VOL. 16, NO. 8, APRIL 2021 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

THE INTEGRATION OF GEO-INFORMATICS TECHNOLOGY WITH UNIVERSAL SOIL LOSS EQUATION TO ANALYZE AREAS PRONE TO SOIL EROSION IN NAN PROVINCE

Preecha Pradabmook[1] and Teerawong Laosuwan[2]
[1]Defence Technology Institute, Office of the Permanent Secretary of Defence, Nonthaburi, Thailand
[2]Department of Physics, Faculty of Science, Mahasarakham University, Maha Sarakham, Thailand
E-Mail: teerawong@msu.ac.th

ABSTRACT

Soil erosion is a natural disaster which frequently takes place in the Northern region of Thailand. Soil erosion causes loss of lives and properties of residents. This study was aimed to integrate a geo-informatics technology with the Universal Soil Loss Equation (USLE) in order to analyze areas which are prone to soil erosion in Nan Province, Thailand. The operation was performed by analyzing 6 factors of USLE including Rainfall erosivity (R-factor), Soil erodibility (K-factor), Slope length (L) and slope steepness (S), Cropping management (C), and Conservation practice (P) with overlay analysis being adopted as the last method. It was found from the analysis that the severity of the soil-erosion prone areas of Nan Province constituted 5 levels that included the least severity of 2,120.192 km^2, the less severity of 2,728.851 km^2, the moderate severity of 2,937.822 km^2, the much severity of 2,133.648 km^2, and the most severity of 1,551.5584 km^2. The findings from this study can be embraced as a guideline to plan on the conservation and the management of land, and applied in a decision making process related to the land use planning in Nan Province, Thailand.

Keywords: soil erosion; geo-informatics; universal soil loss equation; remote sensing.

INTRODUCTION

Soil erosion is a geological natural phenomenon caused by the movement of land and rocks along mountain slope or from a high to low area. There are several elements or factors in combination that cause soil erosion and influence the level of severity of soil erosion in a particular area (Nearing *et al.*, 2017); it starts with one factor to be followed by other factors. However, the first general key factor that causes soil erosion is the quantity of rain (Vita *et al.*, 1998; Guzzetti *et al.*, 2008), in combination with other supporting factors such as geographic, geological and pedological characteristics. Those characteristics involve the property of soil and rocks, the ways the land is used, and the land cover which could decrease the force of rain before falling onto the land surface and hold up the soil. When the mountain slope area loses its balance from a heavy rain to the extent that makes the soil-saturated with water, the physical force of soil decreases. As a result, the weight of water in soil increases, thus causing the soil to move down to damage the lower area (Panagos *et al*., 2014; Ozsahin *et al.*, 2018; Ozsahin & Eroglu, 2019). Soil erosion happens when the mountain slope area loses its balance because when there is a heavy rain to the extent that makes the soil to be saturated with water, the physical force of soil decreases and the weight of water in soil increases, thus causing the soil to move down that damages the lower area (Zuazo & Pleguezuelo, 2008; Mateos *et al*., 2017; Cruz *et al*., 2019). Soil erosion is a natural disaster that causes the loss of lives and properties of residents in many countries (Ighodaro *et al.*, 2013; Burt & Weerasinghe, 2014; Belo *et al*., 2020; Senanayake *et al*., 2020). In Thailand, especially in the Northern region, which consists of steep and high mountains, where the land use is without conservation of land and water, has been facing the soil erosion problem annually and the severity is increasing due to more land use which causes more invasion into mountainous areas and more changes of area conditions (Plakayrungrassamee et al., 2011; Pholkerd *et al*., 2012; Suk-ueng & Chantima, 2017). When considering the cause of soil erosion due to abnormally heavy rain, it is a natural one which is unavoidable. Other factors that cause soil erosion include the crack of land, the slope gradient, the geography, and land use. On land use, the improvement and correction can be made by refraining from the invading into and damaging the forest, and then use the land properly. Therefore, it is necessary to conduct the study in order to find factors that are causes and to perform assessment to detect the area which is prone to soil erosion, so that the problem could be further solved correctly. The analysis into the soil erosion is quite complicated and depends on many factors in combination and each factor changes constantly (Ganasri & Ramesh, 2016; Conforti & Buttafuoco, 2017).

