The effect of land-use change on river watershed quality (case study: Cimahi Watershed, West Java, Indonesia)

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Abstract. Increasing population growth is one of the impacts of the growth of a city or district in an area. This also happened in the Cimahi watershed area. As the population grows, so does the need for land which increases the land-use change in the Cimahi watershed. Land-use changes will affect the surrounding environment and one of them is the river, especially river water quality. As a watershed area, there is one main river that is the source of life as well as the Cimahi watershed, whose main river is the Cimahi River. The purpose of this study was calculated the relationship between land-use change in the Cimahi watershed and the water quality parameters of the Cimahi River. The correlation between the two was calculated using Pearson correlation. Water quality parameters can be seen based on BOD and DO values. BOD and DO values are the opposite because good water quality has high DO values and low BOD values. The correlation between land-use change and BOD was 0.328 in the area of settlements area. In contrast, to DO values, an increase in settlements/industrial zones will further reduce DO values so that both have a negative correlation, which is indicated by a value of -0.535. The correlation between settlements with pH and temperature values is 0.664 and 0.812. While the correlation between settlements with TSS and TDS values are 0.333 and 0.529, respectively. In this study, it can be seen that there is a relationship between the decline in water quality and changes in land use.

1. Introduction
Cimahi watershed is a part of the Upper Citarum Watershed, which is one of the most threatened watersheds in the world and the most degraded in Java Island [1]. This is because the Upper Citarum Watershed is undergoing rapid land changes as a result of rapid urbanization processes, such as the conversion of forests and agriculture [1]. Land cover is a basic variable that has an impact and connects various parts between humans and the environment, so land use that can improve the quality of the environment is highly recommended to prevent flood, ensure the availability of groundwater, and so on [2].

Land change is the most important anthropogenic driver in environmental change on both spatial and temporal scales [3] [4]. Environmental problems caused by land changes include the change in surface runoff, which has the potential of flood [5] [4] [6] [7], loss of biodiversity [3], water, soil and air pollution [3] [8], climate change [3] [9], environmental degradation [1] [10] [11] [12] [13] [14], reduce infiltration [15] and decreased water quality [1] [16] [17] [18] [19]. Transfer of land for plantations, agriculture, settlements, and industry has the potential to reduce the quality of waters as receiving bodies.
Deforestation activities in the upstream watershed are the main factors causing the low ability of the soil to maintain the entry of excess nutrients into the water and domestic activity is the biggest factor affecting the BOD value in the river [20] [21] [22].

The purpose of this study was to investigate the effect of land-use change on the water quality of the Cimahi River as the main river in the watershed area. The scope of this research was the Cimahi watershed area, land-use change during the period of 2014 to 2018, and the water quality of Cimahi River during the period of 2014 to 2018.

2. Materials and methods

2.1. Location of study
Cimahi watershed has an area of 72.7 km² with the main river is the Cimahi River, which has a length of 30.6 km leading to the Citarum River. Cimahi Watershed is located in 3 (three) administrative regions, namely West Bandung District, Cimahi City, and Bandung District. The circumference of the Cimahi watershed is 66 km with an average slope of 17.84%. Geographically, this watershed area is a basin valley that slopes to the south and a height in the north that is 1,040 meters above sea level. Cimahi watershed has a monsoonal climate type that has two rain peaks, which are January-May and October-December [23] [24] [25] [26]. As an illustration, the Cimahi watershed can be seen in figure 1 [26].

![Figure 1. Map of Cimahi Watershed [26].](image-url)

2.2. Methods
This study consists of two stages, which are spatial analysis of land-use change and the effect of land-use change on river water quality. The spatial analysis phase was carried out using GIS (Geographical Information System) software. The spatial analysis phase is calculated the area in the Cimahi watershed which data is obtained from the Agency for Regional Development of West Java. From the map can be known changes in the land-use area in the watershed area. The second stage was to analyze the relationship between land changes and river water quality using the Pearson correlation calculation [8] [16]. The types of land-use change are divided into forests, agriculture/plantations, grasslands/meadows, rice fields, and settlements/industrial zones.

The parameters used to calculate river water quality consist of physical and chemical parameters, such as temperature, acidity (pH), TSS (Total Suspended Solid), TDS (Total Dissolved Solids), BOD
(Biological Oxygen Demand), and DO (Dissolved Oxygen) [20] [16] [19] [27]. In this study, the chemical parameters used are BOD and DO because they are indicators to determine water quality [28]. BOD is considered to represent a source of pollution because the COD method only mimics biological oxidation reactions (which occur in nature), so it is only an approximation [29].

