AN OPEN SOURCE GIS APPROACH FOR SOIL EROSION MODELING IN DANANG CITY, VIETNAM

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ABSTRACT

This study is objective to establish the model of soil erosion hazard in Danang city, Vietnam using Revised Universal Soil Loss Equation (RULSE) and Geographical Information System (GIS) tool. Rainfall erosivity (R), slope length-steepness (LS), soil erodibility (K), cover management (C), and conversation practice (P) were used to generate soil erosion map. Rainfall map was interpolated from rainfall points data that were collected in some weather stations in Danang city. A 30m digital elevation model (DEM) was generated from 1:25.000 scale topographic map, and used to extract slope length-steepness (LS) parameter. Soil erodibility (K) was calculated from soil map of study area using Wischmeier equation (1978). Cover parameter was calculate using Normalized Different Vegetation Index (NDVI) extracting from Landsat satellite data. In this research, an Open Source Geographical Resources Analysis Support System (GRASS) tool was used for developing potential soil erosion map for Danang city.

1. INTRODUCTION

Da Nang is the international gateway to the sea of Central Region, Central Highlands of Vietnam, and is also an important part of the strategy built East-West Economic corridor, which is end in the seaport system of the city. In this developed city, hilly terrain occupies an area of mostly 75%, the average annual rainfall is large (1500 to 2000 mm), therefore the risk of erosion as well as natural disaster is very high. Presently, the production and exploitation of territory in western mountains have a negative impact on the erosion situation in Danang city. Research on mapping the erosion situation, potential erosion of Danang city is very important in urban planning and natural resources utilities for the objective of sustainable development of the city.

There are many approaches and different methods of research soil erosion. Currently, the application of geographic information systems (GIS) integrated modeling approach in soil erosion is a powerful tool, capable of analyzing space in a short time, calculations and construction soil erosion map of the basin, the territory with ease and accuracy. Within the scope of this study, the authors applied the model USLE (universal soil loss equation - Wischmeier and Smith, 1978), integrated with OpenGIS (GRASS and QGIS) to study erosion in Da Nang city. The USLE equation is a multiplicative function of five factor controlling erosion process, has the form:

$$A = R * K * LS * C * P \quad (1)$$

Where:
A: annual soil loss rate (ton /ha/yr)
R: rainfall factor (MJ.mm/ha.yr)
K: soil erodibility factor (ton.ha.h / MJ.ha.mm)
LS: is slope steepness and slope length factor (dimensionless)
C: cover factor (dimensionless)
P: conservation practices (dimensionless)

2. METHODOLOGY

2.1 Study area

Study area is Danang city which is characterized with an area about 950 square km and the elevation range from 0m to 1655m above mean sea level. Danang city is located on the Eastern Sea coast extend from latitudes of $15^{o}55'N$ to $16^{o}14'N$ and the longitudes of $107^{0}18'E$ to $108^{0}20'E$. It is located in the south of Thua Thien - Hue province, east and north of Quang Nam Province. Danang's topography is quite varied, hilly terrain which dominates mostly at an altitude of 700 - 1500m, high slope ($> 40^{0}$) are concentrated in the west, northwest, north and northeast . To the east is the narrow coastal plain. Between highland and lowland coastal areas are many intermediate forms hilly midlands.

