Alternation of the Vegetation Type for Reducing of Potential Contaminated Overland Sediment from the Upstream Area of the Mae Tao Basin Thailand

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***Abstract*—The Mae Tao basin, reported as the largest zinc deposition area of Thailand, has been considered to be a remote cadmium (Cd) - contaminated area since 2002. According to the reports from both government and private sectors, the agricultural area in the upstream of the basin were discovered to be one of potential cadmium sources. In this study, the integrated spatial technology between remote sensing, digital mapping, GIS, and RUSLE were applied to conduct the simulation of vegetation's alternation to reduce the potential erosion of the area in the upstream of the basin. According to the study's results the complex vegetation shows better capability in reducing the potential erosion. Additionally, overlapped cropping with straw mulch cover is the practice that contains the highest erosion reduction efficiency at 92.05% while vetiver, supported by many researches can reduce 62.07% of the erosion at the earlier state.**

***Index Terms*—erosion, land utilization, GIS, heavy metal contamination, erosion, spatial modelling**

I. Introduction

Overland sediment, which occurs during rainfall runoff over the contaminated ore resources area, was found to be one of the transmission intermediates that reinforces the mine contamination [1]. The Mae Tao Basin is a remote area, continuously monitored for this contaminated case since 2002. The contamination of cadmium in the Mae Tao Creeks was intimated by [2], resulting in the conducting of various studies in the mechanisms and factors. Total Cd and Zn concentrations in sediments or soils were approximately 596 and 20,673 mg kg−1 in tailing pond area, 543 and 20,272 mg kg−1 in open pit area, 894 and 31,319 mg kg−1 in stockpile [3]. This mine is located in a remote area of the Mae Tao Basin which has been facing this contaminated case since 2002 [2]. Fig. 1 demonstrates the location of the mine.

Rainfall erosion, affected by the slope and land cover of the area, was discovered to be one of the major mechanics that make cadmium available for transport in form of adsorbed-suspended sediment [4]. Additionally, erosion, took places in the agricultural area in the upstream, can be related to the contamination in the Mae Tao Creek. With a correlation factor ranges from 0.4 to 0.6, the agricultural area were classified as one of the main contributors of the contaminants [5].

This study aims to examine the effect of the land use alternation over the agricultural area of the basin .Since changing in land use refers to changes in land cover practices, the integrated spatial techniques between Revised Universal Soil Loss Equation (RUSLE) accustomed to the remote sensing technique and Geographic Information System (GIS) technology were applied to simulate the change in the potential erosion of the upstream area. This integrated method has been evidenced to be the effective approach for estimating the magnitude and distribution of erosion practice [4], [6]. It also widely applied as an accommodating equation to estimate surface erosion and it requires a fewer data and a shorter period of time to complete the evaluation compared to other erosion estimations [6]. By the advantages of this integrated approaches, the efficiency in reduction of the potential erosion can be clarified, leading to the appropriate selection of cover practices in the reclamation's operation.

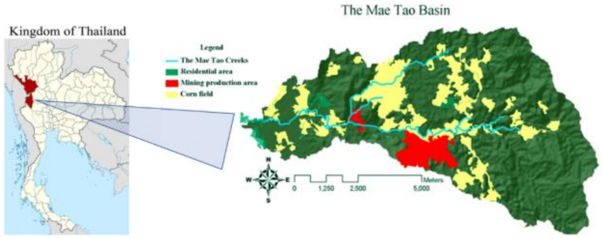

Figure 1. The Mae Tao Basin.

II. Methodology

The overall framework of the study is established in Fig. 2. The study started with data acquisition. The

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secondary data from various sources were collected and assigned as the RUSLE's inputs. R factor was computed using 50 years data from Thai Meteorological Department (TMD). Satellite images of the Mae Tao basin during 2002 to 2016 from LANDSAT^{TM} and soil type map were respectively assigned as the inputs for the calculation of C and K Factors. The Digital Elevation Map of the basin were supported by the Royal Thai Survey Department. Afterward, 10 alternation-scenarios of land cover types were simulated to compare the efficiency in the reduction of potential erosion.

