Influence of Rainfall Spatial Distribution on Total Suspended Solid (TSS) in Cilutung Watershed

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Abstract. The study aims to analyze the influence of rainfall spatial distribution on total suspended solid and the connection between total suspended solid with river stream discharge on the condition of physical characteristics in Cilutung stream area, Majalengka regency. The extraction process of Himawari 8 Imagery used to find out the rainfall spatial distribution pattern while taking samples in April, 2018. Curve Number Data have the form of hydrologic soil groups and land use required to give score to each five sub-watershed that has been delineated for region physical characteristic. The Rainfall spatial distribution pattern has strong correlation with total suspended solid concentration generated through runoff discharge with coefficient of determination number $r^2 = 0,8416$. The varied rainfall spatial distribution pattern take part to the occurrence of fluctuation of total suspended solid concentration with average 190 mg/l , and amount of total suspended sediment yield 820 kg/m^3.

Keywords: Total Suspended Solid; Cilutung; Rainfall; Spatial Distribution; Curve Number; Himawari 8.

1 Introduction

The good quality of river water becomes a very important factor in order to support water needs in the area around the watershed. Recently, water quality in the watershed tends to get worse and it is not feasible for consumption anymore. According to [1] claimed that water quality from nine watersheds in Java island is categorized as bad. One of the nine watersheds is the Cimanuk watershed, which is the main part of the Cilutung sub-watershed. The water pollution index in Cimanuk watershed is hazardous to the environment and public health. On the object study of water resources, one of the consequences of decreasing water quality is caused by sedimentation in the form of transportation of substances especially phospor, heavy metal, and pesticide [2]. Excess sediment deposition will also reduce the stream capacity of the river due to the resulting siltation. In a long period, sedimentation can affect to the performance and productive age of the river.

Rainfall is one of the climatic elements that create rate of erosion that causes the accumulation of sedimentation [3]. Several studies show the effects of rainfall on the increase of sedimentation in the form of total suspended solid (TSS) that impact on the decreasing quality of river water. TSS are all solid particles suspended in water consisting of biotic and abiotic components that can be trapped by a filter size of 0.45 μm [4]. Sedimentation in the form of suspended solid causes many aquatic problem such as silting of the river, coastal erosion, coastline changes. Another impact that can arise is the occurrence of turbidity in river water, which disrupt the penetration of sunlight into the waters. Further, turbidity causes the water productivity to be affected and at levels that exceed 100 mg/l can cause death in fish [5].

Cilutung watershed located in the middle segment sub-stream of Cimanuk watershed in West Java Province. Cimanuk watershed is one of the priority watersheds that belongs to the critical watershed category. The upper Cimanuk watershed area is vulnerable to erosion, it related by lithology of the Cimanuk watershed that predominatly containing by volatile quarter volcanic materials, which are generally not well-formed so it easily to be crushed [6]. Combination between active tectonic and lithology in the upper segment of Cimanuk watershed plays an important role in the high intensity of sedimentation in the middle and downstream.

The main concern of research is about accumulation of sediment in the form of TSS, which influenced by the intensity of rainfall in the Cilutung watershed. The purpose of this research is to analyze relationship between TSS with stream flow discharge and turbidity on physical characteristic condition of Cilutung watershed. Himawari 8 satellite imagery were needed to help the spatial and temporal analysis of rainfall on research area.

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2 Methodology

The parameters in this study are physical characteristics of watershed which is represented by soil moisture map that is covered with soil type according to [7] classification rules (Table 1&2). Afterwards will appears (HSG) hydrologic soil group of Cilutung watershed that will be weighted with land use map according to [8] rules (Table 3) resulting in weighted (CN) curve number on each sub-watershed.

Rainfall which further affects fluctuation of stream discharge temporally, will be associated with the TSS concentration resulting from sediment sampling at the station. The relationship between stream discharge and TSS concentration is correlated through the suspended sediment rating curve. Result of curve number in each sub-watershed will be analyzed in relation to the TSS and turbidity concentration values through a spatial comparative approach.

Data analysis used in this research are spatial comparative analysis, descriptive analysis and statistical test. Spatial comparative analysis with temporal approach is intended to explain the TSS fluctuation in every day of sampling as well as its relation to the intensity of rainfall and stream discharge. The effect of rainfall on TSS is analyzed by descriptive analysis based on daily discharge data and also its relation to physical characteristics of watershed area. Correlation test is used to see the relationship between turbidity variable with TSS and TSS with discharge.