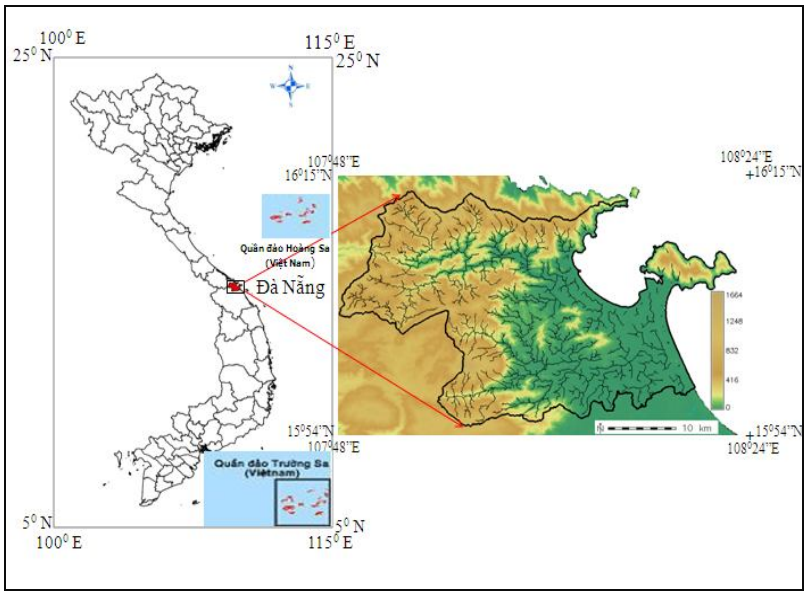

Figure 1: Location of study area

Located in the south of Hai Van Pass and the south part of Vietnam, the climate of Danang is naturally tropical monsoon. The common characteristic of the climate is the abundant amount of solar radiation in Danang, high temperatures and abundant rainfall.

2. Data used

- The average rainfall data for many years of some meteorological stations in the region from Thua Thien Hue to Quang Nam, including the stations: A Luoi, Hue, Nam Dong, Da Nang, Tam Ky, Tra My.
- Soil map of Da Nang (2007, source Department of Natural Resources and Environment)
- Topographic map of Danang in scale of 1:10000 (2010, Department of Natural Resources and Environment, Danang city)
- Satellite images: Landsat 8 OLI of Middle Central are free download from http://earthexplorer.usgs.gov.

3. Methodology

Modeling soil erosion process based on USLE equation (Mitasova *et al*, 1996) integrated with the Open Source GIS technique (using GRASS GIS and QGIS software) is the primary method of this research. In particular, QGIS software is used to prepare, standardize some of the input data; GRASS GIS software also performs the main tasks of the study: calculation, establishment, transformation, integration of map coefficients in the model; Statistics current status, potential erosion ...

In addition, in this study the authors have proposed a new approach in the calculation of the coefficient C in the USLE model, through the use of remote sensing technology, the normalized difference vegetation index (NDVI) map from Landsat 8 satellite images. Through these Landsat 8 images the calculation of the coefficient C in the USLE model becomes easier. The soil erosion modeling work flow can be generated in figure 1.

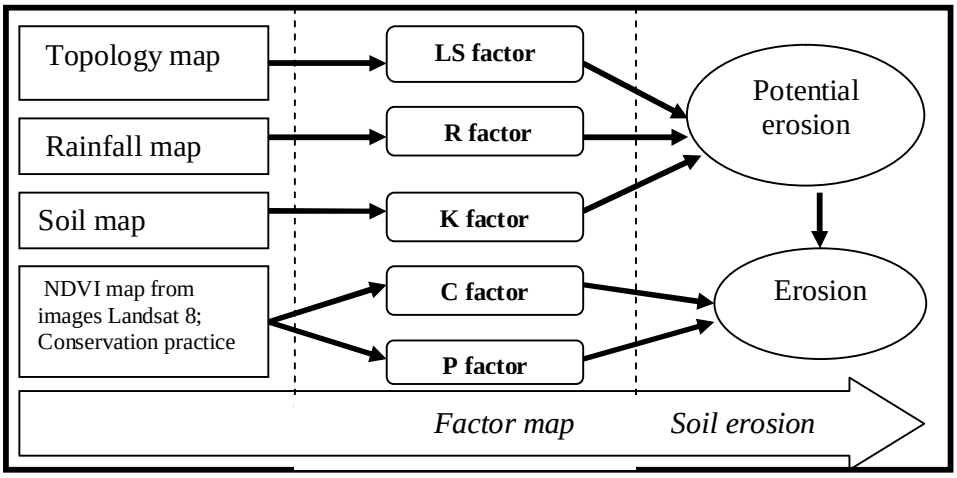

Figure 2: The soil erosion modeling work flow

3. RESULTS

3.1. Slope length-steepness (LS)

To establish the LS factor, the author used the input DEM model of Da Nang. DEM model was built from the contours and spot heights that were extracted from 1/10000 topographic map.

Danang DEM model was built using IDW interpolation method (Inverse Distance Weighting), that was integrated in the Interpolate Surface module of GRASS GIS (Figure 3).