The analysis into the soil erosion is complicated and dependent upon many combined factors, each of which changes constantly. Consequently, it is difficult to assess soil erosion accurately without extended time of study and experiment; for example, in the US, Wischmeier and smith (1965) had conducted the study related to the soil loss from 10,000 land plots/year for many decades to the extent that it was possible to predict soil loss by using a widely used equation called Universal Soil Loss Equation (USLE). According to the study into related documents, there were many researchers trying to find the soil loss rate due to the washing of rainfall. In 1930, the study and experiment were conducted by taking various factors that affected soil erosion and concluded as criteria in form of a mathematical model. Subsequently, the equation had been developed to assess the soil erosion by

ARPN Journal of Engineering and Applied Sciences

many researchers that include Cook, (1936); Baver (1933), Zingg (1940), Smith (1941), Smith and Whitt (1947), Browning *et al.* (1947), Musgrave (1947), Van Doren and Bartelli (1956), and Smith and Wischmeier (1957). It was just a simple equation and was used by next generations of land and water conservationists. The equation has been updated and improved to become USLE by Wischmeier and Smith (1965). This current study was aimed at integrating the geo-informatics technology with the Universal Soil Loss Equation (USLE) in order to analyze areas which are prone to soil erosion in Nan Province of Thailand.

STUDY AREA

Nan Province (Figure-1) is located at latitude 18° 46' 30" N and longitude of 18° 46' 44" E and averaged of 2,112 meters above mean sea level. Much of the area is mountainous lying along the Northern and Southern line. Around the Northern and Eastern sides, it borders with Lao People's Democratic Republic. The weather is tropical grassland with 3 seasons; including summer, rainy, and winter, each of which is distinctively different. Nan Province covers 11,472.076 km^2 divided into 5,500.0 km^2, forest and mountain or 47.74%, 4,502.37 km^2 deteriorated forest or 39.24%, of 1,401.67 km^2 agricultural area or 12.22 %, and 69.64 km^2 residential area and others or 0.60%.

MATERIALS AND METHODS

Data Collection

Primary data

Primary data was collected from the study area. It included data in general of the study area and data on land use.

Secondary data

It was requested from government agencies and reconstructed to a new database. The obtained data from government agencies included the locational data of measuring station and rainfall from the Thai Meteorological Department, 30 m DEM from USGS, soil of Nan Province, land use, and provincial boundary.

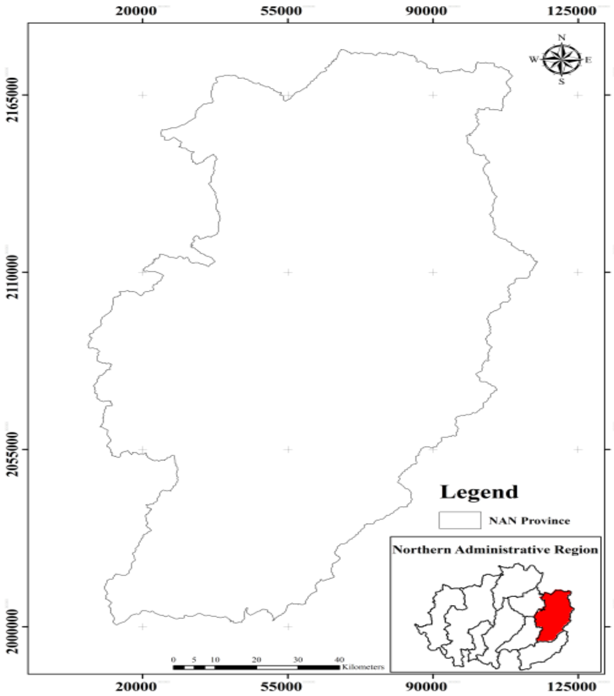

Figure-1. Nan Province.

Data analysis by ULSE

On the analysis of area which is prone to soil erosion b by using geo-informatics technology in combination with USLE under the Wischmeier method (Equation 1) in this study, it is to take various factors that affect soil erosion including R, K, L, S, C, P into consideration together (Figure-2) with procedures and methods as follows:

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

Where;

A = Average annual soil loss (ton/ha/year)
R = Rainfall erosivity factor
K = Soil erodibility factor
LS = Slope length and slope steepness factor
C = Cropping management factor
P = Conservation practice factor

R Factor Analysis

The potential of rain that caused soil erosion was calculated to R factor analysis by using the rainfall data during 5 months i.e., May to September, from rainfall measuring stations in Nan Province and nearby. It was calculated to find the rainfall on a yearly basis in millimeters of each station. The data, then, was used to analyze and plot the graph of mean rainfall by interpolation with Kriging method. The result was used to calculate in a mathematical equation. The R factor was determined from the average rainfall on a yearly basis by Equation 2.

$$Y = 0.163X - 0.0375 \qquad (2)$$

VOL. 16, NO. 8, APRIL 2021 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

Y = Rainfall erosivity factor
X = Average rainfall
Where;

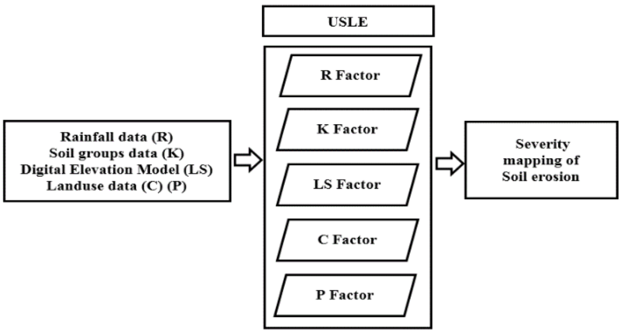

Figure-2. USLE analysis.

