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Trend Analysis of Rainfall, Land Cover, and Flow Discharge in the Citarum Hulu–Majalaya Basin

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***Abstract*— Floods and drought have been essential aspects of the water issue for over the past 50 years. Several studies have found that they are caused by massive land cover and climate changes. Many climate change studies have been conducted to establish their characteristics using historical data. However, land cover change is a human need that inevitably has to be undertaken to improve the standard of living. Changes in land cover affect the response of land to rainfall, which inevitably affect the amount of run-off generated into rivers. Discharge, land cover, and rainfall are variables that are related to each other. By understanding one variable, we can understand the condition of others, which can describe the situation of the catchment area. This study aims to determine the rain, land cover, and discharge trends in the Citarum Hulu - Majalaya Basin. The historical data obtained by the ground station were used to analyze the rainfall and discharge. A hydrology model was used to establish the change in the land cover parameters, specifically a semi-distributed SWAT model. The non-parametric Mann-Kendall test was employed for the trend analysis and was applied to the annual maximum rainfall and discharge data and the curve number (CN) values. The results show the three are positive trends in maximum rainfall and CN value which affect the discharge value.**

***Keywords*— Trend analysis; rainfall; land cover; discharge; SWAT.**

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I. INTRODUCTION

Citarum River is the longest river in the Province of West Java. It is very strategic for West Java and Jakarta City, the Capital of Indonesia, to provide fresh water, energy, irrigation, and flood control [1]. The river's length is around 300 km, and its basin covers 5960 km^2 [2], [3]. During the last 30 years, the Upper Citarum Basin has experienced rapid development, which has led to an increase in water extraction and land conversion from green or conservation areas to open or developed ones [4]–[6]. This affected the run-off production from that basin during periods of rainfall.

Population increases affect human needs, especially food and space. Urbanization, industrialization, and regional expansion result from population growth and economic strategy, resulting in a slow change in land cover [7]–[9]. Land cover, vegetation, and soil structure changes affect infiltration capacity [10]–[12]. Therefore, the amount of run-off generated by a watershed depends on changes in land cover, which may indicate changes in the basin's hydrological conditions. An increasing flow downstream could be part of the effects of deforestation or land conversion that have taken place upstream [13]–[16].

Several studies have been conducted to learn about the relation between land cover, rainfall, and run-off using hydrological models, from lumped to distributed models [17], [18]. Hydrologic modeling is conducted to understand the effect of land cover change on the production of water flow in rivers. It can also be used in urban planning and to develop policies [19], [20].

The characteristics of the flow of the Upper Citarum River Basin have changed. The discharge is higher in the wet season and lowers in the dry season than in the 1990s due to anthropogenic factors, such as land cover and climate change [21], [22]. Based on historical rainfall, climatology, land cover, and discharge, the flow decreased from 1988 to 2009 [5]. The forest plays a crucial role in decreasing and increasing maximum and minimum discharge [15], [23].

The tendency of rainfall, climatology and land cover change determine the flow discharge and can be seen by analyzing groups of data. Trend analysis of climate, rainfall, and flow conditions has been widely performed in several countries, such as Turkiye [24]. Many kinds of data can be analyzed, including daily, weekly, monthly, seasonal, or annual. They also can be categorized by maximum, minimum, mean, or classified data. Karlsson et al. [25] studied water balance variables in Denmark's wet and dry seasons using 133 years of data. The trends in hydrology parameters for each region have different patterns [26]. Trends in rainfall-runoff can affect erosivity, but there is no direct relation between change in temperature and rainfall [27]–[29].

The frequency of flood events, land cover change, and the decrease in the low flow in the Upper Citarum River Basin, together with the climate change issue, make a question what happens in the basin. Another question is which variable is dominant in affecting the frequency of flood events. This study attempts to explain these issues.

Based on recorded data from BNPB from 2002 to 2017, there was a tendency to increase flood events in Kota Bandung, Kabupaten Bandung, and Kabupaten Bandung Barat [30]. The correlation between rainfall, run-off, and flood hazard risk in that area increased and became more difficult to predict than three decades ago. Several previous studies [23], [31]–[35] have discussed this issue and concluded that a more complex correlation between the parameters is involved when compared to three-decade ago. Most research has also concluded that the effects of land use and climate change might have generated the complexity of the correlation. Papagiannaki et al. [33] and Kusuma et al. [35] discussed the influences of land use and climate change in relation to improving the method of analysis of rainfall-runoff and water.

Sarmaningsih et al. [36] discussed and suggested a correlation curve of rainfall-runoff with damage level, but this required a further comparative study with more detailed field observations. Several structural efforts, such as dredging, river shortcuts, and water ponds, have also been made to reduce flood risk, but these effects last no more than five to seven years [3], [35]. Improving the contribution of river dredging to flood risk reduction may also require an improvement in sedimentation rate prediction. However, Gunawan et al. [37] had done a study about reasonable results of sedimentation rate prediction for the river with a lack of data observation using a neural network method. Another study had conducted by Kusuma et al. [38] using a two-dimensional mathematical model. Improving the contribution of river normalization to flood risk reduction may also require an improvement in flood hazard model prediction. Good results related to flood hazard model prediction for the river with a lack of data observation were obtained by Farid et al. [32] using a two-dimensional mathematical model.

