Erosion Prediction Analysis and Landuse Planning in Gunggung Watershed, Bali, Indonesia

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Abstract. The purpose of this research is to predict the erosion that occurs in Gunggung watershed and sustainable landuse management plan. This research used the USLE (Universal Soil Loss Equation) methodology. The method used observation / field survey and soil analysis at the Soil Laboratory of Faculty of Agriculture, Udayana University. This research is divided into 5 stages, (1) land unit determination, (2) Field observation and soil sampling, (3) Laboratory analysis and data collection, (4) Prediction of erosion using USLE (Universal Soil Loss Equation) method, (5) The permissible erosion determination (EDP) then (6) determines the level of erosion hazard based on the depth of the soil, as well as the soil conservation plan if the erosion is greater than the allowed erosion, and (7) determining landuse management plan for sustainable agriculture.

Erosion which value is smaller than soil loss tolerance can be exploited in a sustainable manner, while erosion exceeds allowable erosion will be conservation measures. Conservation action is the improvement of vegetation and land management. Land management like improvements the terrace, addition of organic matter, increase plant density, planting ground cover and planting layered header system will increase the land capability classes. Land use recommended after management is mixed plantation high density with forest plants, mix plantation high density with patio bench construction, seasonal cultivation and perennial crops, cultivation of perennial crops and cultivation of seasonal crops.

Key words: erosion prediction; land use planning; watershed

1. Introduction

Watershed according to Law No. 7 Year 2004 on the Watershed is a land area that is a unity of ecosystem with river and its tributaries, which functions to accommodate, store, and drain water from rainfall to the lake or naturally occurring sea, whose boundaries on land constitute topographical separators and boundaries at sea up to waters areas that are still affected by land activities. Watersheds consist of upstream, middle and downstream. Upper river basin ecosystems are an important part because they have a protection function for all parts of the basin. This protection in terms of water system functions, upstream and downstream areas have biophysical linkages through the hydrological cycle [1]. Watershed has specific characteristics and is closely related to its physical conditions such as soil type, land use and topography. Land use change in the upstream will also affect the downstream area in the form of decreasing the reservoir storage capacity or silting of river and irrigation channels which in turn may increase the potential of flooding.

Optimal and well-managed watershed conditions will support all activities and businesses in the region. Conversely, poor management will cause damage to the watershed. The rapid deterioration of watersheds affected by the land use change and poor land use planning will increase the danger of erosion that occurs in the watershed. The occurrence of floods, landslides, droughts and high erosion is a sign of damage to the watershed. Erosion causes the loss of fertile soil layers for plant growth and reduced soil's ability to absorb and retain water. Land carried by erosion is deposited in some places such as reservoirs, lakes or irrigation channels. This sediment will cause silting in river bodies, reservoirs or irrigation canals. This condition will increase overland flow and flood hazard.

Damage to the watershed includes damage to the biophysical or water quality aspects. Watershed damage will occur faster if the community is not aware of the importance of maintaining and preserving the surrounding environment. Besides the role of the very large community, the government's role in the formation of regulations that pay attention to the preservation of natural environment will also affect the rapid slowdown of the watershed that occurred. The rapid degradation of the watershed is influenced by the number of buildings that do not pay attention to river borders, cutting trees without a selective cropping system, planting seasonal crops on sloped lands above 45% of these measures will increase the erosion hazard occurring in the watershed. The occurrence of floods, landslides, droughts and high erosion is a sign of damage to the watershed. Erosion is the event of moving or transporting soil or parts of the land from one place to another by natural media [1]. Factors that affect erosion are climate, topography, plants, soil and humans. Factors that can be controlled by humans are plants while climate and topography are directly not controlled by humans and for land can be controlled indirectly by certain processing [2].

Watershed damage caused by erosion can be minimized by taking conservation action. Soil conservation measures are aimed at preventing erosion, repairing damaged soil, and maintaining and improving soil productivity so that land can be used sustainably. Water conservation in principle is the utilization of rainwater that falls to the ground for agriculture to be used as best as possible, and regulate the flow time in order to avoid devastating floods and there is enough water in the dry season. The way that can be done is to give mulch to the cultivated plants whose area has high rainfall and make a rainwater reservoir in areas that have low rainfall. Every treatment given on a plot of land will affect the water system in that place and places - Downstream. So that all soil conservation measures are also water conservation measures [1].

Conditions of watersheds in Bali have decreased in quality, this is happening in some areas in Bali which experiencing floods, droughts, landslides and land degradation. Land degradation is caused by the erosion. Land will gradually reach critical level until very critical. The Gunggung watershed is an upstream of the Jinah Watershed and is included in the Oos Jinah river basin, which has a function and an important role in supporting the water needs of the Bangli and Karangasem Regency. Gunggung watershed which covers 727,278 ha passes 3 villages namely Menanga, Pempatan and Abang Batu Dinding village which located in Karangasem and Bangli Regency. Gunggung watershed has an area of 12.98% of the area of the Jinah basin. The area of the Gunggung watershed which is estimated to have a large erosion is the area that has a slope of 30-45% and greater than 45%.

