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Assessment Erosion 3D Hazard with USLE and Surfer Tool: A Case Study of Sumani Watershed in West Sumatra Indonesia

Aflizar[1], Roni Afrizal[1] and Tsugiyuki Masunaga[2]

[1]*State Polytechnic Payakumbuh for Agriculture, Payakumbuh 26271, Indonesia.*
Fax +62-752- 7750220, e-mail: aflizar_melafu@yahoo.com
[2]*Faculty of Life and Environmental Science, Shimane University, Nishikawatsu 1060, 690-8504, Japan*

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ABSTRACT

Quantitative evaluation of soil erosion rate is an important basic to investigate and improve land use system, which has not been sufficiently conducted in Indonesia. The Universal Soil Loss Equation (*USLE*) and Erosion Three Dimension (*E3D*) in Surfer were used to identify characteristic of dominant erosion factors in Sumani Watershed in West Sumatra, Indonesia using data soil survey and monitoring sediment yield in outlet watershed. Climatology data from three stations were used to calculate Rainfall erosivity (R) factor. As many as101 sampling sites were used to investigate soil erodibility (*K*-factor) with physico-chemical laboratory analysis. Digital elevation model (*DEM*) of Sumani Watershed was used to calculate slope length and Steepness (*LS*-factor). Landsat TM imagery and field survey were used to determine crop management (*C*-factor) and conservation practices (*P*-factor). Calculating soil loss and map of *USLE* factor were determined by Kriging method in Surfer 9. Sumani Watershed had erosion hazard in criteria as: severe to extreme severe (26.23%), moderate (24.59%) and very low to low (49.18%). Annual average soil loss for Sumani watershed was 76.70 Mg ha^{-1} y^{-1} in 2011. Upland area was designated as having a severe to extreme severe erosion hazard compared to lowland which was designated as having very less to moderate. On the other land, soil eroded from upland were deposited in lowland. These results were verified by comparing one year's sediment yield observation on the outlet of the watershed. Land use (*C*-factor), rainfall erosivity (*R*- factor), soil erodibility (*K*-factor), slope length and steepness (*LS*-factor) were dominant factors that affected soil erosion. Traditional soil conservation practices were applied by farmer for a long time such as terrace in Sawah. The *USLE* model in Surfer was used to identify specific regions susceptible to soil erosion by water and was also applied to identify suitable sites to conduct soil conservation planning in Sumani Watershed.

Keywords: Erosion *3D*, sediment yield, Surfer, *USLE*

INTRODUCTION

Soil erosion in Indonesia is one of most serious environmental degradation problems (Kusumandari and Mitchell 1997). In Java average erosion was 6 – 12 Mg $ha^{-1}y^{-1}$ on volcanic soils and much higher loses on agricultural land has been reported to have caused economic loss US$ 340-406 million in 1989. Nearly 80% of this is due to declining in the productivity of agricultural land and the other is due to off-site cost such as siltation of irrigation systems and the loss of reservoir capacity (World Bank 1994).

Sumani Watershed is the main rice producing area in West Sumatra facing to lake Singkarak (107.8 km^2, 364 m asl) which supplies electricity by hydro power plant for West Sumatra and Riau Province. In addition, the increasing population has accelerated shift of land use from forest to agricultural field with intensive cultivation. Sumani Watershed soil is under a serious risk in which soil fertility and crop productivity decline due to hilly topography mainly exacerbated by soil erosion conditions by water because of high rainfall (2,201 mm y^{-1}) (Farida *et al*. 2005). Agricultural practices such as excessive soil tillage and cultivation on steep slopes has also increased the risk. Typical erosion rate monthly by Sediment Delivery Ratio (*SDR*) method was 49 Mg $ha^{-1}y^{-1}$ (Saidi 1995). So far, this research could not show where main area of soil loss was located and a dominant effect on erosion and erosion hazard for determining suitable land uses and soil conservation measurement for the watershed.

Evaluation of current situation of erosion is very important for improvement of endangered areas. Determining the type of conservation measurement to be applied for the purpose of estimating a 3D distribution of erosion is required for sustainable management and conservation of the agricultural areas (Ahmet *et al*. 2007). Process-based methodologies for soil erosion prediction are: SEMMED (de Jong *et al*. 1999), WEPP (Elena *et al*. 2004), EUROSEM (Morgon *et al*. 1998), GUEST (Ciesiolka *et al*. 1995), ANSWERS (Seyed *et al*. 2006), FUERO (Matternicht *et al*. 2005), AGNPS (Walling *et al*. 2003), LISEM (Takken *et al*. 1999), MMF (Morgon 2001) and Erosion 3D (Schmidt *et al*. 1999). Some models, in spite of their strong theoretical base, may not be very suitable for Indonesia as it is a developing country. Situations such as those in Indonesia are prohibitive since detailed rainfall, topographic and other input data which is required to run them are often either not available or difficult to collect due to resource constraints. However, at present the most commonly used methods of predicting the average water erosion rate from agricultural lands are the Universal Soil Loss Equation (*USLE*) (Wischmeier and Smith 1978) and the Revised Universal soil Loss Equation (*RUSLE*) (Renard *et al*. 1994).

Soil erosion models, such as the *USLE* estimates gross soil erosion rate at plot-scale. Erosion rates estimated by *USLE* are, therefore, higher than those measured at watershed outlet (Hua Lu 2006). Sediment delivery ratio (*SDR*) was used to correct this reduction effect. Erosion 3D (*E3D*), which is a raster-based physical soil erosion model that predict the spatio-temporal distribution of erosion and estimate where to locate the main area of soil loses on a watershed scale (Schmidt *et al*. 1996; Annekatrin 2006) were combined with *USLE* and *SDR* models. We used *USLE* with kriging in Surfer to evaluate the present situation and to assess further activity and passivity of dominant erosion factor in order to control soil loss more efficiently with the aim of finding out suitable conservation methods in relation to agriculture sustainability.