K Factor Analysis

K factor analysis is the calculation of possibility of the soil erosion. In this study, the soil group map at 1:50,000 scale from Land Development Department was used as input. The comparison is made with the data upon the classification of K factor under the soil group of Nan Province and that of K factor obtained from the geological division of the Land Development Department. That created the map that showed the factor in regard to the possibility of soil erosion occurrence.

L and S Factor Analysis

In this study, the calculation of slope length (L) and slope steepness (S) factors were conducted upon 30 meter DEM from USGS.

C Factor Analysis

It is the calculation of factors concerned with the plant management. In this study, the land use It is the calculation of factor concerning plant management. In this study, the land use map of 2017 at 1:25,000 scale was used where C factor was input. A omparison was made with the factor that concerned plant management of the Land Development Department. That created the map that showed the factor of plant management.

P Factor Analysis

It is the calculation of factor concerning soil conservation. In this study, the land use map at 1:25,000 scale of 2017 was used with P factor as input. A comparison was made with the factor that concerned the soil conservation of the Land Development Department. That created the map that showed the factor of plant management.

RESULTS AND DISCUSSIONS

Result of R Factor Analysis

The result of the analysis into the erosion was calculated using the rainfall data on a yearly basis of the study area and nearby from the rainfall measurement station of Thai Meteorological Department. The use of geo-informatics software package was integral for the result that constructed the plotted graph of average rainfall from Kriging method interpolation. It was found from the measured data that the minimum rainfall on a monthly basis was 117.913 mm, while the maximum one was 224.570 mm, the rainfall mean was 171.242 mm. After that, data were classified for R factor in 5 levels (Figure-3) in order to assess the distribution of rainfall in the study area.

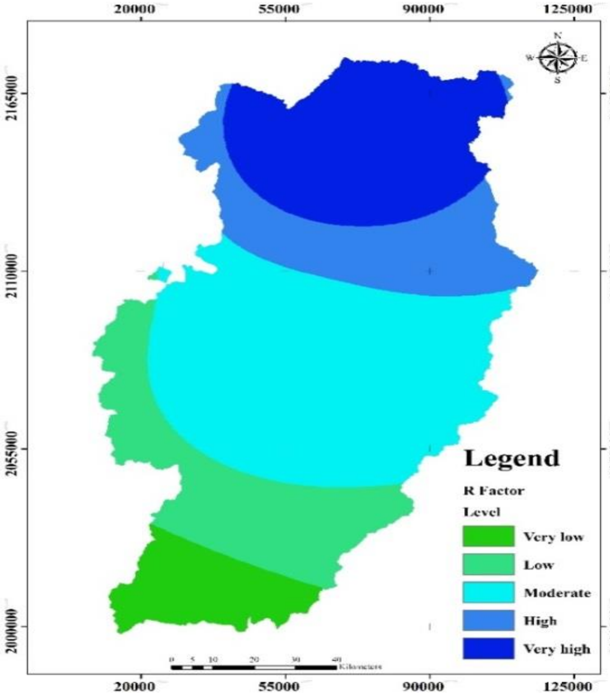

Figure-3. R factor analysis.

It was found from the study that the rainfall at the very low level (117.913 - 152.630 mm) was in Na Muen District covering area of around 0.538 km^2 equal to 4.69 %; rainfall at the low level (152.630 - 174.318 mm) was found in Na Noi District covering area of around 0.678 km^2 equal to 5.92 %; the rainfall at moderate level (174.318 - 192.367 mm) was found in Wiang Sa District and Ban Luang District covering the area of around 1,976.673 km^2 equal to 17.23 %; the rainfall at high level (192.367 -208.262 mm) was found is Mae Charim District, Phu Phiang District, and Mueang Nan District, and Santi Suk District covering the area of around 5,307.617 km^2 equal to 46.27 %; and the rainfall at very high level (208.262 - 224.570 mm) was found in Bo Kluea, Pua, Tha Wang Pha, Chiang Klang, Song Khwae, Thung Chang, Chaloem Phra Kiat Districts covering area of around 2,970.931 km^2 equal to 25.90 %.

