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Soil Erosion Prediction Using GIS and RUSLE: Study at Sampean Watershed

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ABSTRACT

Soil Erosion Prediction Using GIS and RUSLE: Study at Sampean Watershed (A Faisol and Indarto): Erosion is one factor that cause soil degradation in Indonesia. RUSLE (*Revised Universal Soil Loss Equation*) is widely used to predict average annual rate of soil erosion. This research integrate the Revised Universal Soil Loss Equation (RUSLE) and Geographic Information System (GIS) to predict potential soil erosion losses. Study was conducted at Sampean Watershed where located in Eastern part of East Java. Firstly, GIS layer was obtained from available database that cover East Java Province. All treatment of GIS layer was done using Mapwindows GIS. Furthermore, RUSLE method was used to predict rate of soil erosion from GIS layer treated previously. Results showed that up to 82% (102,921 ha) area of the watershed have tolerable soil erosion rate.

Keywords: Erosion, Geographical Information Sistem, RUSLE, Sampean watershed

INTRODUCTION

Soil erosion is one of main factor that stimulate soil degradation. Land management and land exploitation for different land use (agriculture, urban settlement, industries, etc.) were sometimes less consider the soil conservation practice that acceletared the damage. USLE (Universal Soil Loss Equation) was presented primarily by Wischmeier and Smith (1978). USLE is applied around the world and upgraded by RUSLE (Revised Universal Soil Loss Equation) (Milward and Mersey 1999; Stone and Hillborn 2002; Lorito and Vianello 2006). Furthermore, RUSLE method has been widely used around the world as practical tool to predict rate of soil erosion. Development of GIS (Geographic Information System) (Burrough 1986; Sutopo 1999) and possible integration with RUSLE accelerates the use of this practical tool for prediction of soil erosion. This study integrated GIS and RUSLE to estimate rate of soil erosion in the watershed. In this case, Mapwindow was used as a platform for GIS treatment of the data.

MATERIALS AND METHODS

Study Site

Study was conducted during 2008, at Sampean Watershed (±700 km^2). The watershed was located in Eastern part of East Java Province (Figure 1).

GIS layer and other data used for this study were provided from Database available at Research Centre for Water Resources Development, Research Institute, University of Jember.

Research Procedure

Research was conducted by integrating GIS and RUSLE using flowchart as shown in Figure 2. Pincipal steps were: (1) preparation of input layer, (2) calculation component factor of RUSLE, and (3) overlaying and finishing.

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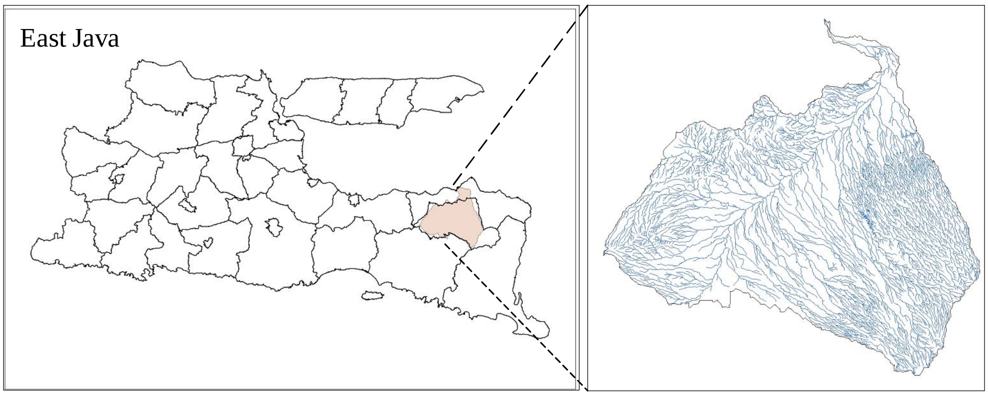

Figure 1. Study site: Sampean Waterhsed.

