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Direction for Land Conservation Based on Determining the Erosion Hazard Index (EHI) Using the RUSLE Method in Sub-Watersheds Gunting, Jombang

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ABSTRACT

The Kali Gunting sub-watershed has land use dominated by forest and plantation land in the upstream part and settlements in the downstream area. The slope of the upstream area is quite steep, and changes in land use result in the land losing its ability to infiltrate, which causes river water discharge to become very high. Changes in land use in the Kali Gunting subwatershed cause soil erosion. The research was conducted in the Kali Gunting Sub-watershed in Wonosalam Regency, Jombang, East Java, from January 2021 to April 2023. The research locations included several villages, namely Galengdowo, Distance, Wonomerto, Sambirejo, Wonosalam, Carangwulung, Panglungan, Wonokerto and Sumberrejo. Meanwhile, the analysis of soil samples was carried out at the Land Resources Laboratory I and II, Faculty of Agriculture, National Development University "Veteran" East Java. Determination of the Erosion Hazard Index (EHI) is carried out using the RUSLE method. The study findings indicate that the EHI in the very low category is present in the villages of Carawangwulung, Distance, Wonokerto, Sumberejo, Wonosalam, Wonomerto, Galengdowo, Sambirejo, and Panglungan. Maintaining annual plants, adding organic mulch derived from leftover twigs and leaves, converting conventional terraces into bench terraces, and putting in place a Ground Water Conservation Area system are some ways to control the pace of erosion. Additionally, bench terraces can be built in place of the conventional terrace conservation land in the Sambirejo and Wonokerto Districts.

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1. Introduction

Population growth is directly proportional to land requirements. The pressure on land requirements causes the amount of land use to exceed the carrying capacity of the land itself, resulting in soil exhaustion and land damage (Anasiru & Tilongkabila, 2015). The Ministry of Environment (2019) stated that until 2011, the eastern region of Java Province had a land area of 1,271,194,490 ha, which was declared to be at a critical potential level. Increasing the status of critical land is possible if the land still needs to be processed or rehabilitated. Land is a physical environment that includes soil, climate, relief, hydrology, and vegetation; these factors mutually influence its potential use, including factors resulting from human activities, both past and present. The Kali Gunting sub-watershed has land use dominated by forest and plantation land in the upstream part and settlements in the downstream area. The slope of the upstream area is quite steep, and changes in land use result in the land losing its ability to infiltrate, which causes river water discharge to become very high. Changes in land use are a serious factor related to the problem of soil erosion. Changes in land use in the Kali Gunting subwatershed, which should have been a protected area, have become an area for cultivating seasonal crops and residential areas, causing soil erosion.

The most common cause of soil deterioration is erosion brought on by precipitation running off the land's surface. The slope of the ground and the rainfall in a region are directly correlated with erosion. An environmental issue that, if ignored over time, can lower soil fertility is soil erosion (Sansakila, 2015). Human activities cause a high erosion rate by using hilly land intensively, thus triggering the emergence of critical watershed areas (DAS). Surface erosion can be grouped into four types, namely: 1. splash erosion, 2. sheet erosion, 3. Rill groove erosion; 4. Gully erosion (Gallo *et al*., 2023).

The Erosion Hazard Index (EHI) controls erosion in certain locations. Predictions of erosion in the Wonosalam area can be done directly or indirectly. Several erosion prediction models, including the RUSLE (Revised Universal Soil Loss Equation) method, can be used. RUSLE is used to estimate the amount of erosion due to surface water flow in annual units on a certain stretch of area with a slope with plants and using certain land management systems. The RUSLE model is an empirical model that incorporates many advances in the computation of different components while using empirical principles equivalent to the USLE model (Kumar & Kushwaha, 2013). The five factors that make up the RUSLE model are rain erosivity (R), soil erodibility (K), slope lengths (L), slope (S), and land management (CP). These parameters are used to forecast the erosion related to runoff. The USLE and RUSLE formulas use the same equation but differ in the slope segment. While the slope phase is used in the RUSLE, the macro slope is used in the USLE. There are variations in the way the slope length (L) and slope (S) parameters are calculated in the implementation (Asdak, 2010).