MATERIALS AND METHODS

Study Area in Sumani Watershed

The Sumani Watershed, covering 58,330 ha and was located in Solok regency and city (latitude 0^o 36’08" to 1^o 44’08" S, longitude 100^{o}24’11"-101^{o}15’438" E), West Sumatra (Figure 1). The outlet of the watershed is Lake Singkarak. The average annual rainfall for the watershed varied with altitude from 300 m to 2,500 m asl varies from 1669.4 mm to 3,230 mm, respectively. Average temperature was 19.19 to 30.19 0C varying from hight to low altitude. Average Humidity was 78.1 to 89.4%. Average wind flow varyied from 2.1 to 3.8 m s^{-1} (Istijono 2005). The Sumani Watershed was chosen because it was one of the priority watersheds in Indonesia where water captured in Sumani Watershed inflows into Lake Singkarak. Hydroelectric power plant with capacity of 4 × 43 MW at Lake Singkarak wa used to fulfill the electric demand of the resident population 4.4 million in both West Sumatra and Riau Province. Before 2004, due to instability of water dynamic and extent soil erosion in Sumani Watershed power generation has been excessively affected to an extent of sudden power cuts. Besides, soil loss has also affected the rice yields in West Sumatra. The third reason for choice of this site was because it provided flexibility to conduct comparison experiment since in these areas exist various land uses. Sumani Watershed consists of various land uses such as primary forest, tree crop garden (mixed garden, coconut and tea gardens), vegetable garden, sawah, bush (shrub, grass and alang-alang (land occupied by *Imperata cylindrica*) and settlement. The term sawah refers to a levelled and bounded rice field with an inlet and outlet for irrigation and drainage (Wakatsuki *et al*. 1998). Mixed garden refers to land where perennial crops, mostly trees such as coconut, clove, coffee, teak, mahagony, sawo (*Achras zapota* L), avocado, melinjo (*Gnetum gnemon*), rubber, cinnamons, are planted with a combination with annual crops (Karyono 1990). Chilli (*Capsicum annum* L), onions (*Allium cepa* L), soy bean (*Glycina max* L), corn (*Zea mays* L) and sweet potato (*Ipomea batatas* L) were the major crops in vegetable garden. The relative flat areas (< 10%) covered 26% of the area mostly lying in the lower elevation (< 500 m asl). In higher elevation area (> 500 m asl) mainly under vegetable production was on slopes of 10 – 30%, and covered 40% of area. The slopes mostly occured in foothills in the South of Mt. Talang. Agricultural land like mixed gardens, vegetables gardens were still found in this class slope *i.e*. below 1,000 m asl. In the higher elevation in Barisan hill (> 1,000 m asl) forest dominated this slope class. Combination of steep slopes (30% - 100%) appeared as dissected plateau in the west side of the basin. These various steep areas were covered by natural vegetation like forest, shrubs, grass and patches of less intensive agricultures *i.e*. mixed gardens (Farida *et al*. 2005). The watershed had soil family namely Aeric Tropaquept, Typic Kandiudult, Typic Distropept, Oxic Hapludand and Typic Eutropept with developed three geology, whose types are Tufa volkan, alluvial and alluvial fan (Farida *et al*. 2005). Five soil texture types found are silt, silt loam, silty clay loam, light clay and heavy clay with four soil structure whose types are granular, angular, sub angular blocky and blocky. A network of five major rivers, viz., Lembang river, Sumani river, Bagawan river, Ujung Karang river and Barus Rivers feel drain into the Lake Singkarak. Sumani Watershed (SW) consists of five subwatershed that is Sumani (S1), Lembang (S2), Gawan (S3), Aripan (S4) and Imang (S5).

Fields Survey and Analytical Methods

Soil survey was conducted in 101 sites (42 sites in 2002, 39 sites in 2007 and 20 sites in 2011) occupying a variety of geomorphic position and land uses types. Soils were collected from these sites at the depth of 0 – 20 cm and 20 – 40 cm. Soil samples were air dried and sieved with the mesh size of 2 mm for the physico-chemical analyses. Organic carbon was determined by Walkley and Black type method, soil texture was determined by pipette method, soil permeability was done by De Boot (1967) method and bulk density was determined by volumetric sample (Blake 1986). During the field survey, we also confirmed the soil and vegetation types and land uses in the watershed.

The study framework emphasized the importance of planning based on an area's specific demand and problem, which in the case of this area was soil and watershed conservation. The proposed planning process consisted of erosion hazard analysis, land suitability analysis, and economic feasibility analysis. The results of these analyses were integrated into the proposed agro-ecological land-use, which was proposed as the final study. In the present study, we focused to soil erosion 3D hazard analyses.

Data Processing for Mapping and Erosion 3 Dimension (E3D) Modeling Approach

The overall data processing involving use of *USLE*, was conducted in Surfer® 9 (Golden software 2010) dealing with factors gained from meteorological stations, detailed soil surveys, topographic maps, and attendant of other applicable studies. Outline of the mapping procedure is summarized in Figure 1. The data sources were converted into the grid format. Each defined grid had an exact location in space determined by the grid orientation and grid size and a list of allocate attributes. To predict soil erosion rate in the spatial domain, a map unit was set to the size of 125 m by 125 m, which was the finest resolution size concerning with the available data set and authors' computer facilities. Each grid was assumed as a single slope plane in order to apply for which *USLE* in grid.

The study was based on Erosion 3D, which was a raster-based physical soil erosion model that predicted the spatio temporal distribution of erosion and deposition as well as the delivery of suspended soil material to surface water course on a watershed scale (Schob *et al*. 2006). Erosion 3D model required at least the following data: (1) relief parameter: digital elevation model (*e.g.* interpolated grid from a digitized topographical map, topographic data was used to construct a surface map of the landslide and surrounding Sumani Watershed. A block diagram showing geomorphic feature and sampling location in watershed was generated by kriging topographic data using Surfer from Golden Software; Golden, CO (Lee *et al*. 2001), (2) standard soil parameter: particle size distribution of the top soil (four main texture classes) and organic carbon content (%) (Schob *et al.* 2006), (3) specific soil parameter: bulk density (kg m^{-3}), soil permeability (cm hr^{-1}), soil structure, effective soil depth, (4) percentage land slope: digitize map was generated by grid data using Surfer program, (5) soil sampling polygon, (6) land use: digital maps *e.g.* digital topographical maps combined with orthophotos and field mapping with land use boundaries and land use-related information (Schob *et al*. 2006), and (7) meteorology parameters polygon: Data recording from tree station in Sumani Watershed and polygon map was generated using Surfer 9. Since 1996, the Erosion *3D* model has been integrated into the official agricultural soil conservation programs. Further validation of the Erosion 3D model has been done internationally (Schob *et al.* 2006).

