(p-issn: 2089-8630)
Jurnal Sains dan Teknologi Tadulako

THE ANALYSIS LANDSLIDES POTENTIAL DUE TO CHANGES OF LAND-USE IN MIU WATERSHED

Izza Nadrata Thamrin[1], Nina Bariroh Rustiati[2]
[1,2]Department of Civil Engineering, Tadulako University (Untad) Palu
Jl. Soekarno-Hatta Km. 9 Palu, Sulawesi Tengah
E-mail: Izzanadratathamrintirza@gmail.com

Abstract
This study aims to determine the magnitude of land-use change in the Miu watershed and to determine the relation between slope and soil type to erosions. The method used to predict the rate of erosion is the Universal Soil Loss Equation (USLE) in 2005, 2010, and 2016 with the help of the Geographic Information System (GIS). This study uses data on rainfall, slope, soil type, land use, and conservation and crop management factors which are then entered into the USLE equation. From this equation, the actual erosion rate in 2005 was 2,634,104.25 tons/year, 2010 was 3,285,025.34 tons/year, and 2016 was 1,856,140.79 tons/year. The average actual erosion in 2005, 2010, and 2016 was 2,591,756.79 tons/year, which is classified as minor erosion. The landslide-prone area based on the lowest slope of 5.50% is equivalent to an area of 36 km^2, for the medium it is 34.81% equivalent to an area of 228 km^2, and a height of 59.69% covering an area of 391 km^2 where very steep slopes dominate this river basin. The effect of significant land-use change affects the rate of erosion when there is a high intensity of rain on a steep slope so the potential for erosions in the area.

Key words: *Landslides, USLE Method, GIS, Miu Watershed*

Abstrak
Penelitian ini bertujuan untuk mengetahui besarnya perubahan penggunaan lahan di DAS Miu dan untuk mengetahui hubungan antara kemiringan lereng dan jenis tanah terhadap erosi. Metode yang digunakan untuk memprediksi laju erosi adalah Universal Soil Loss Equation (USLE) tahun 2005, 2010, dan 2016 dengan bantuan Sistem Informasi Geografis (SIG). Penelitian ini menggunakan data curah hujan, kemiringan lereng, jenis tanah, penggunaan lahan, serta faktor konservasi dan pengelolaan tanaman yang kemudian dimasukkan ke dalam persamaan USLE. Dari persamaan tersebut, laju erosi aktual pada tahun 2005 sebesar 2.634.104,25 ton/tahun, tahun 2010 sebesar 3.285.025,34 ton/tahun, dan tahun 2016 sebesar 1.856.140,79 ton/tahun. Erosi aktual rata-rata pada tahun 2005, 2010, dan 2016 adalah 2.591.756,79 ton/tahun yang tergolong erosi ringan. Daerah rawan longsor berdasarkan kemiringan terendah 5,50% setara dengan luas 36 km^2, untuk sedang 34,81% setara dengan luas 228 km^2, dan ketinggian 59,69% seluas 391 km^2 dimana lereng yang sangat curam mendominasi daerah aliran sungai ini. Pengaruh perubahan penggunaan lahan yang signifikan mempengaruhi laju erosi ketika terjadi intensitas hujan yang tinggi pada lereng yang curam sehingga berpotensi terjadinya erosi di daerah tersebut.

Kata kunci: Longsor, Metode USLE, GIS, DAS Miu

Diterima 1 Maret 2022, Direvisi 14 Maret 2022, Diterima untuk publikasi 1 April 2022

1. Introduction

A landslide is a natural event that is currently increasing in frequency. This natural phenomenon turned into a natural disaster. Landslides can cause casualties, both in the form of loss of life and loss of property and human cultural products. The cause of landslides is mainly due to rock resistance which decreases sharply beyond shear stress and occurs along with increasing water pressure due to discussion or increase in water content, as well as an increase in groundwater level (Sulistiarto and Cahyono, 2007).

Land conversion occurs due to an increase in population so that it requires land for settlements, plantations, rice fields, and even industry. As a result, residents are forced to use land that is not suitable for example, steep slopes for agriculture, causing the land to be easily eroded and transported by rainwater, causing the load on the slopes to be heavier and resulting in landslides.