Based on the research results of Nugraheni *et al*. (2013). It contains a comparison of erosion rate predictions using the USLE, MUSLE, and RUSLE models; it is known that the RUSLE model approaches almost the same value as the results of previous research. There has been no erosion mapping using the RUSLE method, and there has yet to be an update regarding erosion mapping that occurs in the Kali Gunting subwatershed, considering that land use has the potential to change every year. Based on these conditions, this study examines the level of erosion hazard that occurs in existing land conditions and land use directions by land capability classes in the Kali Gunting Sub-watershed.

2. Methodology

The research was conducted in Wonosalam District, Jombang Regency, from January 2021 to April 2023. Sampling and field data collection activities were conducted in the Sub-watershed Gunting Wonosalam District, Jombang, East Java, which is located at 112˚21'05" to 112˚23'22" East Longitude and 07˚44'59" to 07˚40'01" South Latitude. The research locations include several villages, namely Galengdowo, Jarak, Wonomerto, Sambirejo, Wonosalam, Carangwulung, Panglungan, Wonokerto and Sumberrejo. Meanwhile, soil sample analysis activities were conducted at the Land Resources Laboratory I and II, Faculty of Agriculture, Pembangunan Nasional University "Veteran" East Java.

Materials used in the research include an administrative Map of the Wonosalam District Land Use Map obtained from Ina-Geoportal Jombang Regency, a Slope Map of Wonosalam

District from a Digital Elevation Model (DEM) data processing with a scale of 1:25.000, a land cover map; and daily rainfall data was obtained from the Power Data Access Viewer site.

The tools required for research include Soil sampling tools consisting of a field knife, sample ring, shovel, plastic bag, rubber band, writing tool, and label; observation tools at the research location include; compass, altimeter, clinometer, rope meter, and GPS; soil analysis tools in the field, namely the Munsell Soil Color Charts book and tools for mapping and inputting secondary and primary data, namely a laptop with ArcGIS 10.3, Google Earth and Microsoft Office 2010 software.

The research uses a survey method to collect data by reviewing and making direct observations in the field. The determination of sample points was done using purposive sampling based on the distribution of slope categories referring to the slope map. Data collection is done to support the implementation study. The data needed covers:

1. Monthly rainfall data from Power Data Access Viewer was calculated using the Polygon Thiessen method to evaluate erosivity.
2. Data type land from shpfile by USDA (United States Department of Agriculture) and soil characteristics data were obtained with take sample land use ring sample.
3. Slope data from field observations using a clinometer for determination mark LS (Land Slope)

Data management plant and action conservation land from the results land cover analysis obtained from Google Earth with process digitization image landsat. Besides That, we also analyzed the density of NDVI vegetation (band four and band 8 Landsat 8 or Sentinel 2A). These data are used to determine mark factors C and P.

2.1 Calculation of the Amount of Erosion Using the RUSLE Method

RUSLE is an erosion model designed to calculate the possibility of soil being lost due to being washed away by runoff water due to sloping land in a certain area over a long period (years) in a certain cropping and management system (Hanafi & Pamungkas, 2021). As for calculations used to determine the quantity erosion on method RUSLE, as follows:

$$A = R \cdot K \cdot L \cdot S \cdot C \cdot P$$

Note:

A = Amount land lost (ton/ha/year)
R = Erosivity rain
K = Erodibility land
L.S = Long and Slope
C = Management plants
P = Action conservation

2.1.1 *Rainfall Erosivity Factor (R)*

Rainfall erosivity factor is parameters that indicate the erosion process and direct repair (conservation) efforts using existing erosion prediction models (Yue, Juying, Bingzhe, Binting, & Hang, 2020). The equation used to calculate rainfall erosivity is as follows:

$$Rb = 2,21 . p^{1.36}$$

Note:

Rb = Erosivity Rainfall monthly
P = Rainfall Monthly (cm)

2.1.2 *Soil Erodibility Factor (R)*

Soil erodibility is a form of resistance of soil particles to movement due to kinetic energy from rainwater, which is influenced by the shape of the land surface, degree of slope and human disturbance. Soil type is verified during field surveys to validate against existing values (Machiwal *et al*., 2015). Qualitative classification of soil types refers to Munsell's book and the National Soil Classification Technical Guide book published by the Agricultural Research and Development Agency in 2014. The soil erodibility factor in the RUSLE model is obtained by the following equation:

$$100K = 2.1M^{1.14} (10^{-4}) (12 - a) + 3,25 (b - 2) + 2,5 (c - 3)$$

Note:

K = Soil erodibility
M = (percentage of dust and very fine sand) (100 – percentage of clay)
a = Percentage of organic
b = Value of soil structure
c = Value of solid permeability level

2.1.3 Length and Slope Factor (LS)

The length and slope are formulated as a function of the length factor value and the slope. Slopes are divided into 2, that is <9% and ≥9%. The LS calculation is presented below:

$$LS = L \times SL;\ L = (1/22.1)\ m$$
$$S = 10.8 \sin a + 0.03\ i \text{ for } s < 9\%$$
$$S = 16.8 \sin a - 0.5\ i \text{ for } s \geq 9$$

Note:

LS = Length and Slope factor
L = Length factor
I = Long slope

2.1.4 *Crop Management Factors (C)*

Crop management shows comparative figures regarding the amount of soil eroded in regularly planted areas with and without crops. The level of erosion is said to be low if the soil surface is protected by food plants or other vegetation. The lowest C value is 0,001 for undisturbed forest areas, while the highest is 1,0 for land without plants.

2.1.5 *Conservation Action Factor (P)*

Conservation is carried out by adjusting land conditions. P factor mapping must be detailed using aerial photography or surveys. The P factor data is recorded by dividing new land based on the length and slope to be further divided based on ground cover vegetation (C factor)

2.2 Erosion Hazard Index (EHI)

The erosion hazard index (EHI) compares the amount of erosion that will endanger the sustainability of soil productivity and the erosion that is allowed or erosion directly proportional to soil formation. EHI is calculated using the formula:

$$EHI = A/T$$

Note:

A = Amount of soil lost (ton/ha/year)
T = Tolerated erosion (yon/ha/year)

3. Results and Discussion

3.1 Calculation of the Amount of Erosion Using the RUSLE Method

The RUSLE method calculates the amount of soil lost due to significant surface water flow. Calculating erosion rate predictions using the RUSLE model is known to provide more consistent results than the USLE and MUSLE models. (Nugraheni *et al*., 2013).

3.1.1 *Precipitation Erosivity (R)*

A recapitulation of monthly regional rainfall for five years (starting from 2017-2021) with eight rain gauge stations for the Gunting Sub-watershed rain gauge area shows that the highest rainfall is at the Bareng, Jatirejo, Mojoagung, Pujon and Wonosalam stations with an average of 828,11 mm/year. This high rainfall could increase the amount of erosion at this location. The higher the intensity of rain, the higher the rate of erosion. The large number of raindrops that fall to the ground surface can increase the kinetic energy provided, thereby increasing the potential for destroying soil aggregates. (Sitepu, Selintung, & Harianto, 2017). Erosivity is also called the ability of rain to create erosion. The calculation of the erosivity of rainfall at the research location is obtained from the sum of the rainfall monthly in the station area every month. The results of erosivity are in Table 1, with the area erosivity being as big as 967,03.

Table 1. Average Erosivity Region Study Period 5 Years

Month	CH (cm)	Erosivity
January	100,99	1175,41
February	23,21	159,14
March	14,93	87,34
April	20,74	136,53
May	46,47	409,06
June	91,40	1026,24
July	106,62	1265,42
August	76,67	808,14
September	90,63	1014,60
October	126,02	1588,43
November	131,95	1690,97
December	162,42	2243,10
Average Rb	967,03	

3.1.2 *Soil Erodibility Factor (K)*

Soil erodibility is the nature of the soil's sensitivity to erosion or whether the soil is easily affected by erosion. Soil that shows high sensitivity has a high erodibility value, which means that more soil is lost when it rains (Wang *et al*., 2020). This difference in sensitivity is related to the soil's different physical and chemical properties, so soil types have different sensitivity levels. Several parameters taken into account to assess soil sensitivity include the percentage of dust and sand fraction, coarse sand, soil structure class, permeability class, and soil organic matter content.