Erosion research in Gunggung Watershed is focused on how to estimate the erosion rate and to cope with erosion by using best practice of landuse planning. Therefore this paper aims to predict erosion hazard at the Gunggung Watershed and to develop sustainable landuse planning to give contribution in soil conservation practice related to erosion hazard in Bali and Indonesia

2. Methodology

Erosion is the result of the interaction between function of climate, topography, vegetation and human to soil which expressed in the following equation: $E = f (i, r, v, t, m)$, while E: The magnitude of erosion; i: Climate; r: topography; v: plants; t: ground; m: man. These factors can be distinguished

into two factors, factors that can be controlled by humans and factors that cannot be controlled by humans. Factors that can be controlled by humans are vegetation; while climate and topography are directly not controlled by humans. Meanwhile land can be controlled indirectly by certain processes [2].

Erosion measurements and forecasting are difficult to do, because the processes that affect erosion are complex. Based on several assumptions and simplifications, the measurement and forecasting of erosion can be done at a reasonable level of confidence [3]. The most widely adopted equation of erosion values in Indonesia is Universal Soil Loss Equation (USLE) proposed by Wischmeier and Smith [1].

The USLE method is a fairly practical method because the required parameters are easy to obtain and free to change depending on space and time. This method combines the main factors causing erosion and its quantitative relationship to predict the soil loss from sheet and flow erosion caused by rain and surface flow in a particular area [4]. The USLE method equation is:

$$E = R*K*LS*CP$$

With A = Erosion or loss of land per unit of land area; R = rainfall Erosivity;
K = Erodibility of soil; L = Length of slope; S = slope;
C = Cropping/ farming method; P = Method of land management

The soil loss tolerance needs to be calculated as it is impossible to suppress erosion rates to zero on land cultivated for agriculture, especially steep soil. In principle, the soil loss tolerance is the rate of erosion that occurs does not exceed the rate of soil formation so there is still a top layer as a place to grow plants. the factors considered in determining the value of EDP is the depth of soil, physical characteristics and other soil properties that affect root development, prevention of trench erosion, depletion of organic matter, nutrient losses, and problems caused by sediment in the field [1].

If the erosion exceeds the rate of soil formation then conservation is needed. Soil conservation is the placement of each plot of land on the appropriate use of the soil's capability and treats it in accordance with the conditions required to avoid soil damage. Soil conservation methods are measures or treatments or facilities that can be used to prevent soil damage or to repair damaged lands. Soil conservation methods are basically divided into three groups, namely (1) vegetative methods, (2) mechanical methods, and (3) chemical methods. The vegetative method is the use of plants or residuals. Included in the vegetative method are tree planting, grass planting, crop rotation, mixed cropping, and use of plant or crop residues such as mulch and green manure. The mechanical method is the development of erosion prevention and manipulation of soil and earth surface structures. Including in the mechanical method is the processing of soil according to contour, planting and processing according to contour, planting in strips, making of bunds, terrace, channel switch, drainage channel, check dam and gully plug. Chemical methods in soil and water conservation are the use of synthetic or natural chemical preparations. Certain organic compounds can improve the aggregate stability of water effectively, but the materials used are still too expensive to be widely used [1].

2.1. Research Location

Gunggung watershed is located between UTM zone of 50 South and coordinates of 3024000 mE; 9079000 mS until 302600 mE; 9079000 mS and 3024000 mE; 9072000 mS until 3026000 mE; 9072000 mS. Gunggung watershed past 3 villages namely Abang Batu Dinding Village, Pempatan Village and Menanga Village in Banglidan Karangasem Regency, Province of Bali, Indonesia with total area of Gunggung Watershed is 727,278 ha.