Erosion Hazard Analyses

In the *USLE*, mean annual soil loss is expressed as a function of six erosion factors:

$$E = R \times K \times L \times S \times C \times P \qquad [1]$$

Where E is the estimated soil loss in Mg $ha^{-1}y^{-1}$, R is the erosivity of rainfall, dimensionless; K is inherent soil erodibility, dimensionless; L is length of the slope factor, dimensionless; S is slope factor, dimensionless; C is crop cover factor, dimensionless; and P is a factor that accounts for the effects of soil conservation practices, dimensionless.

The watershed was divided by 39,316 grids with size of 125 m × 125 m mesh basic data were allocated or estimated in each grid by means of reading of maps and a Landsat image for land use types and altitude or kriging method for application and soil properties. Base on these data, respective *USLE* factor were calculated in each grid unit. Among the above factors, *C*- and *P*-factors are the ones that we can modify to improve soil erosion and agro-economical conditions in the watershed.

Rainfall Erosivity Factor (*R*-factor)

R-factor is rainfall erosivity factor which is the potential ability of the rain to cause soil erosion. For computing the monthly value of the *R*-factor, the following equation is proposed for Indonesia by Bols (2000) was used:

$$R = 6.19(Rf)^{1.21}(Rn)^{-0.47}(Rm)^{0.53} \quad [2]$$

Where *R* is monthly erosivity, *Rf* is total monthly rainfall, *Rn* is number of rainy days per month, and *Rm* is the maximum rainfall during 24 hour in the observed month.

Soil Erodibility Factor (*K*-Factor)

K-factor represents both susceptibility of soil to erosion and the rate of run off measured under standard plot conditions. The value for *K*-factor was computed using the following equation (Wischmeier and Smith. 1978):

$$100K = 2.713\, M^{1.14}(10^{-4})(12-a) + 3.25(b-2) + 2.5(c-3) \quad [3]$$

Where *M* is given by *(Svf + St) (100 – Cf)*, *a* is the percentage of soil organic matter content, *b* is the structural code, *c* is the permeability class code of the soil, *St*, *Svf* and *Cf* are the percentage of silt, very fine sand and clay fractions, respectively.

In general, *R*-factor and *K*-factor are the most important factors that need evaluation based on local conditions for successful application of the model (Chris and Harbor 2002). Not all the grids possessed its own data of precipitation or soil analyses to calculate *R*-factor and *K*-factor. In this case, interpolation by the nearest neighbor kriging method (Golden software 2010) assigned the value of the nearest grid possessing soil analyses data. This method was useful and gave good results as reported by Goovaerts (2000) and Takata *et al*. (2008). Rainfall erosivity varied in each month of the year and in the same month with a different period of the year also showed different rainfall erosivity. This we expected because of the influence of local climate caused by topography, hydrology and morphology of Sumani Watershed.

Slope Length and Steepness Factor (*LS*-Factor)

Each grid was considered as a single slope plane. For *LS*-factor calculation, the original *USLE* formula for estimating the slope length and slope steepness could be used (Wischmeier and Smith 1978). In this study equation in power form was used. Liu *et al*. (2000) reported that an increase in the slope steepness from 20% to 40% and 60%, the slope length exponent did not change. Therefore, in the present study separate equation for slope gradient 21% as given in the *USLE* (Equation 4) and for areas with a slope gradient > 21% as incorporated in the *USLE* (Equation 5) had been used (Renard and Jeremy 1994; Irvem *et al.* 2007)

$$LS = (L/22.1)^{m}(65.41.\sin^{2}X + 4.56.\sin X + 0.065) \quad [4]$$

$$LS = (L/22.1)^{0.7}(6.432.\sin(X^{0.79}).\cos(X)) \quad [5]$$

Where *L* is the slope length in m, *X* is angle of the slope in degrees, *m* is exponent that varies with slope gradients as in 0.2 for < 1%, 0.3 for 1 – 3%, 0.4 for 3.5 – 4.5% and 0.5 for > 5%. m is an exponent that depends on slope steepness (0.5 for slopes $\geq$ 5%, 0.4 for slopes 4% and 0.3 for slopes $\leq$ %3). m was taken 0.5 for slopes between 5% and 21% and 0.3 for slopes < 5% in Equation (4).

Cover Crop (*C*-factor) and Conservation Practices (*P*-Factor) Factors

C-values for the Sumani Watershed were evaluated by interpretation of image photo from Landsat TM 2002 and rechecked with field survey in July 2012. *C*-factor values were taken as 0.001 for natural Forest, 0.29 for grasslands (*Brachiaria* sp.), 0.4 for agriculture land (arable land on upper slope mainly cultivated by crop like chili, onion, soybean, maize and mix garden), 0.2 for a mixed garden (agroforestry) were dominated by (perennial crops as coconut, clove, coffee, teak, mahagony, sawo (a kinds of tropical fruit), avocado, melinjo (K.O. Tree), rubber. cinnamons), 0.3 for coconut, 0.01 for sawah, 0.01 for shrub, 0.002 for pine and 0.95 for settlement. Sawah area had conservations practice as a traditional terrace with *P*-factor value 0.4 and for agricultural field, mix garden and coconut had *P*-factor 0.5 because having plantation crop which had middle land cover. For the other land use pattern very small area had conservation practices, P factor values were assumed as 1 for the Sumani Watershed. The *C*- and *P*-factors were cited from Abdurachman *et al*. (1990). as these factors were known to be not much different in regions.

Sediment Delivery Ratio (*SDR*)

Walling *et al*. (1994) reported that *USLE* calculated the total mass of sediment delivery, which would be approximately two to seven times higher than the sediment yields measured at the outlet of watersheds. Sediment delivery ratio (*SDR*) is the amount of sediment that is actually transported from eroding sources to a measurement point such as watershed outlet compared to total amount of soil that is detached over the same area above the point (Lu *et al*. 2006; Zhow and Wu 2008). It is dimensionless and is conventionally expressed as:

$$SDR(\%) = Y/E \times 100 \quad [6]$$

Where *Y* is the average annual sediment yield per unit area and *E* is the average annual erosion over rate the same area in Mg $ha^{-1}y^{-1}$. Sediment yield data for 1992 was collected by Saidi (1995). Sediment samples were collected from the five sub-watershed outlets and a watershed outlet that was collected at a monthly time-step for a 1-year period observation (August 1992-July 1993). The *SDR* in 1992 was calculated based on this sediment yield values and the soil erosion rate was estimated in the present study. *SDR* in 1992 was used to estimate sediment yield for 2011.