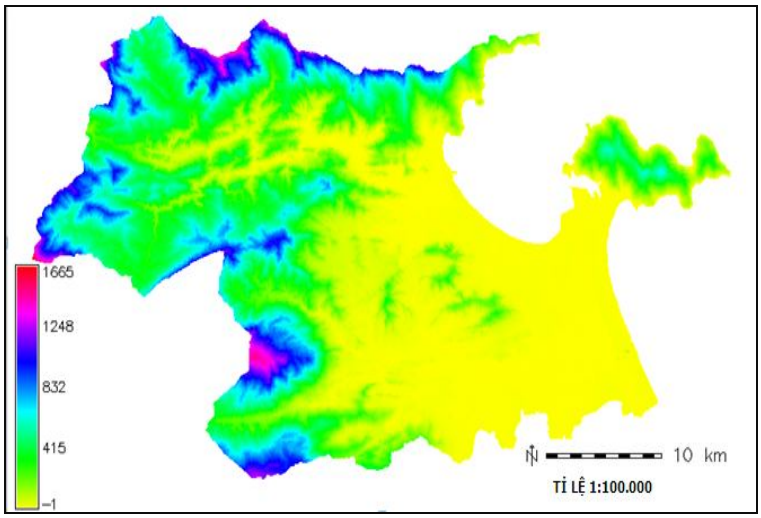

Figure 3. DEM data of Danang generated from 1:10000 topographic map

DEM model is the basic input to calculate the erosion caused by LS factor. The terrain factor LS is determined by the formula of Mitasova *et al* (1996) as follows:

$$LS = (t+1)\left(\frac{A}{L_0}\right)^t \left(\frac{\sin\beta}{L_0}\right)^n \quad (2)$$

LS coefficients calculated by the formula (2) using the Map Calculator module in GRASS GIS:

*r.mapcalc "LSfactor"=1.5*exp(flowacc*30/22.1,0.5)*exp(sin (slope) /0.09,1.3)*

Results LS factor map of study area is shown in Figure 4.

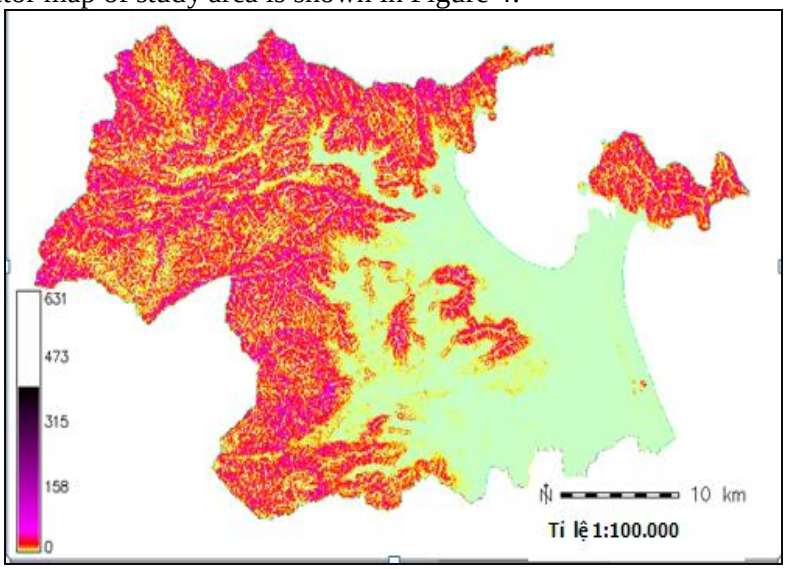

Figure 4. LS factor calculated by the formula of Mitasova *et al* (1996)

3.2. Rainfall erodibility (R)

Rainfall data along with geographical coordinates of five meteorological stations near Danang, including: A Luoi, Hue, Nam Dong, Da Nang, Tam Ky, Tra My (Quy Toan Do *et al*, 2010) are used as the input data to interpolate rainfall distribution map for the entire area. This rainfall distribution map was used to calculate the erosion caused by R factor. In this case, we apply the formula developed by Nguyen Trong Ha for the work system of erosion by rainfall for Danang (Nguyen Trong Ha, 1996):

$$R = 0{,}548257P - 59.9 \quad (3)$$

R: coefficient of erosion by average annual rainfall (J/m^2)

P: average annual rainfall (mm/year)

The process of calculating the coefficient R is also done through Map Calculator modules in GRASS GIS, as follows:

*r.mapcalc "Rfactor" = 0.548257 * Rainfall - 59.9*

3.3. Soil erodibility (K)

Refer from the previous studies, along with analysis of soil properties from soil maps of Da Nang city, the authors has identified K for soils in Danang as shown in Table 1. The class of "others" here are mainly ground water, rivers and lakes, so K coefficient is considered as the smallest one (0.01).

