APPLYING SPATIAL ANALYSIS TO ASSESS SOIL EROSION FOR FOREST PLANTATION AT HONG LINH TOWN, HA TINH PROVINCE

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SUMMARY

This study has assessed soil erosion in some protection plantation models at Hong Linh town, Ha Tinh province by applying soil loss prediction equation and spatial analysis. We conducted 20 plots & 80 random points to collect data. To assess soil erosion, the study was based on IDW interpolation in ArcGIS to conduct maps. The results show that (1) There are five main forest types (Pine, mixed Pine and Acacia, Acacia, Eucalypt, mixed Eucalypt & Acacia) in which Pine (*Pinus merkusii*) is a native species and dominant in protection plantations with 47.65% (665.96 ha); (2) Potential erosion in this study is not high, from 0 - 3.75 and the erosion rate is highest in other forests. Pine forests is from 1.57 to 3.75, vegetation cover is from 0.9 to 1.53, that means C1 coefficient map of each forest type is not much different; (3) Current erosion based on TCVN 2009 are classified into 5 levels in which almost area is eroded slightly and medium. Assessing amount of current erosion based on standard of Hundson (1971), there are 364.74 hectares in the protection plantation are exceed erosion threshold (> 0.8 mm/year) occupied 26.22% in which erosion area of other forest is highest. (4) Keep ground cover and planting replaced species are one of the best solutions to reduce erosion in the protection plantation at Hong Linh.

Keywords: Hong Linh, plantation, potential erosion, soil erosion, soil loss, spatial analysis.

1. INTRODUCTION

Soil erosion is movements of soil particles from one place to the another under the influence of water or wind (Vuong Van Quynh et al., 2013; Bui Xuan Dung, 2014). Soil erosion by water is one of the most serious environmental problems in the world (Tran Quang Bao and Melinda J. Laituri, 2011). It causes adverse effects on soils, agricultural production and water quality (D. Pimentel and Kounang, 1998). Worldwide, soil erosion rate are highest in Asia, Africa and South America, averaging 30 to 40 tons/ha/year. However, erosion rates are low on land with natural vegetation cover, about 2 tons/ha/year in relatively flat land and about 5 tons per ha/year in mountainous areas (D. Pimentel and Kounang, 1998). Vietnam has about 25 million of steep land, with huge potential of erosion, about 10 tons/ha/year (Tran Quoc Vinh, 2009; Do Viet Quang, 2016). According to systematic monitoring from 1960 until now, there is 10 - 20% of area affected by erosion from moderate to strong level (Nguyen Tu Xiem and Thai Phien, 1999; Do Viet Quang, 2016). There are many different approaches and methods in researching soil erosion, the one is field observation and predicting models. Field inventory way is often applied in long-term with small scale, so it is not efficient. Using modeling to predict soil erosion will save time and money, moreover it also measures erosion faster in bigger scales (Do Viet Quang, 2016). In practice, the Revised Universal Soil Loss Equation (RUSLE) model initially developed by Wishchmeier and Smith (1965) has been most widely used (K.G. Renard et al., 1997; Tran Quang Bao and Melinda J. Laituri, 2011). However, this equation has some disadvantage in Vietnam, amount of erosion is predicted in long-term period (more than 30 years) based on average annual rate of erosion and suitable for place with slope less than 20%; only applying on sheet erosion and small rill erosion; and experimental plots must be designed in a small range of the factors. Due to the complexity of defining factors of RUSLE for a given region, the application of the RUSLE in Vietnam has been challenging in term of prediction accuracy and its validation (Vuong Van Quynh and Nguyen Ngoc Lan, 1996; Tran Quang Bao

and Melinda J. Laituri, 2011). Soil loss prediction equation of Quynh et.al resolved these disadvantages of RUSLE. And this equation is suitable for in slopes of Vietnam (5 - 36^0) and predict soil erosion in short-term average annual rate (Tran Quang Bao and Melinda J. Laituri, 2011). In recent decades, the development of GIS techniques has facilitated the estimation of soil erosion and its spatial distribution over large areas (Tran Quang Bao and Melinda J. Laituri, 2011). Therefore, spatial analyses and interpolation techniques in GIS were used for this study. The input data layers for mapping include DEM, rainfall and vegetative cover.

