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Erosion Hazard Level in Jenelata Watershed, Gowa Regency, South Sulawesi, Indonesia Based on RUSLE Model

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ABSTRACT

Erosion is the main problem that affects soil health related to agricultural activities, therefore this study aims to determine the level of erosion hazard in the Jenelata Sub Watershed. RUSLE is used to calculate erosion prediction using rainfall erosion information, soil erodibility value, topographic value and using maps for vegetation and conservation practices, so that erosion values are obtained for Buakkang, Bissoloro, Bontomanai, Jenebatu, Sapaya Village, Paranglompoa, Pattalikang, Tassese, Mangempeng, Paladigan, and Ronaloe. Each was divided into very low classes with land loss of less than 15 t/ha/year with a land area of 7812.38 ha. The low class was land loss of 15 to 60 t/ha/year with a land area of 3263.04 ha. The medium class was land loss of 60 to 180 t/ha/year with a land area of 694.76 ha. The high class was land loss of 180 to 480 t/ha/year with a land area of 3234.03 ha, and the very high class was land loss that is greater than 480 t/ha/year with a land area of 5272.67 ha. This study showed high and very high erosion with a land area of 3234.03 ha and 5272.67 ha and very low erosion with a land area of 7812.38 ha.

INTRODUCTION

Indonesia is a country that has a significant population growth rate every year. In 2010 the total population of Indonesia was 234.2 million people, which increased to 268.1 million people in 2019 (Central Bureau of Statistics, 2011; Central Bureau of Statistics, 2020). The data shows an increase in the population of 33.9 million people in 9 years with a population growth rate of 1.15% (Akasumbawa et al., 2021). The high level of population causes the dynamics of land use to change significantly, which will cause various problems such as erosion, floods, droughts, and heat waves on Earth to increase (Thomas & López, 2015). Indonesia's frequent hydrometeorological disasters are flooding and erosion (Asdak et al., 2018; Narulita & Ningrum, 2018).

Soil erosion is a significant problem affecting soil health and safety (Li et al., 2021). In addition, soil erosion causes pollution of the aquatic environment, shallowing of rivers, and intensifying floods, thereby affecting the health of ecosystems, and threatening the security of the ecological environment and human survival (Guo et al., 2021). Additionally, the degradation of soil caused by water erosion presents a range of risks to terrestrial ecosystems (Han et al., 2016; Borrelli & Panagos, 2020; Li et

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al., 2022). Furthermore, land systems and natural resources are undergoing to environmentally be depleted and deteriorated, encompassing factors such as climate change, desertification, drought, scarcity of freshwater, and the loss of biodiversity. Therefore, the process of land degradation with soil erosion is of great importance for global attention (Prăvălie, 2021).

These challenges pose significant risks in rural regions where the well-being of people is intricately tied to agriculture and livestock grazing, emphasizing the essential role of fertile land in ensuring food security. Tackling the root causes of soil erosion, halting additional land degradation, and rehabilitating areas affected by erosion emerge as primary objectives in these areas, aligning directly with the United Nations' Sustainable Development Goals aimed at eradicating poverty (UNCCD, 2019). Based on the records of the National Disaster Management Agency, Gowa Regency experienced flooding in seven sub-districts, namely Somba Opu, Bontomarannu, Pattalassang, Parangloe, Pallangga, Tompobulu and Manuju. The flood was caused by high rainfall, which caused the volume of river water to increase, resulting in flooding in the surrounding area (National Board for Disaster Management, 2019). The Gowa area is hilly, and the upper reaches of the Jenelata watershed are densely forested and have experienced significant land conversion. Hence, This research seeks to assess the level of erosion hazard in the Jenelata region.

MATERIALS AND METHODS

Geographically, the Jenelata watershed is part of the Jeneberang Watershed, which is located at 119º 34'45" - 119º 49'48" East Longitude and 05º 15'40" - 05º 25'50" South Latitude, Gowa Regency, South Sulawesi Province, Indonesia which has an area of 20276.89 ha. Administratively, the Jenelata Watershed is in the Manuju District, Bungaya District, and Bontolempangan District and is divided into 11 villages and sub-districts, namely Buakang village, Bissoloro village, Botomanai village, Jenebatu village, Parangloe village, Pattalikang village, Tassese village, Manegempeng village, and Sapaya village. The resources employed in this investigation include precipitation data spanning the previous decade (2012-2022), administrative maps, slope maps, land utilization maps, and soil classification maps.