RESULTS AND DISCUSSION

Rainfall Erosivity (R) Factor

Rainfall erosivity values were calculated using Equation 2. Sumani Watershed was grouped into 3 rain erosivity classed pursuant to distribution of 3 climatology stations which still exist hitherto. Sumani Watershed almost each month in a year rainfall was happened. Using calculated and estimated *R*-factor values for each station, input maps of *R*-factor were generated with Surfer (Figure 2a). This map shows distribution of R values over Sumani Watershed using combined method as, Nearest Neighbor gridding method. *R*-factor values increased from lowland to upland watershed depending on precipitation characteristics. *R*-factor values of any place for *USLE* could be obtained from the map (Figure 2a). O'Neal *et al*. (2005) reported that increasing precipitation and decreasing cover were increasing erosion. Obi *et al*. (1995) reported that the magnitude of rainfall erosivity caused the catastrophic erosion problem. *R*-factor was low in lowland near to Lake Singkarak and increased to upper topographical positions in the watershed, which was attributed to the difference in amount of precipitation.

Soil Erodibility (*K*-Factor)

Figure 3b shows that *K*-factor in subwatershed such as Lembang-SW, Sumani-SW, Aripan-SW and Gawan-SW and Imang-SW had different characteristic. The results, suggest that there was need to conduct soil survey to investigate real conditions of soil erodibility (*K*-factor). The traditional approach assumed that one soil erodibility value represented the entire area of soil series. Therefore, the traditional approach for estimating soil erodibility did not account for spatial variability of individual soil properties or spatial correlation among those properties, including soil erodibility (Parysow *et al*. 2003).

K-factor values for different family soil groups, land use, geology, slope, altitude are given in Figure

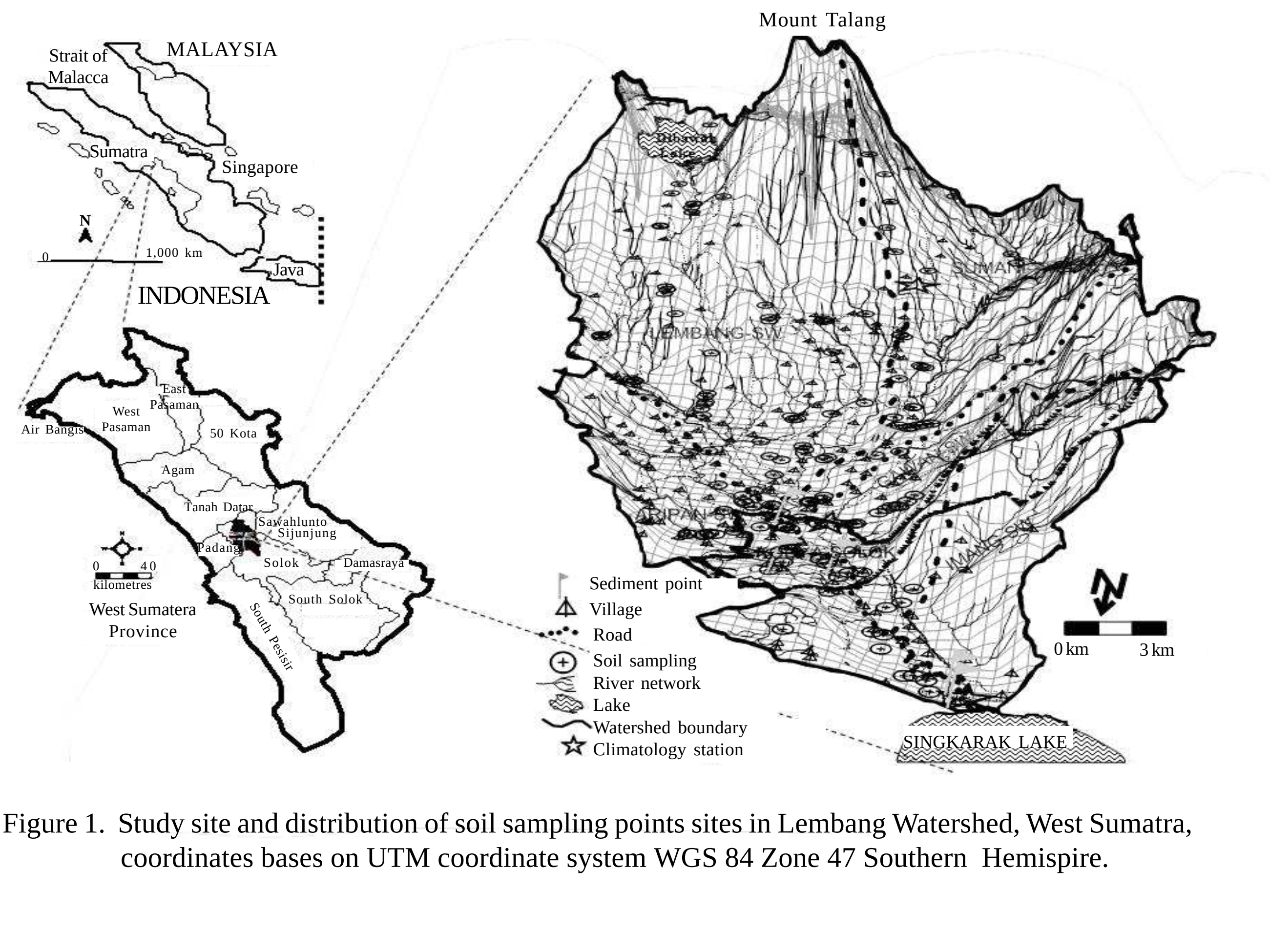

Figure 1. Study site and distribution of soil sampling points sites in Lembang Watershed, West Sumatra, coordinates bases on UTM coordinate system WGS 84 Zone 47 Southern Hemispire.