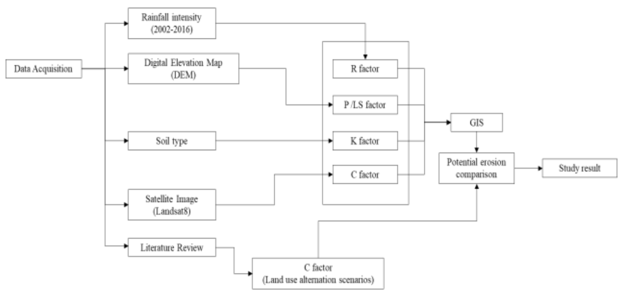

Figure 2. Overall framework of the study

A. Revised Universal Soil Loss Equation

Soil loss or soil erosion refers to the amount of soil moved from one area to another. This circumstance depends on the relationship between raindrops, runoff and the erodibility of a certain area. RUSLE have an ability in estimating of the intensity of erosion in the form of quantifiable results. Since cadmium adsorbed from overland sediment as residue from surface runoff, so the potential erosion of the area can reflect the possibility of potential cadmium that can be release into the environmental phases. The Revised Universal Soil Loss Equation is presented in (1).

$$A = R \times K \times LS \times C \times P \tag{1}$$

The R factor is the erosivity by rainfall runoff at a location. The K factor refers to the specific value of the inherent erodibility of the soil surface material at a specific area. The LS reflects the effects of topography, specifically a hill's slope, length, and steepness, on the rates of soil loss at a site. The C factor expresses the effects of surface cover and roughness from the biomass to the rate of soil loss, while the P factor represents effects of soil conservation practices such as buffer strips for cover vegetation.

R factor calculations were conducted base on the study of [7]. The equation was expressed as the linear relationship between rainfall erosivity (R) and total accumulation of rainfall intensity (X) as can be seen in (2).

$$R = 0.4669X - 12.1415 \tag{2}$$

K factor was derived from soil classification map of the Mae Tao Basin are afforded from LDD in association with the study's result of [8].

C factor values were assigned using classified remotely sensed images. Principally, NDVI' results present high correlation with ecological variables as leaf-area-index, total vegetation cover or above ground biomass [9]. The C factor assigned in this study were based on the study of [10] which can present the high accuracy when applied the calculation to the South-East Asia's NDVI analysis. The calculations were performed following (3) to (4)

$$NDVI = (NIR - R)/(NIR + R) \tag{3}$$

$$C = 0.6 - 0.77NDVI \tag{4}$$

where NIR and R indicate channel or band of Landsat which are near infrared and visible red respectively. In this study, the C factor will be derived from the NDVI analysis result of the satellite image from Landsat 8 ^{TM}.

The support practice factors (P) were derived from the combination between slope data from the spatial analysis of DEM and land use map based on the criteria, prescribed by [10] The classification of p factor value can be describe by the slope of the area which are 0.5 for agricultural area with slope under 8%, 0.75 for 0.5 for agricultural area with slope between 8 to 20%, 0.9 for area with has slope over 20% and 0.1 for other support practice type.

LS-factor calculations were operated under the remote estimation technique using GIS application, following the equation of which is presented in (5). The calculation of LS factor for the surface area of The Mae Tao Basin is presented in Fig. 3.

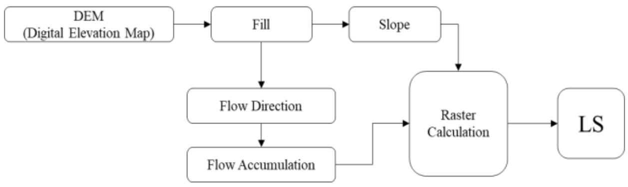

Figure 3. Determination of LS factor

$$LS = \left(\frac{Flowacc \times resolution}{22.13}\right)^m (65.41\sin^2\theta + 4.56\sin\theta + 0.0654) \tag{5}$$

The LS-factor refers to the surface terrain of the basin and can be obtained by the slope gradient of in the form of percent gradient [11]. The value of m, varied from 0.2 to 0.5, depending on the slope gradien which can be defined as 0.5 for slope > 5 %, 0.4 for slope between 3 %s to5 %, 0.3 for slope range pf 1 % to 3 %, and 0.2 for under 1 % slope.

In a purpose of calculating the flow accumulation, a DEM of the basin was analyzed under fill technique to diminish the discontinuity in the flow simulation from the trapped-cells in the higher elevation. Subsequently, the flow direction was generated from these filled grids. Flow accumulation was calculated based on the direction acquired from the flow direction analysis. As a final process, the raster calculation was applied to determine the LS-factor.

B. Simulation of Vegetation's Alternation

In a purpose of comparing the effectiveness of reducing the potential erosion of the mine, 10 different values of cover practice factor (*C*) were assigned as the data input in RUSLE. Table I demonstrates the value applied in this study [12], [13]. The land cover practice, applied in this study, were the regular land use, appeared in the Mae Tao Basin such as soybean, paddy field and cassava.

