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TRAN MINH CHINH

RESEARCH TO DETERMINATE THE QUALITY MODEL OF SOIL EROSION SUITABLE FOR TYPICAL AGRICULTURAL SYSTEM ON SLOPING LAND

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SUMMARY OF TECHNICAL DOCTORAL THESIS

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Associate Professor. Dr. Nguyen Trong Ha

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Address: 171 Tay Son - Dong Da - Hanoi

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INTRODUCTION

1. The necessary of the study

The area of mountain land (sloping land) of Vietnam accounts for 3/4 of natural land, these are difficult types of land to exploit and use, if exploitation and use are not associated with maintaining and protecting the land, it is effective. exploitation is very low, especially when the soil is stripped of vegetation cover. In many parts of our country, especially the Northern mountainous region of Vietnam, because there is no productive land, farmers still cultivate with slopes greater than 15^0 degrees for their livelihood. With such a slope, combined with the traditional practice of fire farming, the erosion and soil runoff increase sharply during the cultivation process, which is unavoidable.

Over the past years, studying the operation of soil erosion in our country has achieved many remarkable successes. However, the above studies have only stopped at the scale of experiments, experiments or trials of farming models on sloping land. Building experimental models requires a lot of effort and huge costs in terms of finance, time, and space, while many models have been deployed to predict relatively accurate data. Therefore, the use of existing models for testing is the optimal problem and brings the desired results.

The model is the basis for policy making, planning and sustainable agricultural production development on sloping land. In forecasting models, the Universal Soil Loss Equation (USLE) has been widely used since 1965, in addition, there are models such as Morgan's model (MMF) (Morgan et al., 2008), Stanford’s model (Gregory, 1973), models used in Europe such as EPIC, EUROSEM, PESERA (Bahrawi et al., 2016). The models each have their own advantages and limitations and are specific to each region. Therefore, in order to apply the models to different regions, it is necessary to have suitable data for each region and experiments to calibrate the parameters of the model (Benavidez, 2018).

Faced with these practical requirements, the project "***Research to determinate the quality model of soil erosion suitable for typical agricultural system on sloping land***" is carried out as extremely necessary.

2. Research objective

- Evaluation of quantitative soil erosion models, determining factors affecting soil erosion and applicability in conditions in Vietnam.

- Study the characteristics of the agricultural farming system, the distribution of ground cover by crops and the distribution of rainfall to correct the crop factor (C) in accordance with the typical farming system. on sloping land in the Northern mountainous region of Vietnam.

- Evaluate and propose a model for predicting soil erosion suitable for farming systems on sloping land in the Northern mountainous areas of Vietnam.

3. The scientific and practical meaning of the thesis

- *The scientific meaning:*

By conducting research to apply quantitative soil erosion models to farming systems on sloping land of the world in the conditions of Vietnam, using experimental studies, forecasting models made in Vietnam to study and calibrate the model from which to select and complete a model for predicting soil erosion suitable for the Northern mountainous region of our country.

Proposing specific calculation methods to apply the model appropriately for typical agricultural farming model on the steep slopes of the Northern mountainous region of our country.

Completing the calculation methods, the methods of determining the parameters of the quantitative model of soil erosion for typical farming models on sloping land, providing the scientific basis of sustainable agricultural management production by structural, non-structural or combination methods.

- *The practical meaning:*

The research results have provided a method to correct the crops factor (C) and a suitable soil erosion prediction model for the Northern mountainous region of our country.

Forecasting is more accurate than currently applied conventionally. The prediction of soil loss due to erosion and analysis of factors affecting soil erosion at the soil erosion test sites will be the basis for making appropriate farming and tillage techniques to minimize soil erosion

4. New contributions of the thesis

- The crops factor (C) has been adjusted based on the distribution of crop cover, rainfall and soil impact techniques suitable to farming conditions in the Northern mountainous area of our country.
- The conventional and corrected models of erosion prediction and crops factor (C) have been tested, based on the test results, a suitable soil erosion prediction model has been developed for the Northern mountainous area of our country.

CHAPTER 1. OVERVIEW OF RESEARCH

1.1. oil erosion and factors affecting soil erosion

There are many definitions of soil erosion, in this thesis using the definition of Nguyen Quang My (2005): Soil erosion is the process of destroying the soil layer (including destruction of the mechanical, physical, chemical and nutrient properties etc. of the soil) under the influence of natural and human factors, reducing soil fertility, causing soil degradation, lateritization, inert gravel ,... directly affects the life and development of forest vegetation and other vegetation.

1.1.1. Effects of climate factors to soil erosion

Erosion on slopes is mainly caused by raindrops and surface runoff. Erosion is affected by climatic factors such as: total rainfall and the nature of rain, time and intensity of rain, etc. Erosion process occurs more strongly when the soil surface is ploughed or burned tree cover. The impact of rain on erosion is divided into three phases: (i) separation of soil particles from the soil mass; (ii) movement of soil particles; and (iii) deposition (Ellison, 1947).

1.1.2. Effects of terrain factors to soil erosion

Topography is also a natural factor that greatly affects soil erosion. If considered on a large scale, topography has the effect of changing the distribution of heat and precipitation. Topographic factors such as slope,

slope length, shape (convex, concave, straight, ladder,...) the degree of cross-section of the terrain directly affect soil erosion.

1.1.3. Effect of vegetation cover on soil erosion

Vegetation cover has a great influence on the process of soil erosion. If the thickness of the vegetation cover increases, the erosion process decreases. The anti-erosion role of vegetation cover depends on its age and coverage. Plants have the ability to protect soil against erosion by reducing the influence of raindrops on the ground by foliage and allowing water to flow down to 50-60% of the vertical of the roots.

1.1.4. Effects of soil factors to soil erosion

Soil is subject to damage by rain and surface runoff, so the development of erosion depends on the nature and condition of the soil. The main soil factors affecting soil erosion are the mechanical composition, structure and water permeability as well as the organic content of the soil.

1.2. Soil erosion is a limiting factor to sustainable agricultural production on sloping land.

1.2.1. Erosion causes loss of agricultural land

Intosh (1980) proposed factors that inhibit the development of crop production on sloping land. In which, the rapid loss of fertility is the most obvious manifestation, usually after 2 - 3 years reclaimed land will lose its inherent fertility and lose its production capacity.