2.2. Methodology

The method used in this study was field survey/ observation and data collection using field observation, then the result is analyzed at the laboratory of Soil Science and Environment, Faculty of Agriculture of Udayana University. The research stage is divide into7 stages: , (1) land unit determination, (2) Field observation and soil sampling, (3) Laboratory analysis and data collection, (4) Prediction of erosion using USLE (Universal Soil Loss Equation) method, (5) The tolerable erosion determination (EDP) then (6) determines the level of erosion hazard based on the depth of the soil, as well as the soil conservation plan if the erosion is greater than the allowed erosion, and (7) determining landuse management plan for sustainable agriculture. The flow diagram is shown in Figure 1.
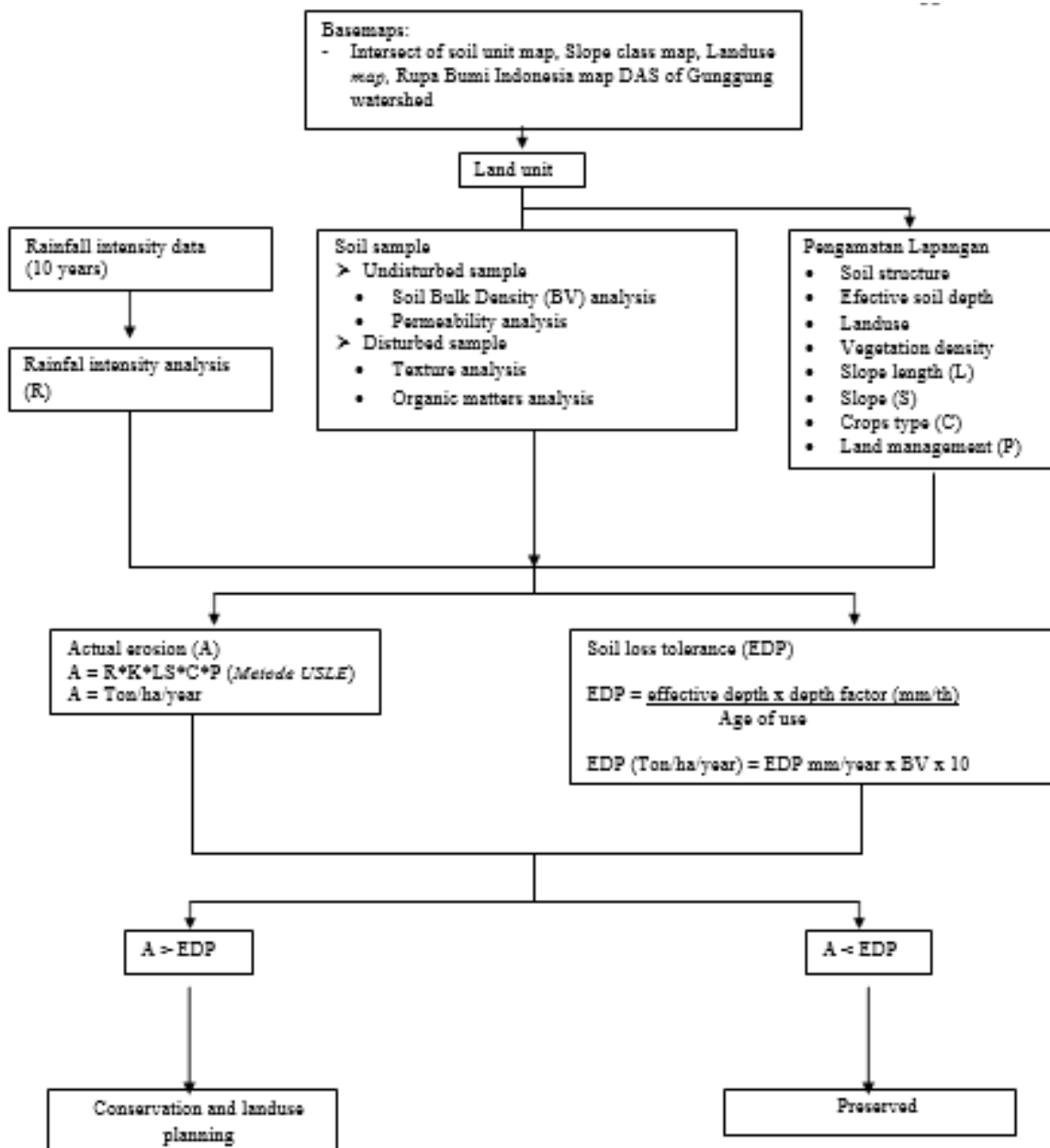

Figure 1. Research Diagram

The main aspect to be concerned is the tolerable erosion (EDP). If Actual erosion is more than EDP then conservation and landuse planning must adopted. If actual erosion is less than EDP then the recent soil condition and landuse practice can be preserved. In order to maintain the productivity of the soil, erosion that occurs should be lower than the tolerable soil loss [5]. The erosion process also brings about a loss of soil quality, and one of the ways of minimizing and even correcting the consequences of erosion is the adoption of conservationist practices [6].

2.2.1. Land units

The determination of land units is based on overlays on the soil type, slope classes and land use using QGIS software. From the overlay results obtained 17 units of land. Land unit that has the same class of slope, soil type and land use is grouped into 1 land unit. Each soil sample will represent one land unit. Full description presented in Table 1. Figure 2 shows the land unit map of Gungung Watershed

Table 1. Land Unit of Gunggung Watershed

Land Unit	Soil Type	Slope	Landuse
1	Regosol	>45%	Plantations
2	Regosol	30 – 45%	Plantations
3	Regosol	15 – 30%	Plantations
4	Regosol	8 – 15%	Moor
5	Regosol	0 – 8%	Moor
6	Regosol	30 – 45%	Plantations
7	Regosol	30 – 45%	Moor
8	Regosol	15 – 30%	Plantations
9	Regosol	15 – 30%	Moor
10	Regosol	8 – 15%	Plantations
11	Regosol	8 – 15%	Moor
12	Regosol	0 – 8%	Plantations
13	Regosol	>45%	Bush / scrub
14	Regosol	30 – 45%	Bush / scrub
15	Regosol	15 – 30%	Bush / scrub
16	Regosol	8 – 15 %	Bush / scrub
17	Regosol	0 – 8%	Bush / scrub

