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5 Rainfall erosivity in climate changes and the connection to landslide events

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Abstract. Climate anomalies lead to changes in rainfall patterns in Indonesia. Climate change has an impact on the increase in seasonal rainfall in December, January, and February, significantly in most areas in Java, Sulawesi, and Eastern Indonesia. Changes in the pattern of rainfall in Indonesia, especially for the sloping area of South Sulawesi, have resulted in increasing intensity of landslides. The objective of this study was to determine changes in rainfall patterns and erosivity that occur in East Luwu District which have an impact on landslide events. Rainfall data used from 1979 to 2017, erosivity value (R-factor) with Lenvain equation, IDW interpolation application are used for resulting erosivity map. Data from land cover, geology and soil are used as supporting data in the assessment of landslide events. Changes in the rainfall pattern since 1998-2017, as a result of global climate change, have resulted in increasing rainfall ability to erode the soil. Rainfall erosivity increased by 22% in 1999-2008, and increased to 33% in 2009-2017, most of the study areas in the last 10 years (2007-2017) have erosivity values (R-factor) >200 with high landslides activity. The high level of rainfall erosivity could be reflected to the high level of climate variability as climate change phenomenon.

1. Introduction

The widespread consequence of the green revolution technology is increasing land use change, where deforestation processes are increasing [1]. The forest land conversion has increased significantly, in 1950-1985 forest conversion reached 32.9 million hectares or 942 thousand hectares per year or 2,616 thousand hectares per day. In 1985-1993 the amount of forest lost reached 45.6 million hectares per year, until 2004 the number reached 59.17 million hectares with land critical outside the forest area of 41.47 million hectares. It also has disturbed the balance of ecosystems, especially the balance of soil as part of the ecosystem [2,3]. Soil ecosystems are damaged, so they cannot function as an aquifer, disrupt the microorganism cycle, and loss of soil function as a carbon sink. This has resulted in declining land productivity, floods, droughts, and the emergence of new critical areas that have the potential to mass movements.



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The conversion of forest land has resulted in climate anomalies in various regions of the world [4-7]. Climate anomalies lead to changes in rainfall patterns in the western part of Indonesia, especially in the northern part of Sumatra and Kalimantan, where the intensity of rainfall tends to be lower, but with a longer period. In contrast, in the South Java and Bali Region the intensity of rainfall tends to increase but with a shorter period [8]. Spatial changes in rainfall occurred [9,10], where rainfall in the rainy season is more varied than the dry season. Climate change also has an impact on the increase in seasonal rainfall in December, January, and February, significantly in most areas in Java, Sulawesi, and Eastern Indonesia. In contrast, climate change has a significant impact on the decline of seasonal rainfall in June, July, and August, in most parts of Java, Papua, West Sumatra, and South East Kalimantan.

Changes in the pattern of rainfall in Indonesia, especially for the sloping area in South Sulawesi, have resulted in increasing intensity of landslides. Several of landslides occurred in East Luwu District with high intensity, compared to other areas in South Sulawesi, especially in the Sub-Districts of Mangkutana, Angkona, Malili, and Towuti. Therefore this study aims to determine changes in rainfall patterns and erosivity that occur in East Luwu District which have an impact on landslide events.

2. Methodology

The study site was located in $2^{\circ}3'00''-3^{\circ}3'25''$ S and $119^{\circ}28'56''-121^{\circ}47'27''$ E, and the administration area was 6994.88 km^2 with 12 Sub-District (Figure 1). The area had an elevation from 15-300 m asl, with slope topography varied from 2% to 60% (Figure 2).