This study utilized the Revised Universal Soil Loss Equation (RUSLE) model for its research purposes. It is one of the empirical models designed to predict the magnitude of annual erosion by runoff from sloping landscapes with vegetation (Chuenchum et al., 2020). The empirical model is developed based on valuable variables obtained from studies and observations during erosion. The equation used in the RUSLE model is still the same as the previous model, namely USLE. The RUSLE model equation, namely erosivity (R), soil erodibility (K), slope length and slope (LS), plant management (C), and soil conservation aspects (P). So that there are three stages in this research, namely: (1) The data collection stage, consisting of primary data, namely obtaining soil samples in the field, and then analyzing them in the laboratory and secondary data, namely maps and rainfall data for the last 10 years, namely 2012-2022, obtained from CHIRPS data (https://www.chc.ucsb.edu/data/chirps); (2) The stages of the research are determining land unit maps obtained from the overlay results between rainfall maps, soil type maps, land use maps, and slope maps, conducting field surveys to ensure the correctness of data (land cover and topographical factors), conducting soil sampling from the field based on land unit maps to analyze texture, organic matter content, and soil permeability in order to obtain soil erodibility values, give scores for crop factors and conservation measures based on land use maps, and calculate the amount of erosion using the RUSLE method; (3) Data analysis, each factor value that has been obtained is then calculated using the RUSLE method (Equation 1).

A = R.K.LS.C.P ....1)

Where: A represents the yearly average soil loss (t/ha/year), R signifies a rain erosion index (rain erosivity), K denotes as a soil sensitivity index to erosion (soil erodibility), LS combines a length index and slope factor, C is a plant management factor, and P refers to soil conservation measures.

RESULTS AND DISCUSSION

Most of the land use in the Jenelata watershed, Gowa Regency, was fallen into several categories, i.e. the use of secondary dryland forest land with a land area of 8259.88 ha, dryland agriculture with a land area of 5693.21 ha, rice fields with a land area of 6323.78 ha, with the type soils are Typic Eutrudepts, Fluvaquentic Endoaquepts, Typic

Hapludands, while the slopes are on a gentle to a very steep slope.

Erosivity of Rain

The average value of the rain erosivity factor (R) can be seen in Table 1. Based on the results obtained from the average erosivity of rain (R) in Table 1, the highest average erosivity of rain (R) is 1848 mm/year with a land area of 5357.62 ha, while the lowest average erosivity of rain (R) namely with a value of 1781 mm/year with a land area of 5183.09 ha. In determining the prediction of the erosion rate, the value used is the erosivity of the annual rainfall obtained from the results of calculations using the Hurni formula (1985):

$$R = - 8.12 + (0.562 \times P) \quad \text{.......................................2)}$$

Where: R is the erosivity factor and P is the average annual rainfall.

Table 1. Rain erosivity value (R)

No	Rainfall (mm/year)	Land Area (ha)
1	1,781	5,183.09
2	1,809	9,736.18
3	1,848	5,357.62
	Total	20,276.89

The erosive component of the rain (R) in the research area is rainfall information for the last ten years (2013-2022) obtained from Chrips, so rainfall values are 1781, 1809, and 1848 mm/year, with the highest rainfall. High rainfall has a high erosion rate, followed by sub-humid and semi-humid areas with a tropical rainforest climate. In contrast, the arid desert climate zone has the lowest average annual soil loss rate (Watene et al, 2021).

Rainfall factor or raindrops that fall to the soil surface with sizeable kinetic energy fall directly to the soil surface, thus destroying the soil and resulting in poor soil structure in combination with high rain received during the rainy season. These can lead to the acceleration of soil erosion and the top layer which can cause a decrease in soil organic matter and nutrients (Singh et al., 2020). Changes in land use will not only change the process of inflow of surface water but can also increase the intensity of short-duration (sub-daily) extreme rainfall (Li et al., 2020; Yang et al., 2017). The extreme rainfall is the main trigger of flooding and causes surface runoff, which can trigger erosion on a plot of land surface (Hjelmstad et al., 2021).

Soil Erodibility

Soil erodibility (K) represents the soil's susceptibility to erosion, indicating whether the soil is prone to easy erosion or not. The erodibility of soil is affected by factors such as soil texture (proportion of sand, silt, clay), soil structure, permeability, and organic matter content. In the Jenelata watershed, there are three soil types i.e. Typic Eutrudepts with a K value of 0.38, Fluvaquentic Endoaquepts with a K value of 0.04, and Typic Hapludands with a K value of 0.39. The erodibility (K) of the land area is described in Table 2 and depicted in Fig. 1.