2.2.2. Field Observation and Sampling

The parameters observed in the field are
a. Length of Slope (L): measured from the tip of the slope to the change of slope shape.
b. Slope (S): measured using abney level
c. Soil Structure: observed by type of soil structure.
d. Effective Depth: searchable with a soil drill.
e. Dominant vegetation and vegetation density (C): observed visually
f. Land Management (P): observed field management of the field.
g. Ground sanding for texture analysis, permeability and soil organic matter.
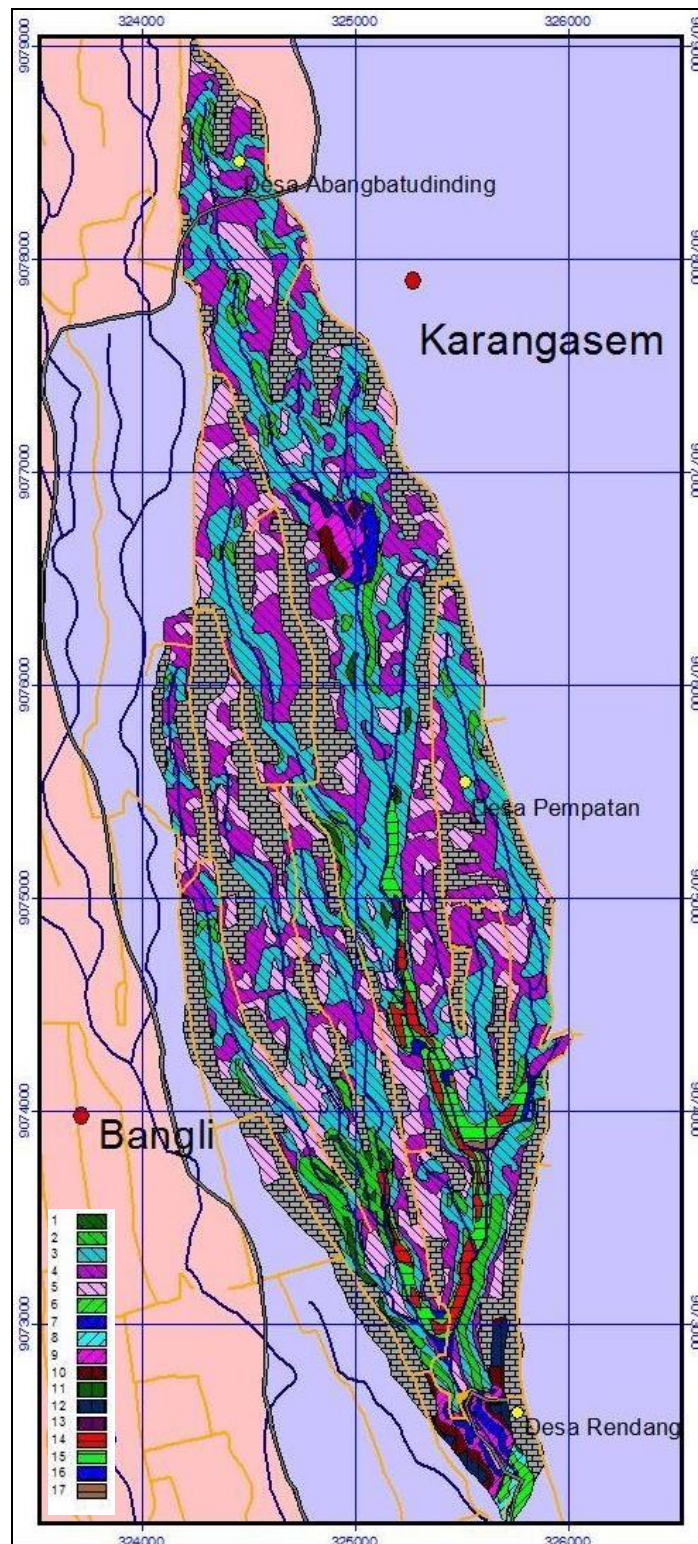
Figure 2. Land Unit Map

2.2.3. Soil Analysis

Soil analysis conducted in Soil and Environment laboratory of Faculty of Agriculture of Udayana University is land permeability, soil volume weight, soil texture analysis, and organic matter. Detailed soil analysis methods are presented in Table 2.

Table 2. Detailed Soil Analysis

No	Parameter	Methods	Unit	Equation
1	Permeability	De Booth method	cm/hour	$K = \dfrac{Q}{t} X \dfrac{L}{h} X \dfrac{1}{A}$ K = permeability Q = The amount of water flowing at each measurement t = Observation time (hour) L = soil thickness (cm) h = Surface water level from surface of soil sample (cm)
2	Soil texture	Pipet method	%	-
3	Organic matter	Walkey and Black method	%	$x = \dfrac{(B-A)N\,FeSO4\,x\,3}{\dfrac{100}{100-KL} X Berat\,tanah\,(g)} \; x\,10\,x\,\dfrac{100}{77}\,x\,100\%$ B = Blangko A = Sample KL = Soil moisture
4	Bulk volume	Ring Sampel method	gr/cm^3	Bulk volume(pb)= $\dfrac{Z}{A}$ Z = dry soil wight(gr) A = Volume (cm^3)

2.2.4. Erosion Prediction

The effects of processes is modified by biophysical environmental comprising soil, climate, terrain, ground cover and interactions between them. Susceptibility of soil to agents of erosion, soil erodibility, is determined by inherent soil properties, e.g, texture, structure, soil organic matter contents, clay minerals, exchangeable cations, water retentions and transmissions properties. Soil erodibility is a dynamic property and influenced by management [7]. The prediction of erosion (E) on this research will use the USLE (Universal Soil Loss Equation) as follows:

$$E = R*K*LS*CP$$

1) Rainfall factor (erosivity) (R)