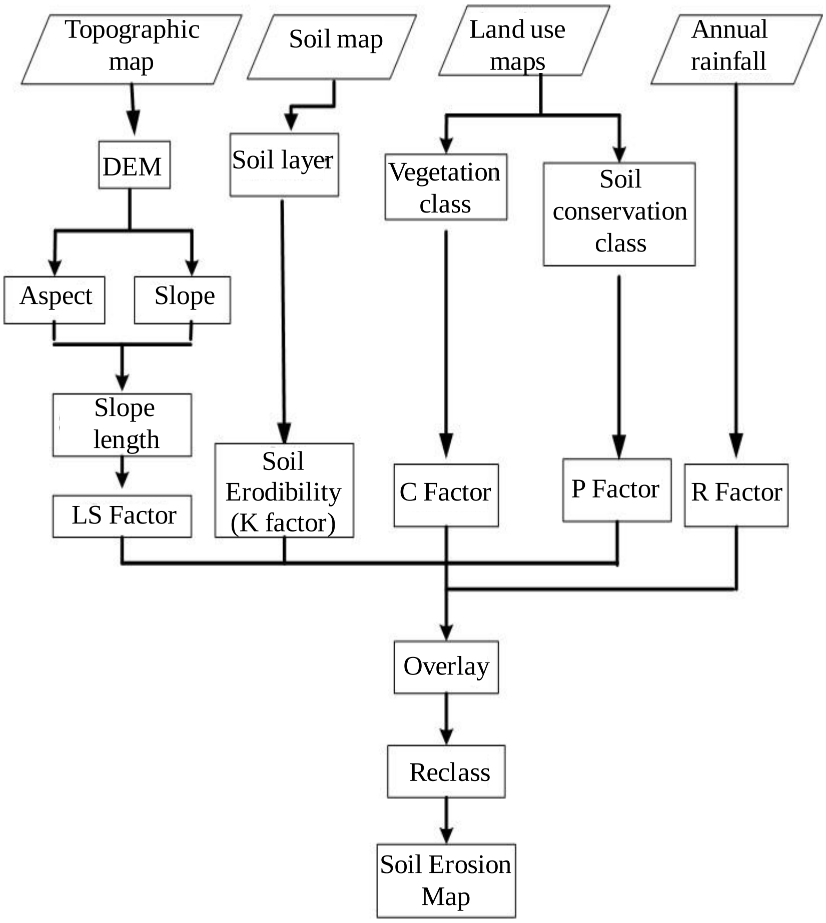

Figure 2. Flowchart of research procedure.

Preparation of Input Layer

All input layers needed to provide the principal data (*e.g.*: DEM (Digital Elevation Model), soil and land use map) were imported from database to Mapwindow GIS. Then, those layers were clipped by watershed boundary layer.

Firstly, DEM was used to represent topographical properties of the watershed. DEM is derived from existing layers (contour map, river network, and datum). DEM is produced by means of CatchmentSIM Software (Ryan and Boyd 2003; Ryan 2005a; 2005b; 2005c). The pixel resolution of DEM was 18m x 18m. This resolution was supposed suffi-

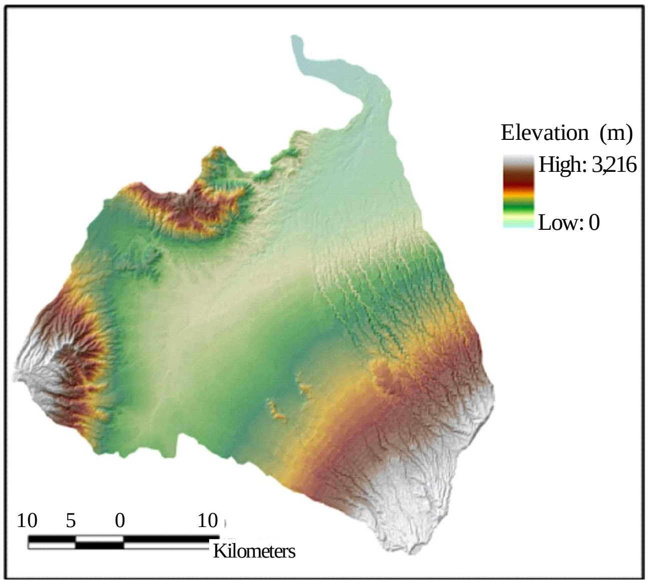

Figure 3. DEM (resolution of 18m x 18m).