Cimahi River water quality data were obtained from Cimahi City Environment Agency. The available data from 2014 to 2018 but lack of data in 2016. Based on the data obtained, there is a trend for rising temperatures almost every year. When compared to 2014, the trend values for pH, TSS, TDS, and BOD in 2015 to 2018 have a much higher value, while the DO value has a declining trend.

Pearson's correlation was used to describe the relationship between land-use change and river water quality because this correlation coefficient was used to measure the closeness of the relationship between observations from populations that have two variants (bivariate). The Pearson correlation equation can be seen in equation (1) [30].

$$ r = \frac{n \sum xy - (\sum x)(\sum y)}{\sqrt{[n \sum x^2 - (\sum x)^2][n \sum y^2 - (\sum y)^2]}} $$

(1)

wherewith:
\( n \) = amount of data, \( x \) = independent variable, and \( y \) = dependent variable.

Pearson correlation coefficient (r) was used to determine the correlation of quantitative data on the scale of intervals and ratios at the range of 0 to 1. The closer the number 1, the stronger the relationship and vice versa, if the value approaches number 0, the weaker the relationship occurs [30] [31].

3. Results and discussion

3.1. Land-use change

Based on the calculation of spatial analysis by overlaying and extrapolating, the amount of land-use change in the Cimahi watershed area was obtained. Land use in this watershed is dominated by areas without plants, namely settlements and industrial zones by 62.45%. Then followed by forests at 20.003%, agriculture/plantations at 12.82%, rice fields at 2.44%, and meadow at 1.60%. Table 1 below shows the results of land-use change in the watershed areas from 2014 to 2018. Due to data limitations, there is no data for 2016.

| Land use                | 2014   | 2015   | 2017   | 2018   |
|-------------------------|--------|--------|--------|--------|
| Forest                  | 14.573 | 14.565 | 14.550 | 14.542 |
| Agriculture/plantation   | 12.061 | 11.377 | 10.007 | 9.322  |
| Meadow/ grassland        | 3.686  | 2.555  | 2.294  | 1.163  |
| Rice fields              | 6.294  | 5.164  | 2.905  | 1.775  |
| Settlement/industrial zone | 35.584 | 38.539 | 42.448 | 45.402 |
| Total                   | 72.7   | 72.7   | 72.7   | 72.7   |

Table 1 shows the most significant changes in land use in the Cimahi watershed in the settlements/industrial zones, which amounted to 9.818 km², or an increase of about 14% from 2014 to 2018. This proved that the population grew and increase in settlements as well. Population growth causes the need for shelter and all supporting facilities [32]. Change in land use that decreased after agriculture is rice fields that decreased by 4,519 km² or about 6%. For forest land-use type, there tends to be no significant change, only decreased around 0.005 km² from 2014 to 2018.
3.2. River water quality parameters

The maximum, minimum, mean, and standard deviation values of the temperature are 26.5 °C, 20.6 °C, 20.5 °C, and 4.83 °C. Whereas the TSS value was at the maximum of 327.4 mg/L, minimum of 22.25 mg/L, and standard deviation of 121.36 mg/L. The TDS value was at the maximum of 1044.5 mg/L, minimum of 53 mg/L, mean 285.89 mg/L, and standard deviation of 385.93 mg/L. The maximum value of pH was 8.34, its minimum was 4.65, its mean was 6.6 and its standard deviation was 1.668. The BOD had a maximum value of 46.25 mg/L, a minimum value of 1.203 mg/L, a mean of 13.86 mg/L, and a standard deviation of 17.38 mg/L. DO values in rivers have a maximum value of 6.138 mg/L, a minimum of 0.335 mg/L, a mean of 2.802 mg/L, and a standard deviation of 2.242 mg/L. The graphic image below shows the values of the water quality parameters in Cimahi River.

![Figure 2. Cimahi River’s temperature.](image1)

![Figure 3. Cimahi River’s total suspended solids.](image2)
Figure 4. Cimahi River’s total dissolved solids.

Figure 5. Cimahi River’s acidity (pH).

Figure 6. Cimahi River’s biological oxygen demand (BOD).
A zero value is a data void. Because Cimahi River does not yet have specific regulations, then based on Government Regulation No. 82 of 2001 the standard criteria for quality for Cimahi River is class II that can be used for water recreation facilities, water sources to irrigate crops, farms, freshwater fish cultivation, and or other provisions that are the same condition as the quality of the water. Based on the regulation when comparing the water quality of Cimahi River, then based on the temperature value Cimahi River is still in accordance with its designation because the standard criteria limit of quality class II is deviation 3° from natural temperature. The value of TSS in 2017 exceeded the quality standard criteria with a value of 299.67 mg/L. The acidity value of the Cimahi River was still at the range of class II water quality standard, which is between 6-9.