1.2.2. Erosion causes loss of soil nutrients

If the average annual loss of soil is 10 tons/ha, the loss of macronutrients of 20 million hectares of sloping land in our country is equivalent to 634,000 - 1,505,000 tons of urea; 278,000 tons - 3,967,000 tons of superphosphate and 200,000 - 610,000 tons of potassium chloride, estimated at VND 6,445 billion, not including the loss of organic matter and other trace elements (Nguyen Trong Ha, 1996).

1.3. Research on soil erosion in the world.

In the world, the study of soil erosion has been studied very early, mainly based on 3 research methods: field experiment, laboratory experiment, combined experiment.

The first experiments to determine soil erosion quantitatively conducted in Utah, USA in 1915. Shortly thereafter, Miller, 1923 was conducted field experiments in Missouri. Bennett (1993) established a network of 10 experimental stations to prevent erosion in the years 1928 to 1933. The first study on the mechanical impact of raindrops on the soil was conducted by Ellison in 1944 (Zakharov, 1981).

Soil erosion has been empirically studied by 20th century scientists and generalized into mathematical formulas such as Horton's soil erosion equation (1945), Musgave's soil loss equation (1947), and destroy the texture of raindrops equation of Ellison (According to Ellison, 1958); the Universal Soil Loss Equation (USLE) of Wischmeier and Smith (1978); the sedimentation model of Stanford (Gregory, 1973), models like Morgan's model (MMF) (Morgan et al., 2008), models used in Europe such as EPIC, EUROSEM, PESERA (Bahrawi et al., 2016),etc.

1.4. Research on soil erosion in Vietnam

The history of soil research in Vietnam is hundreds of years old, but the research on soil erosion has only been around for more than 5 decades. According to Nguyen Quang My (2005), the process of studying soil erosion in Vietnam can be divided into three stages:

- In the period before 1954: Mainly works to prevent soil erosion were carried out from farmers' production experience such as building works on sloping land with wooden blocks, building terraced fields in H'Mong and Dao ethnic groups in the Northeast and Northwest of Vietnam.

- Period from 1954-1975: Studies on soil erosion began in the 1960s, the period when the North was building socialism. In 1963, a regional erosion study was conducted. Several scientists, led by Ton Gia Huyen, have published studies on soil erosion in the Northwest. During this period, a number of works by many authors (Nguyen Quang My, 2005,...). In general, the works have solved many problems of soil erosion, measures to prevent soil erosion, but the ability to quantify soil erosion is not high.

- Period from 1975: During this period, a number of monitoring stations for studying soil erosion were built such as: soil erosion research station in the Central Highlands located in Gia Lai province built in 1976, soil erosion research in Thai Nguyen province, soil erosion research station in Huu Lung, Lang Son and Ekmat soil erosion research station (Buon Ma Thuot). Various authors have studied soil erosion in groups such as: (i) Research on active factors of soil erosion; (ii) Research on methods to prevent soil erosion; (iii) Study of soil erosion by mathematical model; (iv) Study on soil erosion zoning; (v) Study of soil erosion using remote sensing and GIS.

1.5. The quantitative research methods of soil erosion

1.5.1. Experimental methods

Practical solutions include: (i) Field experiments; (ii) Laboratory experiments; (iii) Combination experiment

In recent years, the use of a combination of field experiments and rain simulations has increased.

1.5.2. Quantitative modelling method for soil erosion

Some quantitative equations are widely used: (i) Quantitative model (a simple model, or so-called “black box” model); (ii) Universal Soil Loss Equation (USLE); (iii) Stehlík Model; (iv) Morgan and Finney (MMF) Model.

In the models mentioned above, the Universal Soil Loss Model (USLE) and the Morgan - Finney model (MMF) are two models that are considered to be quite suitable when applying soil erosion prediction for farming systems on sloping land. Both models have advantages that can overcome each other's limitations and doubts about the appropriateness of each model in practice. The results of model testing allow necessary adjustments to be made to suit the study area. None the research results will provide solutions to agricultural cultivation appropriate to recommend land use planners, planning and protection forests, flood control effectively based on safeguards protect and prevent soil erosion.

1.6. Overview of the crop system in the Northern midland and mountainous region of Vietnam

Northern midland and mountainous region with a total natural area of 95,270 km^2 (accounting for 28.79% of the nation's area), a population of 12.5 million people with over 30 ethnic groups living together.

1.6.1. Current status of agricultural land use

Although the mountainous terrain, annual cropland accounts for 17.11% of the area of the whole region (21.04% for the whole country), of which rice land accounts for 6.09% (the whole country is 12.46%), land for growing other annual crops (maize, potatoes, cassava, peanuts, beans,...) accounted for 11.2% (compared to 8.58% for the whole country).

1.6.2. Distribution of crops according to topographical conditions

In the northern hills, on a hillside, the distribution of crops depends on the distribution of rainfall, the source of irrigation water and the topographical conditions. Areas along rivers and streams with water sources for irrigation often grow two rice cultivation or rice rotation with annual crop. Higher areas are often arranged with crops with less water requirements such as upland rice, cassava, maize, beans, fruit trees, agroforestry models, etc (Figure 1.1).

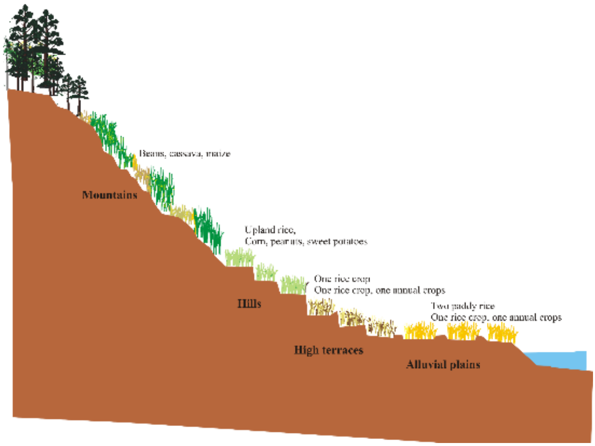

Figure 1.1: Characteristics of the arrangement of plants according to topographical characteristics and water sources in the Northern mountainous region of Vietnam

CHAPTER 2. CONTENTS AND RESEARCH METHODS

2.1. Theoretical foundations of research problems

2.1.1. Theoretical foundations of the causes of soil erosion

Researches on the causes of erosion in the world agree that there are two main groups of causes: natural and human. The impact of natural erosion is due to 5 main factors: Climate (mainly temperature, water, vegetation; parent rock, topography and time). In their activities, humans affect the nature in both positive and negative directions, these activities can be a direct or indirect cause of soil erosion.