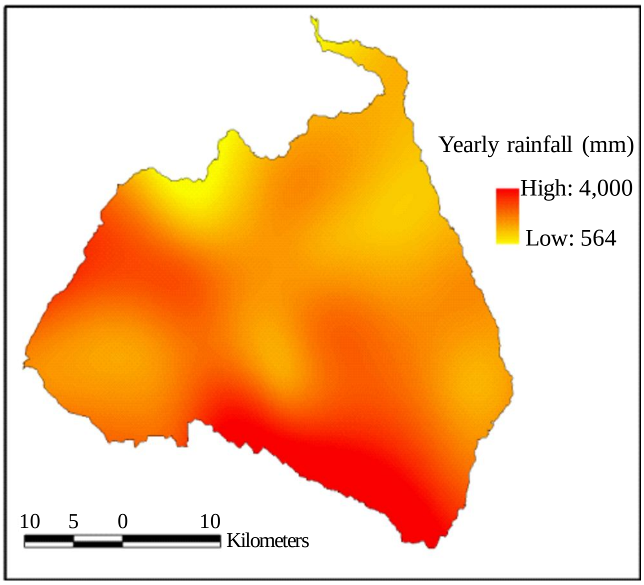

Figure 4. MAR map.

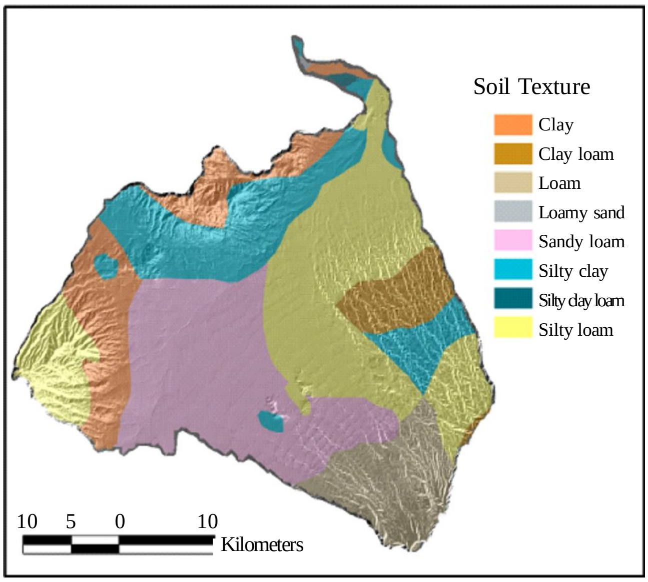

Figure 5. Soil class texture.

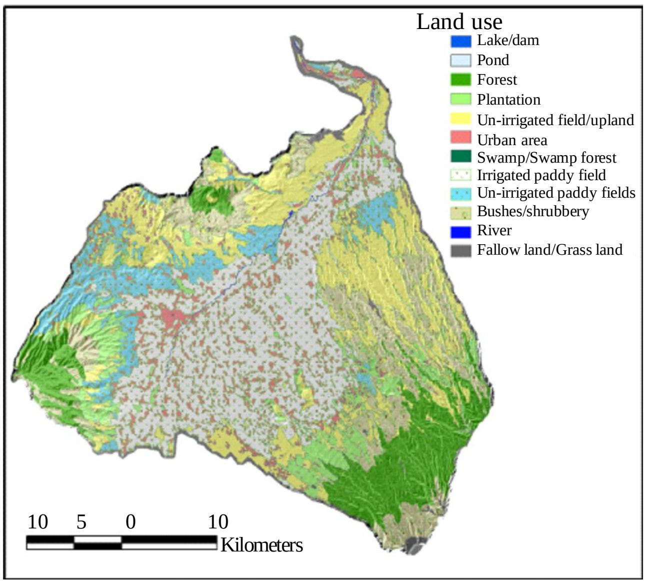

Figure 6. Land use map.

cient to describe topographical properties of the whole watershed area (that extend up to 700 km^2). Classified topographical map (Figure 3) was visualized from DEM.

