1 (< 1 tons/ha/year): counts for 29.93%, this area has low slope (fluctuating from 3 - 150): this area has low slope, from 3 - 150, so hardly occur erosion (Fig. 3.6).

Level 4 (10 - 50 tons/ha/year): This area are scattered everywhere in Lam Son commune, due to the high slope of the terrain (Fig. 3.6).

Level 5 (> 50 tons/ha/year): This area distributed from the North to the South with total area of 10.60 km^2. Almost this area belongs to abandoned hill or still waiting for plan.

In general, it can be seen from the results that, the forest land has least erosion. This shows the importance of forest in preventing erosion, not just only in economic. Usually, forest land has steep slope and high potential of erosion, if we do not protect this area, when losing ground cover, erosion will occur seriously. Below are some assessments about Bui river watershed in Lam Son commune.

- Current erosion of the research area is uneven between levels of erosion. Total area suffered from erosion is up to 80%. Soil erosion happened evenly in level 1 of potential erosion area (Fig. 3.7).

- Erosion level 4 and 5 is up to 60%, with sparse population density, topographic are mainly mountain so the amount of annual erosion is quite high. If the amount of eroded soil is poured into flow or reservoir, it will lead to sedimentation and some negative effects to water environment and also break the balance of ecosystem.

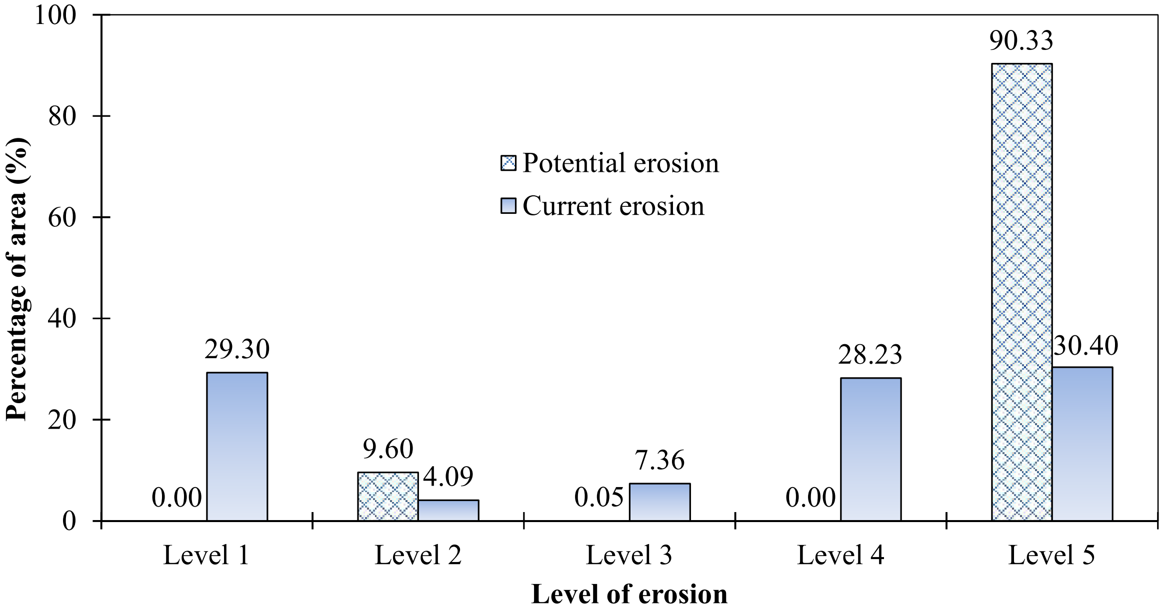
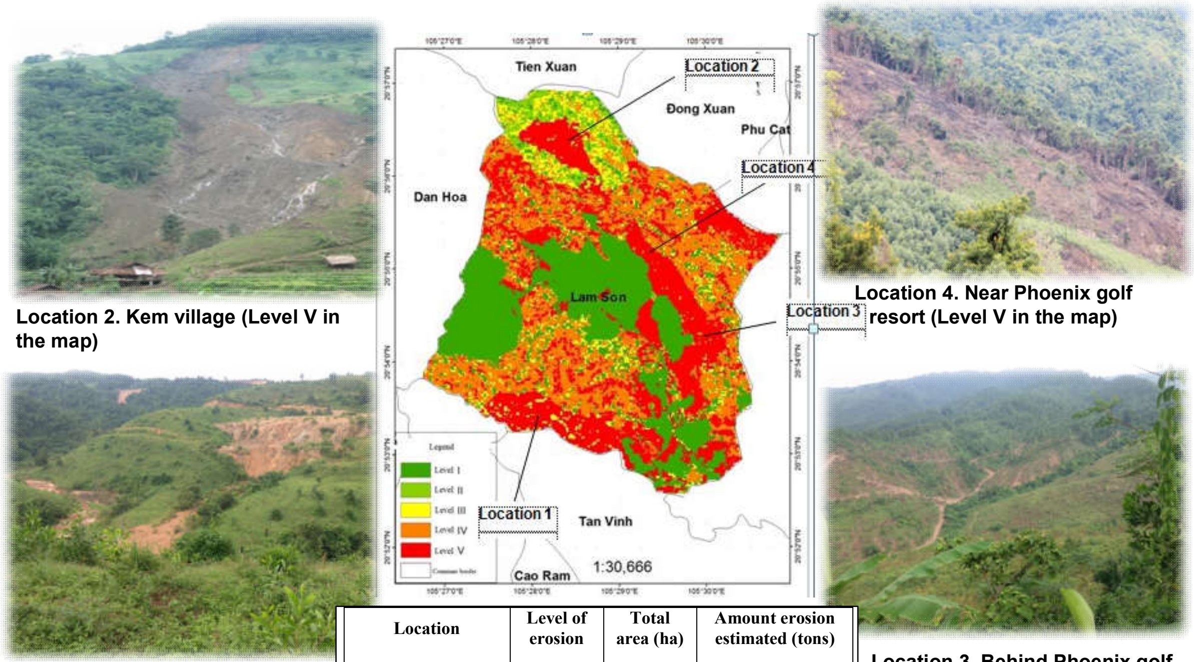