Soil erosion is a significant problem in the uplands of the Central Coast, Vietnam so that it is important to pinpoint estimated locations where soil erosion occurs in order to prevent substantial soil loss. By 2017, Ha Tinh province has 360,700 ha of forest and forest land, with forest cover reached 51.3% (HFPD, 2018). In which Hong Linh protection forest plays an important role in protecting the environment, regulating the climate in the North of Ha Tinh province. At Hong Linh town, area of protection forest is about 1388.91 ha occupied 77.6%. Moreover, there are not report about erosion control though the equation of erosion prediction in Hong Linh.

The paper (1) will analyze characteristics of some protection plantations in Hong Linh Town, (2) generate potential maps and an erosion map, (3) assess ability of soil protection against soil erosion of protection plantations in Hong Linh Town and finally (4) propose some solutions to raise the effective of erosion control of some protection plantations in Hong Linh commune.

2. RESEARCH METHODOLOGY

2.1. Data collection method

2.1.1. Study site

The study site is protection plantations in Hong Linh town, Ha Tinh province. The study are is presented in the following figures.

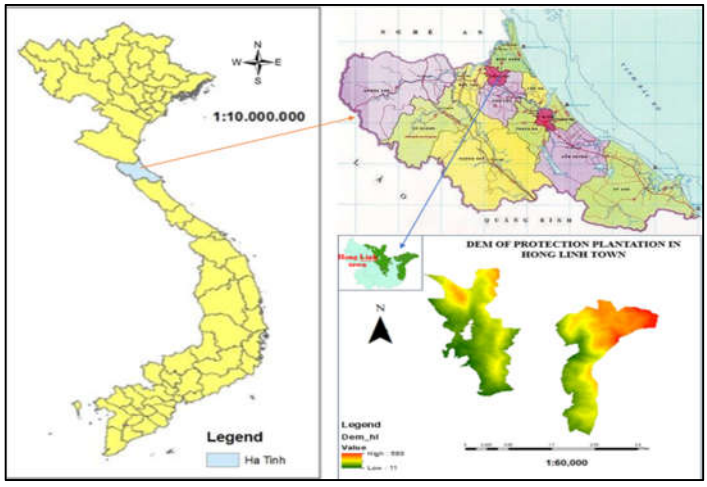


Figure 1. Study site location

(Blue area in the Vietnam map is Ha Tinh provice; Pink areas are Hong Linh town and right-bottom map is the protection plantations)

2.1.2. Investigation data

The study set up 20 plots in which 10 plots for Pine forests, 6 plots for Pine & Acacia, 1 plot for Eucalypt, 2 plots for Acacia and 1 plot for mixed Eucalypt & Acacia depending on area of each forest type in order to collect diameter at breast height (DBH), total height (H), commercial height (Hc) and quality of tree in protection plantations at Hong Linh town. The study measured DBH using a fiberglass tape and tree height using Blume-leiss (Cris Brack, 1999). In addition, tree quality was classified into: Good (A), Medium (B) and Bad (C).

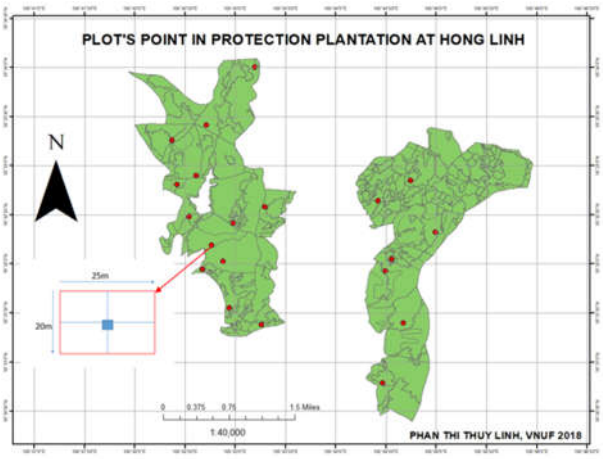


Figure 2: Shape, location of investigation plots

(Red dots are plot locations; Red rectangle is to show side and shape of the plot.)

The plot was divided into 5 strips. We measured canopy closure using Gap light analysis soft-ware in Android mobile phone. Besides, ground cover and dried litter cover was also investigated. If there is ground cover (or dried litter) on the groud, it will be marked 1. If not, it will be marked by 0.

2.2. Analysis method

2.2.1. Assessing characteristics of protection plantation in Hong Linh town

The study used SPSS and Excel software to analysis data to assess stand information such as: density and volume, descriptive statistic such as: mean, standard deviation, variance, skewness and kurtosis and frequency distributions of each forest type (Dr. Bill McNeese and LLC BPI Consulting, 2016; Bui Manh Hung, 2018).