Changes in land use that are relatively extensive in the watershed area (DAS) can disrupt the hydrological cycle. This can disrupt the balance of water resources in a watershed. This land requirement also affects the bad condition of the watershed because it urges and reduces vegetated land so that the visible impact of the incident is erosion when high rainfall opens the gap for landslides in several areas.

Degradation of watersheds (DAS) is characterized by the expansion of critical land, erosion on steep slopes both used for agriculture and other purposes such as settlements, and so on has had a wide impact on the environment, including floods that are getting bigger and the frequency is increasing (Ambar and Asdak, 2001). In addition, river water discharge in the dry season is very low, accelerated sedimentation in lakes and irrigation networks, and reduces water quality, which threatens the sustainability of development, especially agricultural development. The occurrence of this phenomenon cannot be separated from the lack of effectiveness in managing watersheds, mainly due to the integration of actions and efforts made by various sectors, agencies, or parties with an interest in watersheds.

This condition also occurs in the Miu watershed, where changes in land use from forests that are converted into plantations, dryland agriculture, and inappropriate settlements result in the loss of the topsoil which trees in the forest can absorb rain and produce water vapor that is released into the atmosphere through the process of photosynthesis. Finally, climate change and the continuous and unstable conversion of forest land have resulted in land erosion and landslides.

2. Literature Review

2.1. Watershed (DAS)

A Watershed (DAS) is a land area that is topographically limited by mountain ridges that accommodate and store rainwater for later distribution to the sea through the main river. The land area is called a water catchment area (DTA or catchment area) which is an ecosystem with the main elements consisting of natural resources (soil, water, and vegetation) and human resources as natural

Diterima 1 Maret 2022, Direvisi 14 Maret 2022, Diterima untuk publikasi 1 April 2022

resource users. In addition, another definition of a watershed is a unit of regional unity where rainwater becomes surface runoff and collects into the river as a stream. (Herman, R. 2019).

About the hydrological system, watersheds have specific characteristics and are closely related to their main elements such as soil type, land use, topography, slope, and slope length. These biophysical characteristics in response to rain falling in the area can influence the size of evapotranspiration, runoff water, surface runoff, soil water content, and river flow which in turn will also affect the size of sedimentation erosion.

2.2. **Avalanche**

Geologically, a landslide is a geological event where there is a movement of lands such as the fall of rocks or large lumps of soil. The process of landslides can be explained as follows: water that seeps into the soil will increase the weight of the soil. If the water penetrates to the impermeable soil which acts as a slip plane, the soil will become slippery and the weathered soil above it will move along the slope and out of the slope (Nandi, 2007). The occurrence of landslides and the level of landslide hazard are strongly influenced by high and continuous rainfall intensity, sloping to steep slope conditions, land use that is not under the ability of the land in the area, thick soil, and varied rocks and geological structures.

In general, erosion can be said as the process of releasing soil grains from their parent in one place and the material being transported by water or wind movements followed by the deposition of material transported in other places (Suripin, 2002). The stages of soil erosion include the impact of raindrops on the soil, splashing of soil by raindrops in all directions, destruction of chunks of soil by raindrops, soil compaction, waterlogging on the surface, runoff due to inundation and land slope, and transport of sprinkled particles and debris. or soil mass dispersed by runoff water (Rahim, 2003). The occurrence of erosion is determined by several factors such as climate (rain intensity), topography, soil characteristics, ground cover vegetation, and land use. Factors that can be changed include the way humans work, the vegetation that grows on the soil, and some soil properties, namely soil fertility, aggregate resistance, and infiltration capacity. Factors that cannot be changed include climate, soil type, and steepness (Arsyad, 2006). When erosion occurs, the soil will experience erosion or landslides so that it is washed away by water or wind.

The regional policy plan to prevent such disasters is to maintain the hydrological function of the soil which ensures the availability of soil and surface water nutrients by protecting them from activities that interfere with the conservation of soil functions, preserving the existence of forests as a form of forest ecosystem for protection against landslides.

