The effect of land use changes to discharge extremities in Cimahi Watershed – Upper Citarum Watershed, West Java

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Abstract. The development of cities and regencies in the Cimahi watershed area increases the rate of population growth which results in high land requirements in the Cimahi watershed area. Land se change affects the flow of runoff and debit of the Cimahi River. The purpose of this research is to assess the hydrological function area in the Cimahi watershed, the impact of the land use change and to analyze the effect of landuse change in the Cimahi watershed on the extremity of water resources in terms of both quantity and quality. The natural conservation index and the actual conservation index (IK_A and IK_C) are used as a parameter to indicate the existing hydrological conditions and ideal hydrological conditions for conservation which are calculated based on rainfall, rock type, slope, height and land use. The results of the conservation index showed that there was a decrease in the value of the IK_C from 0.637 in 2000 to 0.608 in 2012. The debit extremity could be seen based on the calculations by moving averages on the debit data, and the resulting maximum debit value was greater and the value of the base flow (baseflow) was getting smaller. Land changes in the Cimahi watershed also had an influence on the river water quality.

1 Introduction

The Cimahi watershed is part of the Upper Citarum watershed which covers three administrative regions namely West Bandung Regency, Cimahi City and Bandung Regency. According to West Java Regional Regulation No. 2 of 2016 the Cimahi watershed is also included in the North Bandung Region (KBU) and stated in the West Java Regional Regulation No. 1 of 2008 that KBU functions and plays an important role in ensuring the sustainability of life development. For this reason, improper developments in the KBU area can change the hydrological function and threaten water sustainability. As an illustration, the Cimahi watershed area can be seen in Figure 1 [1].

The growth in the number and density of population in the Cimahi watershed area affects the land use in the area. Uncontrolled population growth can lead to increasing land changes from agricultural land to non-agricultural land and urbanization is one of the phenomena that causes land conversion to be built up where urbanization has occurred in the North Bandung Region (KBU) [2-3].

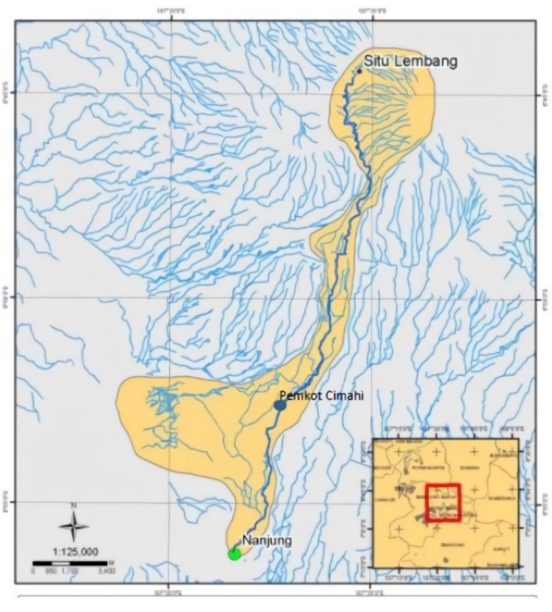

Fig. 1. Map of Cimahi Watershed (Safarina & Ramli, 2014)

Nowadays land use and land cover change are some of the main environmental changes and land use changes that are not in accordance with the plan usually occur in a rainwater catchment area. The changes in land use in a watershed can cause environmental degradation of the watershed starting from the upstream, midstream to downstream watershed [4-9].

Various impacts arising from the changes in the land use and land cover include enlarging runoff due to land cover that turns into a watertight [10-12], causing the occurrence of extreme debit and rain due to the decrease in vegetation area and triggering global climate change [12-14], increasing the flood debit and frequency of flood events in downstream areas [15] [3], reducing infiltration and minimizing riverbed flow (the phenomenon of extreme debit) that affects the hydrological cycle [16], and causes erosion and sedimentation which worsens river water quality [17]. Based on these impacts, land conversion will affect the existing water resources infrastructure in the watershed area. The relationship of land use change with land hydrological conditions can be seen by using a conservation index because with this method there are two main components used as guidelines for controlling spatial use, namely natural conditions and actual conditions (IK_A and IK_C) [16].