Table 2. Area of land erodibility (K)

No	Type of soil	Land Area (ha)
1	Fluvaquentic Endoaquepts	282.64
2	Typic Eutrudepts	15,786.17
3	Typic Hapludands	4,208.06
	Total	20,276.89

Soil erodibility (K) serves as an indicator of the soil's susceptibility to erosion, specifically whether the soil is prone to easy erosion. Factors influencing soil erodibility include soil texture, structure, permeability, and organic carbon content. The soil erodibility value was calculated using the formula proposed by Wischmeier & Smith (1978), so the soil samples were taken to the research location based on the land unit map, and the samples were then analyzed in the laboratory. Based on the analysis results, the C-Organic content at the study sites ranged from 1.07% to 1.87%. Organic matter affects the soil's ability to resist erosion, and organic matter acts as a material to increase the soil's ability to hold water and increase absorption. The greater the value of soil structure, the more sensitive it will be to erosion. Soil erodibility (K) values are then compared with the table to determine the level of erodibility. Typic Eutrudepts has a K value of 0.38, and the K values of Fluvaquentic Endoaquepts and Typic Hapludands are 0.04 and 0.39, repectively. Thomaz & Fidalski (2020) argue that piracy is significant and brings it to the forefront. As a result, a leached horizon, which lacks of clay but abundant in the sand fraction, particularly fine sand, enhances the susceptibility of the topsoil to erosion.

Length and Slope (LS)

The average slope class values obtained for each land use unit were described in Table 3 and Fig. 2. Based on Table 3, the slope area in the sloping class is 1417.10 ha, the flat slope class covers a land area of 4106.05 ha the rather steep slope class occupies the land area of 7235.22 and the steep slope class has the land area of 20276.89 ha. The value of the slope class is obtained from equality with the slope class assessment (LS).

Table 3. Average Value of Slope and Slope Length (LS)

No	Slope Class	Land Area (ha)
1	Slopping	1,417.10
2	Flat	4,106.05
3	Rather Steep	7,235.22
4	Steep	7,518.49
	Total	20,276.89

The land slope was visualized using Digital Elevation Model (DEM) data processing. The greater the slope value, the higher the level of erosion that occurs compared to flat areas. Based on the results of the analysis, the average value of slope classes in the Jenelata Sub-watershed area is categorized into gentle slope classes (0-8%), flat (8-15%), rather steep (15-25%), and steep (25-45%). The topographical factor is that the slope's length and slope will affect the acceleration of runoff. The steeper the slope indicated the higher the potential for erosion, and annual soil loss on land with steep slopes are very prone to occur (Emiru Gonde & Kitila, 2022). Therefore, Implementing terrace and contour farming alongside a no-tillage or minimal tillage system (preserving ≥30% of crop residue on the surface) has the potential to lower soil erosion rates. This approach enhances the soil's physical attributes by improving groundwater infiltration, increasing soil organic matter, decreasing soil evaporation, and promoting groundwater retention (Blanco-Canqui & Lal, 2010).

