The Change Of Hydrological Regime In Upper Cikapundung Watershed, West Java Indonesia

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Submission date: 02-May-2023 03:45PM (UTC+0700)
Submission ID: 2081885065
File name: l_Regime_In_Upper_Cikapundung_Watershed,_West_Java_Indonesia.pdf (609.79K)
Word count: 2747
Character count: 14822

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Procedia Engineering 125 (2015) 229 – 235

Procedia Engineering

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The 5th International Conference of Euro Asia Civil Engineering Forum (EACEF-5)

The change of hydrological regime in upper Cikapundung Watershed, West Java Indonesia

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Abstract

The changes of water movement and distribution are influenced by extreme rainfall and landcover conversions. The rainfall becomes more extreme than before. A research of hydrological regime condition is necessary to be done by managing the rainfall and river flow data. This research identifies and analyses the changes of hydrological components (rainfall, river flow, and landcover). Rainfall data obtained from 5 rainfall stations for 35 years (1978-2012), and river flow data obtained from Maribaya station for 43 years (1970-2012) in Upper Cikapundung Watershed were studied to compare the trend of older rainfall data with the newer ones. The statistical analysis employed were the correllation between area rainfall and river flow; the trend-change between maximum and minimum rainfall and river flow data; and the trend-change between baseflow and runoff coefficient C which were built from monthly rainfall and river flow data in a year. The trend-change analysis used was 5 years moving average method. It was found that the trends of 5 years moving average for Lembang, Cikapundung, and Margahayu stations were decreasing, while the other ones for Cemara and Dago Pakar stations were increasing. It was because the three first stations were located in Lembang Basin, and the last two stations were located in Bandung Basin. These changes were also supported by the changes of landcover data from 1998 to 2012. The rainfall, average river flow, and baseflow tend to decrease because the Upper Cikapundung Watershed that located in Lembang Basin had a decreased rainfall. Runoff coefficient and the river flow of Maribaya Station tend to increase due to increased maximum rainfall distribution and the land conversions.

Peer-review under responsibility of organizing committee of The 5th International Conference of Euro Asia Civil Engineering Forum (EACEF-5)

Keywords: hydrology regime; moving average method; rainfall; river flow

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1877-7058
Peer-review under responsibility of organizing committee of The 5th International Conference of Euro Asia Civil Engineering Forum (EACEF-5)
doi:10.1016/j.proeng.2015.11.033

1. Introduction

Changes in water flow and distribution is influenced by the presence of extreme rainfall and land conversion from forest to cultivation land. Precipitation becomes more extreme than before. The dry season become longer than before, while in the rainy season, rainfall become higher than before. So that the extreme rainfall will cause flooding [1].

Whereas when viewed from land conversion, land cover change from permeable into impermeable areas - especially in urban areas - will affect the movement of water on earth. With increasingly impermeable landcover the less water can infiltrate into the ground and more rain will runoff [2]. Study area used in this research is an urban settlement area in the Upper Cikapundung Watershed because this area have been some problems such as [3]:

- Rainfall is relatively high in a conservation area (750-2400 m above sea level) and the probability of occurrence in a row for 2 to 5 days is increasing. Probability of rain streak for 2 days to 5 days of rain increased from 0.55 to 0.78.
- Land, surface water, and ground water use regulation has not been implemented optimally.

The main problem that may affect the hydrological regime change in Upper Cikapundung Watershed are:

- The effect of climate change and land conversion led the discharge of water become extreme (change the character of flow) so that increased the threat of flooding and drought which affect on the degradation of water resources infrastructure functions [4].
- Extreme rainfall, land conversion from forest being cultivation land and runoff control in urban settlements using drainage systems resulted the characteristics changes of the watershed that shorten the travel time of water into the river, reduce the amount of infiltrates water into the ground, increase flood IDF curves, and shorten the time concentration [5].

To find out the changes that occur, a study of the condition of the hydrological regime was required by doing the processing of rainfall and discharge data to get a tendency of changes in the rainfall intensity and the flood discharge plan in the study area.

So the purpose of this research is:

- Identify and analyze the changes in the hydrological components namely rainfall river flow and landcover.
- Analyze the relationship of the hydrological components that can cause the changes of watershed characteristics.

2. Methods

2.1. Secondary Data Collection

Data required are as follows:

- Map and data from 5 of rainfall and climate stations in the study area, namely Lembang Station, Cikapundung Station, Dago Pakar Station, Bandung/Cemara Station, and Margahayu Station; and consists of 35 years of daily data in series (1978-2012) sourced from Department of Meteorologyst, Climatology, and Geophysics, Department of Irrigation / Water Resources of West Java Province, Center for Research and Development of Water Resources Department of Public Works.
- Data from 2 discharge observation stations in the study area namely Maribaya station and Dayeuhkolot station; data used were 43 years of daily data (1970 - 2012) from Department of Irrigation / Water Resources of West Java Province, Center for Research and Development of Water Resources Department of Public Works or Department of Citarum Watershed.