As the primary means of water input to landscapes, rainfall can exert a significant influence on erosion. Precipitation is characterized by amount, duration, intensity (i.e., amount/ duration) and sequence (i.e., the order and timing of rainfalls). Rainfall intensity is usually the most important of the four factors affecting erosion. As intensity increases so does the kinetic energy of the raindrops, increasing detachment and transport of soil. The intensity and size of raindrops are important because the force of raindrop impact can compress or collapse soil pores and detach soil particles, which can further plug soil pores and increase runoff. Climate change models predict that the earth will experience more intense storm events, resulting in greater erosion rates [8]. Erosivity is influenced by environmental factor primarily climate including drop size distribution and intensity of rain, amount and frequency of rain, runoff amount and velocity, and wind velocity. Another non climate environmental factor affecting erosivity is chemical reaction leading to solusional weathering [7]. The R value represents the destructive force of rain or the erosivity of the yearly rain that can be calculated by the Bols equation [1].

$$R = 6,119 \, (RAIN)^{1,21} \, x \, (DAYS)^{-0,47} \, x \, (MAXP)^{0,53}$$

R   = Monthly rain intensity
RAIN   = Average monthly rainfall (cm)
DAYS   = Number of rainy days per month (days)
MAXP   = maximum rainfall for 24 hours in the month (cm)

2)   Soil Erodibility (K)

The soil erodibility value indicates soil sensitivity to erosion. The soil erodibility is affected by structure, texture, organic matter, and soil permeability. Soil intensity can be measured using the Wischmeier and Smith equations [1].

$$100K = 1,292 [2,1M^{1,14} (10^{-4})(12-a) + 3,25 (b-2) + 2,5 (c-3)]$$

K   = Ground Erodibility
M   = The percentage of very fine sand and dust (diameter (0,1 - 0,05) and (0,05 - 0,02) x (100 -% clay).
a = Percentage of organic matter
b = Soil structure
c = Soil permeability class

To use the above equations, soil analysis data is needed, sand percentage (2.0 - 0.10mm), percentage of very fine sand (0,10 - 0,05mm), percentage of dust (0,05 - 0,002mm), clay percentage Less than 0.002mm), percentage of soil organic matter, soil structure and soil permeability.

The soil structure in this research are divided into four types with different weight values, the types are very fine granular (<1mm), Fine granular (1 - 2 mm), medium until coarse granular (2 - 10mm) and block, blocky, plat, massif structure. The values are from 1 to 4. The soil structure value is presented in Table 3 [1].

Soil structure influences the ease with which it can be eroded. Soils with medium to fine texture, low organic matter content, and weak structural development are most easily eroded. Typically these soils have low water infiltration rates and, therefore, are subject to high rates of water erosion and the soil particles are easily displaced by wind energy [9].

Table 3. Soil Structure

Soil structure (diameter size)	Code
Very fine granular (<1mm)	1
Fine granular (1 - 2 mm)	2
Medium until coarse granular (2 - 10mm)	3
block, blocky, plat, massif	4

Meanwhile soil permeability is divided into six types with different values and wight. The types are very slow permeability, slow permeability, slow to medium permeability, medium permeability, medium to fast permeability and fast permeability. Soil permeability type is presented in Table 4.

Table 4. Soil Permeability

Permeability Class	Permeability (cm/hour)	Code
Very slow	< 0,5	6
Slow	0,5 -2,0	5
Slow - medium	2,0 - 6,3	4
Medium	6,3 -12,7	3
Medium - fast	12,7 - 25,4	2
Fast	>25,4	1

3) Slope Factor (LS)

As the slope increases, so does the probability that splashed soil will move downslope. On sloping land, there is usually net transport of soil downslope because displaced soil can travel further downhill than uphill due to gravity and slope angle [8]. LS is the ratio between the amount of erosion of a plot of land with the length of the slope and a certain steepness to the magnitude of soil erosion. Erosion rates are high especially on marginal and steep lands which have been converted from forests to agriculture to replace the already eroded, unproductive cropland [10]. The LS value of a soil can be calculated by the following equation:

$$LS = \sqrt{} \ x \ (0{,}0138 + 0{,}00965s + 0{,}00138s2)$$

Description: x is the length of the slope in meters and s is the steepness of the slope in percent.

4) Crops Management Factors (C) and Land Management (P)

Land areas covered by plant biomass, living or dead, are more protected and experience relatively little soil erosion because raindrop and wind energy are dissipated by the biomass layer and the topsoil is held by the biomass. For example, in Utah and Montana, as the amount of ground cover decreased from 100% to less than 1%, erosion rates increased approximately 200 times [10].

Land cover greatly affects the amount of erosion that occurs. The CP value determination is done by approach between the field condition and the CP value from the Bogor Research Center [1].

5) Erosion Rate

The erosion rates in the study area according to Finney and Morgan Erosion Method are divide into 5 classes, i.e, very low, low, medium, high and very high. The volume of erosion are varies between less than 15 ton/ha/yr for very low erosion rate until > 480 ton/ha/yr for very high erosion rate. Erosion rate based on Finney dan Morgan presented in Table 5 [1].