Several previous studies have discussed non-structural efforts to reduce the flood risk in the Upper Citarum River, such as those of Juliana et al. [34], Wijaya [39], and Kusuma et al. [35]. Based on 15 years of rainfall data records, Juliana et al. [34] discussed the feasibility of implementing a rain harvesting program to reduce run-off in the Upper Citarum River.

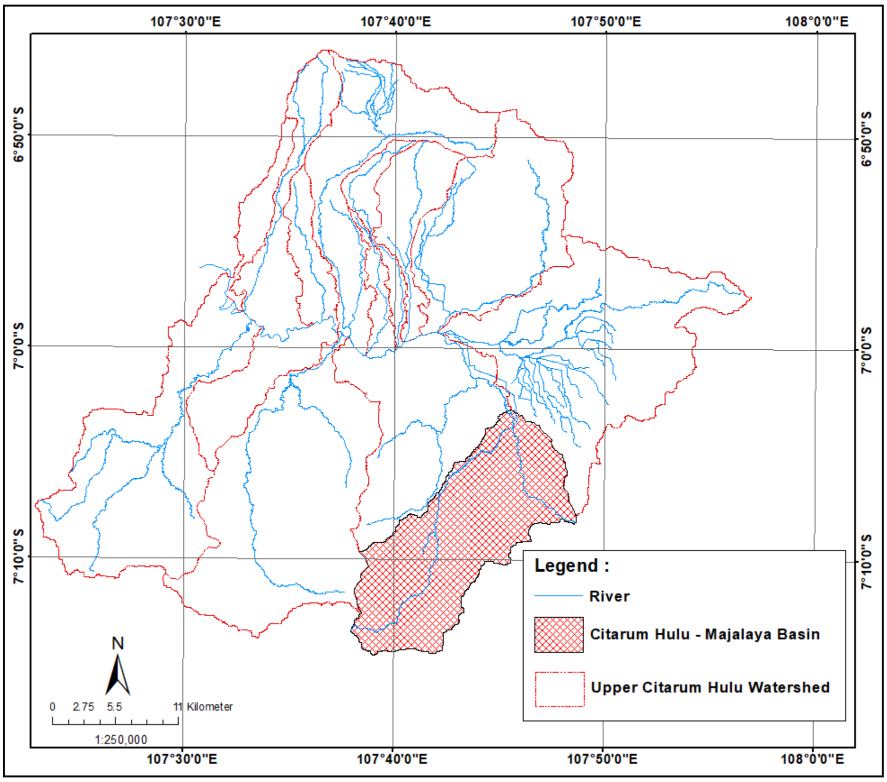


Fig. 1 Study Area

Kusuma et al. [21] concluded that the lack of reliability of hydrology, hydrometeorology, and land-use change data was becoming a significant barrier to correctly estimating the flood characteristic trends of the Upper Citarum River. Their paper was presented to discuss the preliminary study results in finding such trends based on more reliable rainfall and discharge data observation from 2016 to 2017.

II. MATERIALS AND METHODS

A. Study Area and Research Flow Diagram

The study was conducted in the Upper Citarum Watershed Area, more specifically at the Majalaya Outlet. The Citarum Hulu - Majalaya Basin (**Error! Reference source not found.**) is one of 13 basins in the Upper Citarum Hulu Watershed Area, which provide water for living purposes in the Greater Bandung Area. The basin area is around 176.2 km2 and is the location of the source of the Citarum River.

Following the study flow diagram, this research was carried out (Fig. 2). The first step was a literature review, which focused on establishing how to make the trend analysis, including the software or the theoretical approach, and ascertaining a possible location to conduct the study. The location needed a long data series for rainfall and land-use change and water level data representing the flow data.

The rainfall, run-off, and curve number (representing land-use change) were analyzed to develop the hypotheses on what had happened in the study location. A rainfall-runoff model was used to establish the conditions due to land cover change, preceded by a calibration process. The trend calculation started after the variables had been collected and the hypotheses developed. The model and calculation results were analyzed to see observe the tendency of the variables in conclusion to the research.

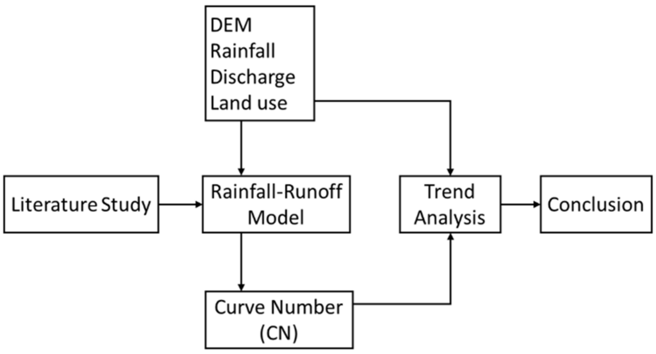


Fig. 2 Research Flow Diagram

B. Data

The study focused on changes in rainfall and land cover and their relationship with Ascertaining the changes that had occurred required long-range data. The primary data used in the study were daily rainfall, daily flow, and land cover with different spans of years. The hydrology model used in the study meant several types of data were also needed, such as soil type, climate data (temperature, humidity, solar light, wind speed), and digital elevation model (DEM) data. The sources and range of data used are shown in Table I.