Diterima 1 Maret 2022, Direvisi 14 Maret 2022, Diterima untuk publikasi 1 April 2022

2.3. USLE Method (*Universal Soil Equation*)

Of the several methods for estimating the magnitude of surface erosion, the Universal Soil Loss Equation (USLE) method developed by Wischmeir and Smith (1978) is the most frequently used method. The fact that this method was first developed in agricultural areas of North America with moderate climatic characteristics (low rainfall intensity and not too mountainous topography) needs to be considered so that in the use of the USLE (Universal Soil Loss Equation) equation it can be identified the limiting factors and not if deemed necessary the equation can be modified (especially in determining the magnitude of each variable itself). In this way, more adequate erosion forecasts can be generated (Asdak, 2002).

Before USLE (Universal Soil Loss Equation) was developed further, the estimated amount of erosion was determined based on data or information on soil loss in a particular place. Thus, the forecast is limited by topographic/geological, vegetation, and meteorological factors. Recognizing the limitations of determining the amount of erosion for places outside the location whose soil specifications are known, a method was developed to estimate the amount of erosion using a mathematical equation known as the USLE (Universal Soil Loss Equation) equation.

$$A = RK\ LS.\ C.\ P \quad (1)$$

2.4. Components USLE (Universal Soil Loss Equation)

2.4.1. Rain Erosivity Factor (R)

Rain erosivity is a rainfall and runoff factor which expresses the rain erosion index as a result of multiplying the rain energy (E) with the maximum rain intensity for 30 minutes (I30).

Smith and his colleague Weischmeier suggested that the equation for obtaining the energy of rain is: $EI_{30} = E \times I_{30} \times 10\text{-}20$ (2)

Another method was developed by Bols (1978) based on monthly rainfall data at 47 rain gauge stations on the island of Java which were collected for 38 years (Asdak, 2002).

Daily EI30 = 2,467 Rh2 / (0.0727 Rh + 0.275) (3)

Monthly EI30 = 6,119 (Rb1,211) (N-0.474) (Rm0.526) (4)

Rainy days are defined as days where there is 0.5 mm of rain or more (Soewarno, 1991).

2.4.2. Soil Erodibility Factor (K)

Soil erodibility value also describes the sensitivity of the soil type to erosion which is influenced by the kinetic energy of rain and surface run off. The value of soil erodibility is not only dependent on topography, slope slope and due to human treatment, it is also determined by the influence of soil texture, aggregate stability, infiltration capacity, organic and inorganic matter content of the soil. For several types of soil in Indonesia issued by the Department of Land Rehabilitation and Soil Conservation (RLKT). Ministry of Forestry, the value of K can be obtained according to Table 1.

Diterima 1 Maret 2022, Direvisi 14 Maret 2022, Diterima untuk publikasi 1 April 2022

Table 1. Tipe of Land and Erodibilty Factors

No.	Type of Soil	Value of K
1	latosol brown rage and latosol	0.43
2	latosol yellow rage, and latosol	0.36
3	mediterian and latosol complexes	0.46
4	latosol brown rage	0.56
5	grumosol	0.20
6	alluvial	0.47
7	rogosol	0.40
8	latosol	0.31

(Kironoto, 2003)

2.4.3. Soil Structure

Soil texture is used to identify grain size, while soil structure is used to describe the arrangement of soil particles.

Soils that have a stable structure against the influence of water, have perfect permeability and drainage and are not easily dispersed by rainwater. Soil permeability can eliminate the power of water to erode the soil surface, while drainage affects the good and bad air exchange and will subsequently affect the activities of micro-organisms in the soil, as well as plant roots. (Herman R, 2019)

Determination of the value of soil erodibility using laboratory analysis, based on the physical properties of the soil. The parameters for estimating the value of K are:

1) Percent dust (2-5 microns) + percent very fine sand (5-100 microns)
2) percent sand;
3) Percent organic matter;
4) Soil structure;
5) soil permeability;

Furthermore, these parameters are entered in a nomograph. To facilitate the calculation of the nomograph, the following formula has been made:

K = [2.713M1.14(104) (12-a) +3.25(b-2)-2.5(c-3)]/100 (5)

In addition to determining the value of erodibility based on physical properties tested in the laboratory, the value of K can also be obtained from a table of estimates of the value of K for several types of soil. In Indonesia, there are currently 3 known soil classification systems used, namely the PPTB system (Bogor Soil Research Center), FAO/UNESCO, and SCS-USDA (The Soil Conservation Services of the United States Department of Agriculture).

The soil classification system derived from PPTB and has been widely known in Indonesia is the Dudal-Soepraptohardjo system (1957).