Table 5. Erosion Rate based on Finney dan Morgan

Erosion (Ton/ha/yr)	Erosion Rate
<15	Very low
15-60	Low
60-180	Medium
180-480	High
>480	Very High

6) Soil Loss Tolerance (EDP)

Soil loss tolerance is the tolerable rate of erosion in order to maintain a sufficient depth for the growth of a plant and not to exceed the rate of soil formation in order to enable high productivity in a sustainable manner. To find EDP can be calculated by Hummer equation as follows:

$$Edp \text{ (mm/ yr)} = \text{(effective soil depth x depth factor)/ soil use age}$$

$$EDP \text{ (ton/ha/yr)} = EDP \text{ (mm/yr) x BV x 10}$$

2.2.5. Landuse Planning

Soil erosion, in particular, is regarded as one of the major and most widespread forms of land degradation, and, as such, poses severe limitations to sustainable agricultural landuse [11]. Landuse planning in this research was conducted by comparing the amount of erosion occurring and the amount of erosion that can be allowed on a particular land. If the permissible erosion is less than the predicted erosion, conservation measures need to be taken by improving the C and P values so that the erosion can be minimized.

To make it easier to choose the soil conservation method, calculated the maximum CP value to know what the maximum CP value in the soil conservation action planning is done so that the erosion is less than the permissible erosion.

3. Results and Discussions

3.1. Erosion Analysis

Rain erosivity result based on calculations using the Bols equation obtained that rain erosivity value ranged from 46.15 to 613.63. The lowest monthly rainfall erosivity occurred in August while the highest monthly rainfall erosivity occurred in January. The value of annual rain erosivity at Rendang station was 3045,40 ton / ha / cm of rain, annual rain erosivity in research location is high because of the high average of rainfall which reach 268,15cm / year. Based on the Oldeman's classification [9] monthly rainfall in the research area is included in the climate type D3. Climate type D3 shows that wet months occur 3 to 4 times consecutively in 1 year and dry months 4 to 6 times in a row. This type of climate suggests that the crops growth only able for once-time rice or one-time crops per year depend on water availability in the area.

The value of erodibility is the soil sensitivity to erosion, the higher the K value the higher the erosion occurs. Based on the calculation of soil erodibility value with the formula of Wischmeier and Smith [1] soil erodobility value in the study area ranged from 0.03 to 0.36. The value of this erodibility is categorized into very low values up to high erodibility. Very low soil erodibility values occur in land unit 2; 17, low erodibility occurs in unit 1; 3; 4; 5; 6; 8; 9; 13; 14, medium erodibility is occurring on land unit 10; 11; 12; 15; 16 and high value of erodibility occurred in land unit 7.

The value of erodibility is influenced by organic matter, composition of sand, dust, clay, structure and permeability value. The value of soil erodibity is rather high due to the high percentage of dust. Dust is easily transported by falling rainwater, so that the dust will close the soil pores and will increase surface flow. The increase in surface flow will increase the erosion that occurs. Land that has a dominant texture of sand, the possibility of erosion is small because sand allows a large infiltration and reduce overland flow. Soil that has a high organic element tends to improve soil structure so that the water holding capacity is high and able to reduce erosion. The granular soil structure allows the rain water to infiltrate the soil so that the surface flow is reduced. The permeability of the research area is very rapid, affecting the rapid flow of infiltrated water.

The length of slope factor and slope steepness (LS) affects the surface flow and the amount of erosion, among the most influential is the slope of the slope. The research area has a slope length of 12 m to 38 m, while the slope of the slope is around 5% to 57%. Wischmeier and Smith's equations indicates that the LS scores of the study areas ranged from 0.39 to 19.55. Lowest LS value on unit 12 and LS highest on land unit 13. The determination of plant management factor values and

conservation measures is done by matching the situation in the field with the CP value of the soil research center. Land use in the research area is mostly mixed farming and some land is used as moor with poor conservation measures. Table 6 present the erosion rate in Gunggung Watershed.

Table 6. Erosion Analysis at Gungung Watershed

Land Unit	R	K	LS	CP	A (ton/ha/yr)	EDP (ton/ha/yr)	TE	Soil Depth (cm)	TBE
1	3045.4	0.13	18.28	0.04	289.48	19,903	B	70	SB
2	3045.4	0.03	8.68	0.12	95.16	22,300	S	100	S
3	3045.4	0.14	3.79	0.20	323.18	28,437	B	90	SB
4	3045.4	0.13	1.47	0.28	162.95	35,680	S	90	B
5	3045.4	0.14	0.69	0.28	82.37	33,345	S	100	B
6	3045.4	0.14	9.45	0.12	483.49	28,627	SB	95	SB
7	3045.4	0.36	5.98	0.28	1835.72	39,930	SB	110	SB
8	3045.4	0.15	2.31	0.12	126.63	27,467	S	80	B
9	3045.4	0.15	3.17	0.28	405.46	19,947	B	55	SB
10	3045.4	0.22	1.43	0.20	191.62	20,453	B	65	SB
11	3045.4	0.21	1.78	0.28	318.74	29,093	B	80	SB
12	3045.4	0.30	0.39	0.20	71.26	33,843	S	87	B
13	3045.4	0.20	13.62	0.12	995.48	24,320	SB	80	SB
14	3045.4	0.20	6.18	0.12	451.69	34,033	B	100	B
15	3045.4	0.22	3.56	0.12	286.22	24,547	B	70	SB
16	3045.4	0.24	2.04	0.12	178.92	25,982	B	85	SB
17	3045.4	0.06	0.92	0.12	20.17	41,873	R	110	R