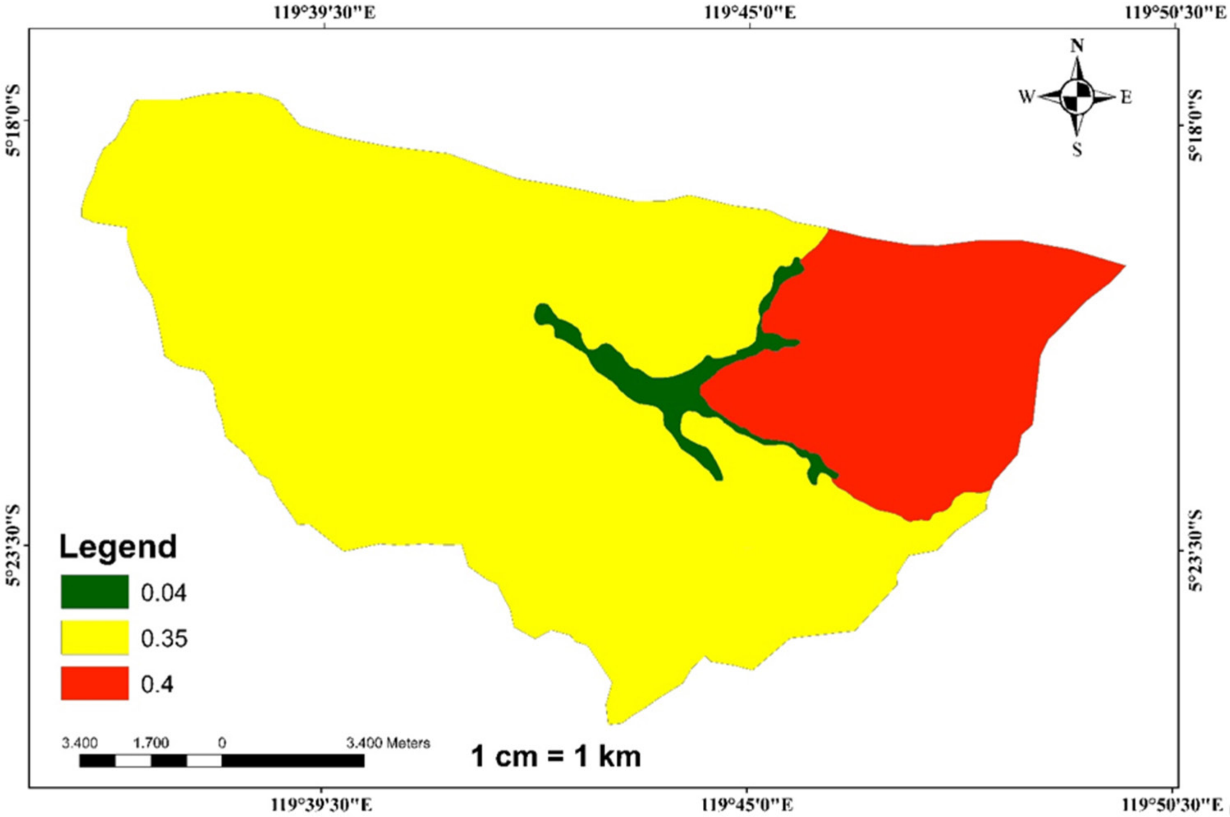

Fig. 1. Soil Erodibility (K) Map

Plant Management (C) and Conservation Measures (P)

The value of the type of plant management (C) and the value of conservation measures (P) were described in Table 4 and Fig. 3. Based on Table 4, the values of plant management factors and conservation measures were obtained from the surveys. At the research location where the conservation measures taken, the implemented conservation effort was the use of traditional bench terraces on paddy field plantation. While, in the rest on other land uses, there was no conservation measure was observed.

Table 4. Area of land use

No	Land Use	Land Area (ha)
1	Secondary Dryland Forest	8,259.88
2	Drylang Farming	5,693.21
3	Ricefield	6,323.78
	Total	20,276.89