Diterima 1 Maret 2022, Direvisi 14 Maret 2022, Diterima untuk publikasi 1 April 2022

2.4.4. Slope Length and Slope

The LS factor is a combination of the length of the slope (L) and the slope of the slope (S), which is the ratio of the magnitude of erosion from a plot of land with a length of 22.13 m and a slope of 9%. In calculating the value of LS Wischmeier (1971) gives the formula:

LS = I0.5 /100 (1.38 + 0.965s + 0.138 s2) (6)

Equation 2.7 is used for land slopes of less than 20%, while for slopes of more than 20% use the following equation:

LS = (I/22.1) 0.6 x (s/9)1.4 (7)

In this study, the maximum slope used in the experimental plot (agricultural field) to determine the magnitude of the S factor is 25%. This figure is in most cases much smaller than the slope in watersheds in tropical countries including Indonesia. The study that has been carried out to determine the rate of deviation from the above conditions shows that the use of the USLE formula in watersheds with wavy topography (a typical watershed condition in Indonesia) will give overestimated results (Asdak, 2002).

Harper (1988) shows that on land with a slope of more than 20%, the use of equation (2.8) will get results that are over estimate. Therefore, the LS value for arbitrary length and slope can be calculated by the equation presented by Wischmeier and Smith, 1978 (in Morgan 1988; and Torri 1996) as follows:

LS = (l/22) (0.006541s2 + 0.065) (8)

Z = 0.5 for s 5%; 0.4 for 5% > s 3%; 0.3 for 3% > s 1%; 0.2 for s < 1%

If s is expressed in degrees, then equation 3.12 becomes:

LS = (l/22) (65.41Sin2 s+ 4.56 Sins +0.065) (9)

In addition to using the equation, the determination of the LS value can be done by using the LS value table for various kinds of slopes issued by the relevant agencies such as the RLKT Service, the Ministry of Forestry. Slope factor value slope, defined by slope class, as in Table 2

Table 2. Assessment of Slope Class and LS Factors

Slope Class	Slope	LS value
I	0 – 8	0.40
II	8 – 15	1.40
III	15 – 25	3.10
IV	25 – 40	6.80
V	> 40	9.50

Source: Kironoto, 2003

Diterima 1 Maret 2022, Direvisi 14 Maret 2022, Diterima untuk publikasi 1 April 2022

2.4.5. Land Management and Soil Conservation (F)

P is the ratio between the amount of soil erosion lost on the land with certain preservation measures, to the amount of soil erosion without preservation measures. The assessment of factor P in the field is easier when combined with factor C because in reality, the two factors are closely related. Several CP factor values have been determined based on research in Java as shown in the table (DPMA, 1982, material from amber S and A. Syarifuddin (1979) and LPT Bogor).

There are two main weaknesses in relation to the use of the USLE (Universal Soil loss Equation) formula for estimating the magnitude of erosion, namely:

1. Sediment deposits in the basin are not taken into account.
2. The USLE (Universal Soil Loss Equation) method is more suppressed for relatively flat agricultural areas with not too high rainfall intensity. Therefore, several attempts have been made to modify the USLE (Universal Soil Loss Equation) equation in the hope of obtaining a new form of equation that is more suitable for non-agricultural areas. One of these efforts was carried out by Snyder (1980) by prioritizing the calculation of K prices directly in the field or the use of K values that were already available in the study area also using LS and CP values that were adjusted to conditions in Indonesia, especially in estimating the amount of erosion in non-residential areas agriculture such as forests and other woody vegetated areas.

Actual erosion is erosion that occurs under actual conditions, both land use and rainfall data. To provide an overview of the erosion potential generated, the actual erosion values are classified as follows (Asdak, 2002):

1) very heavy erosion: more than 330 tons/ha/year
2) heavy erosion: 125 – 330 tons/ha/year
3) moderate erosion: 50 – 125 tons/ha/year
4) small erosion: 12.5 – 50 ton/ha/year
5) very small erosion: less than 12.5 ton/ha/year

2.5. Geographic Information System (GIS)

Geographic Information System (GIS) is an organized collection of hardware (hardware), software(software), geographic data and personnel designed to efficiently obtain, store, manipulate, and / and analyze and display all forms of geographically referenced information (GIS). ESRI, 1990 in Prahasta, 2002). At first GIS was only used specifically for purposes closely related to mapping, planning and geosciences, but now the implementation and application of GIS has developed for various purposes with more diverse fields and a wider range, such as in engineering sciences. engineering) and design in particular in the field of Water Resources Engineering such as water quality modeling, hydrology and hydraulics (Christoper, 1999).