2.2.2. Creating potential maps and an erosion map

a. Method approach

The study applied soil loss prediction equation of Quynh et.al (1996) and GIS. The relationship between soil loss prediction and rainfall, slope, vegetation cover structures and soil porosity factors can be found in the following equation (Vuong Van Quynh and Nguyen Ngoc Lan, 1996; Tran Quang Bao and Melinda J. Laituri, 2011):

$$A = \{2.31x10^{-6} K \alpha^2\} / \{[(CC/H)+GC+LC]^{2} * P\}$$

Where:

- A is estimate average soil loss (mm/year);
- α is slope (^{0});
- H is forest height (m);
- CC is canopy closure (Max 1);
- GC is ground cover (Max 1);
- LC is dried litter cover (Max 1);
- K is rainfall erosivity factor, calculated based on monthly rainfall.

$$K = \Sigma(Ri/25.4)*\{916 + 331lg[(5.8263 + 2.481ln(Ri))/25.4]\}/100$$

In this study, k factor equals 564 mm/year.

- Ri is amount of rainfall in month i (mm)
- P (max 1) is Porosity is determined by the Bulk Density and Particle density of the soil.

After linking the spatial or non-spatial data into Arc-gis, we use the IDW (Inverse Distance Weighted) interpolation to predict.

b. Data investigation

The research collected data from 80 random plots and 20 plots to invest in height, CC, GC, LC, and porosity. Soil porosity is measure from bulk density and using particle density is 2.65 g/cm^3.

c. Creating map

To create potential erosion maps and vegetation map, the study must create slope map, porosity map. Every layer is WGS_1984_ UTM Zone 48N, if anything does not belong to its, we transformed by defining the projection in Data management tool.

- Slope map of protection plantation in Hong Linh town. Slope data layer was derived from National Elevation Dataset (DEM) and

Map of Hong Linh town. DEM is selected in Earth explore (K.G. Renard et al., 1997; ESRI, 2008; Tran Quang Bao and Melinda J. Laituri, 2011; Do Viet Quang, 2016).

- Porosity factor map. Based on investigation points in each forest type, we interpolated porosity and moisaic to a new raster to merge multiple raster datasets into a new raster dataset.

- Erosion risk map (C_2). An erosion risk map (C_2) for Hong Linh was produced from three input layers (porosity, slope maps) (Tran Quang Bao and Melinda J. Laituri, 2011; Le Van Trung et al., 2016). The raster calculation for the erosion risk map was based on the following equation:

$$C_2 = \sqrt{\frac{(2.31*10^{-6}*K*\alpha^2)}{(0.8*P)}}$$

In this study, K factor is rainfall index in Vinh weather station 564 mm/year (Vuong Van Quynh et al., 2013).

- Vegetation cover map (C_1). From the data of vegetation cover structure (i.e., canopy closure, ground cover, litter cover, and height) of previous study (Quynh et al., 1996), calculated C_1 for each investigation point of different main cover types in Hong Linh. Data analyzed based on the equation in Excel software and put into Arc-gis 10.3.

$$C1 = (CC/H) + GC + LC$$

After fulfill C1 index, we turned to transform data into Gis and use Interpolation tool based on C1 index in Hong Linh's area.

2.2.3. Assessing the ability of soil protection against soil erosion of protection plantation

a. Creating current erosion map

Current erosion is presented from the equation of Quynh et. al (1996).

$$A = \{2.31x10^{-6} K \alpha^2\}/\{[(CC/H)+GC+LC]^{2} {}^{*}P\}$$

b. Assessing the ability of soil protection against soil erosion of protection plantation at Hog Linh

- The assessment was based on Standard TCVN5299:2009 about "Soil quality" (TCVN, 2009). It is "Soil quality - Method for determination of soil erosion by rain". Amount of soil erosion is transform from average value of bulk density in this study site that is 1.16. It means that 10 ton/ha/year equal 0.9 mm/year.

Table 1. Classifying current erosion

Level	Amount of soil erosion/year t/ha	Amount of soil erosion mm/year	Assessing
I	To 1	To 0.09	No Erosion
II	> 1 - 5	> 0.09 - 0.45	Slight
III	> 5 - 10	> 0.45 - 0.9	Medium
IV	> 10 - 50	> 0.9 - 4.5	Strong
V	> 50	> 4.5	Very strong

- Two standard soil to protect forests based on Hundson (1971) (Tran Quang Bao and Melinda J. Laituri, 2011; Bui Xuan Dung, 2014).