Result of K Factor Analysis

The Land Development Department collects soil groups under the condition that similar characteristics, properties, potential of cultivation, as well as similar land management in one same group for the convenience in examining the characteristics of soil and land use and

VOL. 16, NO. 8, APRIL 2021 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

providing advices with proper land management for farmers and those who are interested. More than 300 soil groups were regrouped into 62 soil groups. It was found from the data that Nan Province lands mostly fall within 62nd soil group with slope complex of about 80%. This 62nd soil group slope complex was characterized to very steep.

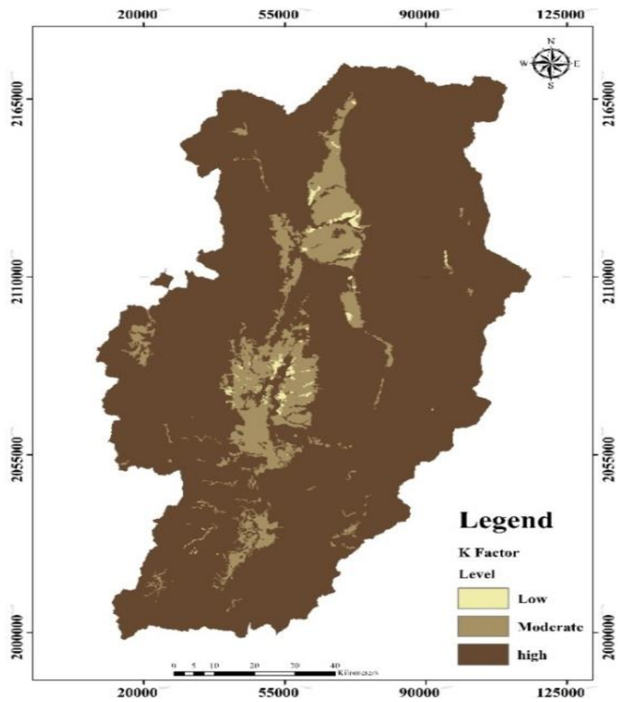

Figure-4. R factor analysis.

In agricultural areas, soil erosion was very intense and lack of water was found. In some area, rock fragments were found scattered around land surface. In the analysis of the soil erodibility factor or K factor, the soil group found in Nan Province was input by K factor within the range of 0.06 – 0.35 while Thailand's K factor was 0.04 - 0.56. After that, data were classified in 3 levels (Figure-4) to determine the distribution of soil erodibility factor. It was found from the study that K factor at low level (0.06 - 0.23) covered an area of approximately 40.697 km^2 or equal 0.35 %, K factor at moderate level (0.23 - 0.29) covered an area of approximately 510.480 km^2 or equal to 4.45 %, and K factor at high level (0.29 - 0.35) covered an area of approximately 10,920.892 km^2 or equal to 95.20 %.

Result of L and S Factor Analysis

Geographic characteristics are factors that affect soil erosion. They triggers the gravity to play more role in causing soil erosion. Two key characteristics of geography include slope length (L) and slope steepness (S). In the area where a high level of slope steepness (S) and a high level of slope steepness (S) are present, the severity of running water follows to thus cause increasingly more erosion than in plain areas. In this study, the L factor and S factor were extracted from the 30 meter DEM of USGS. It was found from the analysis that Nan Province had an L factor of 1% - 6%.

When the data were divided into 5 levels (Figure-5) for the assessment of slope length, it was found that slope length at very low level of 1% covered an area of approximately 618.130 km^2 or equal to 5.39%, slope length at the low level (1% - 2%) covered an area of approximately 388,543 km^2 or equal to 5.42%, slope length at the moderate level (2% - 4%) covered an area of approximately 509.022 km^2 or equal to 4.44%, slope length at the high level (4% - 5%) covered an area of approximately 2,747.928 km^2 or equal to 23.95 %, and slope length at the very high level (5% - 6%) covered an area of approximately 6,975.324 km^2 equal to 60.880 %.

On part of the study into S factor, it was found that Nan Province has S factor of 0.065 - 47.138. When the data were divided into 5 levels (Figure-6) for the assessment of slope steepness, it was found that slope steepness at very low level of 0.065 - 4.864 covering an area of approximately 2,834.048 km^2 or equal to 24.7039%, slope steepness at low level of 4.684 - 10.956 covering an area of approximately 2,447.294 km^2 or equal to 21.332 %, slope steepness at moderate level of 10.956 - 16.679 covering an area of approximately 2,845.091 km^2 or equal to 24.800 %, slope steepness at high level of 16.679 - 23.140 covering an area of approximately 2,292.542 km^2 or equal to 19.983 %, and slope steepness at very high level of 23.140 - 47.138 covering an area of approximately 1,053.096 km^2 or equal to 9.179 %.