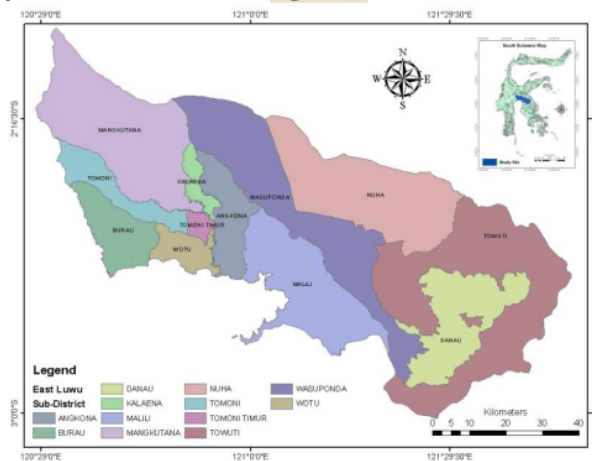


Figure 1. Location map of study area

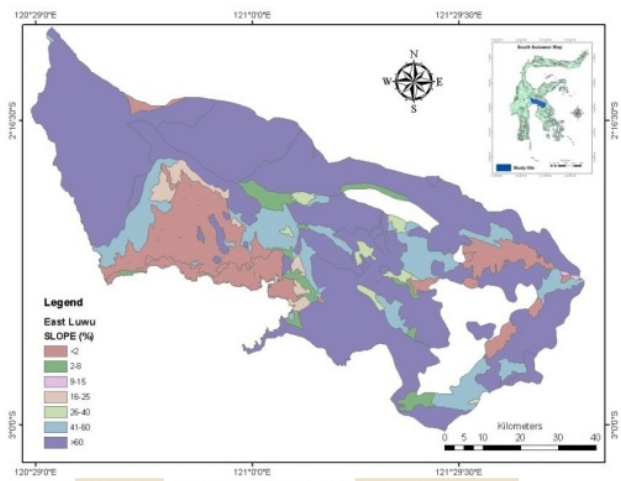


Figure 2. Slope topography of the study area

The rainfall data was taken from BMKG [11] and Global weather [12]. The Data will be calculated to get the erosivity value (R-factor) with Lenvain in Bols (1978) Equation;

$$R = 2.21 (P)^{1.36}$$

Where:

- R = Erosivity Index/factor
- P = Average monthly rainfall (cm)

Software Arcgis 10.3 with IDW interpolation application are used for resulting erosivity map. Data from land cover [13], geology [14] and soil [15] are used as supporting data (Figure 3-5) in the assessment of landslide events.

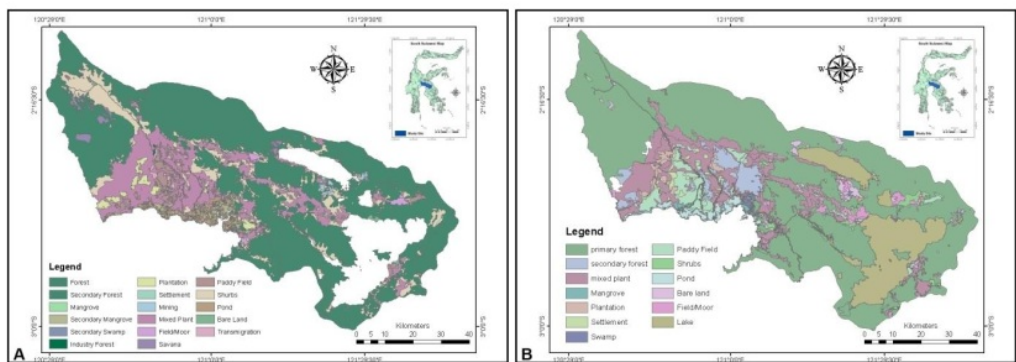


Figure 3. Land cover from 2009 (A) and 2011 (B) at the study site, with forest dominant >60%