Diterima 1 Maret 2022, Direvisi 14 Maret 2022, Diterima untuk publikasi 1 April 2022

GIS consists of several components, namely components of data input, data processing, data manipulation and analysis and data output.

1. Data Input Component
2. Data Management Component
3. Components of Data Manipulation and Analysis
4. Data Output Component

3. Research Method

The analysis is carried out in the form of elaboration or explanation of each parameter used and which has been made. The analysis and evaluation carried out are as follows:

1. Land use change data using Geographic Information System (GIS)
2. Land slope data using a Geographic Information System (GIS) by studying in the field and then comparing it with a map to prove the similarity of the data.
3. The calculation of the rate of erosion using the USLE (Universal Soil Loss Equstion) method.
4. Analyzing Landslide Hazard Potential in Miu Watershed.

4. Discussion

4.1. Land Use Analysis

The impact of land use changes in the Miu watershed for potential landslides will consider crop canopy interception, therefore the first step is to evaluate the image maps of 2005 – 2016 using ArcGIS to determine the percentage of each land use. Then it will calculate net rainfall as the impact of vegetation by adopting a formula (Sutapa, 2014):

a. For mixed garden land, the formula used is:

   $Y = 0.925\ x + 0.333$

b. For forest, the formula used is:

   $Y = 0.886\ x + 0.088$

c. For other land functions (open land) Rnetto = Rgro

Plant vegetation will affect the rainfall that falls to the surface. The impact of vegetation influence is called crop canopy interception. Water loss due to interception in the crop canopy has been investigated by Dunne and Leopold (1978) regarding the intercept which was previously calibrated by Sutapa (2014) for forest plantations, and mixed garden crops.

4.2. Calculation of Rain Erosivity (R)

The data needed to calculate the value of rain erosivity is the amount of monthly rainfall, the maximum amount of rain in one month and the number of rainy days in the month concerned.

Diterima 1 Maret 2022, Direvisi 14 Maret 2022, Diterima untuk publikasi 1 April 2022

Calculation of the analysis of the distribution of the average rainfall in the Miu watershed, rainfall data was taken at (Palu Meteorology and Geophysics Agency), because it was considered the closest to the research location, the data taken was during the The last 12 years starting from 2005 to 2016.

4.3. Slope Factor Calculation

The Miu watershed has a fairly varied topography, ranging from hilly to mountainous. Based on these topographical conditions, this area has quite a variety of slope classes ranging from gentle, rather steep, to very steep. Based on the slope class map, very steep slopes dominate this area.

4.4. Determination of Soil Erodibility (K)

The types of soil found in the Miu River Basin are Regosol, Alluvial and Mediterranean, to assess the erodibility (K) of the above soil types, it can be seen in the table of K values for several soil types in the Miu watershed.

4.5. Determination of CP Faktor Factor

Management factors (how to grow crops) and soil conservation practices are closely related so that they are easier to combine.

4.6. Actual Erosion Calculation

One of the factors that causes erosion is rain, the flow of rain will carry the transported material to the river catchment area which is finally deposited. The results of the evaluation of land use changes in the Miu watershed show the number of shrubs and secondary dry forests. Changes in land use will affect the flow rate when it rains, high rainfall will be associated with the hydrograph flow which will certainly affect the sediment discharge in the catchment area. Based on the availability of data regarding river flow discharge in the discharge rating curve and river sediment discharge in the sediment rating curve, field measurements were first carried out (June to October) and laboratory tests on sediment mass as comparison data. The USLE (Universal Soil Loss Equation) method is a method intended to calculate sediment yields caused by storm events (William, 1982 in Gunedro, 1996). After calculating and analyzing the actual erosion hazard, it can be seen the cause of the location where erosion occurs. Actual erosion occurs on plantation land and residential land.The Total Actual Erosion of the Miu Watershed in 2005, 2010, and 2016 is shown in the following table:

Table 3. Miu Watershed Actual Erosion 2005- 2016

Year	Erosivity Factor (R)	Land (Ha)	Total Actual Erosion (tonnes/year)
2005	121,227.10	65,554.70	2,634,104.25
2010	154,473.95	65,554.70	3,285,025.34
2016	125,651.99	65,554.70	1,856,140.79
Total Actual Erosion (tonnes/year)		7,775,270.38	
Average Actual Erosion (tonnes/year)		2,591,756.79	

Source: Results of Analysis and Discussion

Diterima 1 Maret 2022, Direvisi 14 Maret 2022, Diterima untuk publikasi 1 April 2022

4.7. Landslide Susceptibility Level in Miu Watershed

The class limits for landslide susceptibility in the Miu watershed are divided into 3 classes, namely low vulnerability, medium vulnerability and high vulnerability.

Table 4. Landslide Susceptibility Class

Landslide Susceptibility Level	Score	Area (km^2)	Percentage (%)
Low	<25	36	5.50
Medium	25-40	228	34.81
High	>40	391	59.69

Source: Results of analysis and discussion

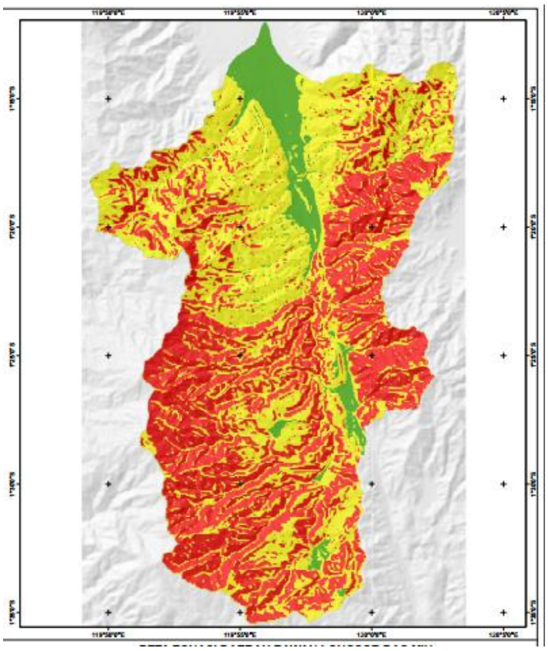

Figure 1. Miu Watershed Landslide Prone Map

For a high level of vulnerability to landslides, it is an unstable area and at any time small or large landslides can occur. Areas that have the potential to be prone to landslides occur in locations with steep to very steep slopes. Land areas that have steep and very steep slopes are primary dry land forest areas, secondary dry land forests, plantations and settlements. Forests, plantations and settlements will be very influential as triggers for landslides because they are located in steep areas or sloped areas because in these conditions the slopes are saturated with water which results in the weight of the soil mass increasing so that it becomes unstable.

The area of moderate susceptibility is influenced by the slope of the slopes from gentle to very steep. Meanwhile, the distribution of land area in this area is evenly distributed between primary dry land forest, secondary dry land forest, plantations, settlements, rice fields, and shrubs.

Diterima 1 Maret 2022, Direvisi 14 Maret 2022, Diterima untuk publikasi 1 April 2022

Areas with a low level of vulnerability are areas that rarely occur if there is no disturbance on the slopes. For land use, the dominant form of rice fields, shrubs and bodies of water.

5. Conclusions

1. From the results of the evaluation of land use change using ArcGIS Software for studies in 2005, 2010 and 2016 the plantation area has decreased and open land has increased significantly. In 2005 the plantation area was 16.16% of the total watershed area while open land was 1.71%, then in 2010 the plantation area was 12.69% while open land was 8.66% and in 2016 the plantation area was which is 2.14% while open land is 8.19% of the total watershed area. Significant land use changes can later affect the rate of erosion that occurs
2. Based on the landslide susceptibility level in the Miu watershed in 2005, 2010 and 2016. Primary dryland forest area with a slope of 6.8% and brown regosol soil type has a small erosion class. Secondary dry land forest area with a slope of 6.8% and brown regosol soil type has a small erosion class. Rice fields with a slope of 3.1% and brown mediterranean soil type have a small erosion class. The plantation area with a slope of 6.8% and the type of brown regosol soil has a large erosion class. The scrub area with a slope of 3.1% and the type of gray alluvial soil has a small erosion class. Residential areas with a slope of 6.8% and brown alluvial soil type have a very large erosion class. Area of a body of water with a slope of 3, 1% and the brown mediterranean soil type has a very large erosion class. The three landslide-prone areas in the Miu watershed are 5.50% low, equivalent to an area of 36 km2, while 34.81% is equivalent to an area of 228 km2, and high is 59.69% equivalent to an area of 391 km2. The effects of significant land use changes affect the rate of erosion when there is high rainfall intensity on steep slopes with soil types that are not suitable for land conditions so that there is a potential for landslides in the area.