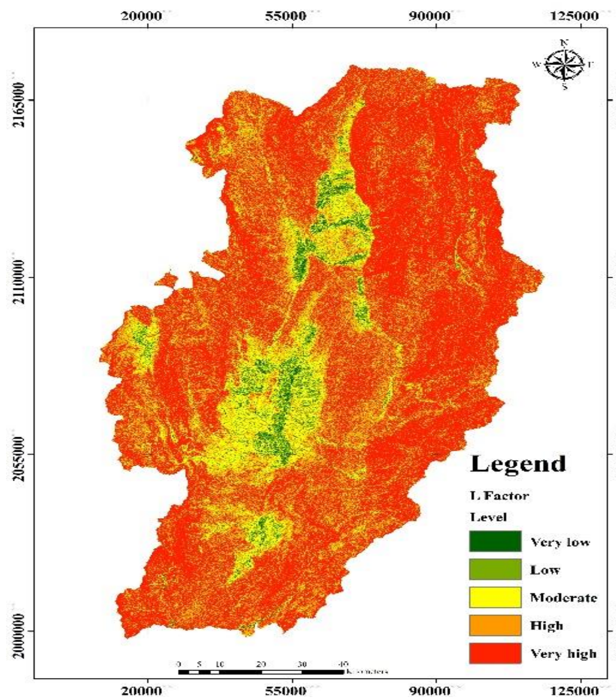

Figure-5. L factor analysis.

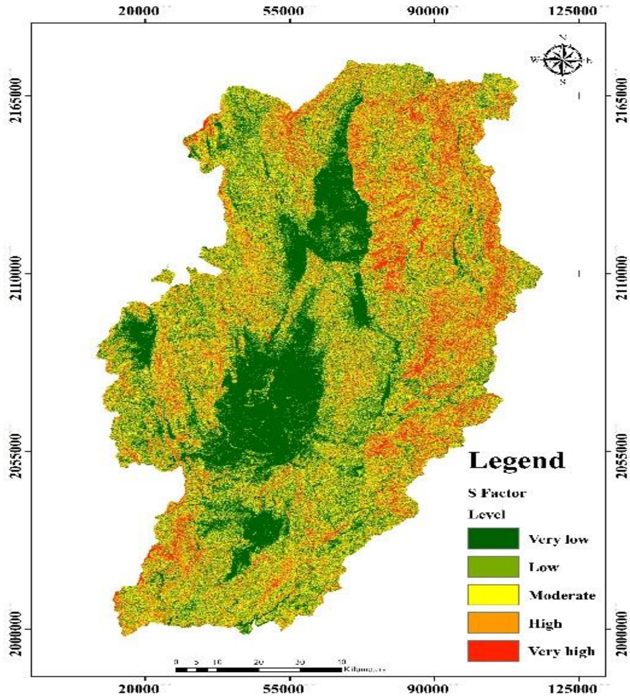

Figure-6. S factor analysis.

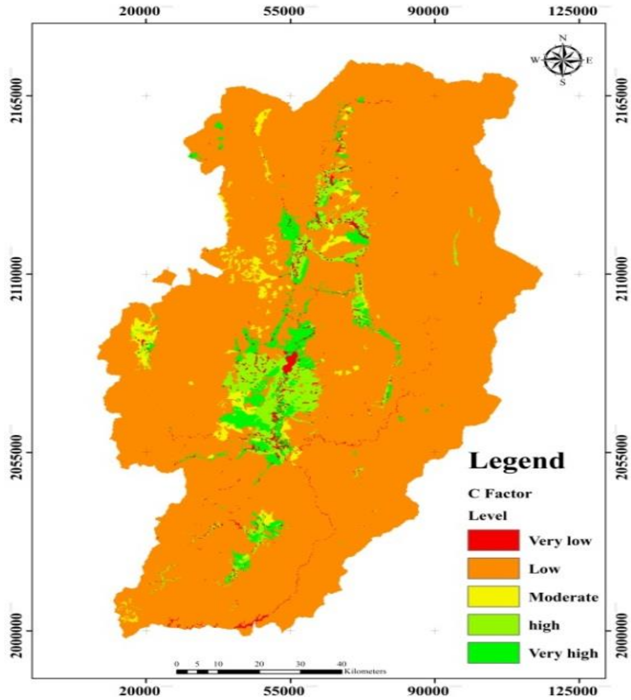

Figure-7. C factor analysis.