TABLE I. C FACTOR APPLIED IN THE SIMULATION OF LAND USE ALTERNATION

Land use type	C factor
Grass plants (Brachiaria sp)	0.290
Bean	0.161
Cassava	0.363
Lemongrass	0.434
Hardwood with scrub	0.012
Perennial grass	0.020
Forrest	0.001
Overlapped cropping and straw mulch	0.079
Vetiver (earlier state)	0.350
Vetiver (aged)	0.037

III. RESULTS & DISCUSSION

A. R Factor's Determination

The rainfall runoff value of the Mae Tao Basin from 1998 to 2016 were assigned. The value of R factor, retrieved from the calculation, were equal to 703.22 MJ mm ha^{-1} h^{-1}.

B. K Factor's Determination

Secondary data on the land use of the Mae Tao Basin from LDD were assigned into GIS calculation layer as can be seen in Fig. 4.

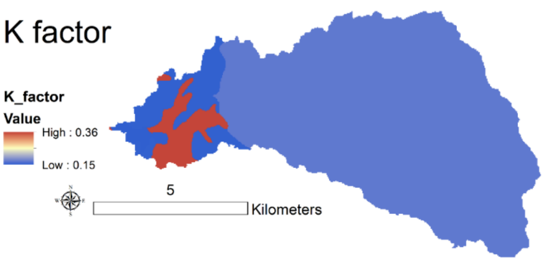

Figure 4. K factor's calculation layer

C. C Factor's Determination

GIS application was assigned to calculate the layer of C factors. Fig. 5 demonstrates the results of NDVI analysis.

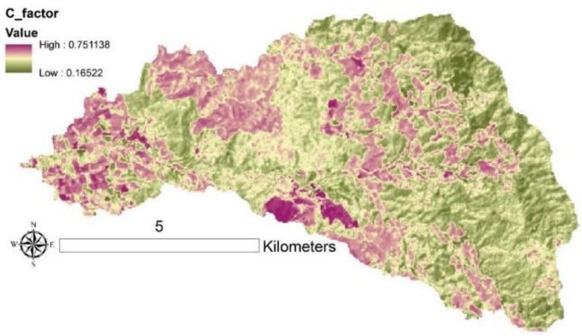

Figure 5. C factor's calculation layer

D. LS Factor's Determination

Fig. 6 exhibits the calculations of LS factor from the DEM of the Mae Tao Basin. More than assigned as the input of percent slope calculation layer, DEM was transformed to illustrate the flow direction layer and flow accumulation of the project area. These layers were combined with the raster calculation to retrieve the LS factor calculation layer.

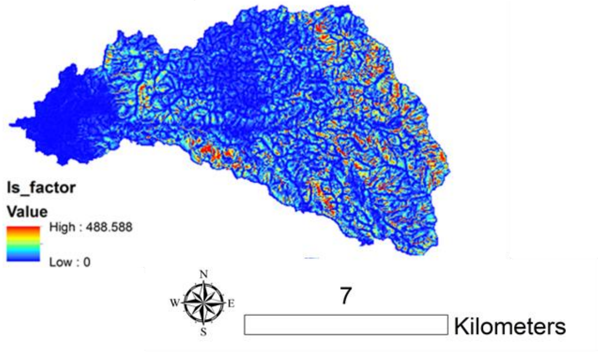

Figure 6. LS factor's calculation layer

E. Potentiel Erosion Estimation's Results

The highest value of potential erosion was found in the eastern part of the basin where the deciduous forest located. The highest magnitude of the potential erosion was detected to be 77.599 ± 1.344 x10^3 t/ha/y as can be seen in Fig. 7.

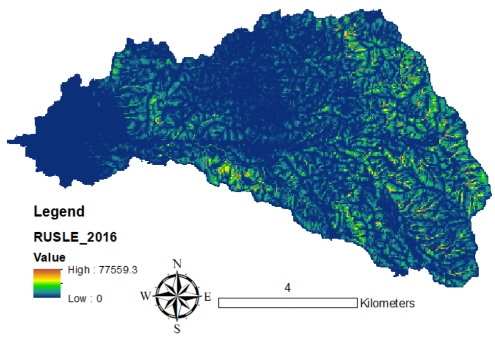

Figure 7. Potential erosion of the Mae Tao Basin area.

Fig. 8 demonstrates the potential erosion of the existed agricultural area. As stated by [4], corn field has been mostly detected in the area since 2002. The highest potential erosion of the area is detected to be 61389.1 t/ha/y.