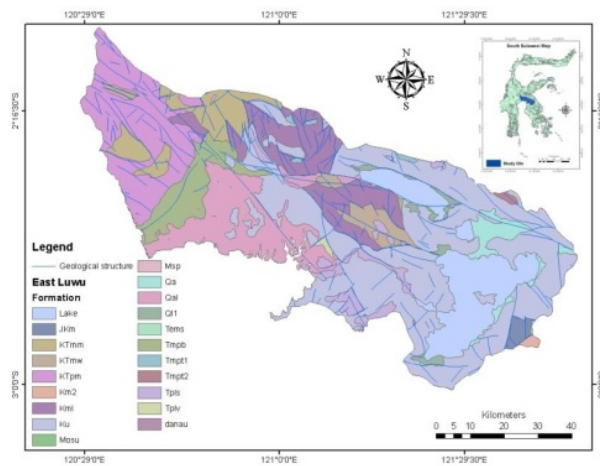


Figure 4. The study site is dominated by metamorphic and sedimentary rock

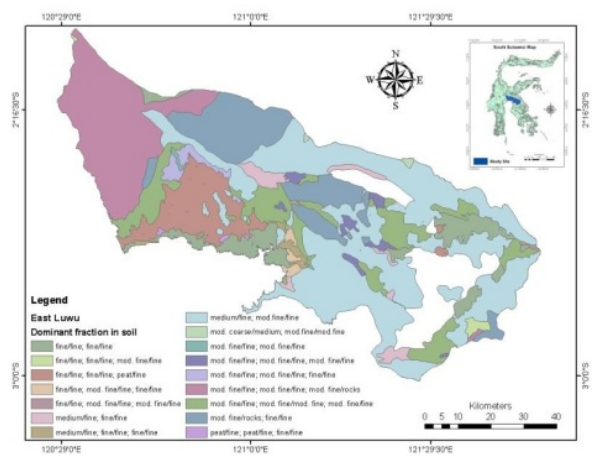


Figure 5. Most of the soil contains silt and clay fractions

3. Results

Rainfall data from 1979-1988 had a range patterns from December to May, as well as the pattern of the Year 1989-1998. The rainfall pattern showed that the changes in 1999-2008 became longer from November to June, and the length of pattern increased until October to July in 2009-2017 (figure 6).

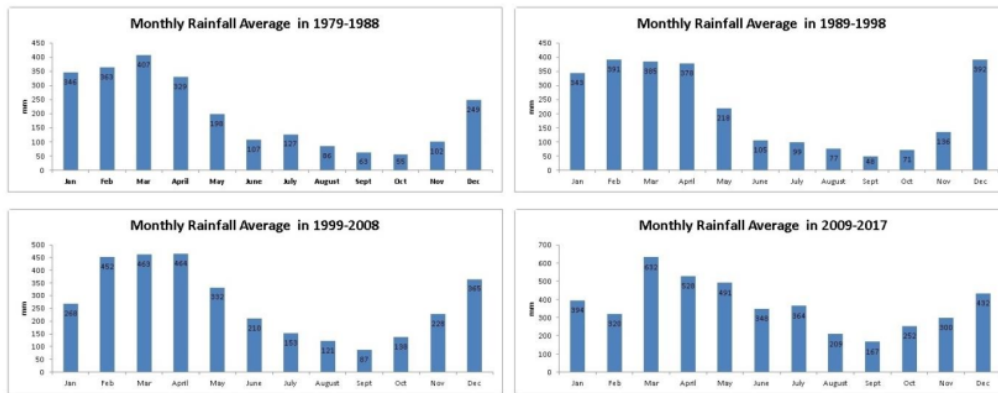


Figure 6. Trend of changes in rainfall pattern over four decades

Erosivity increases with increasing years (Table 1). The increase of erosivity values indicates an increase in the amount of rain falling into the study area, this is in the line with changing in the rainfall pattern in various regions of the world due to global warming phenomenon [9,16].

Table 1. Monthly and Annual of Erosivity

Month	Monthly Erosivity							
	1979-1988		1989-1999		1999-2008		2009-2017	
	P	R	P	R	P	R	P	R
January	34.6	274.0	34.3	270.9	26.8	193.8	39.4	326.7
February	36.3	292.7	39.1	323.3	45.2	393.8	32.0	246.2
March	40.7	341.2	38.5	317.2	46.3	406.8	63.2	621.7
April	32.9	256.0	37.8	309.0	46.4	407.9	52.8	486.7
May	19.8	128.3	21.8	146.5	33.2	259.3	49.1	440.6
June	10.7	55.7	10.5	53.8	21.0	139.2	34.8	275.7
July	12.7	70.1	9.9	49.8	15.3	90.2	36.4	293.6
August	8.6	41.2	7.7	35.5	12.1	65.7	20.9	137.9
September	6.3	27.3	4.8	18.9	8.7	41.6	16.7	101.4
October	5.5	22.3	7.1	31.8	13.8	78.1	25.2	178.0
November	10.2	51.9	13.6	76.6	22.8	155.6	30.0	225.6
December	24.9	175.4	39.2	324.1	36.5	294.8	43.2	370.5
Annual Erosivity	1736.0		1957.4		2526.9		3704.7	

Changes in rainfall patterns increased significantly with $R^2 = 0.99$ (Figure 7), this indicates that erosivity has an effect on increasing soil erosion activity. This is supported by data on land use change from 2009 to 2011 [13], where settlement status ranged from 0.47% to 1.05%, paddy fields reached 4.22% from 2.40%, and bare land was 0.81 in 2009, it increased to 1.54% in 2011 (Table 2)