Table 1. Classification of HSG with Soil Texture

Hydrologic Soil Group	Soil Texture
A	Sandy, loamy sand, atau sandy loam
B	Silt or loam
C	Sand, Clay, Loam
D	Clay loam, silty clay loam, sandy clay, silty clay, or clay

Table 2. Classification of Soil Type with Soil Texture

Soil Type	Soil Texture
Andosol	Clay loam
Regosol	Sandy loam
Latosol	Clay
Grumosol	Clay loam
Mediteran	Silty clay loam
Podsol red yellow	Clay loam

2.1 Study Area and Sampling Period

Cilutung watershed is located between Majalengka Regency and Sumedang Regency in West Java with an area 635,8 km^2. Sampling was conducted for seven days in April 2018, starting date on 6 to 12. The only one sampling station was selected at Kamun Dam, Liangjulang Village, Kadipaten District, Majalengka Regency. The absolute location of Kamun Dam is located at 6 ° 44'52.421 "LS and 108 ° 9'9.63" BT. The reason for determining the location is caused by it located at the lowest point of Cilutung boundary and it is in the main river stream (Figure 1), so it is expected to represent the overall TSS accumulation in Cilutung watershed.

Cilutung watershed is delineated into 5 sub-watershed. Result of delineation will be used as unit of analysis of physical characteristic to determine curve number in each sub-watershed. The following sub division of watershed was given the name based on toponimi (Table 3).

Table 3. Sub-watershed Deineation with Area

Sub-watershed	Toponimi	Area (km2)
1	Cilutung	18,8
2	Ci Jurey	91,8
3	Ci Saar	267,5
4	Ci Hieum	95,6
5	Ci Kijing	161,9
Total		635,8

Figure 1. Maps of Cilutung Watershed Boundary and Location of Sampling

2.2 Sample Collection and Analysis

Water samples were taken by using an automatic pump, set with intervals every 15 or 30 minutes depending on the water level in every occurrence. Stream water samples were collected in a 1 L glass bottle from approximately surface-depth of the stream flow then to be analyzed for turbidity (in-situ) and TSS (ex-situ). The measurement of turbidity is directly in the field using a digital auxiliary device Hanna type HI 93703.

Otherwise the measurement of TSS were analyzed following gravimetry methods [9] through the laboratory. All water samples taken were not measured value of TSS yet only the highest turbidity value sample in each occurrence were selected to be measured its TSS. After doing the TSS measurement, then the result numbers are entered into the formula as follows:

$$TSS = [(A - B) / V] \quad (1)$$

Legend :
TSS = Total Suspended Solid (mg/L)
A = mass of filter + dried residue (mg),
B = mass of filter (tare weight) (mg), and
V = volume of sample filtered (L)

2.3 Conversion Water Level to Discharge

In this study, the discharge data was observed directly on the measuring ruler of the water levels in units of "meters" available at the Kamun dam station. Direct measurements in the field include observation of rising and falling water levels which will then be converted to stream discharge. The convertion formula from water level data to stream discharge obtained from "Badan Besar Wilayah Sungai Cimanuk-Cisanggarung" as follows:

$$Q = C \times Beff \times \sqrt{H^3} \quad (2)$$

Legend :
Q = discharge (m^3/s)
C = 1,64
Beff = wide of weir : 58,55 (m)
H = water level (m)

2.4 Determination of Curve Number (CN)

Before determining the value of CN, making a HSG should have been done. HSG can be identified based on one of three ways namely by soil characteristics, county soil surveys, and minimum infiltration [10]. The identification of HSG in this study was determined based on soil characteristics by overlapping the soil type map with soil moisture based on HSG characteristic guideline [7].

The initial CN value used is the empirical value obtained from curve number tables issued by [8]). Valuing CN is created by making land mapping unit. Land mapping unit is obtained by overlapping 2 types of maps, those are land type map based on HSG and land use map. CN will then be used to determine the value of surface runoff in each sub-stream region.