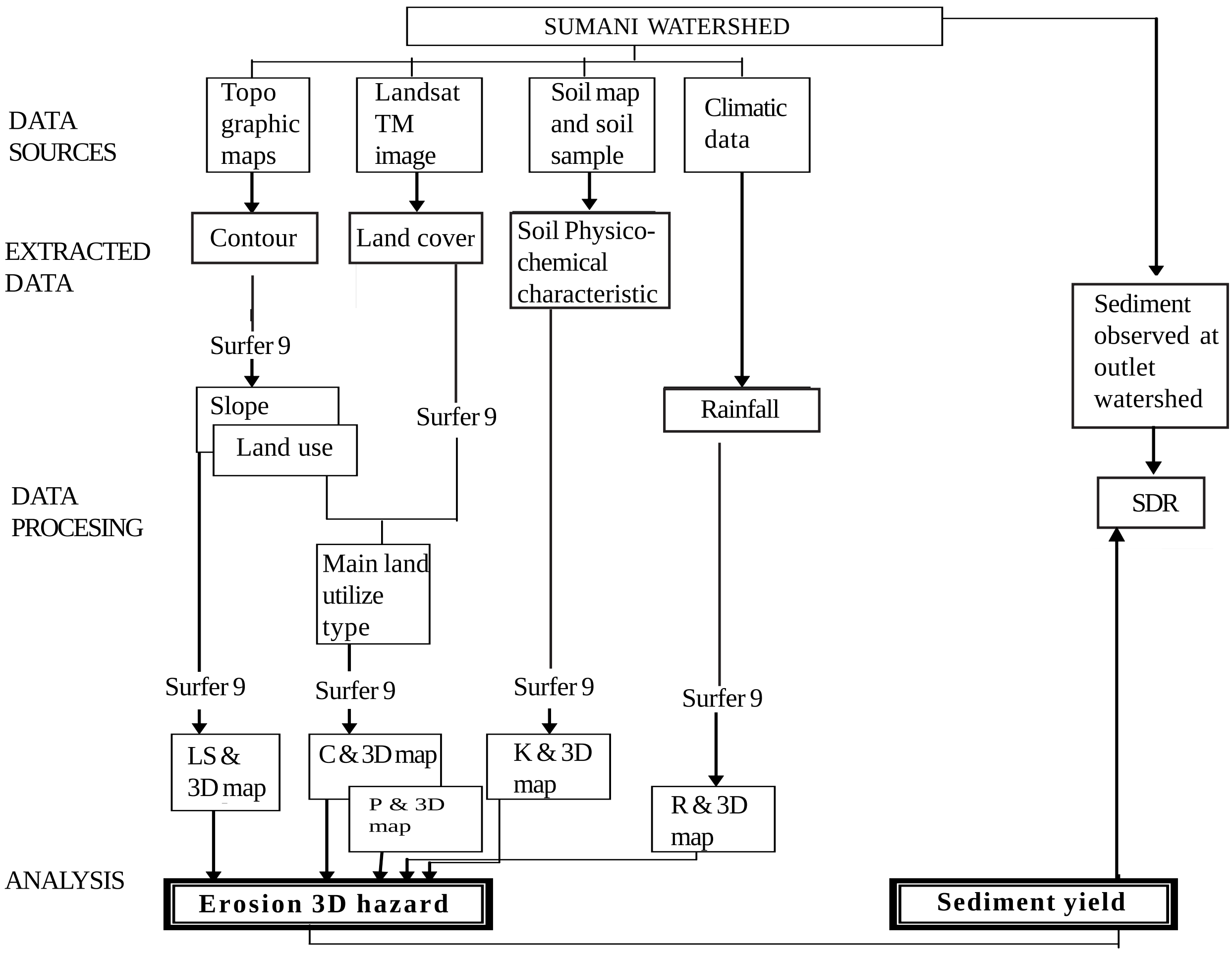

Figure 2. Data sources and data extraction and processing for analysis. SDR: Sediment Delivery Ratio, LS: Topography factor, C: Crop factor, P: Conservation factor, K: Soil erodibility factor, R: Rainfall erosivity factor (Modified from Sarainsong *et al.(*2007))

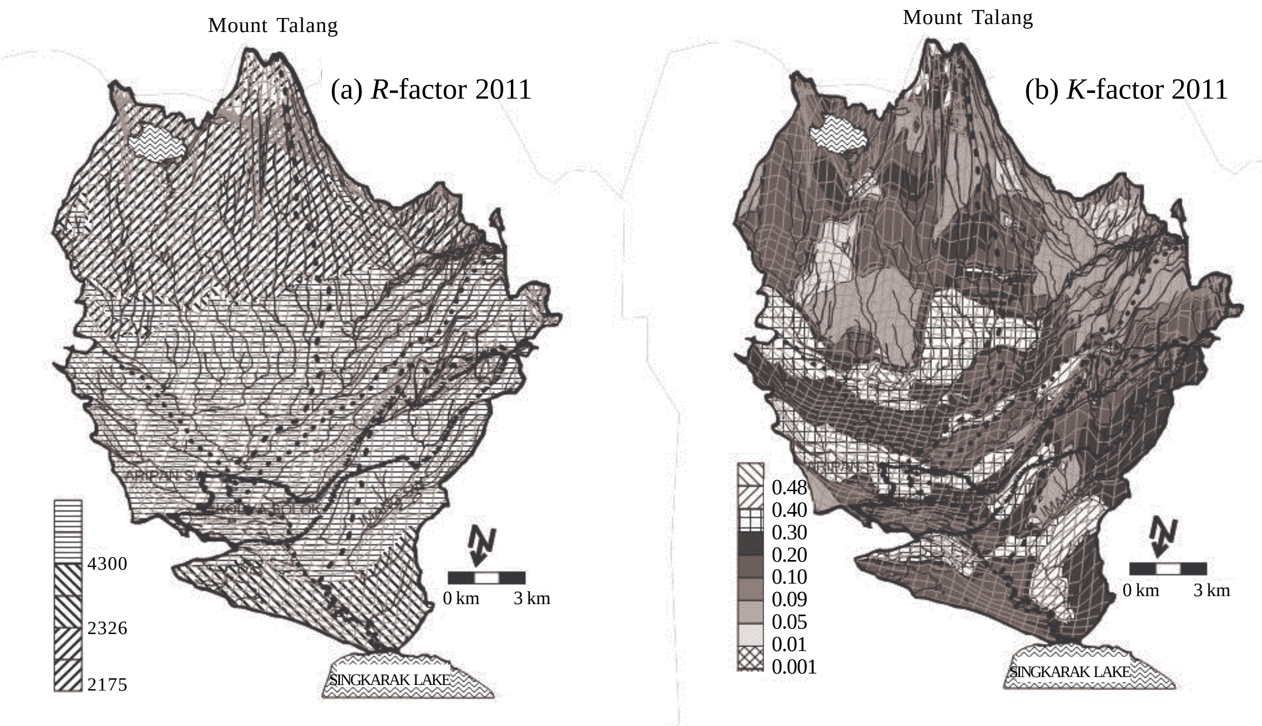

Figure 3. Spatial distribution of *R*-factor (a) and *K*-factor (b) in Sumani Watershed.