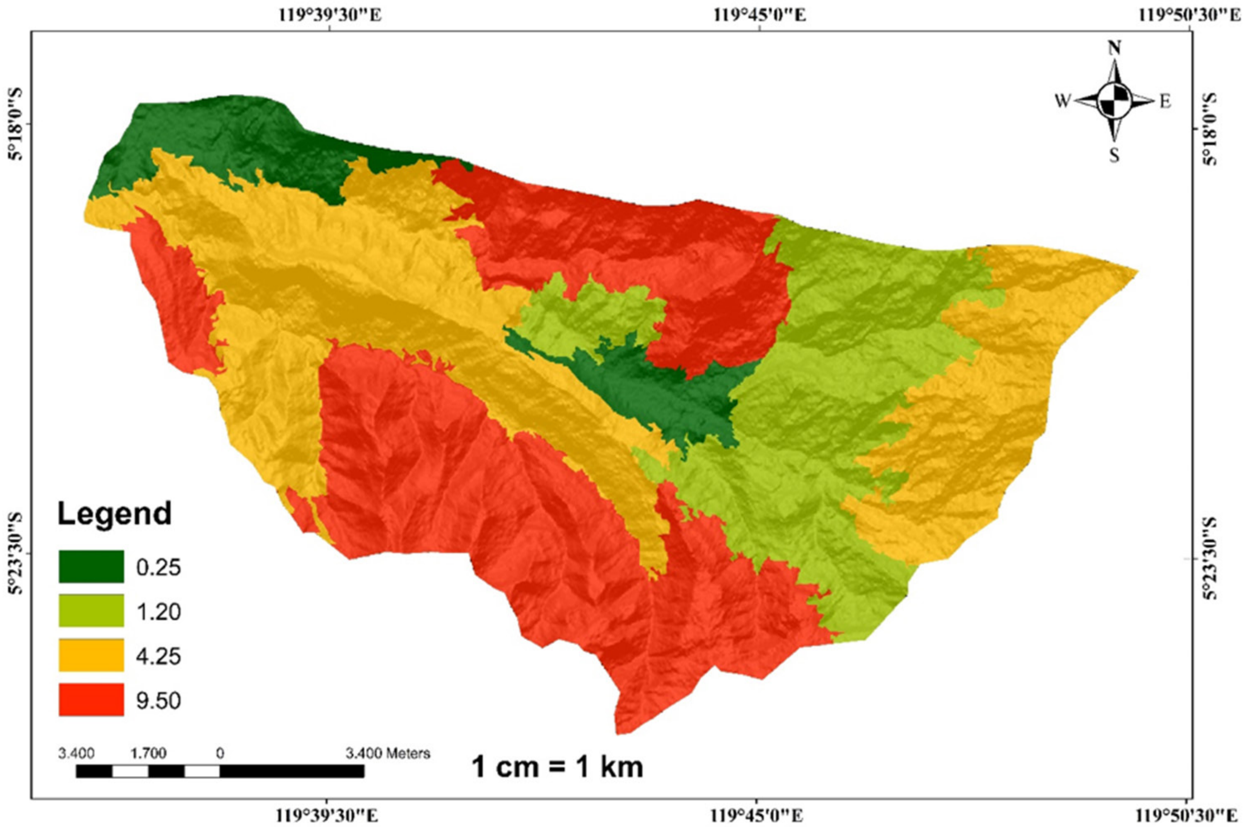

Fig. 2. Slope Length and Class (LS) Map

Most of the land use in the Jenelata watershed is secondary dryland forest with a land area of 8259.88 ha, then dryland agriculture with an area of 5693.21 ha, and paddy fields with a land area of 6323.78 ha. Each land use was then given a score according to the table of factor C values. Based on the survey results at the research location, the conservation action taken was the traditional bench terrace on paddy field land use and was given a score of 0.01; for the rest on other land uses, there was no conservation action done, so it is given a score of 1.00. Giving a score according to the table of P factor values. With dense land cover, it can reduce the rate of rainwater and surface runoff, which can suppress erosion.

However, if land use is loose, then this can trigger erosion because there is nothing to hinder surface runoff. Thus, several methods need to be implemented to reduce the erosion rate, namely by making drainage and improving land cover (Nave et al., 2021). The relationship between land use and changes in land management will lead to soil erosion and different agricultural sustainability. This shows that soil and water conservation measures, such as land cover management, are critical to inhibit surface runoff (Walie & Fisseha, 2016).

Erosion Hazard Level

Using the values derived from diverse erosion factors, the erosion rate is computed, leading to the assignment of an erosion hazard level. The results of these calculations that are representing the erosion hazard level values for each village are presented in Table 5 and Fig. 4.

The erosion hazard level for all villages covered several classes. First, the very low class with soil loss of <15 (t/ha/year) covers the land area of 7812.38 ha. The mild class with soil loss of 15-60 (t/ha/year) has a land area of 3263.04 ha and the medium class with soil loss of 60-180 (t/ha/year) lies on the land area of 694.76 ha. While, the high class with soil loss of 180-480 (t/ha/year) and very high with soil loss up to >480 (t/ha/year) cover the land area of 3234.03 ha and 5272.67 ha, respectively.