2.1.2. Theoretical basis for the quantitative model of soil erosion

Based on the theoretical basis and practical application in Vietnam, this study selects two models, the Universal Soil Loss Equation (USLE) and the Morgan - Finney Model (MMF). These two models use parameters that can be determined through experimental measurements, calculated from measured data (rain, vegetation cover ...) and can be determined easily under the conditions in our country. The feature of the MMF model is that it takes into account the amount of soil erosion on the slope caused by the flow, this method tends to overcome the limitation of the USLE model.

2.1.3. Theoretical basis for correcting quantitative soil erosion models

Models are built from experiments for certain regions. On the basis of experimental measurement data, this study will correct the crop erosion coefficient (C) and apply the correction factor to the USLE model and the MMF model to test.

2.2. Research approach

2.2.1. Experimental approach

This approach is based on standard plots to monitor annual soil erosion and to measure and monitor parameters such as crop cover, rainfall, slope, slope length, physicochemical properties of the soil, etc., to serve as a basis for adjusting factors of soil erosion prediction models.

2.2.2. Inheritance approach

The more experimental data needed to calibrate the model, the higher the reliability of the model correction value. Therefore, in addition to experimental data, it will inherit experimental data of studies done within the study area.

2.2.3. Quantitative modelling approach

This approach is based on using the model to quantify the factors that cause soil erosion, so that it can be applied to areas with similar conditions.

2.3. Research Methods

2.3.1. Experimental method

To assess the evolution of vegetation factors according to different farming methods for C factor correction, this study selects 3 locations for monitoring soil erosion at Co Noi, Mai Son La.

Arrange 3 soil erosion monitoring plots with 9 observations at Co Noi, Mai Son, Son La with geographic coordinates $104^0$9'57"E and $21^0$9'41"N in 3 years from 2015-2017 with the main crops are maize and ricebean, the size of the monitoring plot is 5 x 20 m. Soil loss collection pits are made in trenches (80cm wide x 70cm deep x 4m long).

2.3.2. Inheritance and data collection method

This study selected 5 experimental sites (Figure 2.1) for field soil erosion with 39 monitoring plots. In which, the monitoring points of Co Noi, Mai Son, Son La were built by this study, the remaining 4 points are inherited from other research works (see Table 2.1).

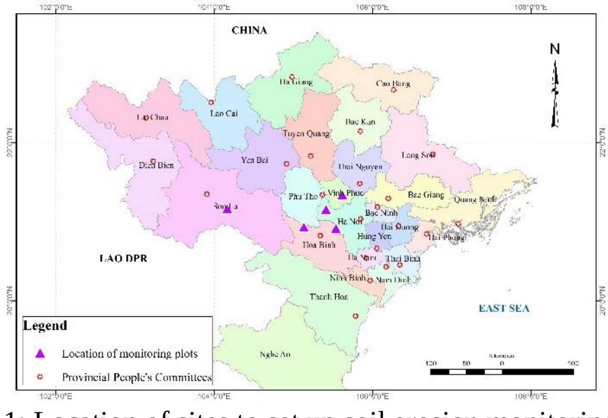

Figure 2.1: Location of sites to set up soil erosion monitoring plots

In addition, it also collects and inherits rain data at neighbouring meteorological stations, including: Co Noi station (2015, 2016, 2018), Hoa Binh station (2000), Vinh Yen station (2000, 2001). 2002), Xuan Mai station, Hoa Binh station, Ba Vi station (1992,1993,1994,1995)

Table 2.1: Information of monitoring plots used for testing

Order	Place	Sign	Coordinates	Experimental plot size	Crops	Reference
1	Tat village, Tan Minh, Da Bac, Hoa Binh.	BT-TM-ĐB-HB	$105^0$11'92"E $20^0$11'92"N	20 x 5 m	Upland rice, cassava.	Nguyen Van Dung et al., 2008
2	Vinh Yen town, Vinh Phuc.	TX VY-VP	$105^0$37’54”E $21^0$18’08”N	20 x 5 m	Cassava; Planting morning glory during fallow time.	Kiyoshi Kurosawa et al., 2009
3	Hoa Son, Luong Son, Hoa Binh.	HS-LS-HB	$105^0$42'2"E $20^0$47'1"N	20 x 5 m	Black beans, corn, peanuts, cassava; legume strip.	Nguyen Trong Ha, 1996
4	Thuy An, Ba Vi, Hanoi.	TA-BV	105°28'12"E 21°3'24"N	20 x 5 m	Peanuts, soybeans, sweet potatoes, cassava; legume strip.	Nguyen Trong Ha, 1996

2.3.3. Methods of using quantitative models

2.3.3.1. Universal Soil Loss Equation

Use the Universal Soil Loss Equation (USLE) to correct for the crop factor (C).

2.3.3.2. The Morgan-Morgan and Finney Model (MMF)

The Morgan-Morgan and Finney (MMF) model was used to test the crop factor (C) before and after correction. The forecast results of the MMF model are also compared with the forecast results of the USLE model to propose a suitable quantitative soil erosion model.

2.3.4. Calibration and validation methods

The indicators to evaluate the error between the forecast model and the actual measurement results at the erosion monitoring plots are the correlation coefficient R and the mean square error (RMSE). The values are calculated according to the following formula:

$$R = \frac{\sum_{i=1}^{N}(Fi-\bar{F})(Oi-\bar{O})}{\sqrt{\sum_{i=1}^{N}(Fi-\bar{F})}\sqrt{\sum_{i=1}^{N}(Oi-\bar{O})}}; \qquad RMSE = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(Fi - Oi)^2}$$

Where: Fi and Oi are the model value and the observed value of a certain variable, respectively (the amount of soil lost); i=1,2,…, N; N is the number of samples.

CHAPTER 3. RESEARCH RESULTS AND DISCUSSION

3.1. Correction for crop erosion coefficient (C)

3.1.1. Selecting a method of correcting crop factor C in soil erosion assessment

This study uses the experimental method, on the basis of established soil erosion monitoring plots and inherits the existing research results to calculate the corrected C factor. On the basis of the value calculated from the experiment, the C factor will be corrected by combining the methods of Wischmeier and Smith (1981), Morgan (2005) and Stone and Hilborn (2000). Accordingly, the correction of C factor will combine the cropping schedule, canopy cover, rainfall and soil impact techniques.