Land cover has been shown to have a significant impact on runoff [18] and is one of the important factors that divides rainfall into various hydrological components such as surface runoff, base flow, ground water flow, evapotranspiration, and so on [5] The coefficient value of land cover has been widely used as a diagnostic variable to represent runoff in a watershed [18]. The changes in land use and land cover are closely related to the problem of sustainable socio-economic development [4]. Embodiment of sustainable development in urban areas can be done by protecting and conserving natural resources, increasing the implementation of supervision and control, law enforcement, institutional improvement and monitoring facilities and infrastructure, increasing adaptation and mitigation to the impacts of climate change, developing water quality monitoring equipment, and changes in land use are responsible for water quality [19].

The rate of land conversion in the Cimahi watershed has an impact on the extreme water flow in the Cimahi watershed, causing degradation of the hydrological function of the watershed area. Reduced water catchment threatens the availability of water in the watershed, which causes a lack of water in the dry season and degradation of dry plan discharge wich has an impact on water quality degradation, especially in the dry year. The amount of runoff will burden the drainage infrastructure, both micro and macro drainage and will add to the burden of water carried in the water body.

The purpose of this study is to assess the hydrological function of the area in the Cimahi watershed area and analyze the changes in land use in the Cimahi watershed region against the extremity of water resources, both in quality and quantity. The scope of this study is the Cimahi watershed area, debit data and rainfall data that have an influence on the watershed area, as well as the use of land use maps, soil type maps and soil slope maps for spatial analysis in the Cimahi watershed area.

2 Research Methodlogy

This study was divided into several stages, namely spatial analysis, hydrological analysis and assessment of the hydrological function of the area in the watershed area due to land changes and land cover in the Cimahi watershed area. The phenomenon of degradation of the hydrological regime can be done with the statistical hydrological model approach [16]:

$$Q = C\ (P \times A) + b \tag{1}$$

where with
Q: river debit (L^3/T)
C: runoff coefficient
P: regional rainfall (L/T)
A: watershed area (L^2)
b: base flow

Based on the equation 1, it is configured that the debit is affected by land changes, which is indicated by the value of runoff coefficient and base flow in the river. Minimum and maximum debit data in the Cimahi watershed are analyzed using moving average analysis because it can eliminate the random nature of the debit to get the tendency of change and can be used to predict values in the next period [20].

In the Presidential Decree of the Republic of Indonesia No. 114 of 1999, it is explained that the conservation index (IK_A and IK_C) is an indicator of the existing hydrological conditions and ideal conditions for conservation which are calculated based on rainfall, rock type, slope, height and land use variables. The equation conservation index can be seen in equation 2 and equation 3.

$$IK_A = F\ (Y_A) \tag{2}$$

$$IK_C = F\ (Y_C) \tag{3}$$

where with
Y_A = f (rainfall, rock type, soil type, morphology & topography), and
Y_C = f (rainfall, rock type, soil type, morphology & topography, cover land) [16].

According to Arwin [21] natural conservation index (IKa) is calculated by combining rain components, slope maps and soil type maps. The results of the combination of the three maps are in the form of land unit maps and each land unit has different water absorbing abilities. The amount of ability to absorb water will be given a range from 0-1. The actual conservation index value (IKc) is calculated based on the rainfall, soil type, slope and land use variables. To find out the value of IKc, an isohyet map (rain variable), slope map, soil type map and land use map are combined. From the merging of the map the infiltration coefficient and infiltration capacity of each land unit will be calculated.

The data used in this study are hydrological data and spatial data. Hydrological data are in the form of rainfall data and debit data obtained from the rainfall station around the Cimahi watershed and discharge station around the Cimahi watershed and the water quality data of the Cimahi River. Spatial data used are in the form of land use data, land type data and slope in the Cimahi watershed area. The map of land use change were found in 2000, 2010 and 2012.

3 Result and discussion

3.1 Regional rainfall and climate type

The rainfall data recorded at the rain station was rain that occurred at one place or point only so that it was necessary to calculate the region's average rainfall to describe the rain in an area. The method that could be used to calculate regional rainfall was the average method of algebra and Thiessen polygons. The method used to calculate regional rainfall in this study was the algebraic (arithmetic) method because the watershed area was less than 500 km^2 [22]. Comparison of regional rainfall with the amount of rain recorded at each rain station can be seen in Figure 2.

