HIGH FLOW AND LOW FLOW FREQUENCY ANALYSIS OF CIKAPUNDUNG RIVER

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Abstract

Climate change that occurs in Indonesia, especially in the upstream and middle Citarum areas is marked by changes in rainfall. In addition to the phenomenon of climate change, an increase in the number of people that occur in an area will have an impact on land cover changes that will affect river flow, so the dominant parameters that cause changes in the flow between changes in rainfall and land cover changes need to be reviewed. This study aims to determine the effect of changes in rainfall and land cover changes on flood discharge and the shift of flow duration curve. The author chose 4 SUH methods, namely SUH Nakayasu, SUH Soil Conservation Service (SCS), SUH ITB-1 and SUH Snyder-Alexejev to analyze high flow, and 2 methods, namely the F.J. Mock and NRECA methods to analyze low flow. The results of the research analysis are land changes that occur does not have a major impact on changes in the value of runoff coefficient, flood discharge analysis for Cikapundung-Pasirluyu sub-watersheds found that changes in flood discharge are dominated by changes in rainfall.

Keywords : *Flow Duration Curve (FDC), High Flow, Low Flow, SUH*

1. INTRODUCTION

Water is one of the main natural resources that plays an important role in the survival of living things on earth and most of which are related to the management of water resources based on the analysis of the calculation of the amount of water managed or the flow of water that must be regulated (Suntari, 2017). Water on earth circulates in a cycle called the hydrological cycle. In the hydrological cycle the process of water falling from the atmosphere occurs as precipitation in the form of rain to the earth's surface, which is the only input in a watershed (Utari & Martini, 2022), the water is partially infiltrated into the ground and the other part moves as runoff which will flow into the river after moving towards the ocean. Sea water heating makes the hydrological cycle run continuously.

Flood event generally caused by the urban growth (Legowo et al., 2019). Other causes of flooding can be caused by changes in land use, land subsidence and increased sedimentation rates (Adzhani & Tayubi, 2019). In addition to flood discharge, the dependable discharge is the discharge available throughout the year with a certain risk of failure (Krisnayanti et al., 2022). The study of flood discharge and dependable discharge is very important to study, because it is to know how much the discharge changes. In the research (Rizaldi, 2018) analyzing rainfall trends, land cover and runoff discharge in the Citarum Hulu-Majalaya watershed revealed that the annual maximum flow has a significant increase of 53 m3/s. In addition, based on research (Bachrein, 2012) monthly discharge in the Cikapundung watershed has decreased by 20-30%. Meanwhile (Marsim & Yudianto, 2017) stated that the dependable discharge for Q50, Q80, Q90, and Q95 has upward trend.

Climate change that occurs in Indonesia, especially in the upstream and middle Citarum areas is marked by changes in rainfall which tend to decrease by 3.64% for every 100 months. The decrease in rainfall is caused by decreased cloud formation and convective rainfall as a result of a decrease in forest area and global climate variability (Ruminta, 2008). This will have an impact on river flow. In addition to the phenomenon of climate change, increasing number of population that occurs in a region will have an impact on changes in land cover of river flow, so that the dominant parameters that cause changes in flow between changes in rainfall and changes in land cover need to be studied. Based on this explanation, it is necessary to conduct a study related to the analysis of the large and small discharge frequency of the Cikapundung River which is a tributary of the Citarum River upstream which flows through West Bandung Regency, Bandung City and ends in Dayeuhkolot District, Bandung Regency.

The main objective of this study is to analyze the effect of changes in rainfall and changes in land cover towards flood discharge. Conduct analysis of shifts in flow duration curve.

2. METHODOLOGY

Description and Location of the Study

The Cikapundung watershed is a sub-watershed of the Upper Citarum Watershed with a drainage area of 144.33 km^2 (14433 Ha). It is an area that has the potential to be the main drainage and raw water source for residents in Bandung City (Maria & Lestiana, 2014). The Cikapundung River which has a stream around the Tangkuban Perahu Mountain with a length of 38.51 km flows through West Bandung Regency, Bandung City and ends in Dayeuhkolot District, Bandung Regency. It has a river width of 22 m upstream and 26 m downstream (Rahayu et al., 2018).