TABLE I
SOURCES AND DATA RANGE

Data	Source
Rainfall	PUSAIR (1986-2016)
Flow	PUSAIR (1999-2016)
Landcover	KLHK (1990, 2000, 2003, 2006, 2009, 2012, 2015)
Climate	BMKG (2013)
Soil type	BBWS Citarum
DEM	SRTM

C. Soil and Water Assessment Tools (SWAT)

The SWAT model is the result of the development of the SWRRB (Simulator for Water Resources in Rural Basins) model, which was introduced in 1980 by the USDA. The model can simulate total run-off, groundwater flow, sedimentation, and even pollutants such as pesticides, all of which are useful for agricultural analysis [40].

SWAT models require various data layers for their rainfall-runoff simulation. The input data needed for running SWAT are digital elevation models (DEM), used to delineate watersheds, land cover, and soil and used to overlay the hydrologic response unit (HRU). Daily weather data were obtained from weather stations in the form of temperature (max-min, °C), wind speed (m/s), relative humidity (%), and solar radiation (MJ/m2). However, the essential weather elements are rainfall and temperature, while other data can be simulated by SWAT by simply entering the annual average data into the database.

D. Model Calibration

Calibration and data validation were performed using a statistical method, Nash-Sutcliffe Efficiency (NSE), to calculate the accuracy level by normalized statistics that determine the relative magnitude of residual variance (noise) compared to the measured data variance (information). NSE is commonly used to make and report on comparisons between simulation and observation in the calibration and validation process, especially in hydrology analysis. The NSE formula is shown below.

$$NSE = 1 - \left[\frac{\sum_{i=1}^{n} \left(Y_i^{obs} - Y_i^{sim}\right)^2}{\sum_{i=1}^{n} \left(Y_i^{obs} - Y^{mean}\right)^2} \right] \quad (1)$$

where Y_i^{obs} is an observation of the constituents being evaluated; Y_i^{sim} is a simulation value (model) of the constituency being evaluated; Y^{mean} is the average value of the data observed; i is for the order of data n is the total number of observations.

NSE ranges between -∞ and 1.0 (1 inclusive), with NSE = 1 being the optimal value. Values between 0 and 1 are generally seen as acceptable performance levels, while values < 0 indicate that the observed average is a better predictor than the simulation value, thus denoting unacceptable performance. The performance of the hydrology model was quantified by static value criteria for NSE, as suggested by Moriasi et al. [41]. The static value criteria suggested are for the monthly timestep model (Table II).

TABLE II
NSE PERFORMANCE CRITERIA

Performance evaluation	Criteria
Very good	NSE > 0.75
Good	0.75 ≥ NSE > 0.65
Satisfactory	0.65 ≥ NSE > 0.5
Not Satisfactory	0.5 ≥ NSE

E. Mann-Kendall Test

Many methods can be used to determine the value of a trend, and some software can produce trend values based on the amount of linear regression performed in the data processing. In this study, trend analysis was performed using the Mann-Kendal Method. This is a non-parametric statistical procedure for data trend analysis. It is widely applied to analyze any kind of data in time series, especially rainfall trend analysis [42]–[44]. It does not require assumptions and can be used for datasets with irregular sampling intervals, even if there are missing data. The Mann-Kendall statistic formula is shown below.

$$S=\sum_{k=1}^{n-1}\sum_{j=k+1}^{n} sgn(X_j-X_k) \quad sgn(\Phi)=\begin{cases} +1 \ if \ \Phi=X_j-X_k>0 \\ 0 \ \ if \ \Phi=X_j-X_k=0 \\ -1 \ if \ \Phi=X_j-X_k<0 \end{cases} \tag{2}$$

The test is based on the Mann-Kendal statistic (S), in which n is the number of data; x is the data point at times j and k (j>k); and the sign(Φ) is the sign function. For the sample size (n) ≥10, the mean of S and variance can be calculated by Eqs. 3-4.

$$E[S]=0 \tag{3}$$

$$var(s)=\frac{[n(n-1)(2n+5)-\sum_{i=1}^{m} t_i(i-1)(2i+5)]}{18} \tag{4}$$

$$Z=\begin{cases} \frac{S-1}{\sqrt{var(S)}} & S>0 \\ 0 & S=0 \\ \frac{S+1}{\sqrt{var(S)}} & S<0 \end{cases} \tag{5}$$

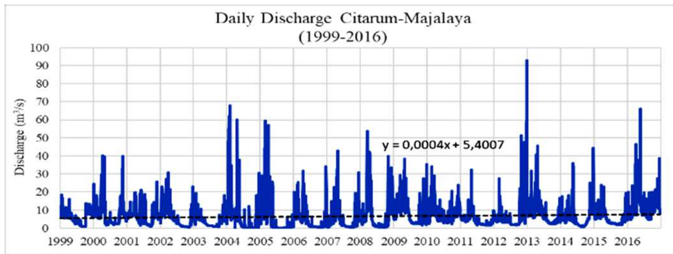
where m is the number of tied groups, and ti indicates the value of data in the ith tied group. The standardized test statistic Z should be calculated (Eq. 5) to establish the distribution of statistic S. The value of statistic Z shows the trend condition and whether it is positive or negative. If the value of statistic Z is positive, it means that the trend is upward. On the other hand, if the value is negative, then the trend is downward. If the absolute value of Z is greater than 1.96 and the critical Z values are at 95% two-tailed confidence intervals, the null hypothesis of no trend is rejected [24].