TE: erosion rate based on Finney dan Morgan method, TBE :erosion hazard level based on the Erosion Hazard Classification method[1]; SR : Very low; R : Low; S : Medium; B: High; SB : very High;

The level of erosion occurs in the study area from low to very high. A low erosion rate occurs on land unit 17, the cause of the low rate of erosion is the low value of soil erodibility. The low soil erodibility value indicates that the soil is not easily eroded, also the area that tend to be flat causing greater infiltration. Medium erosion rate is happening on land unit 2; 4; 5; 8 and 12 because it is influenced by the value of vegetation and land management. Vegetation in the unit is a mixed vegetation with a very low density. Vegetation, which is less stratified and less dense, causing the erosion tend to occur because least canopy that able to block the rain drops to the ground. Rain that directly fall at soil surface will damage the soil aggregate and makes it more easily to be carried away by the overland flow. High erosion rate occurs in land unit 1; 3; 9; 10; 11; 14; 15 and 16 with the slope condition that affect the amount of erosion that occurs. Steep and long song slopes in these land units cause faster overland flow so aggregates of soil are quickly carried away by overland flow and become erosion. Very high erosion rate occurs in unit 6; 7; and 13 caused by the vegetation condition in the land unit. The vegetation mainly are is moors, mixed vegetation with very low density and shrubs. The less dense vegetation can cause the soil to be directly hitted by rain. The direct rainfall hit on the soil will faster damage the soil aggregate and will accelerate the erosion. Besides, the high erodibility value becomes the main factor of a very high erosion rate which happened in these land units. Map of erosion rate is presented in Figure 3.
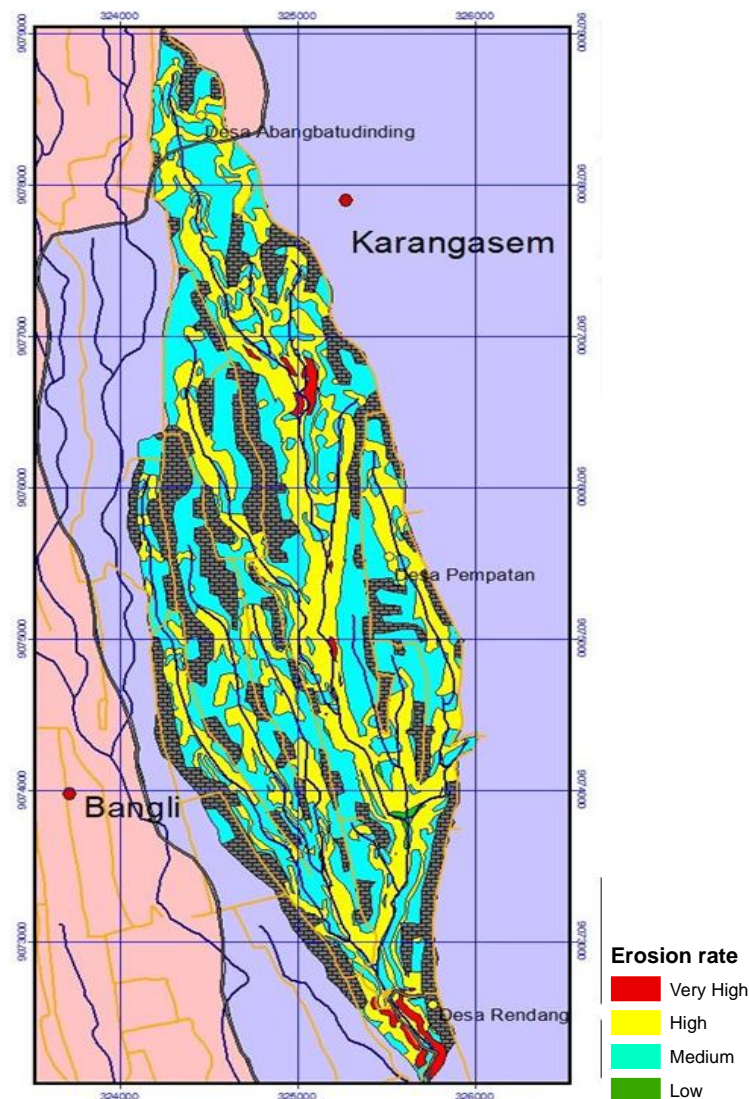
Figure 3. Erosion Rate Map

3.2. Landuse Planning

After the erosion rate calculated using the USLE equation, then it will be compared with the soil loss tolerance (EDP) in order to know the conservation measures. The land unit which erosion is smaller than the EDP is the land unit 17. Land unit 17 must be maintained properly, so that the present erosion conditions do not increase. Greater erosion value than EDP are land unit 1; 2; 3; 4; 5; 6; 7; 8; 9; 10; 11; 12; 13; 14; 15 and 16. Land units with erosion value greater than the soil loss tolerance should be given conservation measures.