Using the Universal Soil Loss Equation (USLE) to determine the crop factor (C) suitable for agricultural farming conditions in the Northern mountainous region of Vietnam. The Morgan and Finney (MMF) model uses the crop factor (C) and the management measure factor (P) of the USLE, so after adjusting the C factor, we will use the forecast results of both USLE and MMF models to test the C factor adjusted.

3.1.2. Crop factor (C) correction for the mountainous area in the North of Vietnam

3.1.2.1. Characteristics of the relationship between farming season, canopy cover and precipitation in the Northern mountainous region of Vietnam

Synthesize data from soil erosion monitoring plots and analyse the relationship between crop seasons, canopy cover and precipitation at 5 points shown in Figure 3.1.

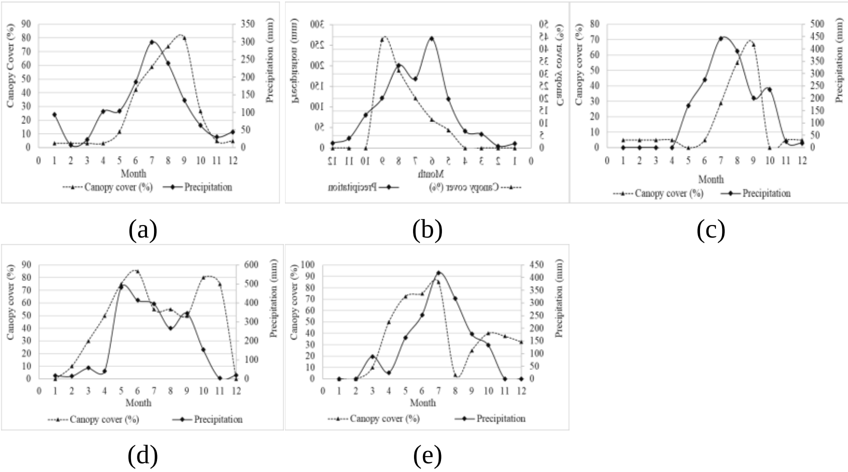

Figure 3.1: Distribution of canopy cover and monthly precipitation in soil erosion monitoring plots.

Notes: a) Method of intercropping maize with ricebean in Co Noi, Mai Son, Son La; b) Method of growing cassava in Vinh Yen Town, Vinh Phuc; c) Ban Tat, Tan Minh, Da Bac, Hoa Binh; d) Thuy An, Ba Vi, Hanoi and e) Hoa Son, Luong Son, Hoa Binh.

The diagram showing canopy cover and rainfall by months of the year with the farming method in Figure 3.1 shows that: At the points in Co Noi, Vinh Yen and Ban Tat, the peak rainfall occurs in the period from May to July, while the peak of the canopy cover occurs later in August to October. Meanwhile, at the monitoring points in Thuy An and Hoa Son, the peak of coverage is quite similar to the peak of rainfall.

3.1.2.2. Adjust the C factor suitable for the Northern mountainous region of Vietnam

- *Determine the C factor from the parameters of the erosion model*

Based on the results of determining the erosion factors R, K, LS, P and the amount of soil measured in the erosion monitoring plots (summarized in Table 3.1), the erosion factor due to crops C was determined, here would assume C_h factor and calculated by the formula: $C_h=\frac{A}{R*K*LS*P}$. Calculation results of C_h factor and C factor according to the table of the International Society of Soil Science (ISSS) were presented in Table 3.1.

Comparing the value of C_h factor calculated from the observation plots with 39 times of experiments with the C factor from the ISSS table shows that there is a big difference, the C factor from the table is higher than the C_h factor calculated from monitoring plots range from 1.32 to 20.0 times, with an average of 6.07 times. This large difference will lead to errors compared with reality in forecasting and assessing amount of soil erosion.

Table 3.1: The results of determining the C_h factor are based on measured and calculated parameters in the erosion monitoring plots

Order	**Place Signs**	**Year**	**R factor**	**K factor**	**LS factor**	**P factor**	**A (tons/ha/ year)**	**C_h factor**	**C factor in ISSS table**	
									Values	**Rate C/C_h**
1	CN-MS-SL (CT T3)	2017	603,44	0,44	5,72	0,14	14,56	0,069	0,24	3,48
2	CN-MS-SL (CT T3)	2016	725,88	0,44	5,72	0,14	18,34	0,072	0,24	3,33
3	CN-MS-SL (CT T3)	2015	676,86	0,44	5,72	0,14	15,45	0,065	0,24	3,69
4	CN-MS-SL (CT T2)	2017	603,44	0,44	10,10	0,14	21,56	0,057	0,24	4,21
5	CN-MS-SL (CT T2)	2016	725,88	0,44	10,10	0,14	27,54	0,061	0,24	3,93
6	CN-MS-SL (CT T2)	2015	676,86	0,44	10,10	0,14	20,45	0,049	0,24	4,90
7	CN-MS-SL (CT T1)	2017	603,44	0,17	8,20	1,00	57,45	0,069	0,24	3,48
8	CN-MS-SL (CT T1)	2016	725,88	0,17	8,20	1,00	64,45	0,064	0,24	3,75
9	CN-MS-SL (CT T1)	2015	676,86	0,17	8,20	1,00	50,75	0,054	0,24	4,44
10	BT, TM, ĐB, HB (Ô 1)	2000	602,16	0,17	12,22	0,50	8,00	0,013	0,24	18,46
11	BT, TM, ĐB, HB (Ô 2)	2000	602,16	0,17	12,96	0,50	8,00	0,012	0,24	20,00
12	BT, TM, ĐB, HB (Ô 3)	2000	602,16	0,17	8,84	0,50	13,00	0,029	0,24	8,28
13	BT, TM, ĐB, HB (Ô 4)	2000	602,16	0,17	12,22	0,50	16,00	0,026	0,24	9,23
14	BT, TM, ĐB, HB (Ô 5)	2000	602,16	0,17	9,80	0,50	25,60	0,052	0,24	4,62
15	TX VY-VP (Ô 6)	2000	445,44	0,44	0,80	0,50	25,60	0,327	0,78	2,39
16	TX VY-VP (Ô 6)	2002	611,57	0,44	0,80	0,50	43,90	0,409	0,78	1,91
17	TX VY-VP (Ô 8)	2000	445,44	0,44	1,87	0,50	59,50	0,325	0,43	1,32
18	TX VY-VP (Ô 8)	2001	544,68	0,44	1,87	0,50	17,60	0,079	0,43	5,44
19	TX VY-VP (Ô 10)	2002	611,57	0,44	1,87	0,50	46,00	0,183	0,43	2,35
20	HS-XM (CT T1)	1993	622,09	0,15	8,46	0,95	35,91	0,048	0,24	5,00
21	HS-XM (CT T1)	1994	803,29	0,15	8,46	0,95	20,77	0,021	0,24	11,43
22	HS-XM (CT T1)	1995	472,69	0,15	8,46	0,95	16,13	0,028	0,09	3,21
23	HS-XM (CT T2)	1993	622,09	0,15	8,46	0,14	5,03	0,046	0,24	5,22
24	HS-XM (CT T2)	1994	803,29	0,15	8,46	0,14	14,84	0,104	0,24	2,31
25	HS-XM (CT T2)	1995	472,69	0,15	8,46	0,50	12,43	0,041	0,09	2,20
26	HS-XM (CT T4)	1993	622,09	0,15	8,46	0,50	4,68	0,012	0,09	7,50
27	HS-XM (CT T4)	1994	803,29	0,15	8,46	0,50	14,21	0,028	0,12	4,29
28	HS-XM (CT T4)	1995	472,69	0,15	8,46	0,50	10,26	0,034	0,09	2,65