3b. The same soil group, land use, geology and topography had different *K*-factor values in the lowland and upland of Sumani Watershed. *K*-factor values ranged from 0.001 to 0.486. *K*-factor values were grouped into ten classes. *K*-factor values in Lowland dominated high values where as in upland it was found that high and low values of *K*-factor were dominant. Distributions of *K*-factor in Sumani Watershed were dependent on natural soil characteristic. *K*-factor value map was generated to show spatial distribution of soil erodibility according to 101 soil sampling (Figure 1 and 3b).

Analysis Topography (*LS*-Factor)

Digital topographic data for Sumani Watershed were obtained by digitizing 3 sheets of topographic maps of scale 1 : 50,000. The contours and the drainage system were digitized separately and used to build up the *DEM* (Digital Elevation Model) of the Sumani Watershed. The contour interval used was 25 m. A grid cell of 125 m was used in building the *DEM*, as this was considered to be less than the maximum slope length, based on reconnaissance surveys. A maximum length of 100 m for forest and arable land was used while for settlement the length of 10 m to 7.5 m which was set in order to get realistic L and S factor values in Sumani Watershed. The *LS*-factor distribution was consequently determined by kriging method in Surfer. The *LS*-factor was calculated using Equation 4 and 5 depending on slope which were smaller than 20% or more.

Figure 4a shows 10 classes of *LS*-factor from upland as compared to values from lowland areas. In general, values from upland were higher than lowland since they were dominated by sharp slopes of > 20%. Topography maps were used to develop a map of the slope length and slope steepness factor (*LS*-factor). Fox *et al*. (1999) reported that rain-impacted erosion increased roughly with the square root of slope gradient. Van Remortel *et al*. (2001) reported that in *USLE* and *RUSLE* models were used to predict soil erosion at regional landscape scale, there were difficulties in obtaining an LS factor. To solve the problem *DEM*, elevation data could be used to compute *LS*-factor based on *LS*-factor grid using *DEM*. Using the physically based topographical factor LS equation and *DEMs* led to a higher correlation of predicted *LS*-factor values with topographical features, compared to a spatial simulation method based on *LS*-factor empirical models and sample data (Wang *et al*. 2001). Slope lengths as generated by the *DEM* were based on the assumption that each slope plane consist of homogeneous soil and vegetation cover (Fox *et al*.1999).

Crop and Management (*C*-Factor).

To determining the *C*-factor values for the Sumani Watershed, it was first necessary to prepare a land cover map of the watershed. This was achieved satellite by the satellite image and field survey (Mati *et al*. 2000). Landsat TM June 2002 was obtained to interpretate land cover of Sumani

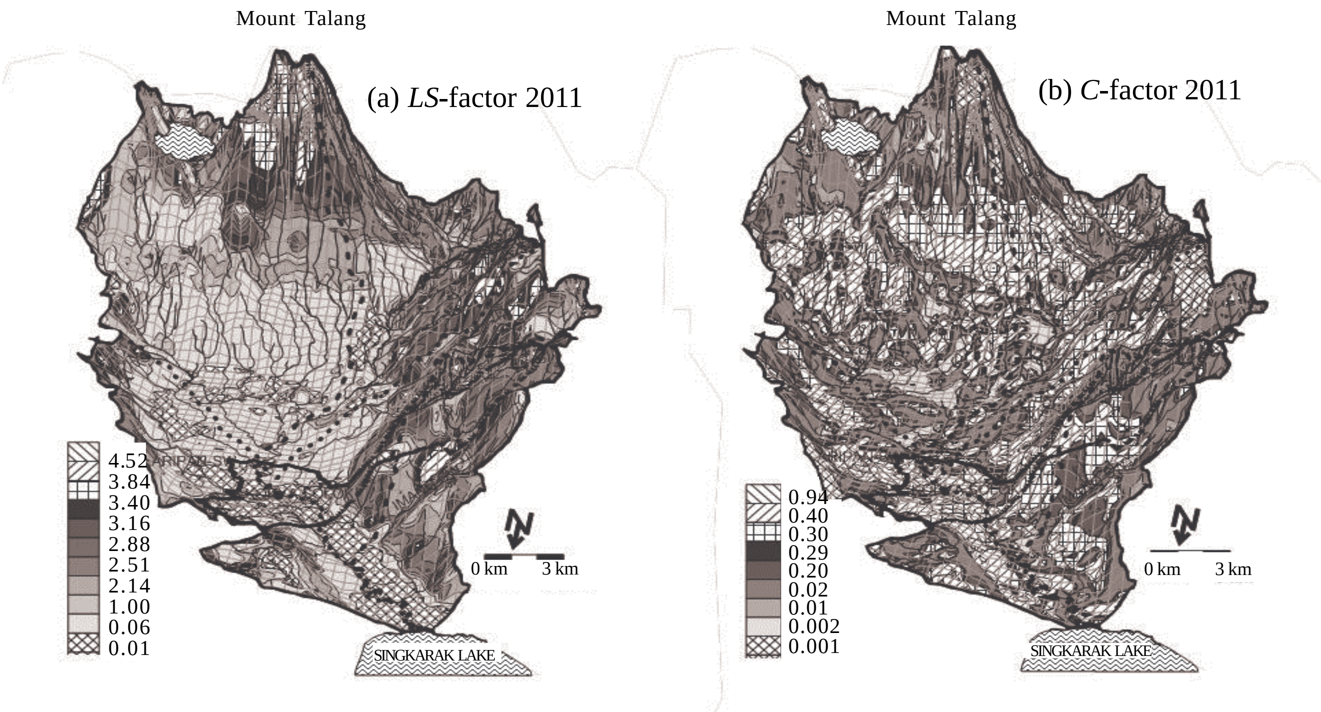

Figure 4. Spatial distribution of *LS*-factor (a) and *C*-factor (b) in Sumani Watershed.