Result of C Factor Analysis

Plants as soil cover are key factors in preventing the soil erosion since they help to absorb and reduce crashing force of rain, to slow down running water on soil surface, to help soil better hold together, to increase soil space so that water can flow down more, and to help to promote activities of living organisms in soil. In this study, the soil group map at 1: 25,000 scale of Land Development Department was used and C factor was input. The comparison was made with the data on the plant management of the Land Development Department. That created a map showing cropping management factors. When the data was divided into 5 levels (Figure-7) for the assessment of C factor, it was found that C factor in very low level of 0 covering an area of approximately 139.286 km^2 or equal to 1.21%, C factor in low level of 0 - 0.02 covering an area of approximately 10,185.410 km^2 or equal to 88.78%, C factor in moderate level of 0.02 - 0.048 covering an area of approximately 241.878 km^2 or equal to 2.11%, C factor in high level of 0.048 - 0.280 covering an area of approximately 503.209 km^2 or equal to 4.39%, and C factor in very high level of 0.280 - 0.340 covering an area of approximately 402.289 km^2 or equal to 3.51%.

Result of P Factor Analysis

The conservation practice Factor is the factor that shows the capability of controlling soil erosion. It was calculated from the ratio of soil loss obtained from experimented land plot where there was a kind of conservation and the soil loss obtained from the experimented land plot where the soil was plowed down the slope when other conditions stayed unchanged. In this study, the soil group map at 1:25,000 scale was used. After that, P factor was input. The comparison was made with the data on factors related to the plant management of the Land Development Department. That created a map showing the conservation practice factor.

When data was divided into 2 levels (Figure-8) for the assessment of P factor in the study area, it was found at P factor at low level of 0 - 0.098 covering an area of approximately 3.891 km^2 or equal to 0.0339%, P factor at high level of 0.098 - 1 covering an area of approximately 1,458.581 km^2 or equal to 99.966%.

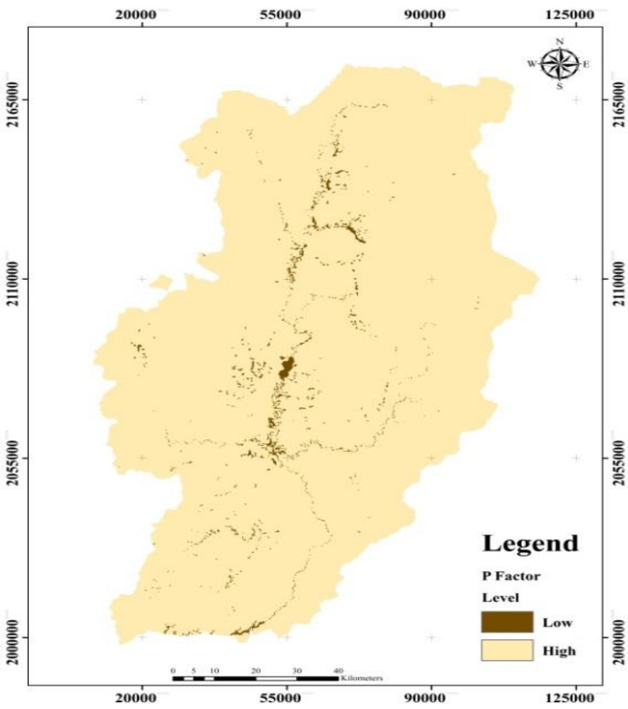

Figure-8. P factor analysis.

Analysis Result of Areas Prone to Soil Erosion

The analysis into the areas that were prone to soil erosion was performed by an overlay analysis of R factor, K factor, L and S factors, C factor, and P factor. Then the results were divided according to the severity of soil erosion into 5 levels (Figure-9). The Figure-9 shows the areas which are predominantly dark green and light green, many areas are lower part and middle part of the province, with the possibility of soil erosion in the very low and low level, covering the area of about 4,849.043 km^2 equal to 42.27%; the area which is yellow is mostly the lower part at the eastern region and western region with the possibility of soil erosion at the moderate level covering the area of about 2,937.822 km^2 equal to 25.61%; much of the orange area is middle region and some part of it in the northern part has the possibility of the occurrence of soil erosion at the high level covering the area of about 2,133.648 km^2 equal to 18.60%; and much of the red area is northern part of the province with the possibility of soil erosion at the very high level covering the area of about 1,551.558 km^2 equal to 13.52%. The areas of the mentioned risk levels are also summarized in Table-1.