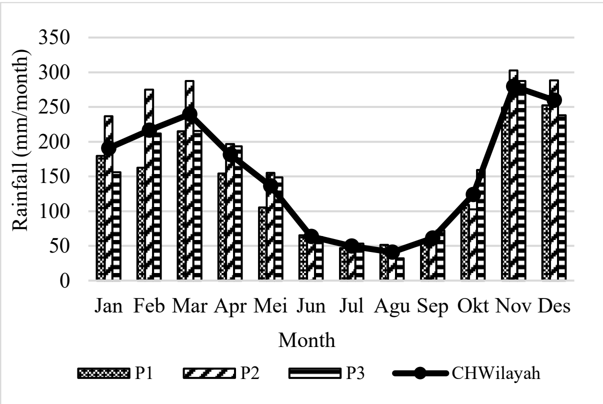

Fig. 2. Regional rainfall in Cimahi Watershed area

Based on the results of the rainfall calculation of the region, we can see the climate type of the Cimahi watershed, which is a moonsonal type. Monsoonal type has 2 rain peaks, in January-May and October-December. In the type of moonson, rainfall is concentrated in the wet season, while the rainfall is relatively below 100 mm/month in the dry season [23].

3.2 Degradation of flow regime

With an increase in maximum discharge data and a decrease in minimum data due to an increase in runoff load and due to reduced infiltrated discharges into the ground, a decrease in base flow occured. Discharge extremity was analyzed using a moving average to eliminate the random nature of the debit and observed every day that was calculated successfully for 5 years. The changes in the hydrological regime of a watershed could be analyzed using a simple linear regression approach that produced runoff coefficients and a base flow that was illustrated by the tendency of its movement with time. A simple linear regression approach that could describe the degradation of flow regimes is shown in equation 1 [3]. Figure 3 shows that the change in runoff coefficient value which is increasing every year and the baseflow is decreasing, which is shown in Figure 4. Figure 5 shows the results of the analysis of the discharge extremity in the upstream area of the Cimahi watershed.