Order	Place Signs	Year	R factor	K factor	LS factor	P factor	A (tons/ha/ year)	C_h factor	C factor in ISSS table	
									Values	Rate C/C_h
29	HS-XM (CT T5)	1993	422,09	0,15	8,46	0,50	2,81	0,011	0,09	8,18
30	HS-XM (CT T5)	1994	803,29	0,15	8,46	0,50	14,21	0,028	0,12	4,29
31	HS-XM (CT T5)	1995	472,69	0,15	8,46	0,50	16,69	0,056	0,09	1,61
32	TA-BV – (CT T2)	1992	396,22	0,31	0,63	0,95	0,83	0,011	0,09	8,18
33	TA-BV – (CT T2)	1993	854,44	0,31	0,63	0,95	2,08	0,013	0,12	9,23
34	TA-BV – (CT T2)	1994	902,14	0,31	0,63	0,95	3,35	0,020	0,12	6,00
35	TA-BV – (CT T3)	1992	596,22	0,31	0,63	0,50	0,99	0,017	0,09	5,29
36	TA-BV – (CT T3)	1993	854,44	0,31	0,63	0,50	0,63	0,008	0,12	15,00
37	TA-BV – (CT T3)	1994	902,14	0,31	0,63	0,50	2,54	0,029	0,12	4,14
38	TA-BV – (CT T4)	1993	854,44	0,31	0,63	0,50	0,65	0,008	0,12	15,00
39	TA-BV – (CT T4)	1994	1450,4	0,31	0,63	0,50	2,52	0,018	0,12	6,67

- *Recommended C factor correction*

Calculation results from actual erosion monitoring plots in Table 3.1 show that correction of C factor is absolutely necessary. Here, the correction of C factor will be approached in accordance with the cultivation conditions in the Northern mountainous region by adjusting the C factor that will combine the canopy cover in each stage of tree growth, crop structure (intercropping), rainfall and farming techniques affecting the soil (ploughing, hoeing, weeding, etc.)

* *Canopy cover and rainfall factor:*

From the canopy cover, the first C factor is determined for each period of the year according to the inverse linear relationship between the C factor and the canopy cover. The sum of the product of the C factor and the adjustment factor (%R) for each period allows the calculation of the C factor adjusted for the distribution of canopy cover and precipitation in the year (Morgan, 1995). The formula to correct the factor C due to the distribution of coverage and precipitation is generally written as follows:

$$C_{cr} = \sum_{i=1}^{n} C_i * W_{ri} \; ; \qquad W_{ri} = \frac{p_i}{p}$$

Where: C_{cr}: is the C factor corrected for the distribution of canopy cover and rainfall; n: is the cultivation stage (land preparation, seeding, canopy growth, harvesting and fallow); C_i: is the C factor according to the table C factor of the ISSS, corresponding to the canopy cover of the cultivation period i; W_{ri}: is the weight due to the amount of rainfall in the cultivation period i; p_i: is the monthly rainfall at the cultivation period i; and p is the total rainfall of the year.

In the case of intercropping (Figure 3.2), this study proposes to determine the C factor calculated for each tree as above, then calculate the C_i factor for the type of intercropping as follows: $\bar{c_i} = \frac{\sum c_i l_i}{\sum l_i}$

Where: C_i: C factor of the i^{th} crop; l_i: Length according to the slope of the i^{th} crop.

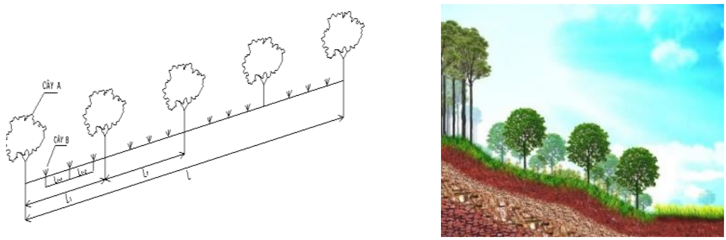

Figure 3.2: Spacing of intercropping to determine the canopy cover for the type of intercropping

** Technical farming factors:*

On the basis of the C_h factor calculated from the measurement results in the above erosion monitoring plots, determine the D coefficient according to the following formula: $D=\frac{C_h}{C_{cr}}$. In which: C_h and C_{cr} were calculated from erosion monitoring plots according to Table 3.1.