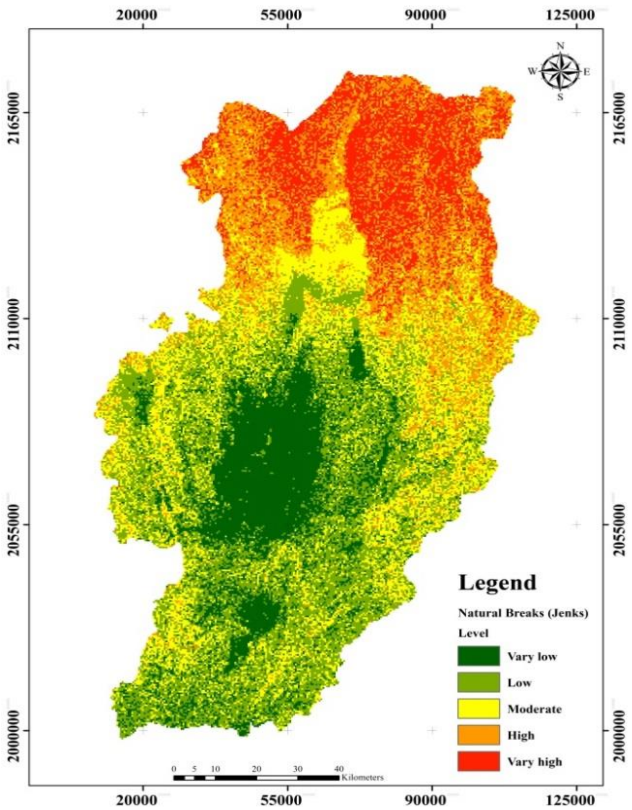

Figure-9. Soil erosion analysis.

Table-1. Areas and risk levels.

No.	Risk level	Area	
		Km^2	%
1	Very low	2,120.193	18.48
2	low	2,728.854	23.79
3	Moderate	2,937.823	25.61
4	High	2,133.648	18.60
5	Very High	1,551.558	13.52
Total		11,472.076	100

CONCLUSIONS

The soil erosion in Thailand frequently takes place in the Northern region of the country following heavy rains over mountains that are sources of rivers. The severity of landslide depended upon the rainfall on the mountain, the steepness of the mountain, the abundance of the forest, and the geological characteristics of the mountain. This study embraced the integration of geo-informatics technology with the ULSE to analyze the areas which were prone to soil erosion where soil erosion took place every year.

According to the study, it could be concluded that Nan Province had areas prone to soil erosion of about 3,685.206 km^2 or equal to 57.73% due to its geography in general which was characterized by forest and mountain for almost 75 % and the plain area for 25 % or at forest and mountain areas to plain area ratio of 3:1. Therefore, many of the agricultural areas where plants were grown was on the mountain at the steepness level of more than 5% with a total area of 6,975.325 km^2 or equal to 60.80%. In such area, land use should be changed from plants to farm plants and further to perennial plants. Also, there should be measures in conserving soil and water deemed suitable for conditions of the area in order to reduce soil erosion.

ACKNOWLEDGEMENTS

This research was financially supported by Defence Technology Institute (Grant year 2020). Help and support from disaster team management of the institute were highly appreciated and acknowledged herewith.

REFERENCES

Baver L.D. 1933. Somes soil factors effecting erosion. Agricultural Engineering. 14(2): 51-52.

Belo D., Ernawati R., Cahyadi T., Nurkhamim. & Amri N. 2020. Analysis of Land Erosion Due to Mining of Clay Material in Sidorejo Village, Sleman District, Yogyakarta. Geographia Technica. 15: 33-41.

Browning G.W., Parish, C.L. & Glass J.A. 1947. A method for determining the use and limit rotation of rotation and conservation practices in control of soil erosion in Iowa. Soil Science Society of America, Proceedings. 23: 246-249.

Burt T. & Weerasinghe K. 2014. Rainfall Distributions in Sri Lanka in Time and Space: An Analysis Based on Daily Rainfall Data. Climate. 2(4): 242-263.

Conforti M. & Buttafuoco G. 2017. Assessing space–time variations of denudation processes and related soil loss from 1955 to 2016 in southern Italy (Calabria region). Environmental Earth Sciences. 76: 457-475.

Cook H.L. 1936. The nature and controlling variables of the water erosion process. Soil Science Society of America Proceedings. 1: 487-494.

Cruz D., María J., Benayas J., Ferreira G., Monteiro A. & Schwartz G. 2019. Evaluation of Soil Erosion Process and Conservation Practices in the Paragominas-pa Municipality (Brazil). Geographia Technica. 14(1): 14-35.

Ganasri B. P. & Ramesh H. 2016. Assessment of soil erosion by RUSLE model using remote sensing and GIS - A case study of Nethravathi Basin. Geoscience Frontiers. 7: 953-961.