Location of rainfall and dicharge stations in Cikapundung Watershed can be seen in the Fig. 1.

Rainfall Station	Coordinate	Data	Data Type	Sources
Lembang	06049'35,6" LS 107037'3,6" BT	1978-2012 (35 DATA)	Daily Data	Department of Meteorologyst, Climatology, and Geophysics, Department of Irrigation / Water Resources of West Java Province, Center for Research and Development of Water Resources Department of Public Works
Cikapundung	06049'15,0" LS 107037'59" BT	1998-2012 (15 DATA)	Daily Data	
Dago Pakar	06052'51,0" LS 107037'59" BT	1978-2012 (35 DATA)	Daily Data	
Bandung (Cemara)	06053'0,8" LS 107035'50,4" BT	1978-2012 (35 DATA)	Daily Data	
Margahayu	06048'1,0" LS 107039'24" BT	2003-2012 (10 DATA)	Daily Data	

Fig. 1 Location and Data of Rainfall and Discharge Stations [5]

2.2. Rainfall Data Processing

Rainfall used in this research is the maximum daily rainfall which is the highest rainfall recorded in one day in one year recording rainfall [6]. In the rainfall data processing carried out several steps namely [7]:

- Generation of data; using algebraic method, correlation method, and normal comparison method
- Consistency test; using Rescaled Adjusted Partial Sums (RAPS) and Double Mass Curve Method
- Homogeneity test; using Pair Sample Test (t - Test)

2.3. Analysis of Hydrological Regime Change and Land Conversion

Analysis of changes in the hydrological regime is performed to determine the hydrologic regime degradation caused by extreme rainfall and land conversion from forest into cultivation area [8]. The analysis of these changes is done by comparing the trend / tendency of rainfall data in the past with the data on the present. The used analysis is the correlation between rainfall-area with the discharge data, trend analysis of changes in precipitation and discharge for maximum and minimum of data, trend analysis of changes in design rainfall and flood at a certain period, and trend analysis of changes baseflow and runoff coefficient C which is generated from the capacity of monthly rainfall data and monthly discharge in one year. The trend analysis of rainfall changes uses 5-year moving average method [9].

3. Result and Discussion

3.1. Preparation of Data Rainfall

Rainfall data for this analysis was obtained from Department of Meteorologyst, Climatology, and Geophysics, Department of Irrigation / Water Resources of West Java Province, Center for Research and Development of Water Resources Department of Public Works or Department of Citarum Watershed. The rainfall stations which is taken to be processed is Lembang Station, Cikapundung Station, Station Dago Pakar, Bandung Station (Cemara), and Margahayu Station. The data used from each rainfall station is the maximum daily rainfall data every year. After the data completion, consistency test, and homogeneity test, the data obtained is ready for use.

3.2. Moving Average Rainfall

Moving average (MA) is the change in the average value for n number of the latest data. The average value can be calculated by removing the oldest data and add the latest data. Moving averages are used to predict the value of the next period. This model is suitable for use on a stationary data or data that is constant, but it can not work with data that contains elements of a trend or seasonal [7]. Here is a picture that shows the moving average for all rainfall stations which are reviewed.

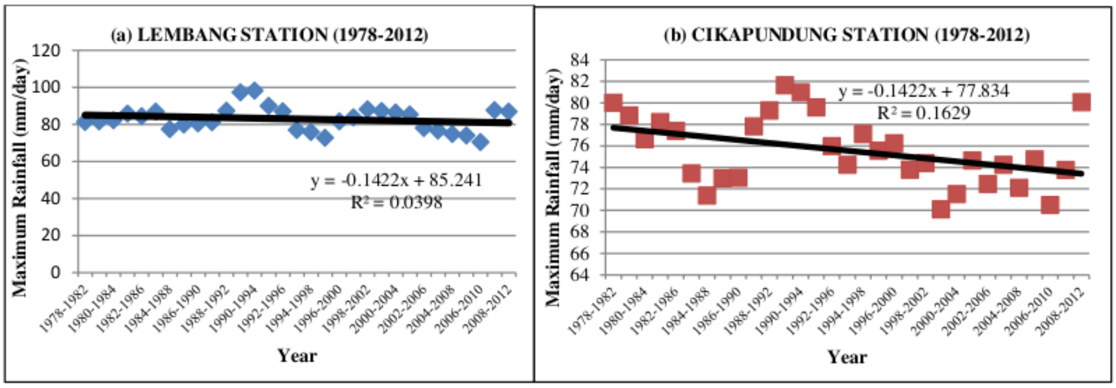

Fig. 2 Moving Average Rainfall Data in Lembang Station (a) and Cikapundung Station (b)