References

Amber. S., Asdak., C., (2001). Watershed Management (DAS) Supporting Sustainable Agricultural Development in the Context of Regional Autonomy in West Java. Papers for One Day Seminar and HITI Regional Committee for West Java. Bandung, June 30, 2001

Ambar, S. and A. Syarifudin, (1979). Erosion Mapping of Jatiluhur Basin. Seminar *Jatiluhur Watershed Erosion Problem. University Ecology Institute* Padjadjaran, Bandung.

Arsyad, S. (2006). Soil and Water Conservation. IPB Press, Bogor.

Arsyad, S. (2010). Soil and Water Conservation. Second Edition. IPB Press Library Series, Bogor.

Asdak, C. (2002). Hydrology and Watershed Management, Gajah Mada University Press, Yogyakarta.

Asdak, C. (2004). Hydrology and Watershed Management, Gadjah Mada University Press, Yogyakarta

Asdak, C. (2007). Hydrology and Watershed Management. Yogyakarta: Gadjah Mada University Press

Asdak, C. (1995). Hydrology and Watershed Management. Yogyakarta: Gadjah Mada University Press.

Diterima 1 Maret 2022, Direvisi 14 Maret 2022, Diterima untuk publikasi 1 April 2022

Asmaranto R. (2014). Application of Geographic Information Systems (GIS) for Land Erosion Analysis. Brawijaya University

Banuwa. (2013). Erosion. Prenamedia Group. Jakarta

Bols, PL (1978). The Iso-erodent map of Java and Madura. Report of the Belgian Technical Assistance Project ATA 105-Soil Research Institute, Bogor. Indonesia

Sutapa, I Wayan. (2014). Analysis of Erosion Potential in Watersheds (DAS) in Central Sulawesi

Lestari, F. (2008). Application of Information Systems

Purwowidodo. 1999. Soil Conservation in Forest Areas. Faculty of Forestry IPB. Bogor: IPB Press

Prasetyo, BH, Adiningsih, JS, Subagyono, K., and Simanungkalit, RDM (2008). Mineralogy, Chemistry, Physics, and Biology of Rice Fields. Center for Soil and Agroclimate Research. Bogor.

Kironoto, BA. (2003). Diktat Lecture on Sediment Transport Hydraulics. PPS-Civil Engineering. Yogyakarta.

Christopher, ET, Olivera, F., and Maidment, D., (1999). Floodplain Mapping Using HEC-RAS and ArcView GIS, CRWS-University of Texas, Austin.

SE uterus. (2003). Soil Erosion Control in the Conservancy of the Environment. Jakarta: Earth Literacy

Suripin, (2002). Conservation of Soil and Water Resources. Andi Yogyakarta, Yogyakartaf

Sulistiarto, B., and Cahyono, AB. (2007). Study on Landslide Identification Using Landsat and Aster Imagery (Jember Regency). Landslide Identification Research Report, Jember

Soedibyo. (2003). Dam Engineering. Pradnya Paramita, Jakarta

Soewarno. (1991). Hydrology Measurement and Processing of River Flow Data (Hydrometri). Nova Publisher, Bandung

Tunas, I Gede. (2005). Prediction of Land Erosion in Bengkulu Watershed using Geographic Information System (GIS). *SMARTek Journal,* 3(1)

Herman, R. (2019). Analysis of Erosion and Runoff Due to the Effect of Land Use Changes in the Miu Watershed. Independent Research Final Report. Tadulako University, Palu

Diterima 1 Maret 2022, Direvisi 14 Maret 2022, Diterima untuk publikasi 1 April 2022