Table 1. Coefficient of soil erosion (K) applied to soils in Da Nang

Symbol	Name	K factor	Resources
Fa	Gold Soil	0.23	Nguyễn Mạnh Hà (2011)
Fs	Ferralsols	0.32	Nguyễn Mạnh Hà (2011)
Smi	soils alkaline	0.04	Lê Huy Bá (2006)
Cc	Sandy soil	0.19	Lê Huy Bá (2006)
Py	Fluvisol	0.44	Nguyễn Mạnh Hà (2011)
Dt	Humic-Feralic Fluvisols	0.61	Nguyễn Mạnh Hà (2011)

Pg	clay silt	0.52	Nguyễn Mạnh Hà (2011)
Nv	golden brown soil	0.21	Nguyễn Tử Siêm và Thái Phiên (1999)
Pb	Fluvisol	0.46	Nguyễn Mạnh Hà (2011)
Others	Others soil	0.01	Lê Văn Biên (2014)

Table K is updated to soil map of Danang by Edit Attribute Table tool in Quantum GIS software. This K map was imported to GRASS software and converted to raster format with the same resolution as 30m as other data layers. The K factor map for Danang is shown in Figure 5.

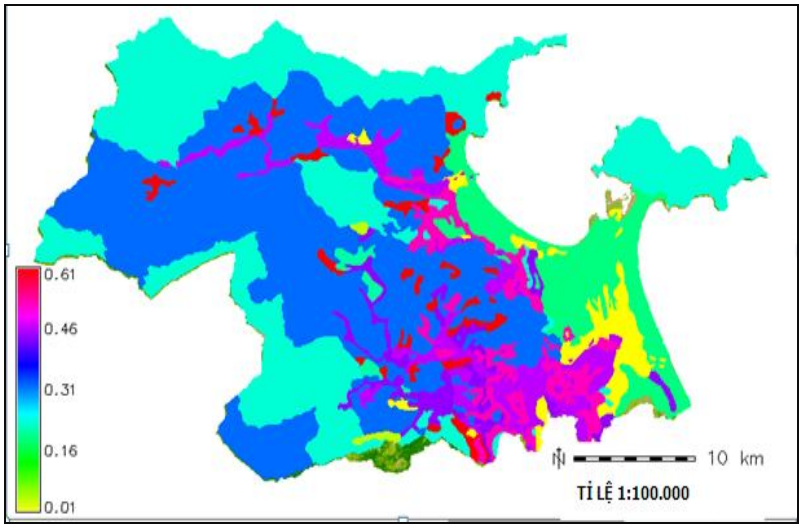

Figure 5. Soil erodibility (K factor) for erosion mapping

3.4. Land cover (C)

In order to determine the erosion caused by land cover, the new approach is used to calculate the coefficient C which is based on vegetation indices NDVI (Normalized Difference Vegetation Index) derived from the Landsat 8 images. Normally, NDVI index is calculated as follows (Jensen, 2000):

$$NDVI = (NIR - Red) / (NIR + Red) \quad (4)$$

In this case, NDVI data derived from Landsat 8 images of Danang area, taken on May 22th 2014 and on April 27th 2014. For Landsat 8, the near-infrared (NIR) band corresponds to band 5, and the red band (Red) corresponds to band 4. Tool to calculate the NDVI is Map Calculator on GRASS software, the input data is the digital number values from band 4 and band 5 of Landsat 8 images.

There are many works have studied the dependence of the coefficient C in NDVI and estimated coefficient C based on vegetation indices. In this study, the authors used the formula (6) developed by De Jong (1994) to calculate the coefficient of erosion by C factor. This calculation is also based on the Map Calculator tool in the GRASS GIS, the input data is NDVI maps. Results coefficient map of vegetation erosion shown in Figure 6.

$$C\ factor = 0{,}431 - 0{,}805*NDVI \quad (6)$$

3.5. Calculation of P factor

Because there is no conservation practice against to the soil erosion in Danang city, P in this study is considered as a constant with a value of 1, meaning that the process of calculating erosion will not be affected by the elements of P.