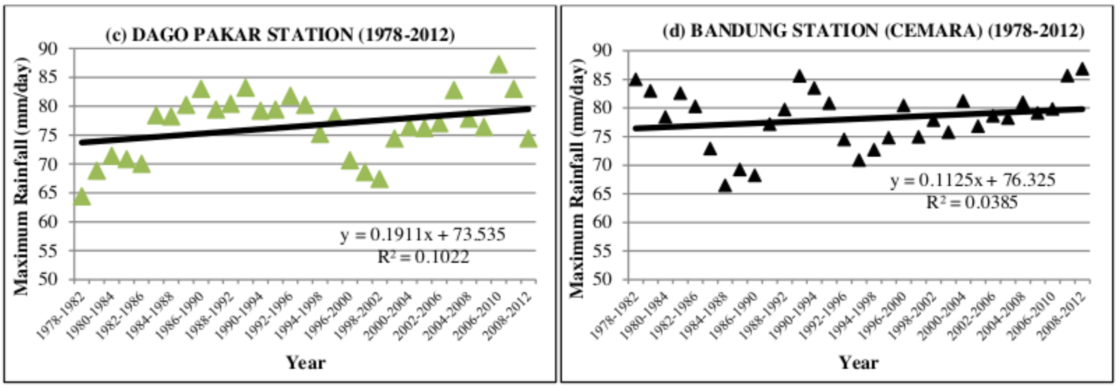

Fig. 3 Moving Average Rainfall Data in Dago Pakar Station (c) and Bandung (Cemara) Station (d)

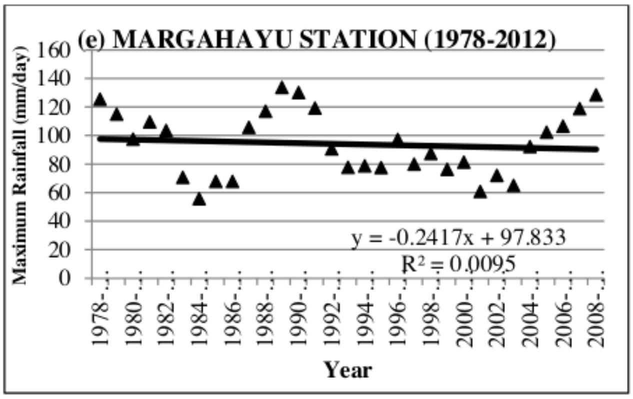

Fig. 4 Moving Average Rainfall Data in Margahayu Station (e)

From the above figures can be analyzed:

- Figure 2 and Figure 4 show that the 5-year moving averages of ranfall data in Lembang, Cikapundung, and Margahayu Stations (1978-2012) tend to decrease. This can happen because those three rainfall stations located on the same morphology area namely Lembang Basin. The decline in trend of rainfall is likely due to the land conversion and also because the three morphological rainfall stations are located in Lembang Basin bounded by a narrow ridge of Tangkuban Perahu Mountain and Lembang Fault where the rains that occurred in this basin is the rest of the rain that falls on the ridge of the mountain / hill before.
- While Figure 3 shows that the 5-year moving average of rainfall data in Bandung and Dago Pakar Stations (1978-2012) tend to increase. This is because the morphological layout of these rainfall stations located in the northern part of the Bandung Basin is relatively wide and can receive direct rain.

3.3. Discharge

In the hydrologic cycle, the relationship between the average discharge of the river with the average rainfall in the watershed which has aquifer can be expressed in a mathematical equation [8]:

$$Q = C.(PxA) + b \quad (1)$$

where:
P = monthly average regional rainfall (m / sec)
A = watershed area (m^2)
b = baseflow (m^3 / sec)
C = runoff coefficient
Q = average river flow (m^3 / sec)

The equation can be associated with a linear equation namely:

$$y = a.x + b \quad (2)$$

By comparing these two equations, the y can replace the Q, A replaces C, x replacing (PA) while b replacing baseflow b [5].

By making the linear regression between data on monthly average discharge (Q = y) and monthly average rainfall (PA = x), will obtain the value of a (= C runoff coefficient) and the value b (= b baseflow) in a year. Thus each year will earn runoff coefficient C and Baseflow in Upper Cikapundung watershed (Station Maribaya). The coefficient of run off and Baseflow manufacture of linear regression results will then be used to find trend changes both by the use of 5-year moving average method. 5-year moving average is used because the landcover changes can be seen clearly after 5 years [10]. In table 1 are presented 5-year moving average value for average discharge, average rainfall, baseflow values and runoff coefficient C. While the figure 5 and 6 show the trend is going.