Based on the results of the C_h value calculation, determine the C_{cr} factor, if the plots have intercropping, use the formula for calculating the intercropping. After determining the C_{cr} factor, the D factor will be determined. The combined results from 39 erosion monitoring plots by type of crop and technical measures, the factors C_{cr}, C_h and correction factor D are summarized in Table 3.2

Table 3.2: Determination of correction factor for technical measures (D) to correct the C factor

Order	**Crop types**	**Technical measures**	**Samples (N)**	**C_{cr} factor**	**C_h factor**	**D factor**	
						Average	**Standard deviation**

Order	Crop types	Technical measures	Samples (N)	C_{cr} factor	C_h factor	D factor	
						Average	Standard deviation
1	Monoculture one crop/year		16				
-	Upland rice	- Chopping, burning (for the first time), harrowing - Punch/slit the row along the contour line sowing by hand - Weeding (rake)	5	0.118	0.058	0.498	0.013
-	Cassava	- Tillage with hoe, shovel, twig - Weeding with a hoe - Harvest and uproot using hoe, shovel	5	0.513	0.208	0.407	0.093
-	Maize	- Tillage with hoe, rake - Sowing seeds by hand - Making weeds with a hoe	6	0.293	0.059	0.203	0.013
2	Rotational		4				
-	Maize - beans	- 2 times tillage with hoe, rake - 2 times sowing seeds by hand - 2 times weeding with a hoe	4	0.140	0.042	0.298	0.004
3	Crop rotation combined with intercropping		2				
-	Peanut crop with sweet potato and soybean	- 2 times creating beds, 1 time for light tilling (hoe, rake) - 2 times weeding with hoe, rake - 2 times of harvesting, rooting, using a hoe	2	0.213	0.106	0.499	0.009
4	Intercropping		17				

Order	Crop types	Technical measures	Samples (N)	C_{cr} factor	C_h factor	D factor	
						Average	Standard deviation
-	Cassava - maize - peanuts	- 1 time for land preparation, 2 times for light tilling with weeding. - 1 time prying, 2 times sowing seeds - 1 time harvesting small roots (cassava and peanuts) using a hoe, shovel.	4	0.088	0.053	0.606	0.007
-	Cassava - peanuts	- 1 time for land preparation, sow the branches, and sow the seeds. - 1 time weeding. - 1 time uprooting harvest (tubers) with hoes, shovels	6	0.080	0.137	0.600	0.014
-	Maize - peanuts	- 1 time for land preparation, sow seeds - 1 time weeding. - 1 harvest, uprooting (tubers) with a hoe	4	0.220	0.055	0.247	0.010
-	Maize - beans	- 1 time for land preparation, sow seeds - 1 time weeding	3	0.321	0.068	0.214	0.018

Calculation results of correction coefficients due to cultivation techniques D for crops and crop structure in the year are shown in Table 3.2. For monoculture, the results of 16 observations of upland rice, cassava and maize show that the correction D factor of the three crops is 0.498, 0.407 and 0.203, respectively.

- For the type of crop rotation: The results of 4 times of monitoring maize and bean rotation shows that the value of the correction coefficient due to the cultivation method D factor is 0.298.

- For the type of intercropping combined with rotation: The D factor for the two crops (sweet potato, peanuts) and annual crops (soybean) is 0.499.

- For the type of intercropping: There are a total of 17 observations, the results show that the D factor of cassava crops after 1 month of intercropping with maize and 3 months of intercropping with peanuts (cassava - maize - peanuts) ; cassava - peanuts; corn – peanuts; corn – beans are 0.606; 0.6; 0.247 and 0.214 respectively.

The calculation results show that the intercropping system has the lowest coefficient of erosion effect due to land cover, the crops grown with high D is upland rice (0.498). ; cassava (0.40); corn about 0.2, when rotating with soybean about 0.3; peanuts and sweet potatoes with soybeans about 0.5. Compare these values with the research results of Karine Vezina et al. (2009) when studying rain-fed farming systems with crops such as soybeans, cassava, and maize grown on hilly areas in Dong Phuc commune, Ba Be, Bac Kan showed similar results with values for cassava of 0.4, soybeans of 0.4, and maize of 0.2. A paddy rice crop cultivated by the terraced method is 0.6 and two paddy rice crops or one paddy rice crop and one annual crop (maize) is 0.8.

Summary of crops and technical measures affecting the soil and correction D factor due to technical measures for C factor are proposed in Table 3.3

Table 3.3: D factor for different cropping systems applied to the northern mountainous region of Vietnam

Order	**Farming system**	**Farming practices (activities and tools)**	**D factor**
1	Upland rice	- Chopping, burning (for the first time), harrowing - Poke holes/tear in line with hand sowing contour lines - Weeding (rake)	0.50
2	2 paddy rice crops in terraced fields (*)	- 2 times ploughing and harrowing (plod, harrow and buffalo) - 2 times sowing (by hand) - 2 times weeding (raking)	0.80
3	1 paddy rice, 1 annual crop in terraced fields (*)	- 2 plods and harrows (plod, harrow and buffalo) - 2 times sowing (by hand) - 2 times weeding (hoe)	0.80
4	1 paddy rice in terraced fields (*)	- 2 plods and 2 harrows (plod, harrow and buffalo) - 1 time sowing (by hand) - 1 time weeding (rake)	0.60

Order	Farming system	Farming practices (activities and tools)	D factor
5	1 crop of potatoes or cassava or peanuts.	- 1 time (picking, sowing) (shovel or hoe) - 1 time weeding (hoe) -1 time rooting (getting tubers) (shovel, hoe)	0.40
6	1 crop of corn or peas or sesame or remaining annual crops.	- 1 time till the ground (hoe, rake) - 1 time sowing (hand, poke hole) - 1 time weeding (hoe)	0.20
7	Rotate one of the crops (cassava, potato, peanut) with the other annual crops.	- 2 times till the soil, sow the seeds - 2 times weeding - 1 harvest, uprooting (tubers) with a hoe	0.30
8	Rotation of 2 crops (cassava, potato, peanut) intercropped with 1 annual crop.	- 2 times to make beds, 1 time to make light soil (hoe, rake) - 2 times weeding with hoe, rake - 2 times of harvesting, rooting, using a hoe	0.5
9	Intercropping 2 of the crops (cassava, potato, peanut) with the remaining annual crops.	- 2 times of tillage, 2 times of light tilling with weeding - 1-2 times prying, 2 times sowing seeds - 2 times of harvesting and uprooting (cassava, peanuts or potatoes) using a hoe, shovel.	0.60
10	Alternating cassava - peanut (potato)	- 1 time to work the soil, prune branches, sow seeds - 1 time weeding - 1-2 times close to each other to harvest and uprooting (tubes) with a hoe, shovel	0.60
11	Intercropping 1 of the crops (cassava, potato, peanut) with the other annual crops	- 1 time till the soil, sow seeds - 1 time weeding - 1 time of harvest uprooting (tubers) with a hoe	0.25
12	Intercropping with 2 annual crops/ season (crops without tubers)	- 1 time till the soil, sow seeds - 1 time weeding	0.21

(*): Inherited from the data of Karine Vezina et al., 2006.