Data Collection

This stage is about collecting the data that would be used in conducting research. Data collected in the form of secondary data. Secondary data were obtained from observations or measurements made by the relevant agencies. The data needed are rainfall which is one of the most important hydrological data for various water resource management analyses (Megariansyah et al., 2022). If there are data limitations, satellite data can be used either to replace observational rainfall data or to fill in empty rainfall data (Suryadi & Nurkhaerani, 2023). Furthermore, the data needed is discharge data, location map data, land use map data, digital elevation model (DEM).

In this study, rainfall, discharge, and location maps data were obtained from BBWS Citarum and also from BMKG and DPSDA Jabar, while land use map data was obtained from RI Ministry of Environment, then digital topographic map data (DEM) was obtained from DEMNAS Website.

Model Calibration

The model that has been made must go through a calibration process. Calibration was performed using NSE (Nash-Sutcliffe Efficiency) statistical parameters. Nash-Sutcliffe efficiency (NSE) is a normalized statistic that determines the relative magnitude of residual variance (noise) compared to the measured variance of data (information). There are several categories in the NSE parameters and the closer it is to value 1, the better the model.

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

Where Y_i^{obs} is the *i^th^* observation for the constituent being evaluated, Y_i^{sim} is the i^{th} simulated value for the constituent being evaluated, Y_i^{mean} is the mean of observed data for the constituent being evaluated, and *n* is the total number of observations.

3. RESULTS AND DISCUSSION

The analysis process of this study was focused into Cikapundung-Pasirluyu Sub-watershed (Downstream). This was done in order to get more specific results.

Land Cover Data Processing

Land cover data to be analyzed sourced from the Ministry of Environment and Forestry (KLHK) are in the form of aerial photo interpretations. The aerial photo data used by KLHK are based on several sources, for the period 1990-2000 data used from Landsat Satellite results, then for the 2001-2010 period from USGS Landsat aerial photographs and from 2013 until now from Landsat 8 OLI aerial photographs with overall the maximum scale data is 144,447,639 and the minimum scale is 36,978,595.5 (Rizaldi, 2018). Land cover data used are in 1990, 1996, 2000, 2003, 2006, 2009, 2011, 2012, 2013, 2014, 2015 and 2016.