Figure 3.7. Comparison between potential erosion and current erosion

3.2.3. Verifying by observation

The result of the soil erosion map was verified by observation. According to the soil erosion map, erosion level 4 and 5 occur most in the area near Phoenix Golf resort, Kem village and Doan Ket village. Above is the land use situation of three villages, as can be seen from the pictures, erosion occurs mainly due to the unreasonably planning of exploiting and planting trees. In detail, 7 areas which show the most clearly about soil erosion in the current erosion map and then calculating the area of erosion. After that we make comparison about the similarities and differences of area of erosion (Fig. 3.8).

The reason for these differences is that land use map is formed in 2015, however the study was carried out in August 2016 so that C factor map is the map for 2015 not for 2016, that is why there are differences between the erosion area in level 4 and 5. The comparison also point out that, the ground cover has increased from 2015 to 2016, that why the area of erosion verified by observation is smaller than that in the map.



Location	Level of erosion	Total area (ha)	Amount erosion estimated (tons)
Doan Ket village (1)	IV	2	20 - 60
Kem village(2)	V	5	50 - 200
Behind Phoenix Golf Resort(3)	V	3	>150
Near Phoneix Golf Resort (4)	V	4	>200

Figure 3.8. Observed locations in map and actual condition

3.3. Solutions for sustainable soil management

3.3.1. Farming method

Using methods to increase canopy cover such as: using crop residue to increase the extent of ground cover, planting some kind of trees to make the cover layer (shrubs, grass). Especially to plant and protect watershed forest or top hill is truly effective measure in limiting soil erosion. Those methods help to protect soil from impact of raindrops and also improve soil fertility. In addition, to increase the ability of erosion resistance, improving the fertility of soil by liming, fertilizing to increase the quality of soil was necessary.

3.3.2. For erosion levels 1, 2 and 3

The amount erosion at those areas is quite small because those regions have high level of ground cover and are well-protected by local community. Therefore it is necessary to keep the current ground cover remain unchanged by suitable plan for planting and exploiting tree as well as suitable crop.

3.3.3. For erosion levels 4 and 5

For these erosion level, erosion areas mainly are bare land or the forest land in steep slope where has just been clear cut or replanted. So we need to plant more tree on those areas, should choose plants that grow fast and are capable of improving land such as Acacia, bamboo. We should minimize negative impacts that make soil eroded.