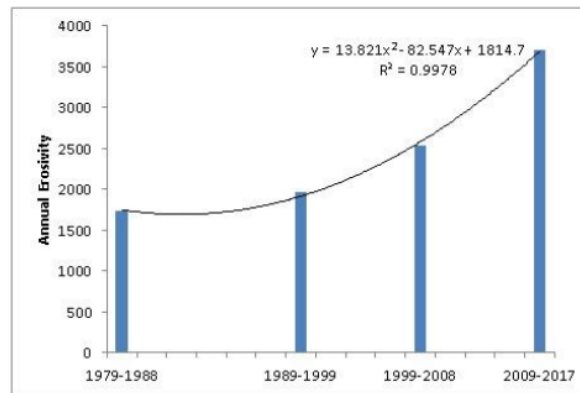


Figure 7. Changes of annual Erosivity

Tabel 2. Land cover from 2009 to 2011

Land cover	2009	2011
	(%)	
Forest	64.19	68.16
Secondary Forest	0.03	3.81
Mixed Plant	15.47	14.31
Mangrove	1.44	0.61
Plantation	1.20	1.12
Settlement	0.47	1.05
Swamp	0.01	0.38
Paddy Field	2.40	4.22
Shrubs	11.77	1.50
Pond	1.73	1.40
Bare land	0.81	1.54
Field/Moor	0.49	1.91
Total	100	100

4. Discussion

Slope dominance is 40->60%, with older rock types dominated by metamorphic rocks, which are beneath sedimentary rocks that have undergone cracks due to past tectonic disturbances [14], inducing sedimentary rocks to experience movement due to gravitational forces with rocks metamorphic as a slip plane.

The soil formed predominantly is silt loam textured [17], making the soil easily to dispersion under saturated conditions. Land cover dominated by primary and secondary forests on the dominant slope of $\geq 40\%$, can be a gravitational burden on soil and rocks, so that it can trigger landslides. Land use changes caused in increasing bare land that allows soil easily to saturate and trigger mass movements [18].

Changes in the rainfall pattern since 1998-2017 (Figure 6), as a result of global climate change, have resulted in increasing rainfall ability to erode the soil (erosivity). Rainfall erosivity can reduce soil erodibility [17,19] and increase erosion and landslides, as happened in Kasintuwu Village, Mangkutana Sub-district (Figure 8), with erosivity is around 217, in Maliwawo Village Angkona Sub-district with erosivity is around 207, Malili Village, Malili Sub-district with erosivity is around 212, and Towuti Sub-district with erosivity is around 212 (Figure 9)

Rainfall erosivity increased by 22% in 1999-2008, and increased to 33% in 2009-2017, most of the study areas in the last 10 years (2007-2017) have erosivity values (R-factor) >200 with high landslides

activity. The high level of rainfall erosivity could be reflected to the high level of climate variability [5,16,20] as climate change phenomenon.



Figure 8. Landslides in Mangkutana Sub-District

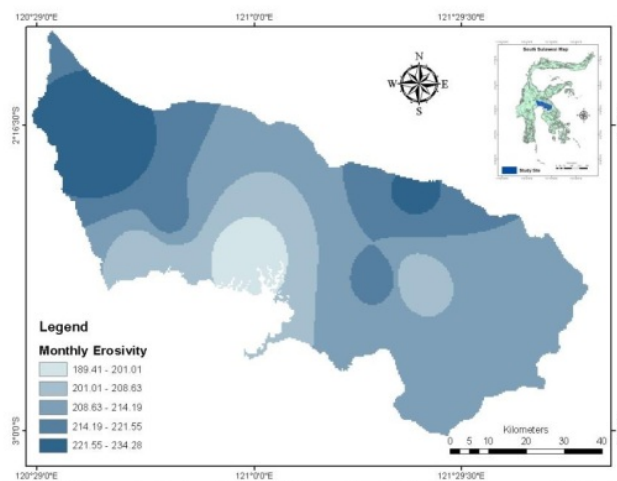


Figure 9. Rainfall erosivity in 2007-2017, with R factor is around 189.41 to 234.28

5. Conclusions

Changes in land use and rainfall patterns in the last ten years have increased landslide events with R-factor was >200 .

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