Table 2. Erodibility Value of Research Location

Sample code	Texture %					O %	SSC	PC	E value	Classification
	Coarse sand	Fine sand	Very fine sand	Silt	Clay					
GD (Galengdowo)	1,68	6,24	1,98	19,68	70,42	3,20	3	3	0,08	VL
J.R (Jarak)	5,52	14,65	2,82	60,78	16,24	2,78	2	3	0,46	H
WM (Wonomerto)	0,28	3,27	1,56	56,29	38,60	2,25	3	4	0,37	SH
SR (Sambirejo)	0,94	6,39	2,14	51,52	39,02	2,95	3	5	0,31	M
WS (Wonosalam)	1,30	3,60	2,07	50,91	42,11	3,09	3	4	0,22	M
CW (Carang Wulung)	16,44	20,77	3,58	49,12	10,09	5,93	3	3	0,11	L
PL (Panglungan)	0,47	5,11	1,76	59,46	33,20	3,23	3	2	0,34	SH
WK (Wonokerto)	0,28	3,27	1,56	56,29	38,60	2,25	3	4	0,37	SH
SB (Sourcerejo)	0,48	5,29	1,54	34,20	58,48	3,17	3	5	0,16	L

Information: O = Organic Material; SSC = Soil Structure Code; PC = Permeability Code;E = Erodibility; VL = Very Low; L = Low; M = Medium; SH = Slightly High; and H = Height.

Table 2. shows that the percentage of texture at the research location is dominated by dust, with organic material values ranging from 1,95% - 5,93%. The highest erodibility value is found in the WM (Wonomerto) sample code with a value of 0,54. In contrast, the lowest erodibility value is found in the GD (Galengdowo) sample code with a value of 0,08. The cause of high erodibility values could be due to the low clay content and organic material. According to Arsyad (2010) The formation of soil aggregates is related to the content of organic matter and clay, so soil types with clay content below 35% are generally sensitive to erosion. Supported by Liu & Han (2020) who explained that the sensitivity of soil to erosion is supported by the high content of very fine sand and dust. Ashari (2013) stated that soil erodibility is influenced by soil structure and organic matter content. In addition, rough soil texture and slow soil permeability also increase erodibility.

The erodibility value can be reduced if the soil contains organic elements, according to research by Dewi *et al*., (2015) who stated that the presence of organic elements on the soil surface could reduce erosion because of its ability to inhibit the speed of runoff water. Another role of organic elements is to improve soil structure by increasing its permeability, water-holding capacity and soil fertility.

3.1.3 *Length and Slope Factor (LS)*

Table 3. Value L.S Location Study

Code Sample	Slope (%)	Slope slope length (m)	sin	S	L	L.S (%)
GD (Galengdowo)	0,097	8,78	0,10	1,13	0,63	0,71
J.R (Jarak)	0,045	5,50	0,04	0,52	0,50	0,26
WM (Wonomerto)	0,025	5,50	0,02	0,30	0,50	0,15
SR (Sambirejo)	0,147	7,78	0,15	1,96	0,59	1,16
WS (Wonosalam)	0,066	11,35	0,07	0,74	0,72	0,53
CR (Carang Wulung)	0,041	3,28	0,04	0,47	0,39	0,18
PL (Panglungan)	0,080	8,00	0,08	0,89	0,60	0,54
WK (Wonokerto)	0,025	12,80	0,02	0,30	0,76	0,23
SB (Sourcerejo)	0,035	6,18	0,03	0,41	0,53	0,22

The observation results in Table 3 show that the LS value at the research location is 0,15%–1,16%, where the lowest LS is in the WM (Wonomerto) sample code, and the highest is in the SR (Sambirejo) sample code. Topographic elements, which include the length and slope, are used to find the value of soil volume loss during erosion (Putera, Efrida, & Pasaribu, 2018). land with a high slope has a low water holding capacity because it is influenced by gravity, which causes the water flow to be high. The higher the slope of the land, the higher the gravity of water compared to land with a low slope. Soil that cannot hold water is also caused by soil conditions, which have few fine pores where water is stored

3.1.4 *Crop Management Factors (C)*

Soil with a vegetated surface or containing food plants is known to have good protection against erosion. Determination of the C value in this study was adjusted to the RTkRHL-DAS Guidelines in Table 4