3.2. Verification of crop factor (C_h) and proposed application

3.2.1. Test results by the Universal Soil Loss Equation (USLE)

Using the corrected C_h factor and C factor according to the table of the ISSS to apply the prediction of soil erosion in the erosion monitoring plots. The forecast results will be compared with the real land loss value.

The research results of five erosion monitoring points with a total of 39 experiments (N=39) (Figure 3.3) show that the C factor correction method has predictive results closer to the actual measurement results in comparing with the conventional model. This is represented by the value of the correlation coefficient R, the USLE equation with the normal and corrected C factor of 0.69 and 0.8 and the mean square error (RMSE) of the normal model is 82.09 and the model using C factor adjusted according to this study is 11.01.

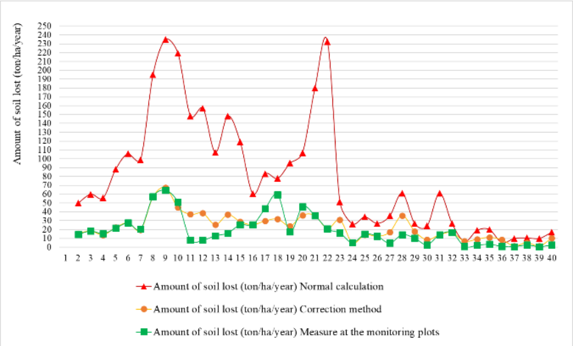

Figure 3.3: The amount of soil loss measured in the monitoring plots and the results of the calculation according to the conventional USLE and corrected for the C factor of this study.

At the peaks the maximum predictive results of the conventional USLE equation (monocrop corn cultivation in Co Noi is forecast at 235.02 tons/ha/year, actual 64.45 tons/ha/year; planted); intercropping maize and peanuts in Hoa Son is expected to be 232.38 tons/ha/year, actually 20.77), the USLE model using the adjusted C factor has overcome this forecast error.

This shows that, the correction method has overcome the limitations due to not taking into account the distribution of crop coverage, the arrangement of crop structure (monoculture, rotation, intercropping), rainfall, technical cultivation into the soil during cultivation compared to conventional methods.

3.2.2. Test results by Morgan and Finney models (MMF)

The detailed results of the calculation of the amount of soil loss according to the MMF model with the values of the soil loss according to J, G values and actual measurements are presented in Figure 3.4.

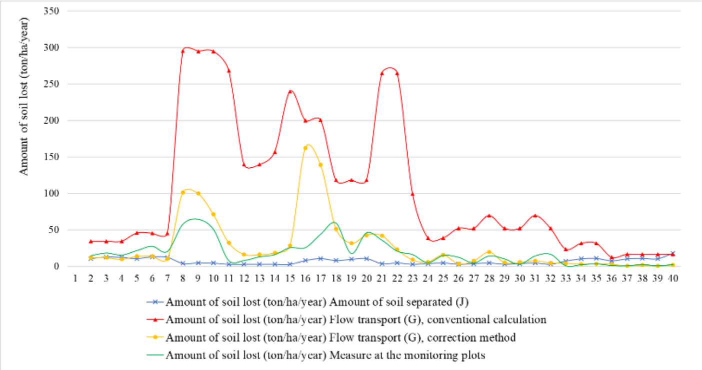

Figure 3.4: Graph showing soil loss in terms of soil separation (J) and flow transport (G)

In the MMF model, the coefficient C is directly related to the flow carrying capacity value (G). Therefore, in order to compare the coefficient C according to the International Planning Association and the corrected C, the amount of land lost due to the transport capacity of G flow will be used for comparison.

The graph in Figure 3.5 shows that, compared with the measured soil loss (green line), the value of soil loss G using the correction C factor is closer, this is shown when calculating RMSE, RMSE of soil loss G using corrected C factor is 21.62, and using normal C factor is 119.01. Thus, applying the corrected C factor of this study would give better results when estimating the amount of soil loss due to the transport capacity of flow (G).

3.2.3. Evaluate the test results using USLE and MMF models.

The results of determining the erosion factors, forecasting the amount of soil loss according to the Universal Soil Loss Equation and the MMF model are presented in the graph Figure 3.5

This is the calculation result for 5 erosion monitoring points with different seasons and years of cultivation with a total of 39 experiments (N=39). Forecast results of USLE and MMF models are presented in Figure 3.5. The actual amount of soil erosion measured at the monitoring plots ranges from 0.63 to 64.45 tons/ha/year; USLE forecast model is 1.28 – 67.64 tons/ha/year; of the MMF model is 2.85-10.84 tons/ha/year.

The calculated result is the mean squared error (RMSE) of the USLE and MMF models compared with the actual measured values of 11.01 and 21.62, respectively. This shows that USLE model gives forecast results with smaller error than MMF model. This result is also consistent with the study of the authors Arun Mondal et al (2016) and Emil Bayramov et al (2013).

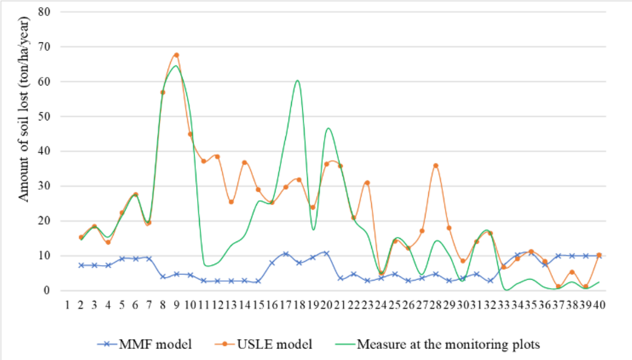

Figure 3.5: Comparison of the forecast results of the adjusted MMF and USLE models with the measured soil loss at the monitoring plots

General discussion:

The calculation results of the coefficients of the models show that the rainfall factor has the greatest impact on the amount of soil erosion at the monitoring points. For the USLE model, it is expressed through the R factor value, while the MMF model is expressed through the Q, J factor value.