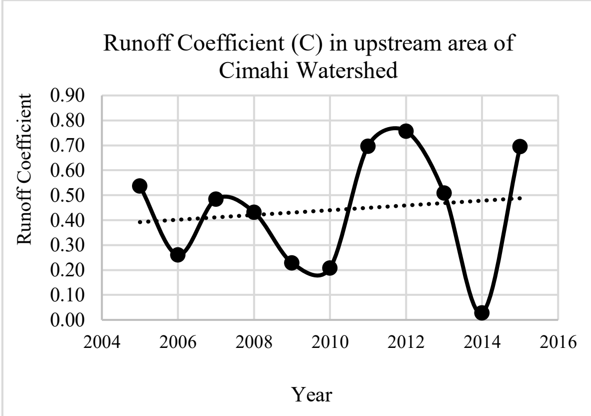

Fig. 3. Runoff coefficient in upstream area of Cimahi Watershed

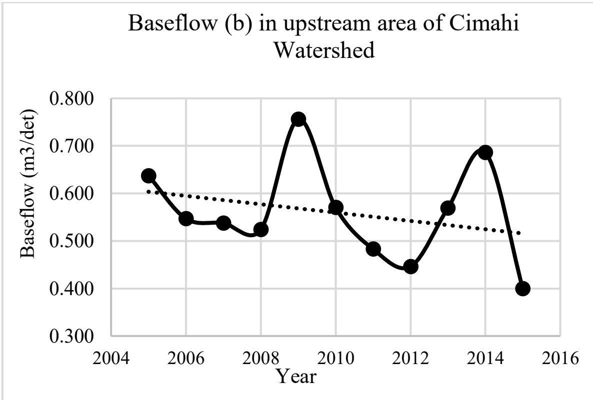

Fig. 4. Baseflow in upstream area of Cimahi Watershed

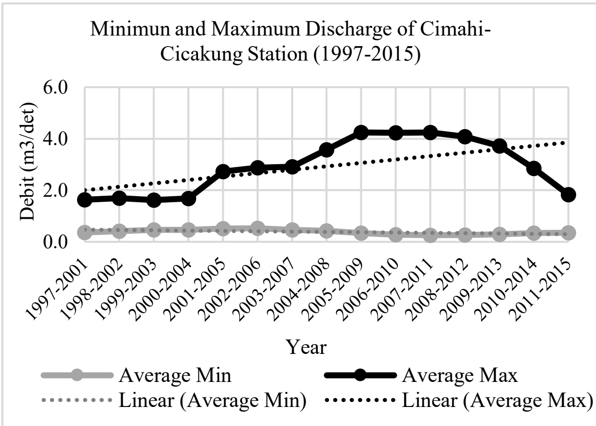

Fig. 5. Cimahi-Cicakung discharge extremities

3.3 Degradation of land functions

An assessment of the condition of the Cimahi watershed area was calculated based on a conservation index. The conservation index had 2 parameters, namely the natural conservation index and the actual conservation index. The two indices were calculated using the help of ArcGIS software and using data in the form of slope maps, maps of land types and maps of land use changes showing the changes in 2000, 2010 and 2012 presented in Figure 6. Slope and soil type maps are considered permanent. From the 3 maps, an overlapping process was carried out (overlay) to produce the index value of the conservation area. The overlay process was done by stacking 3 maps where the first layer was for the slope map, the second layer was the soil type map and the third layer was the land use map. The changes in the actual conservation index value, which was affected by changes in land use can be seen in Figure 7 and the results of the assessment of the condition of the area are presented in Table 1.

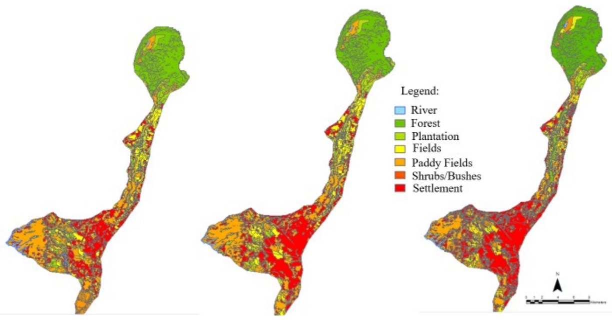

Fig. 6. Land use change in the Cimahi watershed

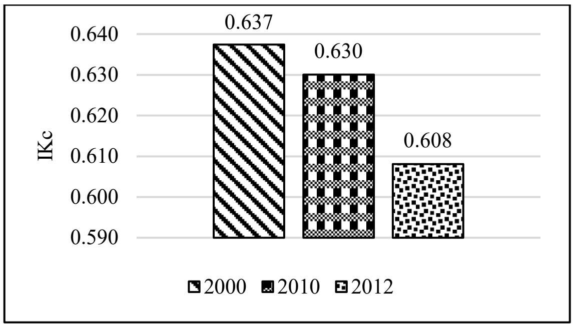

Fig. 7. Changes in the IKc value

Table 1. An assessment of the condition of the Cimahi watershed area

No	Year	IKa	IKc	Assessmenat
1	2000	0.784	0.637	Degradation
2	2010	0.784	0.630	Degradation
3	2012	0.784	0.608	Degradation

Based on the assessment of the hydrological function condition of the Cimahi watershed area, it can be seen that there is degradation in the Cimahi watershed area and conservation is needed as an effort to restore the hydrological condition of the area.

3.4 Relationship between land changes and the quality of the Cimahi River

Land changes in a watershed can affect river water quality [19]. The relationship between river quality parameters and land changes in the Cimahi watershed can be seen in Table 2.

Table 2. Correlation between river water quality parameters and land changes

Para-meter	Land use			
	Forest	**Agricul ture**	**Rice Field**	**Settlemen/i ndustrial zone**
Temp	-0.79	-0.79	-0.79	0.81
TSS	-0.39	-0.39	-0.39	0.33
TDS	-0.46	-0.46	-0.46	0.53
pH	-0.64	-0.64	-0.64	0.66
BOD	-0.28	-0.28	-0.28	0.33
DO	0.48	0.48	0.48	-0.54

Based on the table above, it can be seen that there are initial indications that land changes affect river water quality, which can be seen by the negative relationship between DO values and the addition of settlements/industrial zones.

4 Conclusion

Changes in land use in the Cimahi watershed area increase the value of runoff coefficient so that it has an impact on increasing the frequency of flood events in the Cimahi watershed. The assessment of the hydrological function of the area in the Cimahi watershed area shows that there is degradation or a decline in the Conservation Index value. This is indicated by changes in the value of the conservation index from 0.784 to 0.637 in 2000, 0.630 in 2010 and 0.608 in 2012. This is due to the rampant land use change in the Cimahi watershed area. From the calculation of the extremity of debit using the moving average method, the results obtained are in the form of a higher and higher maximum discharge, which is an indication that the change in land results in an increase in runoff discharge. In addition, based on the correlation test on water quality in the Cimahi River, there are initial indications that land changes in the Cimahi watershed area affect river water quality as indicated by an inverse correlation between an increase in residential areas and changes in DO values in the river.

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