Existing landuse on land unit 1 are mixed vegetation with high density, conservation measures in the form of traditional terraces. Landuse plan can be start with an improvement on the forest vegetation. Forest is recommended because in this land unit there are already has some plants with of economic value, then addition of some kind of woods with high litter will be very beneficial. The land unit 2 planning that will be improvement on the vegetation, ie the planting of a high density with mixed vegetation with a terrace of medium constructed bench. Land unit 3 existing land use is a low density mixed vegetation with a traditional terrace. Conservation planning that will be suggested is the improvement on vegetation and land management is a high density mixed vegetation with a terrace of medium constructed terrace. Land unit 4 existing landuse is moor with dominant plant of cassava with traditional terrace. Landuse planning will be intercropping cassava planting with cowpea with medium

constructed terrace. Land unit 5 with land use of moor with dominant crop is cassava and land management of traditional terrace. Landuse planning is intercropping cassava with peanut with with medium constructed terrace.

Land unit 6 existing land use is a medium density mixed vegetation with a traditional terrace. Landuse plan to be suggested is a high-density mixed vegetation with a good constructed bench porch. Land unit 7 land use is moor with dominant crop is cassava and conservation measures in the form of traditional terrace. Land use planning that will be suggested is cassava planted with cassava peanuts and ground terrace planted with peanuts. Land use of land unit 8 are mixed density medium vegetation and conservation measures in the form of traditional terraces. It will be advised for landuse and conservation planning on land unit 8 is planting vegetation in the form of high density mixed vegetation with a terrace of medium constructed bench. Existing land use of land unit 9 are moor with traditional terraces. It will be better for conservation planning to intercropping cassava with peanuts with terraces of bunds on cassava plantations.

Table 7. Conditions of Existing Landuse, Landuse Planning and Conservation

Land Unit	Existing Landuse	Landuse Plan	Conservation
1	mixed vegetation with high density, traditional terraces	community forest	high litter
2	high density with mixed vegetation	high density mixed vegetation	medium construction bench
3	low density mixed vegetation with a traditional terrace	high density mixed vegetation	medium constructed bench terrace
4	moor with dominant plant of cassava with traditional terrace	intercropping cassava planting with cowpea	medium constructed bench terrace
5	moor with dominant crop is cassava with traditional terrace	intercropping cassava with peanut	medium constructed bench terrace
6	medium density mixed vegetation with a traditional terrace	high-density mixed vegetation	a good constructed bench porch
7	moor with dominant crop is cassava	high density mixed vegetation	ground terrace with cassava
8	mixed density medium vegetation with traditional terraces	high density mixed vegetation	medium constructed bench terrace
9	moor with traditional terraces	cassava with peanuts with terraces of bunds on cassava plantations.	terraces of bunds
10	mixed low density *vegetation* with traditional terraces	high density mixed *vegetation*	medium constructed bench terrace
11	*Moor with* a traditional terrace	high density mixed *vegetation*	medium constructed bench terrace
12	mixed medium density *vegetation* with traditional terraces	high density mixed *vegetation*	medium constructed bench terrace
13	shrubs with traditional terraces	community forest	high litter
14	shrubs with traditional terraces	high-density mixed *vegetation*	good constructed bench terrace
15	bushes with traditional terraces	high density mixed vegetation	medium constructed bench terrace
16	shrub with traditional terraces	high-density mixed *vegetation*	medium constructed bench terrace
17	shrub with traditional terraces	high-density mixed *vegetation*	medium constructed bench terrace

Existing landuse of land unit 10 are mixed low density vegetation with traditional terraces, for landuse planning is high density mixed vegetation and terrace of medium constructed bench. The landuse of land unit 11 is moor with a traditional terrace. For conservation planning is a high density

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mixed vegetation with a terrace of medium constructed bench. Landuse of land unit 12 are mixed medium density vegetation with conservation measures of traditional terraces, it will be planned for high density mixed vegetation with terrace of medium constructed bench. Landuse of land unit 13 are shrubs with conservation measures in the form of traditional terraces, and it will planned for a community forest with a high litter, because this unit is on a very steep slope. Landuse of land unit 14 is bush with a traditional terrace, then the conservation plan is a high-density mixed vegetation with a good constructed bench porch. Existing landuse of land unit 15 are bushes with traditional terraces, then it will be planned with high density mixed vegetation with good constructed bench terraces. The land unit 16 is a shrub with traditional terraces, it will be good for conservation planning is a high-density mixed vegetation with a terrace of medium constructed bench. Table 7 summarizes the conditions of existing landuse, landuse planning and conservation taken.

4. Conclusions

The level of erosion occurring in the study area from low to very high. A low erosion rate caused by the low value of soil erodibility. The low soil erodibility value indicates that the land is not easily eroded. Medium erosion rate is occurring because it is influenced by the value of vegetation and land management. Mixed vegetation with a very low density, which is less stratified and less dense, causing the erosion tend to occur because least canopy that able to block the rain drops to the ground. Rain that directly fall at soil surface will damage the soil aggregate and makes it more easily to be carried away by the overland flow. High erosion rate occurs with steep and long song slopes which cause faster overland flow so aggregates of soil are quickly carried away by overland flow. Very high erosion rate caused by the vegetation condition. The vegetation mainly are moors, mixed vegetation with very low density and shrubs. The less dense vegetation can cause the soil to be directly hitted by rain. The direct rainfall hit on the soil will damage the soil aggregate and will accelerate the erosion.

5. Acknowledgement

6. References

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