2.5 Extraction of Himawari 8

The extraction of Himawari 8 imagery is needed to obtain spatial and temporal rainfall data, with using ArcMap 10.4 software. The imagery in the form of raster data has a continuous classification number. The resulting figure shows the lowest and highest rainfall precipitations in 10 minutes. Selection of captured image data refers to TSS sampling time. The process through initial step to "extract by mask" imagery with watershed area to get spatial distribution map of precipitation and then layouting the map.

3 Rainfall and Precipitation

The spatial distribution of rainfall in Cilutung watershed is explained by observing the pattern of colour uniformity in each single pixel at himawari 8 imagery result at the time of TSS was taken. Number of Precipitation displayed by the legend in the form of continuous data with nominal value, in the form of different colour gradation from low to high. The displayed colour illustrations indicate the older the resulting colour, the greater precipitation number presented so vice versa.

Himawari 8 provides 4x4 KM spatial resolution in each pixel, so it is possible to see the rain pattern during each sampling occurrence and supported by the delineation of 5 sub-watershed to make it easier to explain its relation to the CN value of each sub-watershed descriptively. The following describes the rainfall distribution pattern and the results of the TSS.

The data result of himawari 8 extraction is a number of precipitation in units of mm / 60 minutes or mm / hour. The extracted rainfall data has covered the entire polygon area of Cilutung watershed.

3.1 Equal spatial distribution

Type of rainfall distribution that is equally distributed in the watershed was found in the occurrence of sample 8 (figure 2), 18, 19 and 20. The number of rainfall resulted from the extraction of the Himawari imagery from each time the occurrence releases the rainfall number which is categorized as "very light" in numbers <1 mm / hour. The resulting TSS concentration has an interval number of 6 to 102 mg / l. . Precipitation data in each occurrence with discharge and TSS is are shown in (table 4)

3.2 Random spatial distribution

The random distribution type of rainfall in watershed was found in the occurrence of sample 1 (figure 2), 5.7 and 13. The rain distribution was randomly illustrated by different distinctly different color gradations in each sub-watershed. The number of rainfall resulted from the extraction of himawari from each occurrence 1 and 13 which are categorized as "very heavy" in numbers >20 mm / hour, and occurrence 5 and 7 are categorized as "very light" in numbers <1 mm / hour. The resulting TSS concentration has an interval number of 37 to 374 mg/l.

3.3 Concentrates spatial distribution

This distribution on the watershed was found with the most dominant occurrence, in the occurrence of sample 2 (figure 2), 3,4,6,9,10,11,12,14,15,16 and 17. Concentrated rainfall distribution is illustrated by the thickness of dark blue which indicates high rainfall is centered within one or two adjacent sub-watershed. Number of rainfall from himawari 8 extraction in each single sub-watershed, the CN number is not significantly influenced so that more dominant land use becomes the differentiating factor of runoff power in each sub-watershed.