The acceptance limits of erosion are 11.2 ton ha-1 year-1 with bulk density is 1.4 g/cm^3. This is the maximum rate of soil erosion that can occur and still permit crop productivity to be sustained economically and approximately equivalent to 0.8 mm yr-1.

$$A = \{2.31x10^{-6} K \alpha^2\}/\{[(CC/H) + GC + LC]^{2} {}^{*}P\} \leq 0.8 \text{ (mm/year)}$$

Let vegetation Cover Factor (C_1) is more than or equal Potential Erosion Factor (C_2).

$$C_1 = (C\ C/H) + GC + LC \geq C_2 = \sqrt{\frac{(2.31*10^{-6}*K*\alpha^2)}{(0.8*P)}}$$

3. RESULTS

3.1. Characteristics of some protection plantations in Hong Linh town

In Hong Linh town, plantation's area is 1795.75 ha is divided into three types: protection forest is mainly and occupied to 77% area with 1390.89 ha; production forest is 400.97 ha (22.3%) and another forestry land is

only 0.21% (3.89) ha. Protection plantation in Hong Linh town is a part of Hong Linh mountain and under management of Hong Linh protection forest management board. Almost protection forest area is environment protection forest.

There are 5 types of forest in protection plantations at Hong Linh: Pine, mixed Pine and Acacia, Acacia, Eucalypt and mixed Eucalypt and Acacia. Pine (*Pinus merkusii*) is a native species of Hong Linh mountain that occupies 47.65% with 665.96 ha in area and planted and was a staple crop of the forestry sector from 1978 to 2005. Mixed *Pinus merkusii* & *Acacia auriculiformis* is the second species is concentrated to plant in protection plantation at Hong Linh that occupies 22.17% with 309.08 ha. Eucalypts in Hong Linh mountain were planted in 1990 and some areas were harvested and re-planted in 2008 and 2011. Besides the large amount of area is other forest types concludes some natural tree, grass liner, shrubs, regenerated wood, and bare land, account for 27.44% area of protection plantation (Nguyen Hai Van, 2015).

Stand density of protection plantation in Hong Linh is quite high from 580 to 760 trees/ha. Almost tree in protection plantation Hong Linh is good and no special features.

Based on 20 plots, the DBH, H and Hc data was used to compute descriptive statistics.

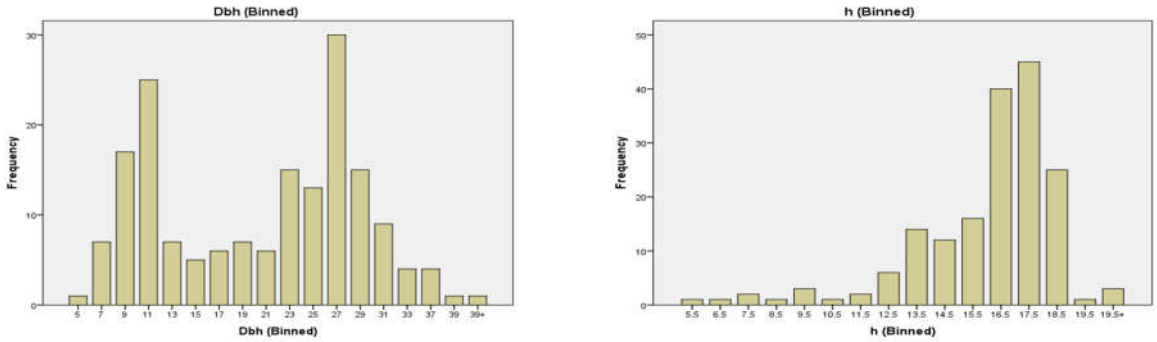
Table 2. Descriptive statistics for variables in each forest type