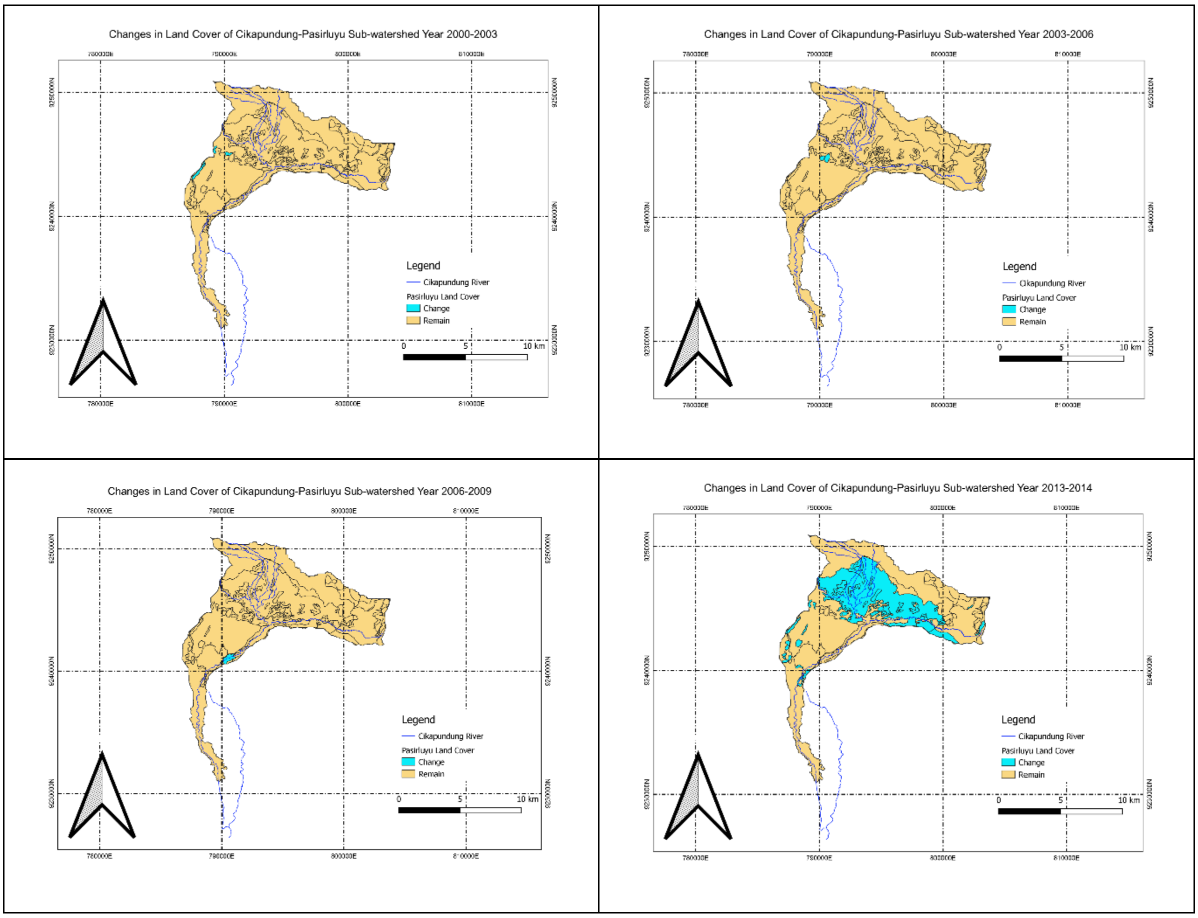

Figure 1. Changes in land cover of Cikapundung-Pasirluyu Sub-watershed

After identifying the changes in land cover of Cikapundung-Pasirluyu Sub-Watershed then interpreted towards runoff coefficient (C).

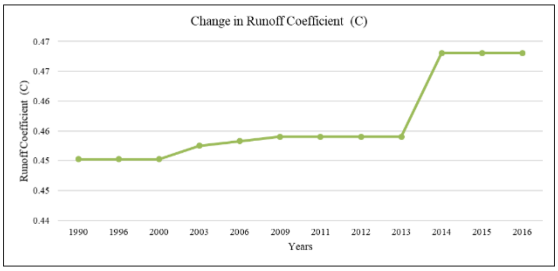

Figure 2. Graph of change in runoff coefficient (C)

Land changes occured were dominated by changes from mixed upland agriculture to dryland agriculture. Even so that did not have a major impact on changes in the value of runoff coefficient which tended to be constant in the last 27 years (1990-2016). This was because the interpretation of the runoff coefficient value of both mixed upland and dryland agriculture had the same value of 0.45.

Calibration of Flood Discharge

The author chose 4 SUH methods, namely SUH Nakayasu, SUH Soil Conservation Service (SCS), SUH ITB-1 and

SUH Snyder-Alexejev. Synthetic unit hydrograph (SUH) is unit hydrograph (UH) that obtained from watershed characteristics instead of rainfall-runoff data (Permatasari et al., 2017). Before analyzing flood discharge it must go through the SUH model calibration process first. Then selected on March 13, 2014 at 14:00 WIB to March 14, 2014 at 13:00 WIB. The following table shows the occurrence of rain and a single peak at the observation discharge.