The slope factor is the second most important factor affecting soil erosion. In the USLE model, it is expressed through the slope and the slope length factor (LS), while in the MMF model, this factor is expressed through the amount of soil separated by surface runoff and the transport capacity of the flow.

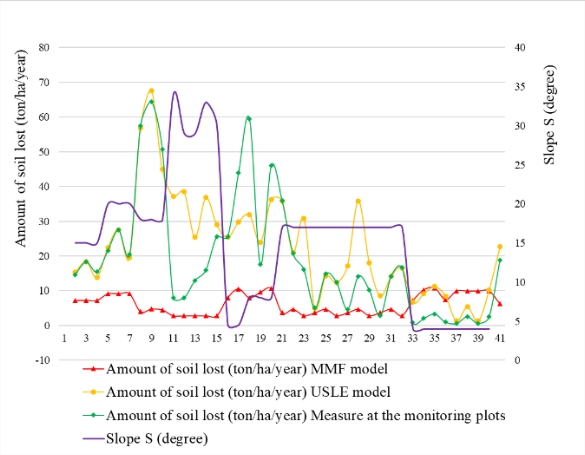

Figure 3.6: Slope, soil loss observed and predicted by USLE and MMF models.

Besides using common coefficients such as coefficients K, C, and P, the MMF model is interested in factors such as ground cover, tree foliage, and height of cover. However, the farming conditions in the Northern mountainous region with the seasonal structure of the crops grown during the year, the height, the tree cover at each stage of crop growth will be different, the rainfall distribution is concentrated in the rainy season (May to September), coincides with the time of planting and harvesting spring-summer and summer-autumn crops, so the kinetic energy of raindrops acting on the surface will be stronger but not considered in the MMF model.

This is also shown in the graph of Figure 3.6, the forecast results of soil erosion by the MMF model are mostly lower than the actual measured value. Only the monitoring plots in Thuy An, Ba Vi have a higher predictive value of the MMF model than the actual measurement and the USLE model, the reason here is that the slope is small (slope 4^0) when forecasting by the MMF model, the slope factor affects through the value of Sin(S) for both the amount of soil separated or transported by the flow, so the change is not large, so the impact on the change of soil erosion is not large. This is shown in the graph of Figure 3.6, the slope of the monitoring plots ranges from 4-34^0 but the forecast results by the MMF model the amount of land loss of 2.85-10.84 tons/ha/year, compared to the actual measurement is 0.63 - 64.45 tons/ha/year..

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

1. The results of evaluation, calculation and correction of the C factor from the monitoring plots with 39 experiments with the C factor, look up from the table of the ISSS, show that the C factor looked up from the table is higher than the C factor calculated from the erosion monitoring plots from 1.32 to 20.0 times, an average of 6.07 times. This large difference will lead to errors compared with actual observations in forecasting and assessing erosion.

Crop factor after correction by using coefficient C look up from the table of the ISSS multiplied by the weight distribution of rainfall and monthly cover, need to adjust the factor of tillage measures (D). For farming systems in the Northern mountainous areas of our country, this coefficient ranges from 0.20 to 0.8.

2. The results of using the universal soil loss equation to test show that using the corrected C factor gives better forecasting results than using the C factor, looking up the ISSS table. This is shown by the value of the correlation coefficient R, the forecast results with the coefficient C look up the table of the ISSS and correct it as 0.69 and 0.8 and the RMSE is 82.09 and 11.0,1respectively. The correction method has overcome limitations due to the fact that the distribution of canopy cover is not taken into account, the arrangement of the crop structure (monoculture, rotation, intercropping), rainfall, and tillage techniques compared with the common method.

The results of using two models to predict soil erosion show that the USLE model predicts the amount of land loss ranging from 1.28 - 67.64 tons/ha/year; MMF model is 2.85 - 10.84 tons/ha/year compared to the measured amount of soil erosion ranging from 0.63 - 64.45 tons/ha/year. The mean square error (RMSE) of the USLE and MMF models compared to the observed values is 11.01 and 21.62, respectively, which shows that the USLE model is better predictor than the MMF model.

The rainfall factor has the greatest impact on the amount of soil erosion at the monitoring points. For the USLE model, it is expressed through the R factor value, while the MMF model is expressed through the Q, J factor value. The slope factor is the second most important factor affecting soil erosion. In the USLE model, it is expressed through the slope and the slope length factor (LS), while in the MMF model, this factor is expressed through the amount of soil separated by surface runoff and the transport capacity of the flow. However, the MMF model does not clearly show the impact of soil erosion, the slope of the monitoring plots ranges from 4-34^0, but the results are predicted by the MMF model, the amount of land loss is 2.85-10.84 tons/ha /year, compared with the actual observation is 0.63 - 64.45 tons/ha/year.

3. Comparing the forecast results of the USLE and MMF models using the corrected C factor shows that using the USLE model with the C factor after correction applied to the Northern mountainous area Vietnam gives a better forecast of soil loss due to erosion.

Recommendations

1. It is proposed to expand the technique of crop rotation and intercropping (compared to monoculture) to reduce the amount of soil being eroded.

2. It is recommended to continue to study in more detail with the coverage and rainfall in each month of the year to serve as a basis for more accurate erosion prediction and solutions to reduce soil erosion.

LIST OF PUBLISHED RESEARCH

1. Tran Minh Chinh, Nguyen Trong Ha, (2020), “Study on the correction of crop factor (C) in forecast of soil erosion applied to mountainous North of Vietnam”. *Journal of Water Resource Science and Technology*, Vietnam Academy for Water Resource, Vol. 62, p. 88-105.

2. Tran Minh Chinh, Nguyen Trong Ha, Nguyen Van Kien (2020), “Research on using soil erosion model applied to mountainous North of Vietnam”, *Science and Technology Journal of Agriculture and Rural Development*, vol. 22, p. 102-112.

3. Tran Minh Chinh, Nguyen Trong Ha, Nguyen Van Kien (2021) “Study on applying the Universal Soil Loss Equation (USLE) in forecast of soil erosion by agricultural production activities in mountainous North of Vietnam”, *Journal of Water Resource and Environmental Engineering*, Thuyloi University, Vol. 74, p. 39 - 45.