Descriptive Statistics														
		N	R	Mi	Max	Sum	Mean		Std. De	Var	Skew		Kurt	
							Sta	Se			Sta	Se	Sta	Se
Pinusmerkusii	D1.3	325	41.4	6.4	47.8	8910.8	27.4	0.45	8.09	65.52	-0.32	0.14	0.04	0.27
	H	325	15.5	7.5	23.0	5681.2	17.4	0.15	2.62	6.88	-0.65	0.14	0.93	0.27
	Hc	325	10.5	2.7	13.2	2779.2	8.5	0.14	2.59	6.71	-0.19	0.14	-0.96	0.27
	N	325												
Acacia &Pi	D1.3	203	31.5	5.1	36.6	4771.2	23.5	0.57	8.14	66.24	-0.7	0.17	-0.9	0.34
	H	203	12.0	9.0	21.0	3077.1	15.1	0.18	2.61	6.81	0.27	0.17	-0.3	0.34
	Hc	203	17.0	4.0	21.0	1824.1	8.9	0.32	4.50	20.21	1.62	0.17	1.4	0.34
	N	203												
Acacia auriculiformis	D1.3	68	21.0	11.8	32.8	1491.1	21.9	0.64	5.25	27.58	0.04	0.29	-0.56	0.57
	H	68	10.0	8.0	18.0	1001.4	14.7	0.25	2.03	4.10	-1.17	0.29	2.25	0.57
	Hc	68	3.5	4.3	7.8	425.8	6.2	0.09	0.76	0.58	-0.23	0.29	-0.67	0.57
	N	68												
Eucalyptus	D1.3	38	6.3	4.8	11.1	300.2	7.9	0.25	1.55	2.39	-0.20	0.38	-0.49	0.75
	H	38	9.0	8.0	17.0	543.4	14.3	0.30	1.86	3.47	-1.64	0.38	3.52	0.75
	Hc	38	7.4	5.0	12.4	360.9	9.5	0.24	1.51	2.27	-0.56	0.38	1.65	0.75
	N	38												
Acacia& Euca	D1.3	36	21.9	3.82	25.8	510.21	14.1	1.03	6.16	37.96	0.25	0.39	-0.95	0.77
	H	36	12.5	5.00	17.5	457.90	12.7	0.52	3.15	9.90	-0.80	0.39	0.18	0.77
	Hc	36	7.0	4.00	11.0	236.50	6.57	0.31	1.85	3.43	0.66	0.39	-0.20	0.77
	N	36												

For all forest types, the DBH have Skewness from -0.7 to 0.25. Skewness of mixed Acacia & Pine type is -0.7. Tt means that the distribution is positive skew and kurtosis is 0.27 that greater than zero, then the distribution has heavier tails and is called a leptokurtic distribution (Dr. Bill McNeese and LLC BPI Consulting, 2016). Skewness of height of the tree in all types is less than -1 or greater than 1, the data are highly skewed and kurtosis of height is greater than zero, then the distribution has heavier tails and is also called

a leptokurtic distribution (Dr. Bill McNeese and LLC BPI Consulting, 2016). Except for kurtosis of the mixed Acacia & pine type is less than zero, then the distribution is light tails and is called a platykurtic distribution. In general, range, standard deviation and standard error in pine forest are highest.

Frequency distributions were generated, we selected one specific plot for each forest type. Frequency distributions were generated using diameter and height data, we had the following results:



a. b.

Figure 3. Frequency distributions in each plot. For diameter in a figure and for height in b figure.

For DBH, in five plots of five main forest types, it was divided into 18 classes and the classs width is 2 cm. Number of treen in class 27 cm is the greatest and then in class 11 cm. For height of tree, each class is 1 cm width and divided into 16 classes and almost the height of tree is 17.5 meters and the distribution is clearly positive skew.

3.2. Creating potential maps and erosion maps.

3.2.1. Erosion risk map

a. Slope factor

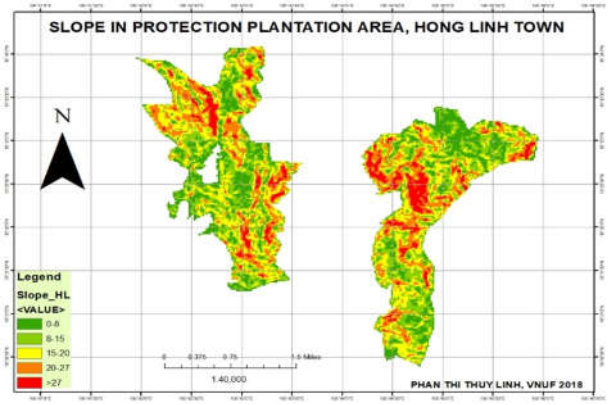


Figure 4. Slope map

The above figure shows the distribution of slope in protection plantation area at Hong Linh town is divided into five groups. The highest slope is presented by red color and lowest slope is dark green color. The maximum slope is concentrate in East-North of the study site, in Dau Lieu commune and apart of Bac Hong commune.