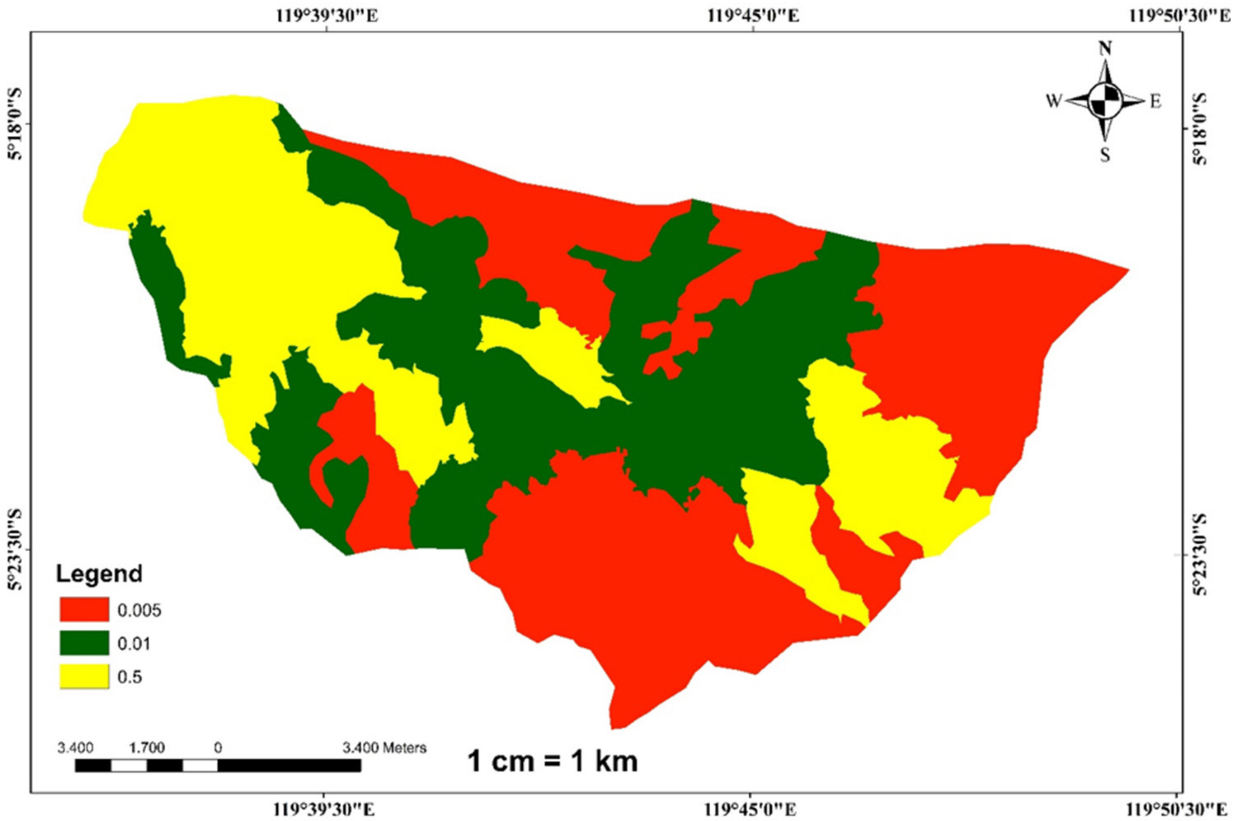

Fig. 3. Land Use Map (CP)

The research found a varied erosion hazard levels in the studied area indicating high and very high erosion covering a combined land area of 3,234.03 ha and 5,272.67 ha, respectively, while areas with very low erosion spanned a total land area of 7,812.38 ha. Elevated erosion levels, particularly in regions with steep slopes, pose a threat to soil quality due to the loss of topsoil rich in organic matter which is crucial for maintaining soil's physical, chemical, and biological conditions. Additionally, erosion contributes to river siltation, reducing river capacity and potentially causing surface overflow during heavy rainfall. The rainfall erosion factor is identified as a significant contributor to soil erosion, and an effective land cover management plays a pivotal role in mitigating excessive soil loss and safeguarding topsoil from the impacts of rainfall (Novara et al., 2019). The distribution of erosion hazard levels can be seen in Fig. 4.

Table 5. Erosion Hazard Class for each village

Village	Class	Area (ha)	Total Area (ha)
Bissoloro	Very Low	399.64	1,831.80
	Low	310.30	
	High	282.64	
	Very High	839.23	
Bontomanai	Very Low	885.47	2,086.91
	Low	785.89	
	Medium	140.08	
	High	114.96	
	Very High	160.50	
Buakkang	Very Low	946.61	2,200.89
	Low	254.54	
	High	59.17	
	Very High	940.56	
Jenebatau	Very Low	1,209.19	1,760.79
	Low	296.40	
	Medium	255.20	
Mangempeng	Very Low	374.25	881.77
	Very High	507.52	
Paladingang	Very Low	409.60	409.60
Paranglompoa	Very Low	1,154.68	2,116.67
	Low	544.95	
	Medium	27.65	
	Very High	389.39	
Pattalikang	Very Low	81.59	1,418.37
	Low	25.68	
	Very High	1,311.10	
Ronnaloe	Very Low	170.59	2,343.97
	Low	214.75	
	High	1,805.27	
	Very High	153.37	
Sapaya	Very Low	1,802.71	4,657.38
	Low	757.02	
	Medium	154.66	
	High	1,603.50	
	Very High	339.49	
Tassese	Very Low	378.05	568.74
	Low	73.52	
	Medium	117.17	
Total			20,276.89