The advantage of a non-parametric test is to make the calculations more efficient; the data can be in the qualitative form (nominal or ordinal), and the distribution of the datasets does not have to resemble a normal distribution. However, the weakness of such a test is that it does not utilize all the information attached to the sample (so is inefficient), but this can be overcome by increasing the sample size.

III. RESULTS AND DISCUSSION

A. Flow Discharge Data

The range of discharge data used in this research was from 1999 to 2016 (18 years). The analysis process was performed based on daily data, the five largest discharge values for each year, and the annual maxima. Based on the data processing from 1999 to 2016 (Figure 3), the daily data show a discharge increase of around 2.68 m3/s over the 18 years. Each year's five largest discharge data indicate a discharge increase of around 2.7 m3/s. Similarly, the annual maxima data are in agreement with this. The annual maxima also increased by around 56.36 m3/s. That information strengthens the indication of an increase in discharge during the period 1999-2016.



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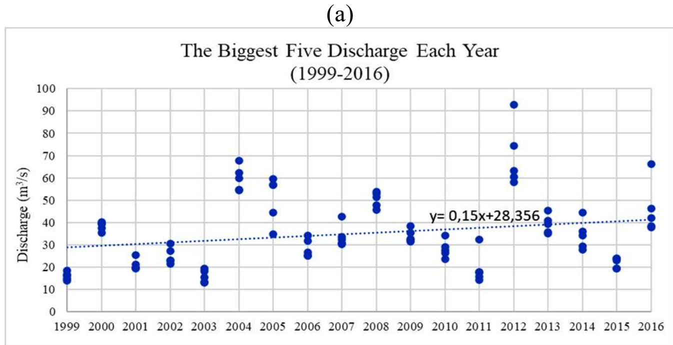

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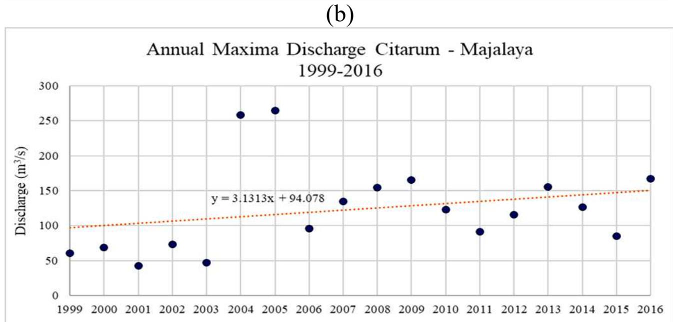


(c)

Fig. 3 Discharge from the Citarum Hulu – Majalaya Basin: (a) daily; (b) the biggest five per annum; and (c) annual maxima.

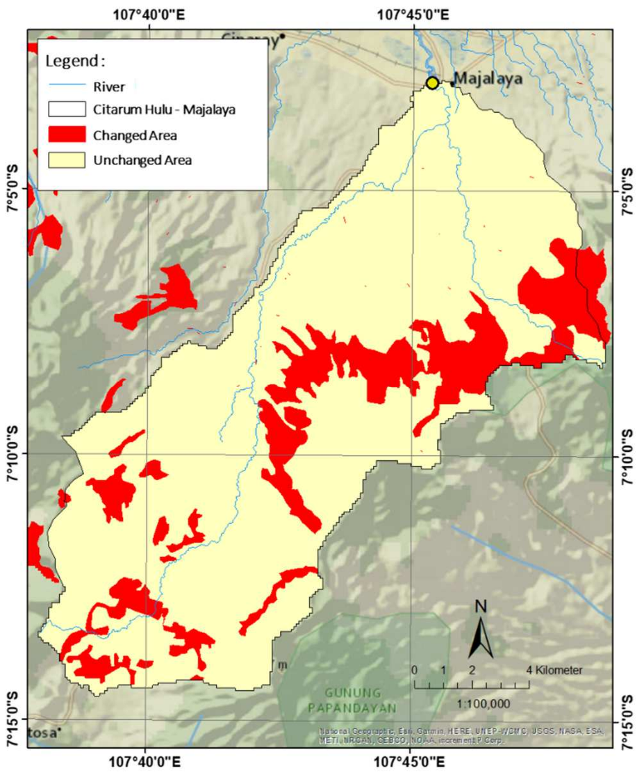


Fig. 4 Changed area during the period 1996-2000

B. Land Cover Change

The changes in land cover were checked using Geographic Information System (GIS) software. The land cover maps obtained from the Ministry of Environmental and Forestry (KLHK) include the land cover in 1990, 2000, 2003, 2006, 2009, 2012, and 2015. The land cover maps were compared year-to-year, and the area was calculated.