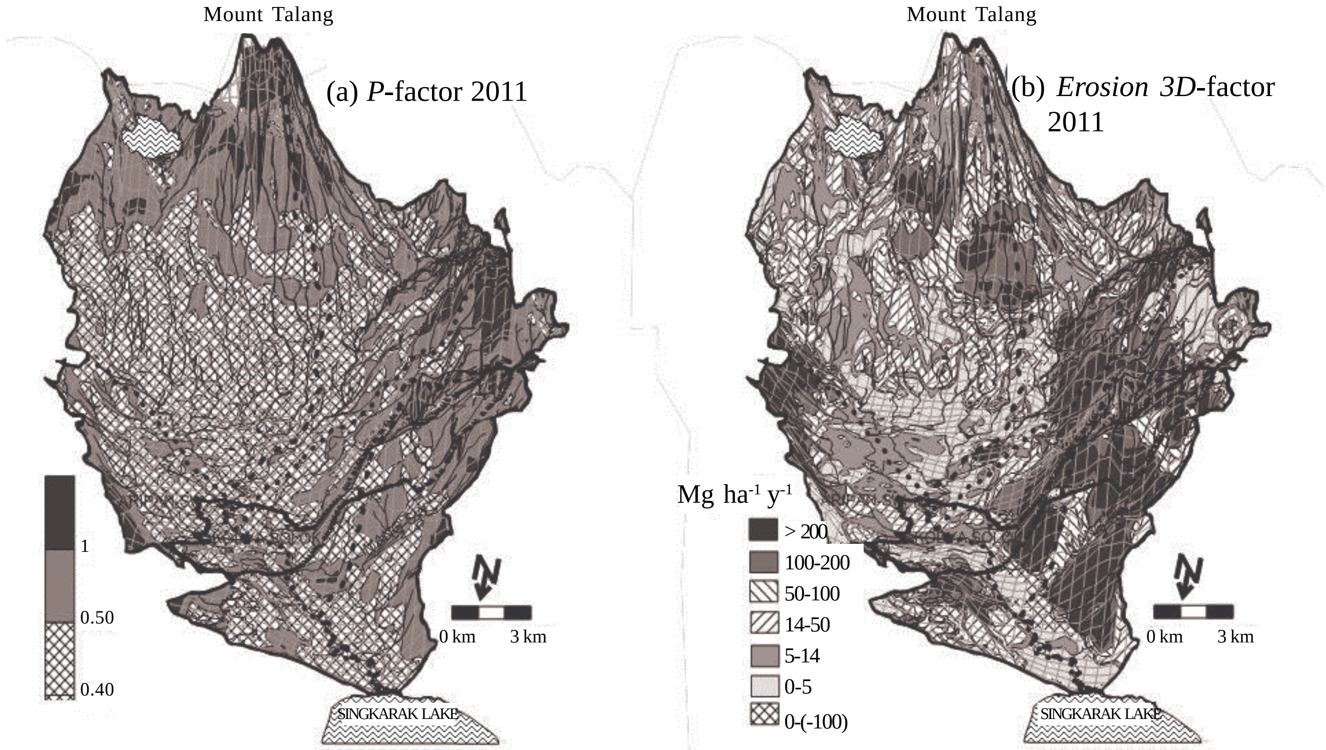

Figure 5. Spatial distribution of *P*-factor (a) and *Erosion 3D (b)* in Sumani watershed.

Watershed, as well as topographic maps of scale 1: 50,000. Ten major land cover types were identified: forest, pine, mix garden, vegetable garden, sawah, shrub, grass, settlement, water body (Farida *et al*. 2005). The *C*-factor of *USLE* in Sumani Watershed corresponding to each vegetation/crop condition were estimated from *USLE* guide tables (Morgon 1985). *C*-factor values ranged from 0.001 to 0.95. Distribution *C*-factor in upland and lowland of Sumani Watersheds was in Figure 4b. Alejandro *et al*. (2007) reported that using landsat TM to produce maps the *C*-factor for use in the modeling soil erosion provided a more detailed spatial variability and validation.

Determining Conservation Practices (*P*-Factor)

To determine the areas covered by soil conservation activities, maps of the cover crop from interpretation of Landsat TM June 2002 were used. These maps were redigitized and used in field survey to obtain the type of conservation practices on each land cover surrounding Sumani Watershed. The commonly used traditional conservation were found to be traditional terrace in sawah, moderate cover crop in mixed garden and vegetables field or agriculture field, and no conservation in forest, grass, brush. Settlement commonly lied around the sawah. The type of conservation for settlement was similar to sawah. The *P*-factor values corresponding to each cover crop was estimated from USLE guide table (Morgon 1985; Abdurachman *et al*. 1984). Figure 5a shows that upland *P*-factor values ranged from 0.4 to 1 and dominated by sawah terrace and mixed garden and vegetable fields however lowland *P*-factor values range 0.4 ,0.5 and 1 and were dominated by sawah, mix garden , settlement and were not found in forests.

Soil Erosion Rate in Sumani Watershed and Sediment Delivery Ratio (*SDR*)

Figure 5b shows a distribution of soil erosion in surrounding Sumani watershed. Based on to the criteria of erosion risk classes by Odura (1996) and Irvem *et al*. (2007), 7.2, 8.8, and 26.9 % of the watershed area were classified into low (14 – 28 Mg $ha^{-1}y^{-1}$), medium (28 – 56 Mg $ha^{-1}y^{-1}$), and high (> 56 Mg $ha^{-1}y^{-1}$) level classes, respectively. Sediment yield data measured in 1992 to 1993 (Saidi 1995) and *SDR* values in Sumani watershed (SW) and in other countries for comparison are shown in Table 1. Sediment yields were 4.53 Mg $ha^{-1}y^{-1}$ in SW. Then, *SDR* was 12.17% in SW. Relatively low *SDR* in SW comparing with the value reported by Walling *et al*. (1994), *i.e.* around 15 to 50%, might be due to deposition of eroded soils in lowland sawah in these study sites. We estimated sediment yield in SW in 2011, which was 9.33 Mg $ha^{-1}y^{-1}$. This

Table 1. Measured sediment yields in Sumani watershed from August 1992 to July 2011.