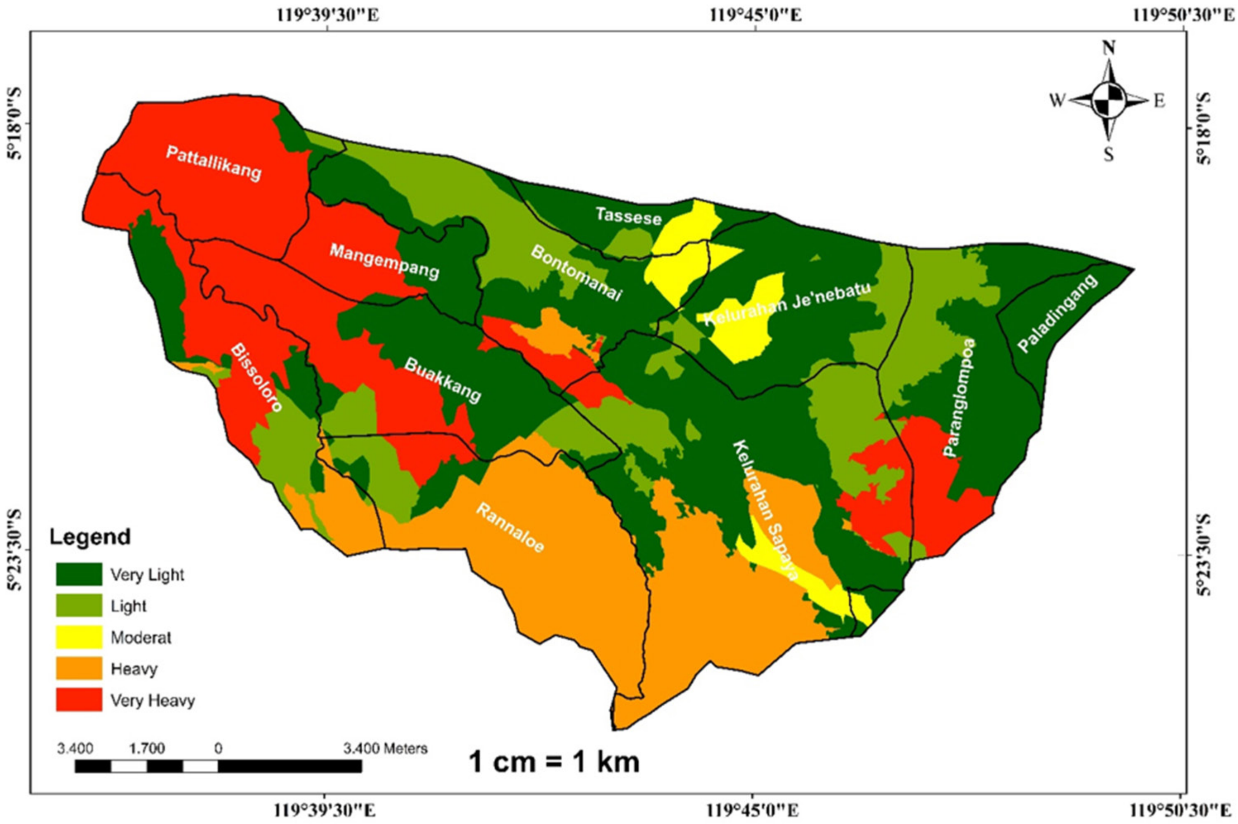

Fig. 4. Erosion Hazard Level Map

CONCLUSION

The value of erosion hazard level was obtained for each village with very low to very high classes spread across 11 villages at the research location. These include the very low class with a land area of 7812.38 ha, the low class with a land area of 3263.04 ha, the medium class with a land area of 694.76, the high class with a land area of 3234.03 ha and the very high class with a land area of 5272.67 ha. The soil protection in high and very high classes is very crucial for sustainable agricultural development.

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