BOD parameters are generally widely used to determine the level of wastewater pollution and it is very important to trace the flow of pollution from the upstream level to the estuary [28]. The BOD value in 2018 exceeded the water quality standard criteria with a value of 13.98 mg/L while the quality standard criteria are only 3 mg/L. Waters that have a BOD value greater than 10 mg/L are considered to be polluted because waters that are considered good have low levels of pollutants with BOD values ranging from 0 to 10 mg/l [33]. The level of pollution of a river can be categorized as low if it has a DO value less than 5 mg/L, which is categorized as moderate if it has a value at the range of 0-5 mg/L and is categorized high if it has a DO value of 0 mg/L [33] [28]. By comparing DO river values in 2018, Cimahi River is included in the moderate polluted category with a DO value of 1.50 mg/L while if looking at the DO value in 2014, the river was still in a polluted condition with a low value of 6.35 mg/L.

3.3. Relationship between land-use changes and river water quality

For the past seventeen years, since Cimahi was part away from Bandung District, Cimahi was later included as part of the Bandung Metropolitan Area (BMA) whose functions as a buffer zone for Bandung City. Based on this, several Bandung City activities such as services, trade, and other economic activities were distributed to serve the residents of Cimahi. In addition, as a new city, Cimahi built many infrastructures that caused land-use changes in the Cimahi watershed area [34]. The relationship between land-use change area and river water quality was calculated using Pearson Correlation. Water quality parameters in this calculation are water quality parameters from one river and the results can be seen in table 2.
Table 2. Correlation of land-use change with river water quality parameters.

| Parameters | Forest | Agriculture/ plantation | Meadow/ grassland | Rice fields | Settlement/ industrial zone |
|------------|--------|--------------------------|-------------------|-------------|-----------------------------|
| Temperature | -0.797 | -0.797                   | -0.819            | -0.797      | 0.812                        |
| TSS        | -0.391 | -0.391                   | -0.129            | -0.391      | 0.333                        |
| TDS        | -0.456 | -0.456                   | -0.739            | -0.456      | 0.529                        |
| pH         | -0.641 | -0.641                   | -0.705            | -0.641      | 0.664                        |
| BOD        | -0.277 | -0.277                   | -0.479            | -0.277      | 0.328                        |
| DO         | 0.480  | 0.480                    | 0.684             | 0.480       | -0.535                       |

Based on that table, it can be indicated that The correlation between settlements/industrial zones with BOD has a positive value, this shows that the addition of settlements/industrial zones will increase the value of the BOD. This can be seen based on the correlation between settlements/industrial zones with BOD values and settlements/industrial zones with DO values. BOD is a parameter that indicates the amount of dissolved oxygen required by microorganisms to break down organic matter in water. DO is a parameter that indicates the content of oxygen dissolved in water as a parameter to measure water quality. Good water quality has high DO values and low BOD values. The correlation between settlement/industrial zone with BOD has a positive value, which is 0.328, this shows that the addition of settlements/industrial zones will increase the value of the BOD.

BOD and TSS values have a weak positive correlation with settlements because according to data series from year to year, land-use changes for settlements increase consistently due to population growth, but the concentrations of BOD and TSS do not consistently increase or decrease because they depend on the discharge of water bodies, and environmental management policies that are being implemented at certain times. In contrast, to DO values, an increase in settlements/industrial zones will further reduce DO values so that both have a negative correlation, which is -0.535.

4. Conclusions

Based on the results of this study, it can be seen that changes in land use in the Cimahi watershed correlate with decreasing river water quality. This is evidenced by the correlation between settlements and BOD of 0.328. This correlation value is a weak positive correlation. In addition to BOD, the correlation between settlements and TSS has a weak correlation of 0.333 because the BOD and TSS values depend on water discharge and environmental policies carried out at certain times. The correlation between settlements with TDS values, pH, and the temperature has a strong correlation, respectively 0.529, 0.664, and 0.812, while the correlation between settlements and DO has a negative value of -0.535 because of the increase in settlements will reduce the DO value in water bodies. The next thing that can be done is to look at the correlation between changes in land use and river water quality by dividing the river into several segments so that it can be seen the influence of the upstream of the river to the downstream of the river.

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