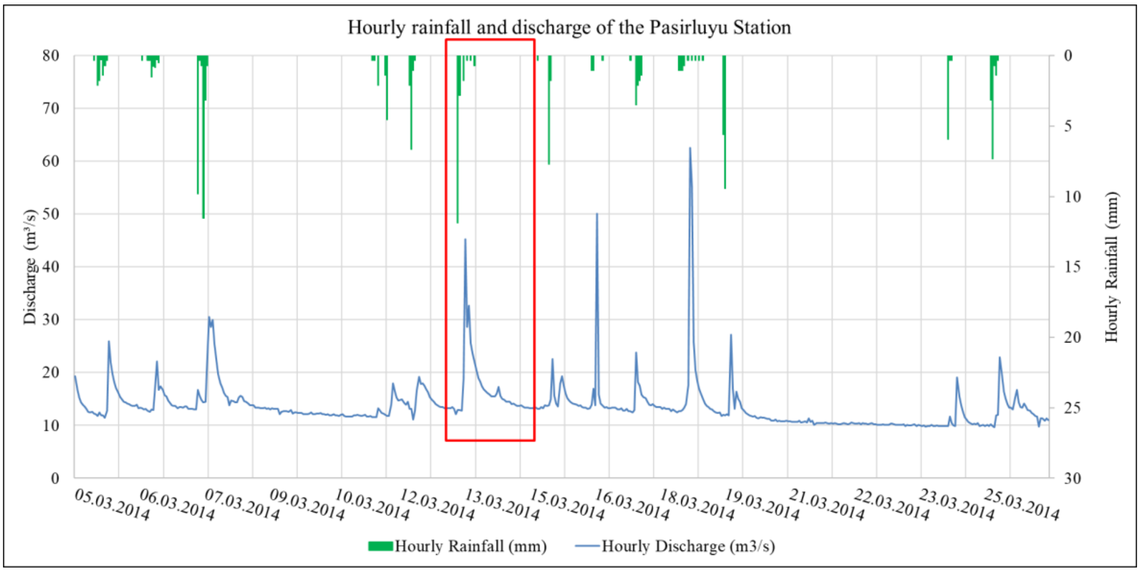

Figure 3. Hourly rainfall and discharge of the Pasirluyu Station

There are calibration parameters for each method. For Nakayasu, the calibration parameter is alpb ha (hydrograph parameter), for SCS the time adjustment coefficient (Ct), for ITB-1 and Snyder-Alexejev, the time adjustment coefficient (Ct), and the discharge coefficient (Cp). After the calibration processes are carried out, the process of quantifying the validity of the model with NSE (Nash-Sutcliffe Efficiency) statistical parameters are carried out. A model is categorized as "Satisfactory" if the NSE value > 0.5

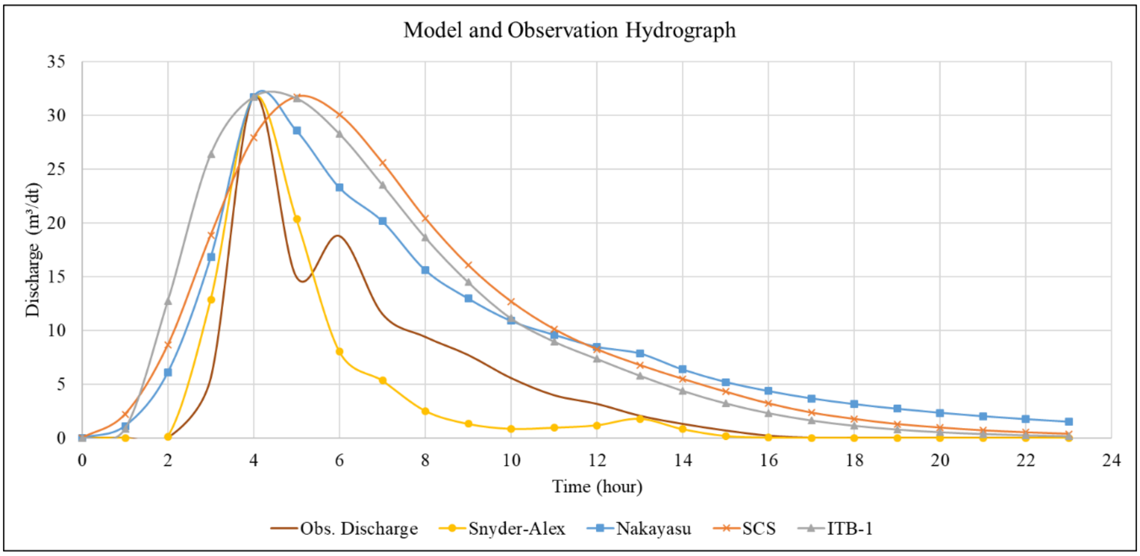

Figure 4. Model and observation hydrograp

Tabel 1. Calibration coefficient and NSE values

HSS	α	Ct	Cp	NSE
Nakayasu	1.78	-	-	0.47
SCS	-	0.63	-	0.09
ITB-1	2.00	0.51	0.80	0.02
Snyder-Alex	-	0.55	0.64	0.74

Based on Table 1 the SUH Snyder-Alexejev method got the largest NSE value of 0.74 so that it could be categorized as "Good". Then for the other three (methods) got an NSE value ≤ 0.5 with the "Unsatisfactory" category. So to calculate the flood discharge the SUH Snyder-Alexejev method used.