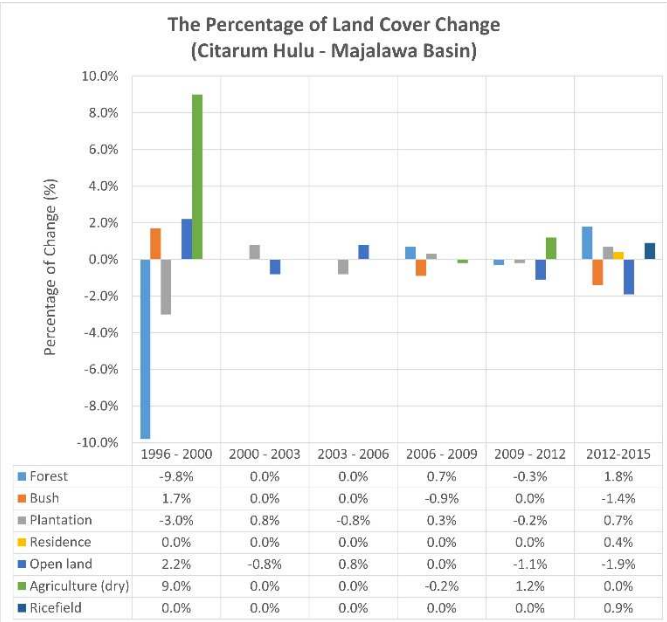


Fig. 5 Percentage of land cover change in Citarum Hulu-Majalaya Basin (1996-2015)

As shown in Figure 5, the most significant change in land cover in the basin happened between 1996 and 2000, with forests constituting the main change. At least 9.8% of the basin area, or around 1729 hectares of forest, was converted into other types of land cover. This is related to the massive land cover changes from 1992 to 2003 [14]. From 2000 to 2006, land cover change was practically non-existent because open land was converted into plantations, then changed back to open land. This is different from the previous study; Landsat images show that the Upper Citarum Watershed experienced massive changes in land cover during the 1997-2014 period [45]. Especially in the Cirasea Basin (Citarum Hulu - Majalaya Basin in this study), in the period 1997-2005, there was an extensive land cover change to residence/settlements, which became worse during the 2005-2014 period, although not as bad as in the last period. Land cover showed good progress in the period 2012-2015. Green areas, such as forests, rice fields, and plantations, increased by around 1.8%, 0.9%, and 0.7%. Between 2012 and 2015, the area was greener and more productive due to reducing unproductive land cover (bush and open land). This may have been the result of the Integrated Citarum Water Resources Management Investment Program (ICWRMIP), part of the collaboration between the central government and ADB, lasting from 2009 to 2023 [46].

C. Rainfall Data

Rainfall data were analyzed at each station together with area-averaged rainfall. There are two rainfall stations, PCH Cipaku and PCH Cibeureum, near the Citarum Hulu - Majalaya Basin. Area-averaged rainfall was calculated by using the Thiessen Polygon method.

The analysis was conducted on the annual maximum and return period rainfall of two and five years. The trendline of each dataset was calculated to observe the tendency over the years. The annual maximum rainfall is shown in Figure 6 and TABLE III.

TABLE III
ANNUAL MAXIMUM RAINFALL (MM)

Year	CPK	CBR	AA	Year	CPK	CBR	AA
1986	85.4	79.2	50.1	2002	80.2	140	87.5
1987	106.5	73.6	47.7	2003	86	121	73.3
1988	62.9	65.0	49.3	2004	76	85.8	51.4
1989	76.8	63.9	57.9	2005	71	80	47.9
1990	51.3	62.6	43.6	2006	86	57	34.5
1991	42.0	78.2	55.5	2007	76	86	51.5
1992	53.4	62.2	46.6	2008	74	94.8	70.8
1993	62.5	63.4	42.1	2009	83	90.2	54.0
1994	55.2	94.0	71.3	2010	82	104.8	67.1
1995	70.9	64.1	51.0	2011	94	73.3	54.0
1996	76.0	64.5	40.9	2012	98	78.8	75.7
1997	73.5	70.4	45.5	2013	86	72.8	56.9
1998	85.9	63.0	53.0	2014	85	72.8	72.9
1999	84.0	68	73.8	2015	88	85.4	51.9
2000	74.1	122	75.5	2016	95	87.3	68.2
2001	109.4	94	65.6				

*CPK = PCH Cipaku
CBR = PCH Cibeureum
AA = Area-Averaged

It was found that the trend in maximum rainfall data from the two rainfall stations increased based on the past 30 years. This means the area-averaged rainfall trends increase, although not as much as at PCH Cipaku and PCH Cibeureum. The reason for this is that the maximum rainfall that occurred at both stations did not happen simultaneously.