Secondly, mean-annual-rainfall (MAR) map of the watershed (Figure 4) was created by interpolating rainfall data from 22 pluviometers around the watershed. Then, simple interpolation method based on Inverse Distance Weighed (IDW) was used. MAR data of each station was obtained by averaging annual data from the last 10 years.

Thirdly, soil texture map (Figure 5) was interpretated from exisiting soil layers. Figure 5 showed the distributuion of soil texture class that comprise of: loam, clay loam, clay, loamy sand, sandy loam, silty clay, silt clay loam, and silty loam.

Finally, land use map (Figure 6) is interpretated from digital RBI (*Rupa Bumi Indonesia*) map. Main nomenclatures of land use in the watershed were: irrigated paddy field; and non-irrigated paddy field; plantation; forest; and urban area.

Table 1. Different parameter setting between USLE and RUSLE.

Parameter	USLE	RUSLE
R	Based on long-term average rainfall conditions for specific geographic areas in the U.S.	Consider average rainfall from many countries of the world, and therefore more global
K	Based on texture, organic matter and other factor depend on soil type	Same as USLE but adjusted by considering climate variability, soil moisture dan soil consolidation.
LS	Based on length and slope of terain, without considering land use	Upgraded from USLE using new equation that consider slope and rill to interrill erosion
C	Based on cropping sequence, surface residue, surface roughness, and canopy cover, with are weighted by the percentage of erosive rainfall during the six crop stages. Lumps these factors into a table of soil loss ratios, by crop and tillage scheme.	Uses the subfactors: prior land use, canopy cover, surface cover, surface roughness, and soil moisture. Refines USLE by dividing each year in the rotation into 15-day intervals, calculating the soil loss ratio for each periode Recalculates a new soil loss ratio every time a tillage operation changes one of the subfactors.
P	Based on installation of practices that slow runoff and thus reduce soil movement. P factor values change according to slope ranges with some distinction for various ridge heights	Based on hydrologic soil groups, slope, row grade, Bridge height, and the 10-year single storm erosion index value.

(Source: Renard *et al.* 1994).

Table 2. Soil erosion rate calculated using RUSLE.

Soil erosion rate ($Mg\ ha^{-1}\ year^{-1}$)	Class	Area (ha)	Percentage (%)
0 – 9	Tolerable	102,921	82.2
9 – 50	low	14,769	11.8
50 – 200	moderate	6,720	5.4
200 – 1,000	high	783	0.6
1,000 – 11,579	Very high	63	0.1
Total		125,256	100

Calculation of RUSLE Component Factor

Principally, there is no different in model structure between RUSLE and USLE. Equation 1 is used by the two models.

$$A = R \times K \times LS \times C \times P$$

Where:
A = Soil loss ($Mg\ ha^{-1}\ y^{-1}$)
R = Erosivity factor ($MJ\ mm^{-1}\ ha^{-1}\ h^{-1}\ y^{1}$)
K = Erodibility factor ($Mg\ h^{-1}\ MJ^{-1}\ mm^{-1}$)
LS = Slope-length index
C = Land management index
P = Conservation index

The differences between RUSLE and USLE are mentioned on the determination of parameters value as shown in Table 1.

Overlaying and Finishing

The last step is conducted by overlaying all necessary layers, according to RUSLE equation.