Table 3. Slope analysis in protection plantation at Hong Linh

Slope (^{0})	Total area (ha)	Percentage of slope (%)
0 - 8	264.11	19.01
8 - 14	379.32	27.31
14 - 20	371.38	26.74
20 - 27	272.11	19.59
> 27	101.99	7.34

b. Soil porosity map

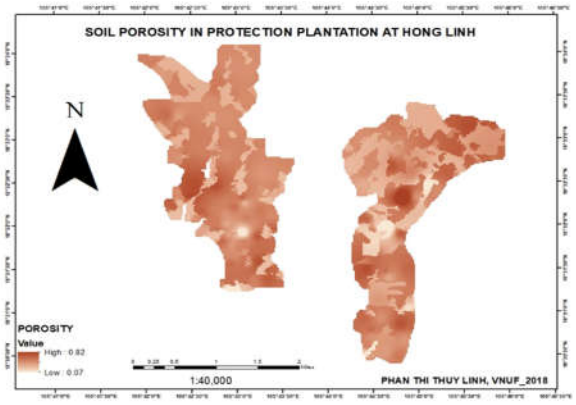


Figure 5. Porosity map

The porosity of soil in protection plantation in Hong Linh town is from 0.07 to 0.82 and decrease from the West to the East. Porosity in *Pinus merkusii* (0.31 - 0.67) and mixed Pine & Acacia (0.07 - 0.82) is highest. That means the ability of protecting forest is higher than other species in this area. The porosity in other forest is lowest (0.35 - 0.56).

c. Map of erosion risk

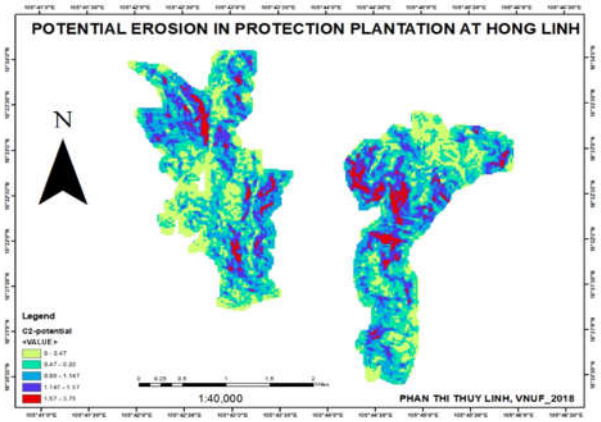


Figure 6. Potential erosion map (C_2)

Amount of soil erosion in potential in protection plantation is from 0 to 3.75. The average of soil erosion is 1.147. The erosion rate is highest in other forest and somewhere of pinus merkusii from 1.57 to 3.75 with red color in figure 6. Amount of soil erosion from 0 to 0.47 is lowest and scattered in mixed pinus &acacia forest.

d. Vegetation cover map (C_1)

To form C_1 factor map, we fulfilled C_1 index in different forest types and transformed into in ArcGIS by IDW interpolation. The result is shown as follows.

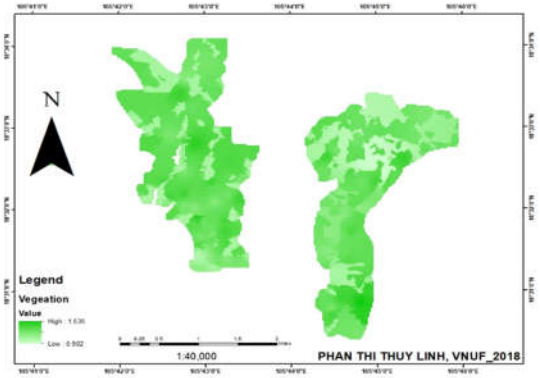


Figure 7. Vegetation cover map (C_1)

Vegetation cover of protection plantation in Hong Linh is from 0.9 to 1.53 that means C_1 coefficient map of each forest type is not significantly different. C_1 coefficient in protection plantation at Hong Linh town is highest in pine forests and mixed pine and acacia. Vegetation cover structure in other forestry land is lowest (0.9 - 1.3).

Vegetation structure plays an important role in protecting the soil of the forest. It reduces the kinetic energy of falling rain to the ground, increasing the chance of seeping into the ground. As we known, the dry vegetation layer is the last layer of the ground that absorbs part of the rainwater and prevents the flow. Therefore, if vegetation cover is higher, so soil erosion is lower.