IV. CONCLUSION

Soil erosion is a natural phenomenon. But under impact of human (mostly negative impact), soil erosion has become a serious problem for nature and society. Based on using USLE model and GIS technology, the study has given some conclusions as follow: (1) R factor in the study area is medium fluctuating from 950 – 1050 mm and decrease from the North to the South; (2) Main soil type in the research area is yellow-red soil on sand (Fs) with K coefficient = 0.27; (3) In general, about 65% of the area is covered by plant, this is the most important factor to determine the capable of erosion, so it is necessary to have a suitable plan for exploiting and planting forest; (4) The research area has total potential erosion (level 5) up to 90% and current erosion is 89% divided equally for 3 levels (level 1, level 4 and level 5). The area of erosion tends to decrease due to good farming method and conscious of local people; (5) The results of this study are trustful because it was verified in the research area. It can be used as document for plan of land using in the research area.

Soil erosion is a long-term process. It occurs in long time and with different intensities, in which rain factor play a decisive role. So that, it's necessary to has enough data and actual survey. The findings of this study suggest the important of canopy cover. So it's significant to have a suitable schedule for crop so that, there will be high canopy cover in rainy season. Limiting erosion has to be stable and effective. Thus, we should make use of some natural factors or human resource to renovate or change natural factors but still maintain these two requirements. It is necessary to have move research about soil erosion with the application of GIS in a larger scale (district level or national level) to synchronize in the process of analyzing, assessing and selecting the best solution. For the later researches, it is needed to combine using GIS with determining erosion in real for enhancing the practical value of the research.

Acknowledgement

This work was supported by the research program of Vietnam National University of Forestry. Otherwise, we gratefully acknowledge the blessings and valuable suggestions from members in the laboratory of Faculty of Forest Resource and Environmental Management.

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[1,2]Trường Đại học Lâm nghiệp

TÓM TẮT

Để xác định lượng đất xói mòn từ lưu vực đầu nguồn Lâm Sơn, Hòa Bình, chúng tôi đã sử dụng phương trình mất đất phổ quát (USLE) để dự báo lượng đất mất đi hàng năm. Để sử dụng mô hình, chúng tôi đã xây dựng bản đồ chuyên đề cho các nhân tố ảnh hưởng đến xói mòn dựa vào phần mềm ArGIS như chỉ số xói mòn của mưa và dòng chảy (R), hệ số xói mòn của đất (K), hệ số chiều dài sườn dốc và độ dốc (LS), hệ số cây trồng (C) và hệ số biện pháp bảo vệ đất (P). Dựa vào bản đồ chuyên đề, chúng tôi hình thành bản đồ xói mòn tiềm năng (dựa trên các nhân tố tự nhiên như R, K và LS) và bản đồ xói mòn thực tế (tích hợp thêm các chỉ số C và P). Các kết quả chính nghiên cứu thu được bao gồm (1) Chỉ số xói mòn của mưa tại khu vực nghiên cứu thuộc ngưỡng trung bình từ 950 - 1050 mm và giảm dần từ phía bắc sang phía nam; (2) Loại đất chính tại khu vực nghiên cứu là đất đỏ vàng với hệ số xói mòn của đất trung bình K = 0,27; (3) Khu vực nghiên cứu có độ che phủ thực vật tốt, chiếm đến 65% nên hệ số cây trồng C thấp, dao động từ 0 - 1, trung bình 0,2; (4) Xói mòn tiềm năng của khu vực nghiên cứu thuộc cấp 5 (> 50 tấn/ha/năm) chiếm trên 90% diện tích khu vực và xói mòn thực tế chiếm 89%, phân đều ở 3 cấp chính là cấp 1 (< 1 tấn/ha/năm chiếm 29.3%), cấp 4 (10 - 50 tấn/ha/năm chiếm 28,23%) và cấp 5 (> 50 tấn/ha/năm chiếm 30,4%). Xói mòn có xu hướng giảm ở những loại hình sử dụng đất có biện pháp bảo vệ đất; (5) Phương trình USLE có thể sử dụng để xác định lượng đất xói mòn với độ tin cậy cao khi hầu hết các địa điểm kiểm tra ngoài thực địa đều tương đồng với các cấp trên bản đồ được xây dựng bằng mô hình USLE. Vì vậy, kết quả nghiên cứu có được là cơ sở khoa học để người dân địa phương sử dụng bền vững tài nguyên đất, đặc biệt là những diện tích đất trống và diện tích canh tác thiếu biện pháp bảo vệ.

Từ khóa: Lưu vực đầu nguồn, mô hình USLE, xã Lâm Sơn, xói mòn.

Received : 14/9/2017
Revised : 26/9/2017
Accepted : 05/10/2017