Table 4. Land Management Factor Values (C) Research Locations

Code Sample	Type	C grade
GD (Galengdowo)	Plant plantation coffee land closed with good (coffee, elephant grass)	0,1
J.R (Jarak)	Plant plantation (sigh) land closed with good	0,1
WM (Wonomerto)	Plant plantation (durian) land in close with meeting	0,1
SR (Sambirejo)	Plant plantation (sigh, snake fruit) ground closed with meeting	0,1
WS (Wonosalam)	Plant plantation (sigh) land closed with good	0,1
CW (Carang Wulung)	Plant plantation (coffee) land closed with good	0,1
PL (Panglungan)	Plant plantation (pine, coffee) land closed with good	0,1
WK (Wonokerto)	Plant plantation (banana, elephant grass) land closed with good	0,1
SB (Sourcerejo)	Plant plantation (sigh) land closed with good	0,1

The research results in Table 4 show that all management factor values (c) at the research location are 0,1. Land use at the research location is plantations with dense soil cover. Soil vegetation can act as a barrier to damage to the soil surface due to pressure from falling rainwater. The type of vegetation affects the protection provided because it adapts to the density and height of the vegetation. The speed of water flow is lower when on land with dense vegetation than on land with trees. At a tree height of more than 7 meters, water that falls to the ground will have greater energy because it is trapped in the leaves and branches, so larger droplets are collected (90% of the original energy) (Hardjowigeno & Widiatmaka, 2015). Efforts can be made to maintain the speed of erosion by maintaining annual plants and adding organic mulch from remaining twigs and plant leaves.

3.1.5 *Conservation Action Factor (P)*

Table 5. Mark Technique Conservation Land (P) Location Study

Code Sample	Technique Conservation Land	P Value
GD (Galengdowo)	Contour cropping slope 8-15%	0,6
JR (Jarak)	Contour cropping slope 15-25%	0,8
WM (Wonomerto)	Terrace bench, medium	0,15
SR (Sambirejo)	Terrace traditional	0,4
WS (Wonosalam)	Contour cropping slope 3-8%	0,5
CW (Carang Wulung)	Contour cropping slope 3-8%	0,5
PL (Panglungan)	Contour cropping slope 8-15%	0,6
WK (Wonokerto)	Terrace Traditional	0,4
SB (Sourcerejo)	Contour cropping slope 3-8%	0,5

Observing the P value at the research location shows that all sample points received soil conservation technique treatment (Table 5). Soil conservation techniques to reduce erosion can be done mechanically by forming slope terraces. Farmers generally use terrace construction because it is considered more effective than without any treatment. The sloping bench terrace type (leaning out) is used in some sample codes even though this type is considered less than optimal. Using medium and perfect bench terraces (sloping inward) is better because planting along the slope can increase erosion, and water can easily flow to the surface without obstructions. Pasaribu *et al*., (2018) stated that efforts to anticipate or minimize the erosion rate need to be conserved; for example, planting with the lane cuts across a slope or in a direction with contour lines. Apart from that, selecting the type of plant has a small factor (C) value so that it can reduce the erosion rate.

3.2 Erotion Hazard Index (EHI)

Table 6. Classification of EHI and TBE at Research Locations

No	Code Region	EHI	Classification EHI	Classification TBE
1	GD (Galengdowo)	0,09	Very Low	Low
2	J.R (Jarak)	0,26	Very Low	Very Low
3	WM (Wonomerto)	0,04	Very Low	Low
4	SR (Sambirejo)	0,31	Very Low	Very Low
5	WS (Wonosalam)	0,14	Very Low	Very Low
6	CW (Carang Wulung)	0,04	Very Low	Very Low
7	PL (Panglungan)	0,30	Very Low	Very Low
8	WK (Wonokerto)	0,09	Very Low	Very Low
9	SB (Sourcerejo)	0,05	Very Low	Very Low

Observation results show that the erosion index in the Gunting Sub-watershed is low, ranging from 0,04 to 0,31 tons/ha/year (Table 6). Anggraini *et al*., (2019) stated that what needs to be done when the erosion index value is high is to control it to prevent damage in the future.