Table 4. Value of vegetation structure in each forest type

Forest types	Range of C_1	Mean of C_1
Pinus merkusii	1.02 - 1.53	1.32
Pinus & acacia	1.18 - 1.46	1.32
Acacia	1.23 – 1.30	1.29
Ecalyptus & acacia	1.08 - 1.26	1.17
Eucalyptus	1.14 - 1.26	1.20
Others	0.90 - 1.20	1.07

3.3. Assessing the ability of soil protection against soil erosion of plantations

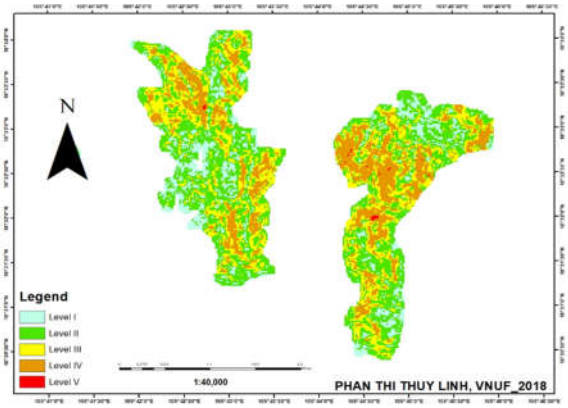


Figure 8. Current erosion map

According to the regulation of classifying current erosion flow Vietnamese standard (TCVN 5299-2009) in this study area, we see that all of the area in protection plantation at Hong Linh town has five levels of erosion. Area of very strong erosion (level V) is presented by red color, area of this level is insignificant. Almost area of protection plantation is eroded slightly (level II) in green color.

Table 5. Classification of current erosion in the protection plantation

Level	year t.ha-1	mm/year	Area (ha)	(%)	Ass
I	To 1	To 0.09	248.25	17.85	No Erosion
II	> 1 - 5	> 0.09 - 0.45	630.31	45.32	Slight
III	> 5 - 10	> 0.45 - 0.9	330.46	23.76	Medium
IV	> 10 - 50	> 0.9 - 4.5	180.49	12.98	Strong
V	> 50	> 4.5	1.38	0.10	Very strong

Applying standard of Hundson (1971), the study classified current erosion into 2 levels, the one is within eroded threshold (≤ 0.8 mm/yr), the other is over eroded threshold (> 0.8 mm/year). We had the result:

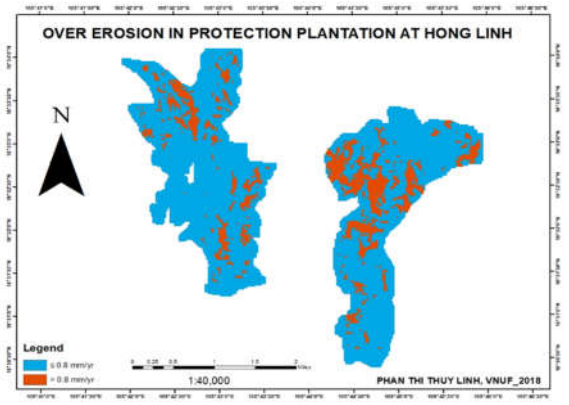


Figure 9. Amount of over soil erosion in protection plantation in Hong Linh

Although current erosion in this study is classified into five level, amount of erosion does not affect to soil significantly. Amount of over eroded threshold more than 0.8 mm/year occupied 26.22% with 364.74 hectares is presented by red color and the blue color is an area of threshold erosion less than 0.8 mm/year with 1026.15 hectares 73.78%. Area of over eroded threshold concentrate in other forest (45.7%) and somewhere of pinus merkusii forest.

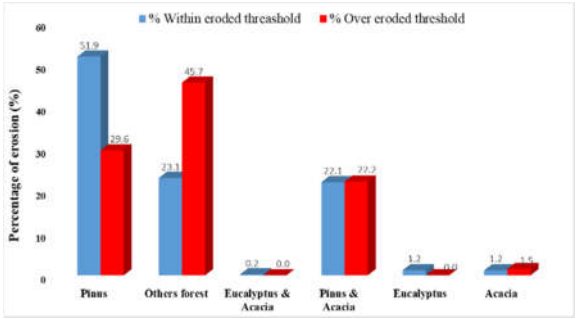


Figure 10. Current erosion in each forest type

Pinus merkusii are the largest area of within eroded threshold (51.9%). Eucalypt and mixed Eucalupt & Acacia forest is no over eroded threshold but amount of within eroded of two species is lowest. Vegetation cover is more than the amount of potential erosion. That means these three types protect the forest well.