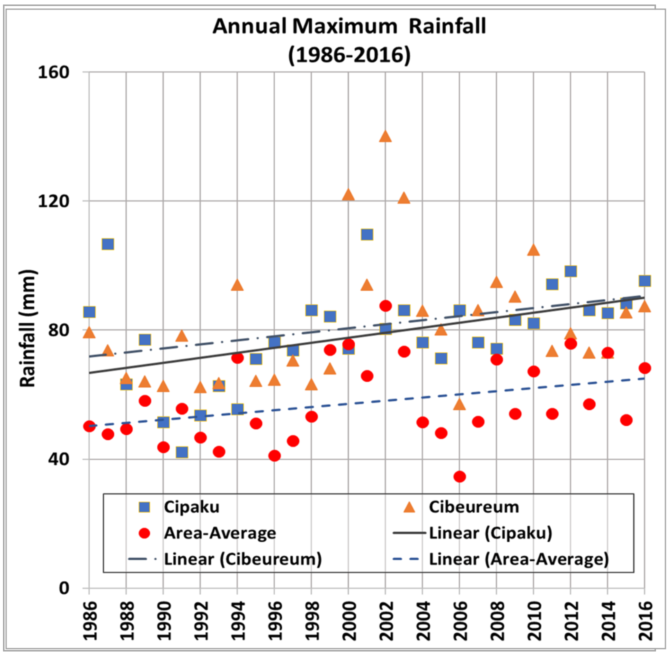
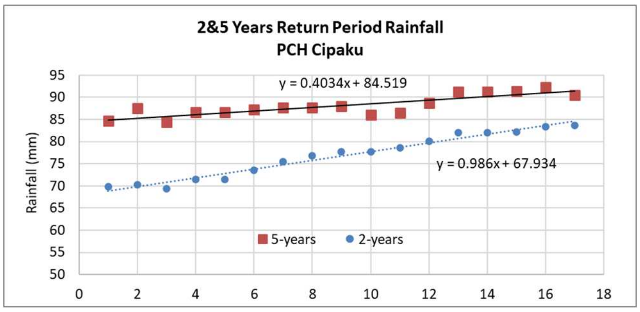


Fig. 6 Annual maximum rainfall at PCH Cipaku, PCH Cibeureum, and area-averaged rainfall

Analysis of the return period rainfall of 2 years and 5 years was then made. The rainfall was calculated statistically based on Log Pearson type III distribution. Frequency analysis was performed with a database of 15 datasets, calculated in increments of 1-year. There were 17 calculations, the first using rainfall data from 1986 to 2000 and the last using data from the period 2002-2016. The extreme rainfall return period of 2 years and five years are as follows.

In Figure 7, both stations' 2- and 5-year return period rainfall shows an increase over the last 17 years. It means the return period of area-averaged rainfall is increasing over the years.



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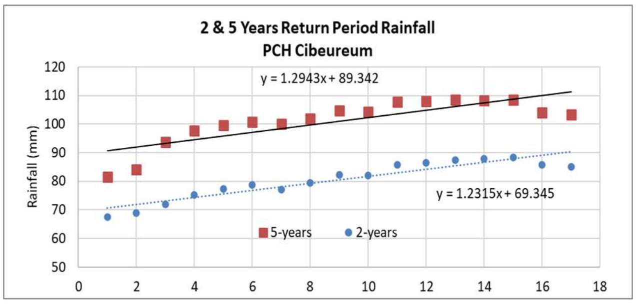

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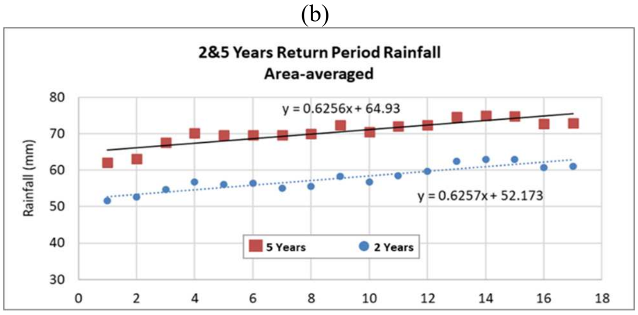


(c)

Fig. 7 Return period 2- and 5-year rainfall: (a) PCH Cipaku; (b) PCH Cibeureum; and (c) area-averaged r

However, even if all the graphs show an upward line, an anomaly is shown in the PCH Cipaku graph (Figure 7a). The value of the slope in linear equations between 2-years and 5-years at PCH Cipaku is quite different, while the slopes of the trendline between 2 years and 5 years of PCH Cibeureum and the area average are quite similar.

D. Curve Number Estimation by using the SWAT Model

In the previous section, the change in land cover was analyzed. The conversion and the area of land cover change are therefore known. However, this cannot describe the impact of the land cover changes that have occurred. Hence, a quantified parameter is needed to explain this, in this case, a curve number.

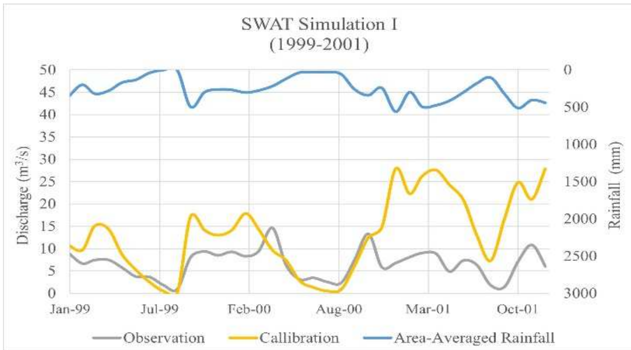
The curve number (CN) is used to show the response given by an area to rainfall in that region. It is a long-term method that can predict surface run-off. In this study, the SWAT model was used to establish the CN value of the basin. As previously stated, CN in the SWAT model is a representation of the hydrologic response unit (HRU), which consists of land cover, slope, and soil type. Therefore, if the soil type and slope are constant, then the land cover is the dominant variable in changing the value of the curve number (CN).