SUH Flood Discharge

In the previous analysis extreme rainfall was calculated and the SUH method was chosen to calculate the flood discharge using the SUH Snyder-Alexejev method. Then the flood discharge is calculated for each sub-watershed, especially peak discharge (Qp). Following is the peak discharge in Cikapundung-Pasirluyu sub-watershed.

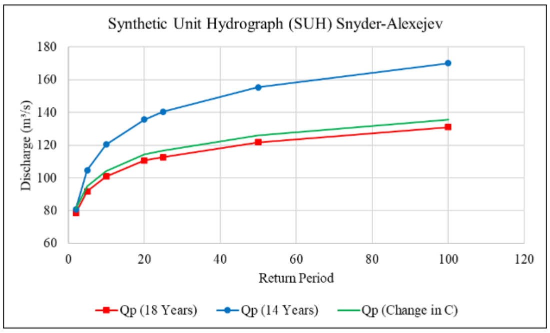

Figure 5. SUH peak discharge of Cikapundung-Pasirluyu Sub-watershed

From the results of flood discharge analysis it was found that changes in flood discharge are dominated by changes in rainfall, this is indicated by changes in the value of runoff coefficient which tends to be constant. Then the magnitude of the effect of changes in land cover (C) towards changes in flood discharge only affects 15.9% for the Cikapundung-Pasirluyu Sub-watershed.

Calibration of Dependable Flow

The author chose 2 methods, namely the F.J. Mock and NRECA methods. Similar to the analysis of flood discharge, the dependable flow analysis must also go through a calibration process using monthly rain data, although research (Suryadi et al., 2021) shows that 10-day rain data can provide more optimal results.

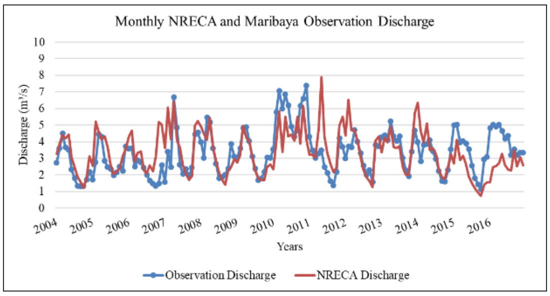

Figure 6. NRECA and Maribaya Observation Discharge

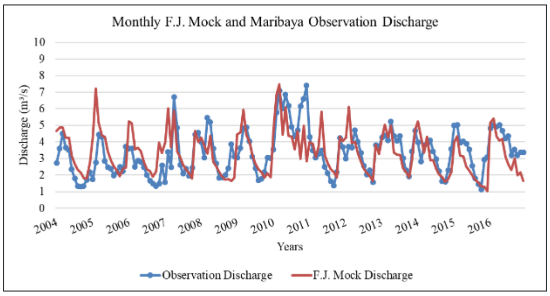

Figure 7. Mock and Maribaya Observation Discharge

Tabel 2. Recapitulation of NSE values

Method	NSE		
	FDC	Pattern	Average
NRECA	0.99	0.94	0.96
F.J. Mock	0.99	0.41	0.70

After the dependable flow analysis using NRECA and F.J. Mock methods for each Cikapundung Sub-watershed, it was known that the NRECA method can provide better results than the F.J. Mock method. This is indicated by the average NSE value of 0.96, while the F.J. Mock method gave an average NSE value of 0.70. This is in line with research (Suryadi et al., 2021) that the NRECA method provides better results.

In addition to the NSE parameter values of FDC, other indicators make the NRECA method better than the F.J Mock method was seen from the dependable flow pattern throughout the year. The dependable flow pattern from the NRECA method gave similar results to the observation discharge pattern. Description of the discharge pattern that tends to increase in the period January to April, then in the period from May to October the discharge tends to fall then tends to rise again in the period November to December.

FDC Shifts Analysis

Flow analysis with FDC (flow duration curve) to describe the flow characteristics based on frequency for 8 (eight) years duration. There are considered 4 (four) periods, the period 1986-1993, 1994-2001, 2002-2009 and 2010-2017. And divided into 5 (five) flow zones, namely high flow, wet flow, middle flow, dry flow and low flow.

FDC were analysed out from hydrographs. FDC shown in normal and logarithmic form. FDC in normal form used to analyze high, wet and middle flow, while FDC in logarithmic form used to analyze dry and low flow, because logarithmic FDC is more sensitive to dry and low flow.