Guzzetti F., Peruccacci S., Rossi M. & Stark C. 2008. The rainfall intensity-duration control of shallow landslides and debris flows: An update. Landslides. 5(1): 3-17.

Ighodaro I.D., Lategan F.S. & Yusuf, S.F. 2013. The impact of soil erosion on agricultural potential and performance of Sheshegu community farmers in the Eastern Cape of South Africa. Journal of Agricultural Science. 5(5): 140-147.

Mateos E., Edeso J. M. & Ormaetxea L. 2017. Soil Erosion and Forests Biomass as Energy Resource in the Basin of the Oka River in Biscay, Northern Spain. Forests. 8(7): 258.

Musgrave G.W. 1947. The quantitative evaluation of factors. Journal of Soil and Water Conservation. 2(3): 133-138.

Nearing M., Xie Y., Liu B. & Ye Y. 2017. Natural and anthropogenic rates of soil erosion. International Soil and Water Conservation Research. 5(2): 77-84.

Ozsahin E., Duru U. & Eroglu I. 2018. Land Use and Land Cover Changes (LULCC), a Key to Understand Soil Erosion Intensities in the Maritsa Basin. Wate. 10(3): 335.

Ozsahin E. & Eroglu I. 2019. Soil Erosion Risk Assessment due to Land Use/Land Cover Changes (LULCC) in Bulgaria from 1990 to 2015. Alinteri Journal of Agriculture Sciences. 34(1): 1-8.

Panagos P., Meusburger K., Van Liedekerke M., Alewell C., Hiederer R. & Montanarella L. 2014. Assessing soil erosion in Europe based on data collected through a European Network. Soil Science and Plant Nutrition. 60 (1): 15-29.

Pholkerd R., Khunrattanasiri W. & Pattaratuma A. 2012. Application of Remote Sensing and Geographic Information System for Soil Erosion Assessment in Huay Nam Rit Watershed, Uttaradit Province. Thai Journal of Forestry. 31(2): 42-52.

Plakayrungrassamee S., Pantanahiran W. & Navanugraha C. 2011. Soil Erosion Analysis Using Universal Soil Loss Equation (USLE) to Estimate the Loss of Plant Nutrient in Huaimaeprachan Watershed. Journal of Social Sciences Srinakharinwirot University. 14: 1-12. (In Thai)

Pradhan B., Chaudhari A., Adinarayana J. & Buchroithner M.F. 2012. Soil erosion assessment and its correlationwith landslide events using remote sensing data and GIS: A case study at Penang Island, Malaysia. Environmental Monitoring and Assessment. 184: 715-727.

Senanayake S., Pradhan B., Huete A. & Brennan J. 2020. Assessing Soil Erosion Hazards Using Land-Use Change and Landslide Frequency Ratio Method: A Case Study of Sabaragamuwa Province, Sri Lanka. Remote Sensing. 12(9): 1483.

Smith D.D. 1941. Interpretation of soil conservation data for fiels use. Agricultural Engineering. 22: 173-175.

Smith D.D. and Whitt D.M. 1947. Estimating soil losses form field areas and clay pan soil. Soil Science Society of America, Proceedings. 12: 485-490.

Smith D.D. & Wichmeier W.H. 1957. Factor effecting sheet and rill erosion. Transactions of the American Geophysical Union. 38: 889-896.

Suk-ueng K. & Chantima K. 2017. Application of Geographic Information System to Land Use Suitability Assessment in Ban Nanglae Nai, Muang District, Chiang Rai Province. Kasalongkham Research Journal. 11(3): 163-174. (In Thai)

Van Doren C.A. & L.J. Bartelli. 1956. A method of forecasting soil loss. Agricultural Engineering. 37: 355 - 341.

Vita P., Paola R., Bathurst J., Borga M., Crosta G., Crozier M., Glade T., Guzzetti F., Hansen A. & Wasowski J. 1998. Rainfall-triggered landslides: A reference list. Environmental Geology. 35(2): 219-233.

Wischmeier W.H. & Smith D. D. 1965. Predicting rainfall erosion losses from cropland east of the Rocky Mountain: guide for selection of practices for soil and water conservation. Agr. Handbook No. 282.USDA, Washington, D.C. p. 47.

Wischmeier W.H. & Smith D. D. 1978. Predicting rainfall erosion losses. A guide to conservation planning. Agr.Handbook No.537.USDA, Washington, D.C. p. 49.

Zingg A.W. 1940. Degree and lenght of land slope as it effects soil loss in runoff. Agricultural Engineering. 21(2): 59-64.

Zuazo V.H.D. & Pleguezuelo C.R.R. 2008. Soil-erosion and runoff prevention by plant covers. A review. Agronomy for Sustainable Development. 28: 65-86.