The model was simulated to calculate the curve number value due to land cover change in 2000, 2003, 2006, 2009, 2012, and 2015. The observed discharge data were obtained from 1999 to 2016, and rainfall data were from 1986 to 2016. The modeling was then simulated following the availability of observed discharge data from 1999 to 2016. Each simulation ran for 3 years, with a timestep of 1 month. The limitation of land cover data meant the simulation was divided into several scenarios, as follows.

TABLE IV
CONFIGURATION OF THE SIMULATION SCENARIOS

Simulation	Land Cover	Rainfall and Discharge
I	2000	1999, 2000, 2001
II	2003	2002, 2003, 2004
III	2006	2005, 2006, 2007
IV	2009	2008, 2009, 2010
V	2012	2011, 2012, 2013
VI	2015	2014, 2015, 2016

The simulated discharge was then compared with the observed flow. The NSE method was used to determine the suitability of the simulated and observed discharges. This NSE value was later be adjusted to the criteria shown in Table II. The CN value was changed until the NSE value was higher than 0.65.



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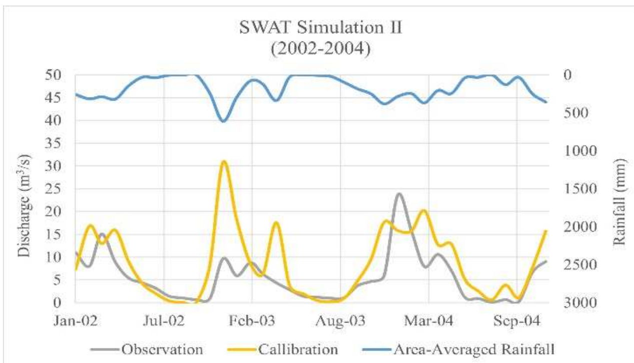

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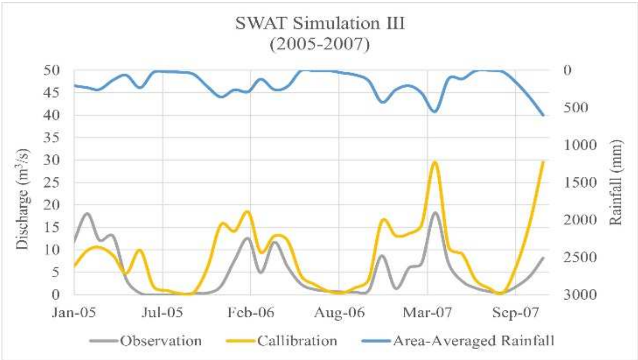

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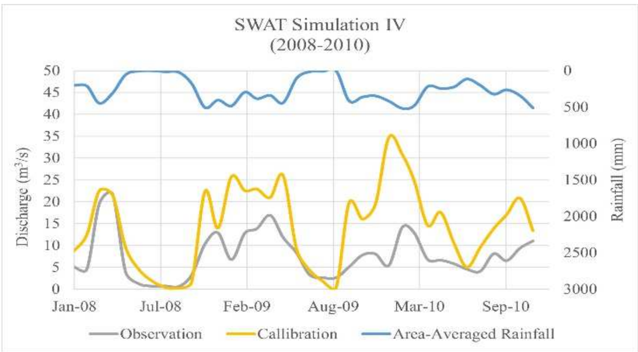

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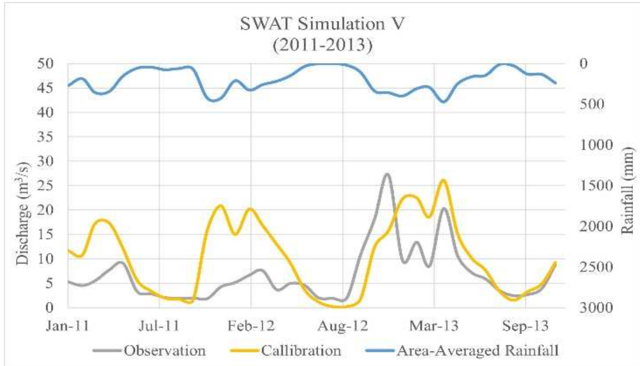

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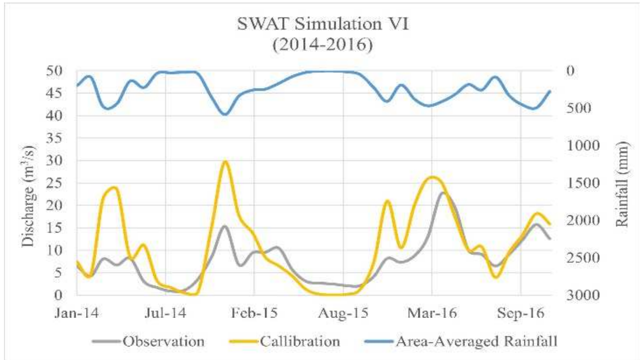