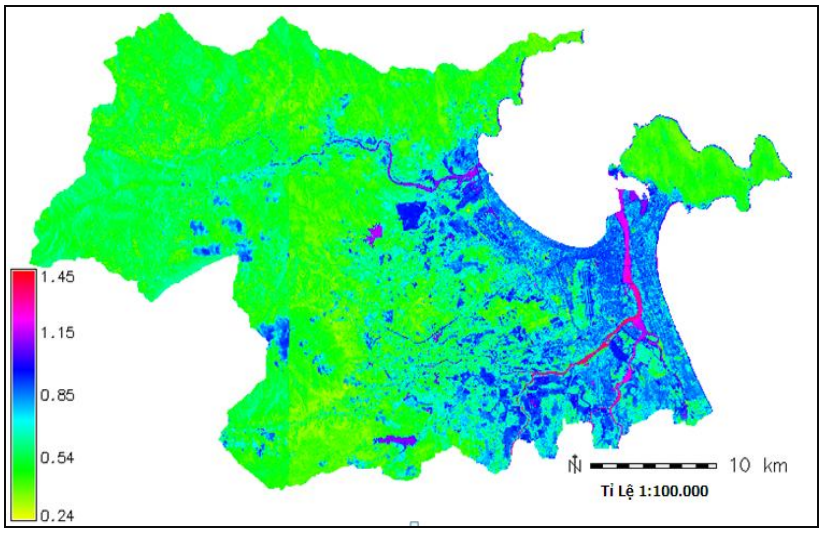

Figure 6. C factor calculated from NDVI derived from Landsat 8 images

3.6. The potential erosion map

Potential erosion is the process of erosion has not considered the impact of the human's implementation factors and cultural practices. Therefore, the potential erosion map was established by integrating the map coefficient R, K, LS. Calculation process using the Map Calculator tool as follows:

*r.mapcalc "Potential_Erosion" = Rfactor*Kfactor*LSfactor*

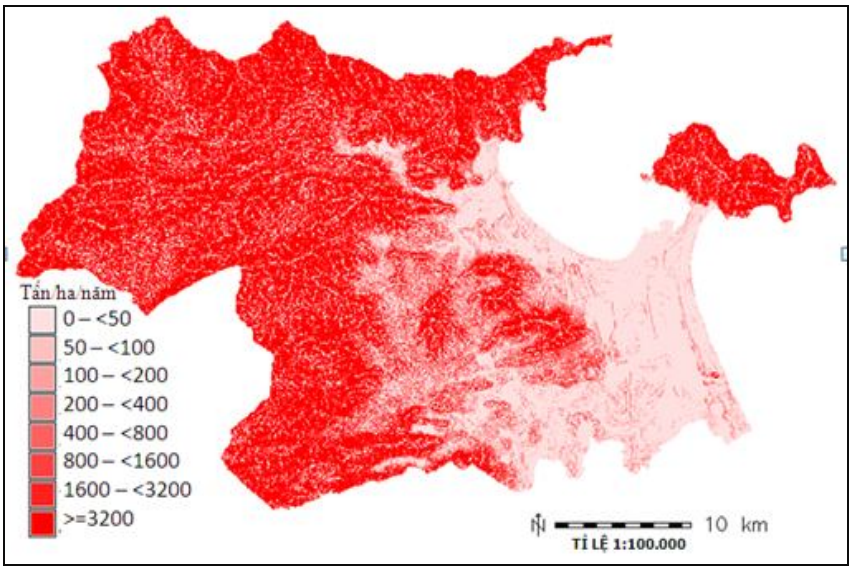

Figure 7. The potential erosion map of Danang city

Based on the Vietnam standards TCVN 5299-1995 for classify the levels of potential erosion, the authors conducted classification model of potential erosion Danang as table 2:

Table 2. Levels of potential erosion Danang.

Level	potential erosion (tonnes / ha / year)	Area (ha)	Percentage (%)
I	0 - <50	29064.7	30.49
II	50 – 100	2818.1	2.96

II	100 – 200	2784.5	2.92
IV	200 – 400	2834.2	2.97
V	400 – 800	3259	3.42
VI	800 – 1600	4281.4	4.49
VII	1600 – 3200	7229.4	7.58
VIII	> 3200	43051.5	45.2
Total		95322.930	100

Basically, the whole city has two levels of erosion mainly: Lowest Level I (30.49% of the area) and the highest level VIII (45.2%). The erosion levels from grade II to grade VII occupy only 24.31% of study area. Erosion levels I focuses mainly in the east, southeast (except the Son Tra Peninsula) Hai Chau, Thanh Khe and Ngu Hanh Son, Cam Le, which are urban districts and the coastal plains with high density urbanization, low slope and rainfall. Erosion levels VIII concentrates mainly in the west and north as Hoa Vang, Son Tra, Lien Chieu, where are the suburban districts and hilly areas with steep slopes, high rainfall, low level of urbanization.