Locations	Soil erosion rate (Mg ha^{-1}y^{-1})		Study area (km^2)	Measured sediment yield (Mg ha^{-1}y^{-1})	Estimated sediment yield (Mg ha^{-1}y^{-1})	SDR (%)
	1992	2011		1992	2011	
Sumani watershed	37.22	76.70	583	4.53	9.33	12.17
Malaysia in 2005[a]						
B. Teh (0.37)	93.76		30.27	10.87		12
B. Cempedak (0.37)	152.72		31.74	18.13		12
Kuala Tasek (0.37)	123.19		63.09	14.50		12
France in 2001[b]						
Lautaret (0.03)	28.34		12.92	0.87		30
Belgium in 2001[b]						
Hangeland (0.24)	11.14		12.92	7.29		65
Portugal in 1990[b]						
Amedoria (0.15)	20.52		10.75	2.89		14
Greece in 1993[b]						
Lagadas (0.13)	12.65		0.24	6.93		55

Number in parentheses indicate of *C*-factor; [a]Shamsyad *et al.* (2008); [b]Bakker *et al.* (2008).

reached to 544,5 Gg y^{-1} of soil erosion from whole SW. Figure 5b shows the reason that trend where each subwatershed (Lembang (S2), Sumani (S1), Aripan (S4), Gawan (S3) and Imang (S5) used *USLE* to predict soil loss from agriculture lands due to rill and sheet erosion (Wischmeier and Smith 1978) while it was not all the erosion product flow to the outlet of river as sediment yield but some part erosion from upland was deposited in lowland at subwatershed at sawah (1 – 100 Mg ha^{-1}y^{-1}) area because sawah had traditional terrace. The Sawah area in Sumani Watershed had traditional terrace which made erosion product be accumulation. Because that there was not all soil loss drain into the river and when was measured sediment delivery in outlet the Sumani Watershed that it was quantity low. Roehl (1962) reported that terrace stopped the downslope transport of soil, so the soil accumulated upslope of boundary, and eroded downslope of the boundary. Terracing, an effective method of soil conservation on steep slopes, had been used extensively to control water erosion in hilly area. Farmer dissected the entire hill slope into a number of slope segment, *i.e.* terracing, for the sake of minimizing soil loss and for the convenience of field management operation (Zhang *et al*. 2003).

This evidence is found in Figure 5b that identified erosion minus 1 up to minus 100 Mg ha^{-1} y^{-1} were deposited in lowland area in distribution in subwatershed (Lembang (S2), Sumani (S1), Aripan (S4), Gawan (S3) and Imang (S5)). Other research reported that observations showed that sediment yield from watershed were often about an order of magnitude lower than the soil erosion rates measured from hillslope plots (Edwards 1993; Lu *et al*. 2006) and was deposited (Lu *et al*. 2006). Roehl (1962) reported that a sediment reduction ratio of 50%, indicating that half of the sediment retention basin and the rest of the sediment left the sediment retention basin to downstream areas. Nearing (1998) reported that evaluation of various soil erosion models with large data sets had consistently shown that these models trend to over-predict soil erosion for small measured values, and under-predict soil erosion for larger measured values. The *USLE* was designed only to predict long-term, average annual soil loss.

Figure 3, 4 and 5 were used to make clear dominant *USLE* factor to affect erosion in Sumani Watershed . Erosion in Sumani Watershed was affected dominantly by *K*, *L*, *S* and *C*-factor that indicated positive correlation with erosion, only soil conservation *P*-factor was not significantly affecting soil loss because in general traditional conservation had been practiced by farmer in Sumani Watershed (field survey data). This result bears testimony to the fact that erosion in Sumani Watershed generally is caused first by natural factor which can not be modified like *R*, *K* and *S* factors, second factor can be modified by humans that is *C* and *L* factors. Kusumandari et al (1997) reported that from six *USLE* factor, two groups can be identified: factor that (1) can and (2) can not readily be modified by human action. First group are slope length (*L*-factor), Cover/ vegetation (*C*-factor) and soil conservation practices (*P*-factor) and second group are rainfall erosivity(*R*-factor) , soil erodibility (*K*-factor) and slope steepness (*S*-factor).

Planning a soil conservation method for Sumani Watershed focused on reducing Crop (*C*-factor) and soil conservation (*P*-factor) or slope length (*L*-factor) can be achieved by computing single numerical values as a cover and management factor (*CP*-factor) or construct terrace. Sang-Arun *et al*. (2006) reported that bench terrace had much less soil erosion and nutrient losses compared bare soil. Reduced *C* -factor values or change in land use can alter the soil erosion rate. Cebecauer and Jaroslav (2007) reported that land cover (*C*-factor) and crop rotation change had a significant influence on soil erosion pattern predominately in the hilly and mountainous areas. Ozhan *et al*. (2005) reported that appropriate conservation can be estimated from single numerical values as cover and management factor (*CP*-factor). *CP*-factor= Tolerable erosion(T)/ R × K × L × S.

CONCLUSIONS

This research was conducted by use of collected soil survey representative data. The data were entered in *USLE* and *E3D* in Surfer and were applied to determine watershed scale soil loss quantitatively and spatially and identified major factors affecting soil loss. Thematic useful *3D* maps were yielded for Sumani Watershed that had not been previously available, such as *R, K, LS, C* and *P*-factor of *3D* thematic map, as well as the *3D* erosion hazard map of Sumani Watershed. Dominant *USLE* factors were affected by soil physic-chemical properties, topography, land use and climate. In Sumani Watershed that were *C, K, LS* and *R*-factor and this factor were identified to provide result that can be used for preparation of soil conservation master plans. The *USLE* and *E3D* in Surfer were found to predict soil loss quite well for large watershed and over estimated for subwatershed and can help predict deposited area. After comparison with sediment yield from a major river in the watershed and reconnaissance survey that *USLE* model in surfer were considered realistic. Sumani Watershed predicted erosion hazard as category of 26.23% (severe – extreme severe), 24.59% (moderate) and 49.18% (very low-low).The highest erosion hazard was predicted in upland where associated with mixed farming and agriculture fields and some erosion from upland of deposited in lowland. Forest and Sawah gave the lowest erosion hazard rates of less than 1 and 5 Mg $ha^{-1}y^{-1}$. As the problem of soil erosion in Sumani Watershed was land use change or crop (*C*-factor) change and natural condition of watershed as high rainfall erososivity (*R*-factor), soil erodibility (*K*-factor) factor and Topography (*LS*-factor). Traditional soil conservation were applied by farmer in Sumani Watershed but there are need research to determine appropriate land use pattern to minimize erosion in the area and keep farmers income.

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