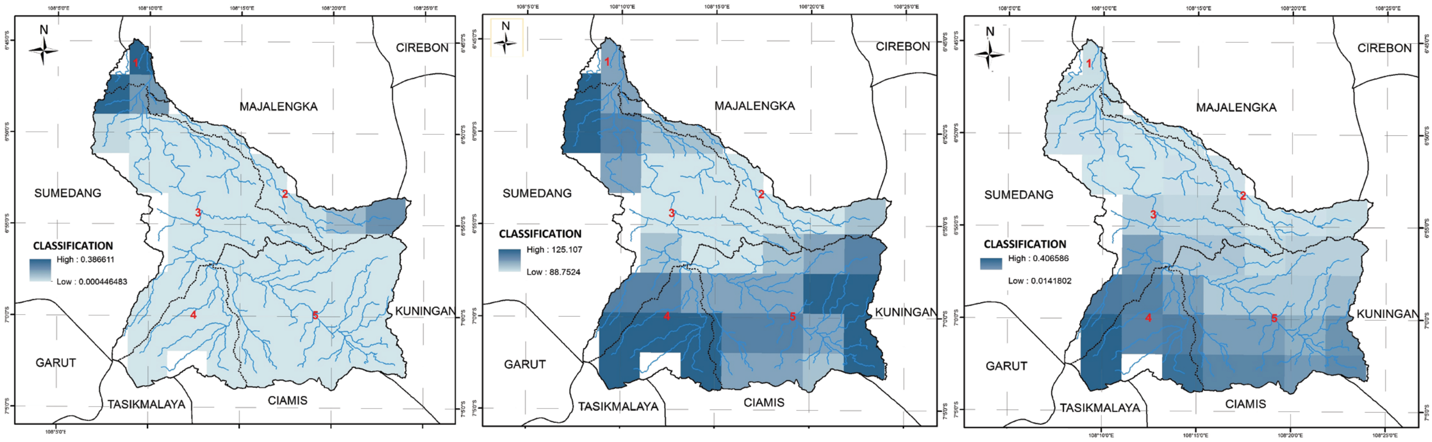

Figure 2. Maps of Rainfall Distibution (1) Equal; (2) Random; (3) Concentrate

time the occurrence releases rainfall figures into all categories. The resulting TSS concentration has an interval number of 22 to 1305 mg/l.

4 Characteristics of CN (Curve Number) on each Sub-Watershed Region

The process of rainfall precipitation into the watershed is strongly influenced by land use. Dynamics of land use are important factors that determine the power of runoff discharge. Analysis to amount of runoff discharge occurring requires CN data from study area divided into 5 sub-watershed. CN is obtained from HSG (table 5) overlay with land use.

Soil type at the study area has hydrologic soil group type D, included in the highest weighting for CN value. The larger value of CN on a sun-watershed, then the larger runoff power. From the results of the analysis through the results map (figure 3) shows that the largest percentage of land use is for agricultural followed by shrubs. According to data processing, the largest CN is found in sub-watershed 5 (Ci Kijing) located at the upstream of DA Cilutung with CN value weights 84,12. While the lowest weighted CN is found in sub-watershed 3 (Ci Saar) which is in the dominant height area below 500 masl.

In sub-watershed 1 (Cilutung) has the smallest area but CN value is not the lowest because the area is dominated by agricultural land use that has high runoff power. The characteristic of each sub–watershed when having large area is not necessarily have a tendency to have high CN value, as well as with sub-watershed with small area. The average CN weight of each sub-watershed has a relatively close number being in the interval 80-85, with a relatively small difference among

Table 4. Precipitation data in each occurrence with discharge and TSS

Sample/ occurrence	Day / Date-Month	Precipitation (mm/jam)	Discharge (m^3/s)	TSS (mg/l)
1	Fri / 06-04	265	68,888	374
2		25	52,296	70
3	Sat / 07-04	2	20,735	72
4		0,02	15,509	34
5	Sun / 08-04	0,08	28,107	107
6		0,05	19,377	55
7		0,05	33,939	70
8	Mon / 09-04	0,5	20,375	102
9		6,2	16,569	22
10		56	93,129	726
11		54	87,486	1305
12		40	79,245	598
13	Tue / 10-04	79	24,285	37
14		1	21,605	35
15		0,14	14,891	88
16	Wed / 11-04	0,01	11,287	19
17		0,14	12,726	40
18		0,07	14,891	21
19		0,07	14,891	21

20	Thur / 12-04	0,2	12,726	6

Table 5. Hydrologic Soil Groups, Types and Area of Land Use in Study Area

No	Land Use	HSG	CN	Area (km^2)	Precentage (%)
1	Forest	D	79	31	7,9
2	Farm	D	86	126,8	17,8
3	Residential	D	92	10,7	2,9
4	Agricultural	D	81	257,9	36
5	Shrub	D	77	158,6	22,3
6	Moor	D	89	50,8	13,1
	Total Area			635,8	100