3.7. Erosion situation map of Danang

Erosion situation is the current state of erosion potential taking into account the effects of vegetation and cultivation methods. Therefore, the coefficient C and P are included in the equation of erosion situation. The formula for calculation is as follows:

*r.mapcalc "Erosion" = Rfactor * LSfactor * Kfactor* Cfactor*

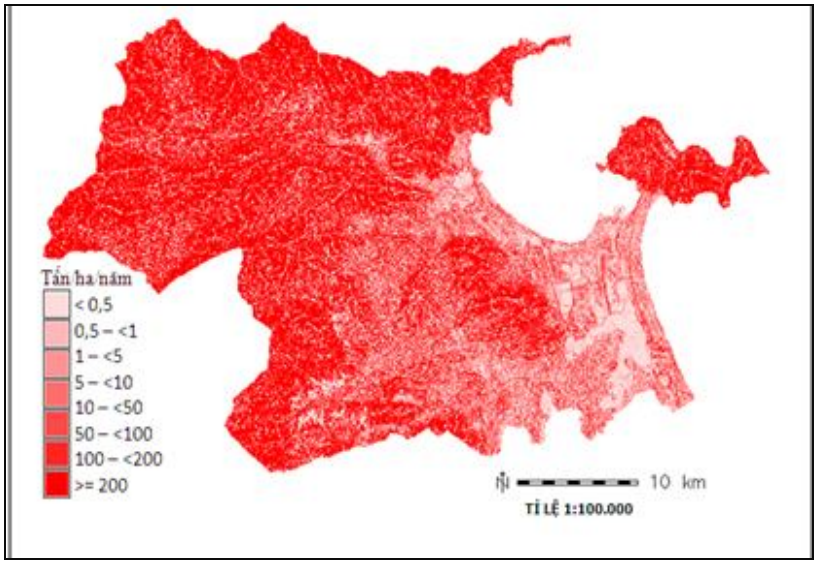

Figure 8. Erosion situation map of Danang city

Based on the Vietnam standard TCVN 5291 - 1995 for erosion situation, the classification for the current erosion models of Danang city is as follows:

Table 3. Levels of erosion situation of Danang

Level	Erosion (tons / ha / year)	Area (ha)	Percentage (%)
I			
Ia	0 - 0,5	22021.6	23.1
Ib	0,5 – 1	894.4	0.9
Ic	1 – 5	3991.1	4.2

Id	5 – 10	2979.6	3.2
II	10 – 50	9371.9	9.8
III	50 – 200	13751.6	14.4
IV	> 200	42312.6	44.4
Total		95322.930	100

From the map and statistical table of erosion situation, it is observed that the erosion in the city has been a change from potential erosion map. The high erosion levels (above 50 tons/ha /year) and the low erosion level (less than 5 tons/ha/year) have decreased; erosion at medium levels increased significantly. Thus, after adding the vegetation cover, the amount of soil loss change to the direction of decreasing. In the whole city, the rate and areas of potential erosion at highest level (grade VIII) was reduced compared to the highest level of the erosion situation map (level IV), from 43051.5 hectares, covered 45.2% of city area to 42,312.6 hectares, corresponding to 44.4% of the area. In some places, statistic from ratio and area of potential erosion was significantly high, but in the erosion situation map, they were observed as not so high levels (under the effect of vegetation cover). Especially in Hoa Vang District, the area of potential erosion at level VIII is 37752.02 hectares, accounting for 52.3%, but in the level IV of erosion situation map is 37335.8 hectares, accounting for 51.7% ... This indicates the positive effects of vegetation cover on reducing soil erosion.

3. CONCLUSIONS

Open source GIS software (GRASS GIS and QGIS) is a new approach as well as method in soil erosion research in Vietnam. This study has also added new methods in modeling soil erosion using USLE equation - methods with the use of Landsat 8 satellite image to interpolate C factor. Through the use of model USLE and GIS technology, this research has built potential erosion and erosion situation maps for Danang area, which was analyzed clearly in term of spatial distribution.

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