Table 1. Rainfall Station in Cikapundung Watershed.

Year Range	Average Flow (m^3/det)	Rainfall (m^3/det)	Baseflow (m^3/det)	C runoff
	(Q)	(A.P)	(b)	(C)
1983-1987	6.034	3.201	2.482	0.122
1988-1992	5.611	3.086	2.366	0.124
1993-1997	5.294	3.338	2.177	0.216
1998-2002	5.225	3.269	2.467	0.154
2003-2007	5.268	2.709	1.881	0.158
2008-2012	5.783	3.212	2.365	0.147

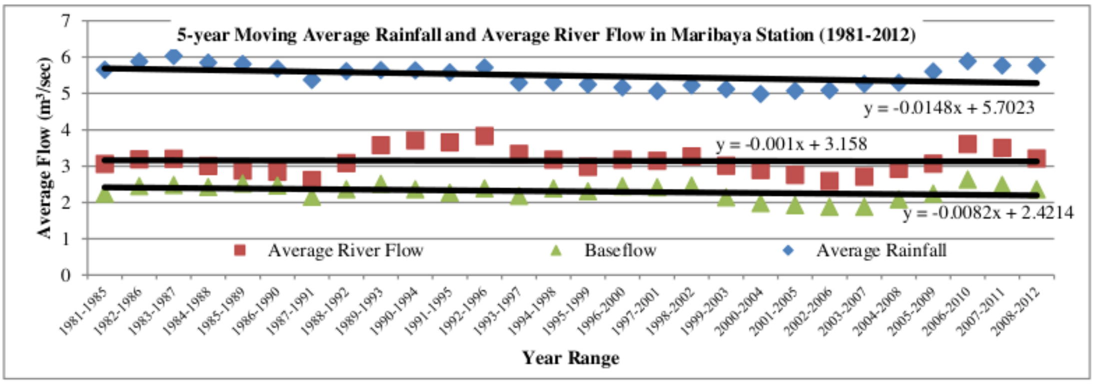

Fig. 5 Moving Average Rainfall, Baseflow, and Average River Flow in Maribaya Station

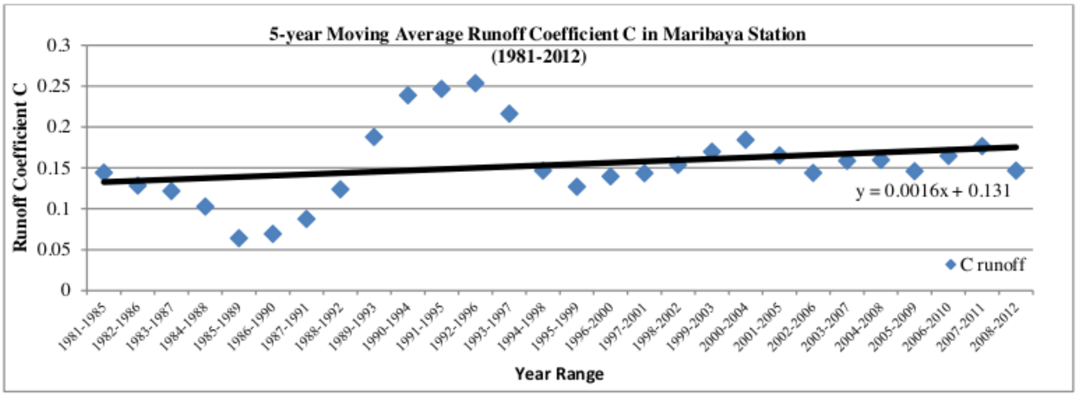

Fig. 6 Moving Average Runoff Coefficient C in Maribaya Station

From figure 5 and 6 it appears that:

- Average rainfall, average discharge, and baseflow tend to decrease. Those are possible because the area of study (Upper Cikapundung Watershed) located in Lembang Basin where rainfall that occurred in the area tend to decrease. With reduced water supply to this area then this will have an impact on the amount of surface runoff both derived from rainwater runoff as well as from the ground (baseflow).
- Run-off coefficient C tends to increase. This is due to the conversion of forest land cover into cultivation area.

4. Conclusion

- Lembang, Cikapundung, and Margahayu Stations located in the same geographical position in the Basin Lembang, so that the rainfall data has the same tendency (decreased); while the Dago Pakar and Bandung/ Cemara Stations has the same geographical position in Bandung Basin, so that it has the same tendency (increased).

  In Upper Cikapundung Watershed, the increasing of Cikapundung River discharge noted in the Maribaya Station was caused by the increasing of the maximum rainfall and land conversion (increased runoff coefficient).

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