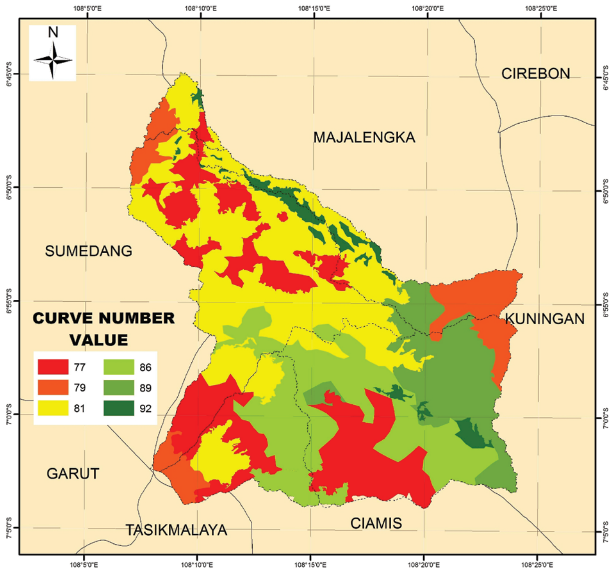

Figure 3. Maps of Curve Number in Study Area

4.1 Sub-watershed 1 (Cilutung)

Cilutung has the smallest area among the other sub-watershed, but does not make CN weighted into the smallest with 80,52. The location of sampling station that located in the area and supported by the presence of residential land use makes Cilutung become one of the largest contributor of TSS for Cilutung watershed. Based on the occurrence of the 8th sample shows that the rain falls centered on the Cilutung sub-watershed with precipitation number are classified as very light i.e. 0.5 mm / hour. Although rainfall is very mild but produces TSS that exceeds the standard quality limits of 102 mg / l.

4.2 Sub-Watershed 2 (Ci-Jurey)

Ci Jurey has a CN weight of 80,33. In the area has dominant land use in the form of agricultural with still found much residential area that extend to the north. The weighted CN value of Ci Jurey sub is the second highest after Ci Kijing sub-watershed. Data of spatial distribution of rainfall on the 3rd and 5th occurrence samples proves that if the rain fall on Ci Jurey produces high TSS number. Each TSS number is 72 mg / l and 107 mg / l.

4.3 Sub-Watershed 3 (Ci-Saar)

Ci Saar having broad the greatest area, but was inversely with weights CN which is only 80,47, while also contributing the least weighted CN value among the other sub-watershed. It has dominant agricultural land use with small residential areas. Data on the spatial distribution of rainfall on the occurrence 14th and 17th samples proves that if rain falls on Ci Saar produces a low TSS (below the quality standard threshold). Each TSS number is 35 mg / l and 40 mg / l.

4.4 Sub-Watershed 4 (Ci Hieum)

Ci Hieum watershed has a CN weight of 81.53 with the dominant land use of farm. The farm possess considerable runoff power characteristics, allowing Ci Hieum to be one of the largest contributors of TSS. However, based on spatial distribution of rainfall data on the occurrence 16th and 18th samples proves that if rain falls on the sub DA Ci Saar produces a low TSS (below the standard quality threshold). Each TSS number is 19 mg / l and 21 mg / l. This is because there is also a shrubs land use area that is also quite balanced with the farm that is by comparison the extent of the shrub of 30 km2 and the farm 37 km2. The use of shrub land itself has the characteristics of small runoff power and infiltration is quite strong.

4.5 Sub-Watershed 4 (Ci Kijing)

Ci Kijing sub-watershed has the largest CN weight valued at 84.12 with moor as the dominant land use. Moor as the land use has large runoff power characteristics and weak infiltration. Data of spatial distribution of rainfall on the occurrence 10th and 15th samples proves that if the rain falls on Ci Kijing produce TSS numbers that are high. Each TSS number is 726 mg / l and 88 mg / l.

5 Relationship Between TSS with Turbidity and Discharge

5.1 TSS versus Turbidity

Assuming that TSS would increase with turbidity intensities as stated by [11], the relation between TSS and turbidity was evaluated. TSS concentration is proportional to the increase of turbidity and inversely proportional to the water brightness. High TSS values contribute to turbidity by limiting the penetration of light for photosynthesis. However, at each different physical condition of regions allows an anomaly related to the correlation of the opposite between the two variables. To find out more, data from TSS and turbidity are made graphs to see fluctuations as well as relationships between them in (figure 4).

From the graph data that appears there are differences in the rise and fall of each variable. But also seen some similarities between the two that is just the last 5 samples of the up and down movement of graphs between the two variables look constant. In 1st to 9th sampling occureence, turbidity value is always higher than TSS, contrariwise in 10th to 12th sampling occurrence turbidity value is lower than TSS that a big difference in the number difference (> 500) when turbidity value is lower than TSS. Turbidity and TSS data are correlated through pearson product moment test. From the results appear coefficient of determination (R^2=0,5416). it indicates the tendency of correlation between the two variables has weak correlation.