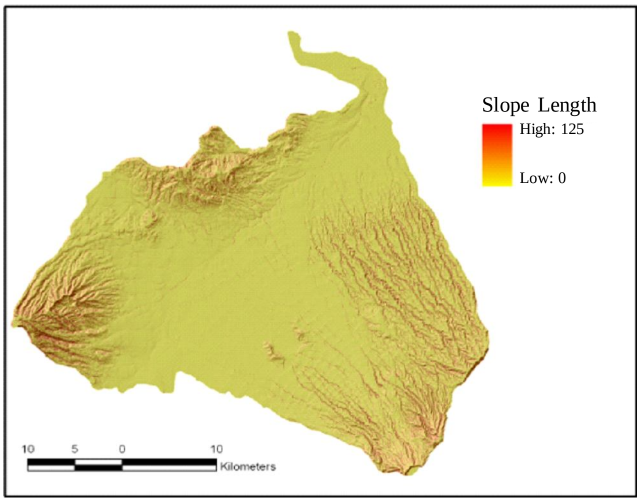

Figure 7. Slope length indice.

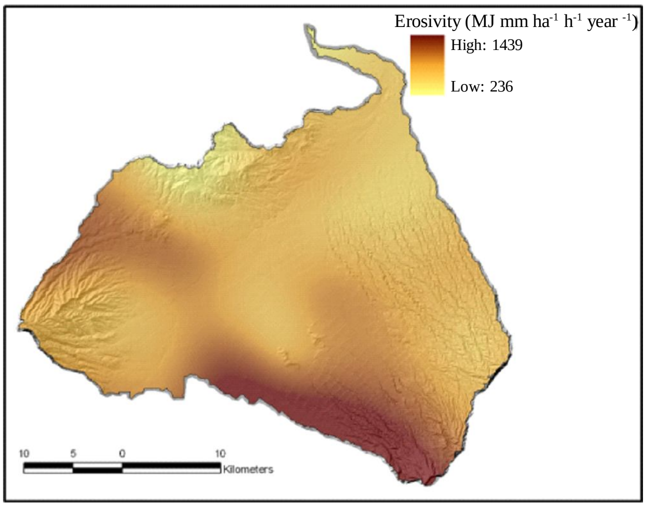

Figure 8. Soil erosivity indice.

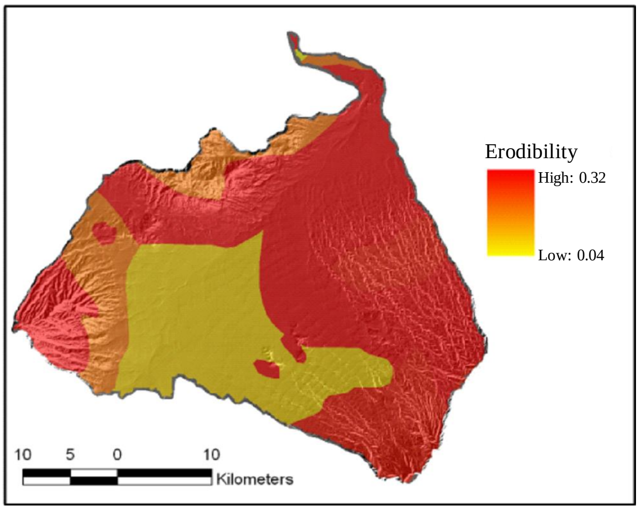

Figure 9. Erodibility indice.

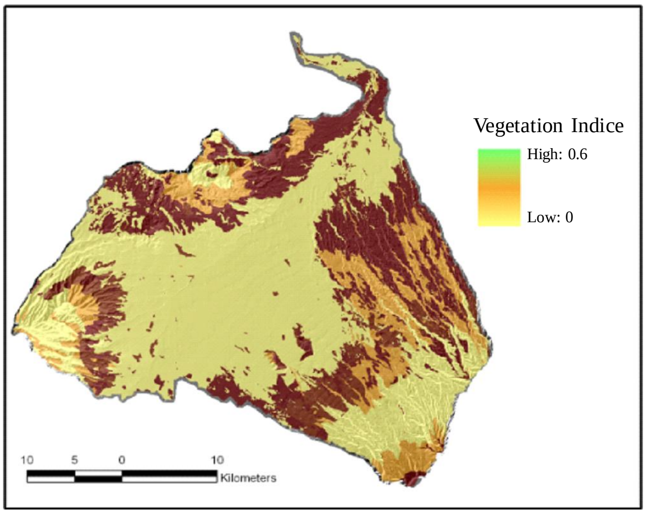

Figure 10. Land management indice.