All of the locations in this research are mixed gardens in forests with good and dense land cover. Mixed gardens consist of annual plant components such as sengon and seasonal plants such as durian and coffee. Planting of sengon is one of the conservation efforts because, according to Pasaribu *et al*., (2018) planting of annual plants can be carried out to block water flow on the surface and prevent landslides because of the strong plant roots. Additionally, conservation efforts can be carried out by adding mulch from plant residues from hedgerows, leaves, and twigs to the research area. Nugroho *et al*., (2017) explain that plant residue mulch is an organic plant residue material that can improve fertility, reserves and soil structure. Mulch is also believed to inhibit weed growth and buffer soil temperature so that the soil temperature is not too hot or cold. Installing mulch is also an effort to attract soil biota such as worms so that with their excretions, worms can act as soil structure improves.

Locations with traditional terrace management, such as in the Sambirejo and Wonokerto districts, can also be replaced with bench terraces. The speed of water flow will be greatly hampered so that soil damage will be minimal if the area uses the bench terrace method. Supported by Lathifah & Yunianto (2013) who stated that one way to compensate for large erosion in high-slope areas is to enforce ground cover vegetation and tall trees as barriers to water runoff. Changes in the forest land area at the research location can be overcome by applying the Groundwater Conservation Area technique. Nugroho *et al*., (2017) believe that creating water catchments is quite effective in restoring the function of soil and water. This technique is carried out by specializing in certain areas, such as rainwater harvesting areas (absorption areas), so that these areas remain empty without processing or development. This conservation requires areas with high infiltration and that are free of pollutants.

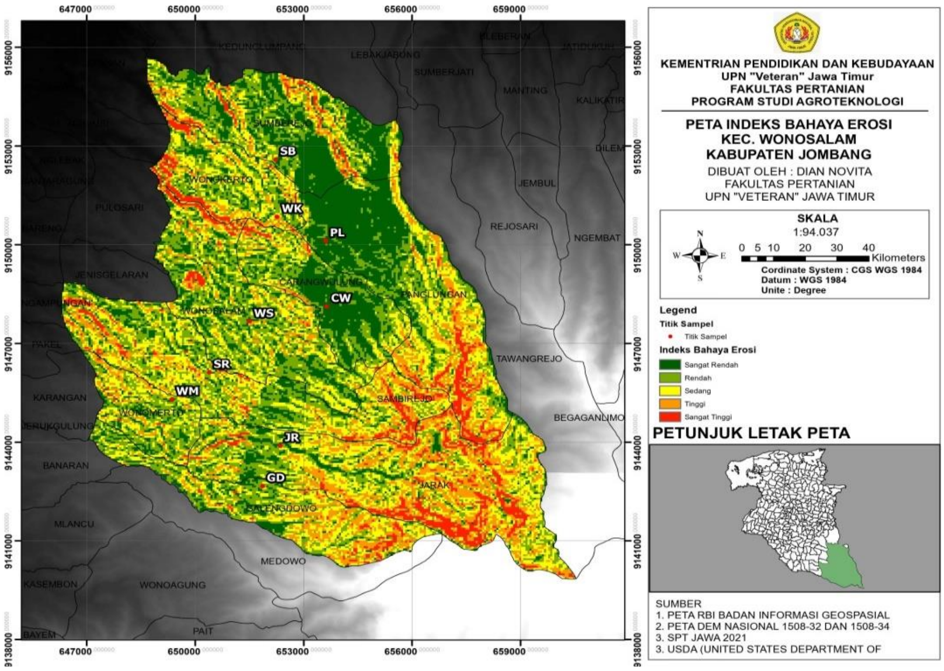

Figure 1. Map of the Erosion Hazard Index (EHI) RUSLE Method for Wonosalam District

4. Conclusion

The villages of Carawangwulung, Jarak, Wonokerto, Sumberejo, Wonosalam, Wonomerto, Galengdowo, Sambirejo, and Panglungan, Wonosalam subdistrict are categorized in the extremely low category according to the EHI classification of the RUSLE technique. Maintaining annual plants, adding organic mulch derived from leftover twigs and leaves, converting conventional terraces into bench terraces, and installing a groundwater conservation area system are all ways to slow down the erosion rate.

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