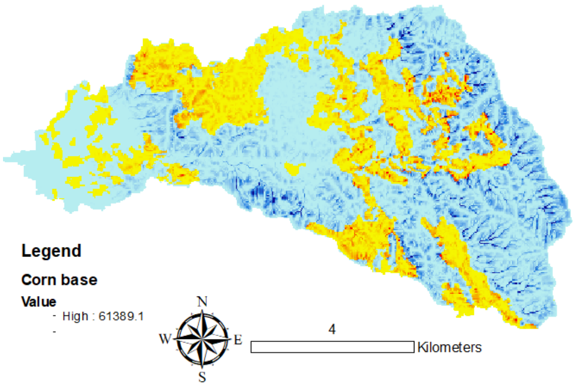

Figure 8. Potential erosion of the agricultural area of the Mae Tao Basin

F. Land Use Alternation Simulation's Results and Discussion

Ten variations of land utilization and practices were applied and converted into calculation layers of c factor to simulate the changes in potential erosion in the mine. Table II demonstrates the results from the repetition of the land use over the mining production area.

TABLE II. SIMULATION RESULTS OF THE LAND USE ALTERNATION

Land use type	Maximum potential erosion	Erosion reduction efficiency
	(t/ha/y)	(%)
Grass plants (Brachiaria sp)	18507.2	54.47
Bean	10274.7	74.73
Cassava	15444.3	62.01
Lemongrass	21864.7	31.86
Perennial grass	857.55	93.32
Hardwood with scrub	812.3	96.13
Forrest	61.8	99.84
Overlapped cropping and straw mulch	741.4	98.79
Vetiver (earlier state)	22860.5	62.76
Vetiver (aged)	2271.3	96.35

G. Land Use Alternation Simulation's Results and Discussion

The results indicate that varying of land cover practice can efficiently reduce the potential erosion of the basin. In keeping with simulation results, changing the land use type into deciduous forest contains the highest efficiency in reducing the potential erosion can reduce the potential erosion of the agricultural area from 61389.1 t/ha/y to 61.8 t/ha/y or 99.84%.

Perennial grass naturally covers some area can reduce 54.47% of potential erosion, while mixed shrub and hardwood tree can enhance the efficiency of the reduction to 93.32%.

Conversely, vetiver grass, considered to be one of the distinguished alternatives in reducing rainfall, cannot effectively applied as the cover practice for the study area due to its low erosion resistivity at the young age. Applying vetiver grass as land cover can effectively reduce the potential erosion after years of plantation with 33.59% higher than the earlier stage.

Agricultural crops are inclined to contain lower effectiveness in the reduction of potential erosion. Corn densely vegetated in the surroundings of mining production area possesses the low resistivity to overland erosion during rainfall incident. Subsidizing corn in the agricultural area with cassava and bean can slightly decrease the erosion at 62.01 and 74.73% respectively.

According to the simulation results, the combination between the vegetation of a good root system plant and cover management, possessing a capability in increasing of erosion resistivity of the agricultural crop [14]. As stated by the estimations, changing of previous cornfield with integrated practice can enhance the reduction efficiency.

Overlapped cropping, covered by straw mulch can reduce 98.79 % of the base potential erosion, while the mixing plantation between hardwood plant and shrub can reduce 96.13%. Despite the fact that the agricultural alternation can reduce the potential erosion of the basin, thus the implantation of the crops in this area cannot be unconditionally accomplished. Since, the risk in contaminating of cadmium can make the products from the area inconsumable, selecting the edible plants should not be assigned into the vegetation plan.

As suggestions, the selection of land utilization for the reclamation over the study area should be focus on the growth period of the plant. Because of the potential of the area that can carry on spreading the contaminant into the environmental phases, rapidly-growth plant can reduce the chance in the contacting between rainfall runoff and the bare surface of the production area. However, at the earlier state, cover material and plantation techniques should be used to enhance the efficiency of the reduction.

Integrated plant and cover management can be one of the alternatives. The combination between perennial tree and shrub were demonstrated to be the most appropriate land use that can response to every aspects of the land utilization.

Perennial grass, contain an ability in reducing of rainfall intensity and erosivity can decrease the magnitude of R factor, resulting in the influencing of the erosion reduction of shrubs at the lower area. Additionally, alternating the study area in food crops such as corn and rice paddy filed are strictly prohibit due to their capability in the recontamination of cadmium from the soil into the food chain.

IV. CONCLUSION

As summary, this integrated spatial approaches, consists of RUSLE, GIS, remote sensing and can be successfully assigned to estimate the potential erosion in the Mae Tao Basin area. The process can be enhanced into a powerful tool in supporting of selecting the land use type of the reclaimed land. According to this integrated approach, iintegrated plant and cover management was the most appropriated land use type that can response to every aspects of the land utilization. In addition, this study has also revealed the capability of customizing this integrated method to be utilized in other similar reclamation case.

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