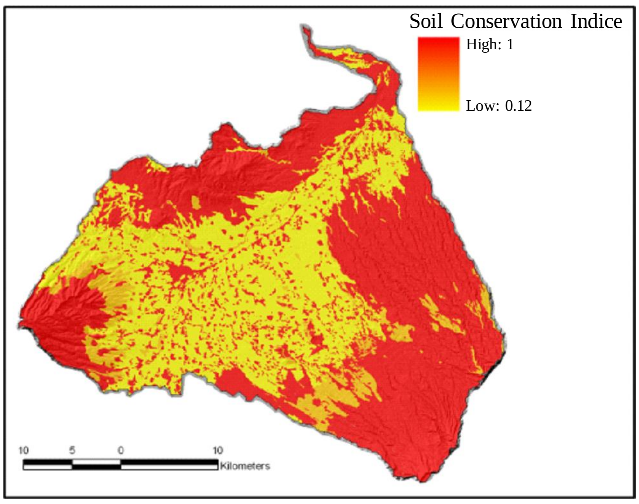

Figure 11. Soil conservation indice.

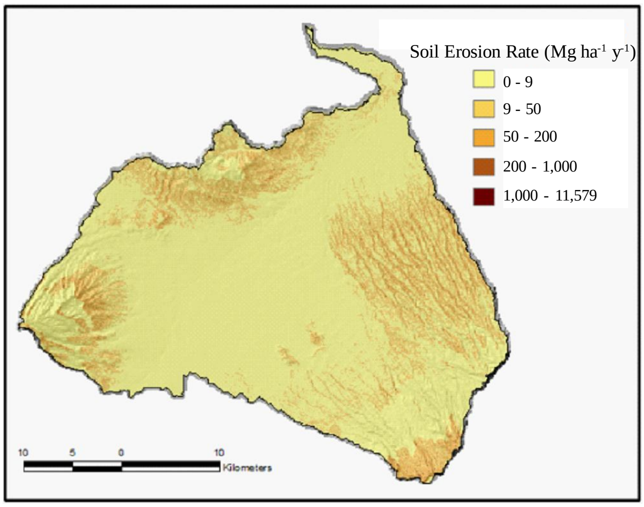

Figure 12. Soil erosion rate.

RESULT AND DISCUSSION

Slope-length indice (Figure 7) was derived from DEM. This indice showed the influence of watershed topographic to the rate of erosion procces. Rainfall erosivity indice (Figure 8) showed the influence of rainfall factor to erosion. This indice was derived from MAR map. Soil erodibility indice (Figure 9) was derived from soil texture map. This indice measure the resistancy of soil agregat dan soil particles subject to rainfall force. Land management indice (Figure 10) described influence factor generated by land management and land use practices, *e.g.*: vegetation, mulch, soil cover, and soil tillage. This indice derived from land use map. Soil conservation indice (Figure 11) showed how soil conservations were applied on the watershed.

Table 2 compared percentage of classified soil erosion rate (form low to very high) of all area in the watershed and Figure 12 shows the map of soil erosion rate around the watershed calculated by RUSLE method.

Result showed that up to 82% (102,921 ha) area of the watershed having tolerable soil erosion rate. Furthermore, up to 11% of watershed area was subjected to low erosion rate and about 5.4% of the watershed area was considered at moderate level of soil erosion rate. The result also showed that only 0.7% of watershed area was classified to high level of soil erosion rate.

CONCLUSIONS

This article shows how GIS and RUSLE can be integrated to predict soil erosion rate at the whole watershed area. From this study, it can be concluded that most of the watershed area was still toloreable to soil erosion rate according to existing regulation decree *(Peraturan Pemerintah No 150 Tahun 2000 tentang Kriteria Baku Kerusakan Tanah pada Lahan Kering).*

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