Comparing over threshold erosion map with C_1 map, C_2 map, P factor and S factor map, we have some key findings. C_2 does not depend on vegetation cover structure or other changeable factors. It is only affected by stable factors (i.e. slope, rainfall factor, and soil porosity). Mainly, amount of over threshold erosion belongs to area of high slope, low porosity and low vegetation cover.

4. CONCLUSIONS

Based on soil loss prediction equation of Quynh et.al and applying spatial analysis, the study had given some conclusions as follows.

There are five main types of protection plantation in Hong Linh (Pine, mixed Pine & Acacia, Acacia, Euacalypt and mixed Eucalypt & Acacia). *Pinus merkusii* is a native species and dominant in this area that occupies 47.65% with 665.96 ha. Mixed Eucalypt & Acacia is smallest area with 2.24 ha (only 0.16%). Stand density of protection plantation in Hong Linh is quite high from 580 to 760 trees/ha. Moreover, standard deviation and standard error in Pinus merkusii forest are highest.

Potential erosion in this area is from 0 to 3.75 in which amount of highest erosion is in other forest type and somewhere of pinus merhusii forest (1.57 to 3.75), the lowest erosion of area is scattered distribution in mixed Pine and Acacia forest. Vegetation structure in protection plantation at Hong Linh is good from 0.09 to 1.53 and the best vegetation structure is *Pinus merkusii* forest.

Current erosion is divided into five levels of current erosion based on TCVN-2009 and

almost area is slight erosion in *Pinus merkusii* forest. Based on the standard of Hundson (1971), protection plantation area is eroded over threshold erosion occupied 26.22% and concentrate mainly in another forest type, somewhere of pinus merkusii and eucalyptus forest.

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ỨNG DỤNG PHÂN TÍCH KHÔNG GIAN ĐỂ ĐÁNH GIÁ XÓI MÒN ĐẤT TẠI MỘT SỐ MÔ HÌNH RỪNG TRỒNG THỊ XÃ HỒNG LĨNH, TỈNH HÀ TĨNH

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TÓM TẮT

Nghiên cứu đã đánh giá lượng xói mòn đất ở một số mô hình rừng trồng phòng hộ ở thị xã Hồng Lĩnh tỉnh Hà Tĩnh bằng áp dụng phương trình dự báo xói mòn và phân tích không gian. Nghiên cứu đã lập 20 ô tiêu chuẩn và 80 điểm ngẫu nhiên để thu thập số liệu. Để đánh giá lượng xói mòn đất, nghiên cứu cũng sử dụng phương pháp nội suy nghịch đảo khoảng cách trong ArcGIS để xây dựng bản đồ liên quan. Kết quả nghiên cứu chỉ ra rằng (1) Khu vực có 5 loại rừng trồng phòng hộ chính (Thông, Hỗn giao Thông - Keo, Keo, Bạch đàn và Hỗn giao Bạch đàn - Keo) trong đó thông là loài bản địa và chiếm ưu thế với 47,65% (665,96 ha); Lượng xói mòn tiềm năng tại khu vực nghiên cứu không cao chỉ từ 0 - 3,75, lượng xói mòn tiềm năng cao nhất ở các loại rừng khác. Rừng thông có lượng xói mòn tiềm năng từ 1,57 đến 3,75 và che phủ thực vật từ 0,9 đến 1,53. Hệ số thực vật trung bình của mỗi loại rừng không khác nhau quá nhiều. (3) Dựa vào TCVN 2009, lượng xói mòn đất được chia thành 5 mức xói mòn và chủ yếu diện tích đất trên khu vực bị xói mòn ở mức nhẹ và trung bình. Đánh giá lượng xói mòn theo tiêu chuẩn của Hundson (1971), có 364,74 ha của rừng trồng phòng hộ bị xói mòn ở mức vượt ngưỡng chop phép (> 0,8 mm/year) chiếm 26,22% trong đó, diện tích xói mòn tại các loại rừng khác là cao nhất. (4) Duy trì lớp phủ thực vật và trồng thay thế loài là một trong những giải pháp tốt nhất để giảm thiểu xói mòn tại một số mô hình rừng trồng phòng hộ tại Hồng Lĩnh.

Từ khóa: Hồng Lĩnh, phân tích không gian, rừng trồng, xói mòn đất, xói mòn tiềm năng.

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