(f)

Fig. 8 Comparison between simulated and observed discharge (a) Simulation I (1999-2001); (b) Simulation II (2002-2004); (c) Simulation III (2005-2007); (d) Simulation IV (2008-2010); (e) Simulation V (2011-2013); and (f) Simulation VI (2014-2016)

TABLE V
SIMULATION RESULTS

Land Cover	Observed Discharge	NSE	CN	Land Cover	Observed Discharge	NSE	CN
	1999	0.71			2008	0.9	69.5
2000	2000	0.76	65.21	2009	2009	0.6	
	2001	0.21			2010	0.39	
	2002	0.66			2011	0.36	69.5
2003	2003	0.47	69.42	2012	2012	0.7	77.7
	2004	0.86			2013	0.84	69.5
	2005	0.67			2014	0.63	69.2
2006	2006	0.86	69.4	2015	2015	0.71	
	2007	0.65			2016	0.88	

In TABLE V, the recapitulation shows the best fit of the calibration results. Although several years show NSE < 0.65, which means poor calibration, many show good agreement. The most considerable change occurred in the period 2000-2003, from CN = 65.21 to CN = 69.21, which is in line with the massive land cover changes. The value of CN changes from 2003 to 2016 varied little. The tendency of the CN value is constant, except for that generated in 2012 (CN = 77.73). This value is considered "anomalous" modeling, even with a value of NSE degrees> 0.6 on the modeling conducted. The CN value tends to be constant, which is in line with the change in land cover.

E. Trend Analysis

The data processed were tested to establish whether there was a tendency or not. Statistically, the annual maximum rainfall data (each station and area-averaged), maximum yearly discharge, and curve number (CN) value were tested using the Mann-Kendall method. The results would determine the condition of the variables and whether there was an upward or downward trend in the datasets.

TABLE VI
MANN-KENDAL TEST RESULTS OF RAINFALL, DISCHARGE, AND CURVE NUMBER (CN)

Parameters	Rainfall Cipaku	Rainfall Cibeureum	Rainfall Area-averaged
Kendall's tau	0.4	0.23	0.26
S	185	108	123
Var (S)	3457	3461	3462
P value (Two-tailed)	0.001	0.033	0.019
alpha	0.05	0.05	0.05
Ha (z)	3.13	1.82	2.07
Parameters	**Discharge**	**Curve Number (CN)**	
Kendall's tau	0.48	0.23	
S	58	108	
Var (S)	493	3461	
P value (Two-tailed)	0.009	0.033	
alpha	0.05	0.05	
Ha (z)	2.57	1.82	

Based on the p-value generated from the rainfall data, discharge, and curve number (CN), it was found that the p-values of the rainfall and the discharges were lower (<) than the alpha value (α = 0.05), meaning that there was a positive trend and shows the hypothesis that there are no trends (H_0) in the rejected data [47]. In addition, the curve number (CN) data p-value is much higher than the alpha (α) value, so the hypothesis of no trend (H_0) can be accepted, and the hypothesis of a tendency (H_a) cannot be accepted. Hence, it can be said that the main cause of increased discharge in the Citarum Hulu - Majalaya Basin area is the increase in rainfall.

IV. CONCLUSION

A comprehensive study based on more reliable river discharge and rainfall recorded data was made to predict land-use change's impact on the trends of maximum rainfall intensity and river discharge. Based on the updated land use map data from 1990 to 2015, it was found that the massive land-use change was dominated by the change from forestation to agriculture/plantation and housing areas. The annual maximum daily rainfall tended to increase by around 10 %, and extreme rainfall by around 15 %. However, the increment trend of the Cibeureum station is higher than that of Cipaku.

An indication of the increase in flow discharge is shown based on daily analysis, the biggest five per year, and the annual maximum. The same was shown in the rainfall data analysis. The rainfall values tended to increase, both the maximum per year and extreme rainfall, with 2 and 5 years of return periods. This occurred at both rainfall stations. Different conditions are shown in the land cover maps in the period 1990 to 2015. Massive changes took place during the period 1996-2000, while in the period 2000-2012, changes occurred in only a small area. On the contrary, several studies have stated that the upper Citarum watershed, including the Citarum Hulu - Majalaya Basin, experienced a massive conversion during the period 1992-2014 [14], [45]. This may be due to the reliability of the land cover maps used, and further studies are needed to conclude this.

Rainfall-runoff modeling was conducted using the SWAT model, with the Nash-Sutcliffe Efficiency (NSE) index showing good agreement. The results of the simulations show that the CN value during the period 2003-2015 tended to be constant. It was also found that rain did not fall evenly throughout the watershed, which is inversely proportional to the assumption. Several events demonstrate this; for example, the observed flow showed a high value even though rain fell in small amounts on the same day, and vice versa. The other reason could be that neither local rain nor flood discharge was detected at the time.

Based on the Mann-Kendall testing for rainfall, discharge, and CN values generated by the model, it was found that there was a positive trend in rainfall and annual maximum discharge. While a pattern was not found when the test was applied to the CN value, this was in line with the CN value generated from the model and land cover changes shown from the KLHK data. It should be noted that the rainfall and discharge data used in the trend analysis were the annual maximum data.

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