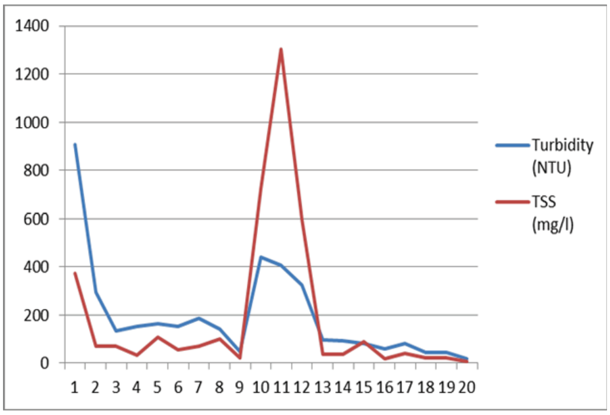

Figure 4. Comparison Graph between TSS and Turbidity through pearson product moment correlation (R^2 = 0,5416).

5.2 Relationship between Discharge and TSS

TSS with the highest value was found in 11th sampling occurrence with 1305 mg / l and the lowest value in 20th sampling occurrence with 6 mg / l. on the Monday occurrence, there were three highest peak values of discharge during the measurements occurring in one period, at 10-12th sample with the lowest discharge rate of 79.245 m^3 / s. In the first and second occurrence on Friday, the difference of discharge was not too far, i.e. 68,888 m^3 / s and 52,296 m^3 / s. However, the value of TSS concentrations produced showed significant differences, ie at 374 mg / l and 70 mg / l, respectively. It is caused by the difference on the falling point of the rainfall location and the presence of a natural dilution.

The highest average of discharge occurred on Friday with 49.47 m^3 / s while the lowest average discharge occurred on Thursday with 11.86 m^3 / s. Then it has been correlated between the discharge of observation with TSS measurement during the research. Discharge and TSS data are correlated in the form of suspended sediment rating curve with linear curve (figure 5). The result proves the coefficient of determination (R^2=0,7604). This shows the tendency of the correlation between the two strong variables between the increase of the discharge that influences increase of TSS. Then it made the estimated accumulation sediment of April 2018 is 820 kg / m^3.

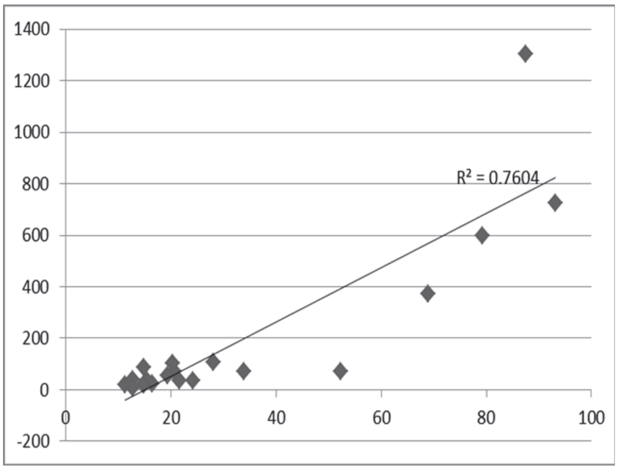

Figure 5. Correlation between TSS and Discharge.Trend line gives best linear fit: y = 10.591x - 160.96 (R^2 = 0,7604).

6 Conclusion

The spatial distribution pattern of rainfall has a strong relationship with the TSS concentration generated through runoff discharge. Rainfall distribution pattern in each sampling occurrence contributed to the fluctuation of TSS concentration and turbidity values. The random spatial distribution of rainfall in each sub-watershed results low TSS values, whereas centralized rainfall contributes to the high yield of TSS. In sub-watershed 1 (Cilutung), sub-watershed 2 (Ci Jurey) and sub-watershed 5 (Ci Kijing), have a strong relationship of producing TSS in high concentrations when the falling rain point is in that location. However, the CN number of each sub-watershed does not show significant differences in effect due to the difference in adjacent CN interval where land use in the form of residential and moor becomes more influential. The strong correlation was found in the relationship between TSS with discharge with the coefficient of determination (R^2=0,7604). Carbon is one of the materials that contained in total suspended solid as an anorganic substances. It mostly appears from the results of household waste such as laundry detergent left over from clothes that are immediately thrown into the river. High curve number can also be caused by changes in land use. Deforestation of land around the watershed adds to the problem of the emergence of additional carbon emissions which causes a derivation in ecological quality. The conversion of forests to sand mining and agricultural areas has caused thousands of hectares of land in study area to be in critical condition. It is important to give more attention in watrsheds conservation from related stakeholders to reduce water pollution.

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