Transition of the FDC curve between 2 (two) periods viewed from the change in the shape of the curve, if the shape of the curve goes up it is expressed as ecosurplus (increasing the curve area) and if the shape of the curve goes down it is stated as ecodeficit (decreasing the curve area).

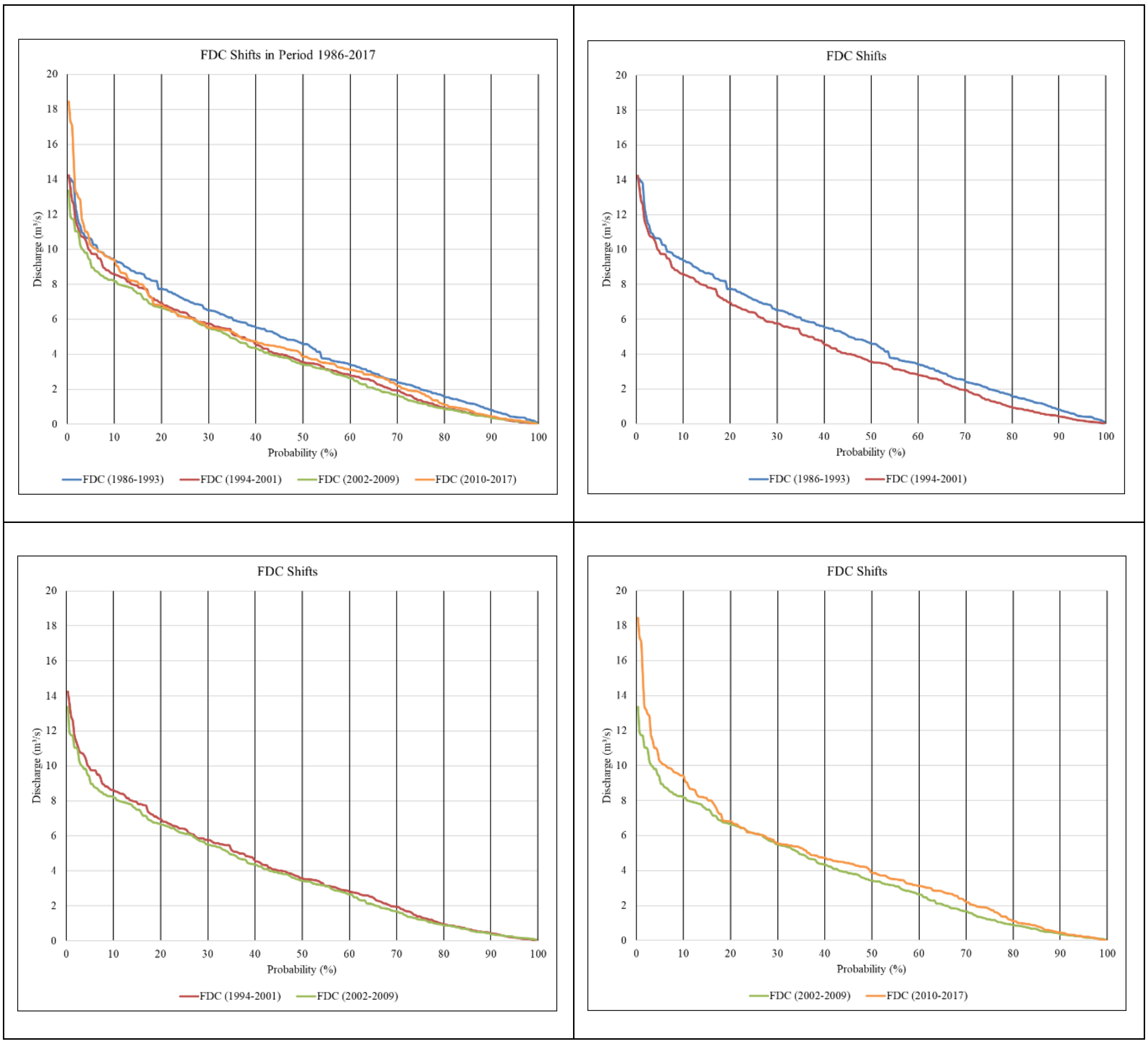

Figure 8. Normal FDC shifts over four periods

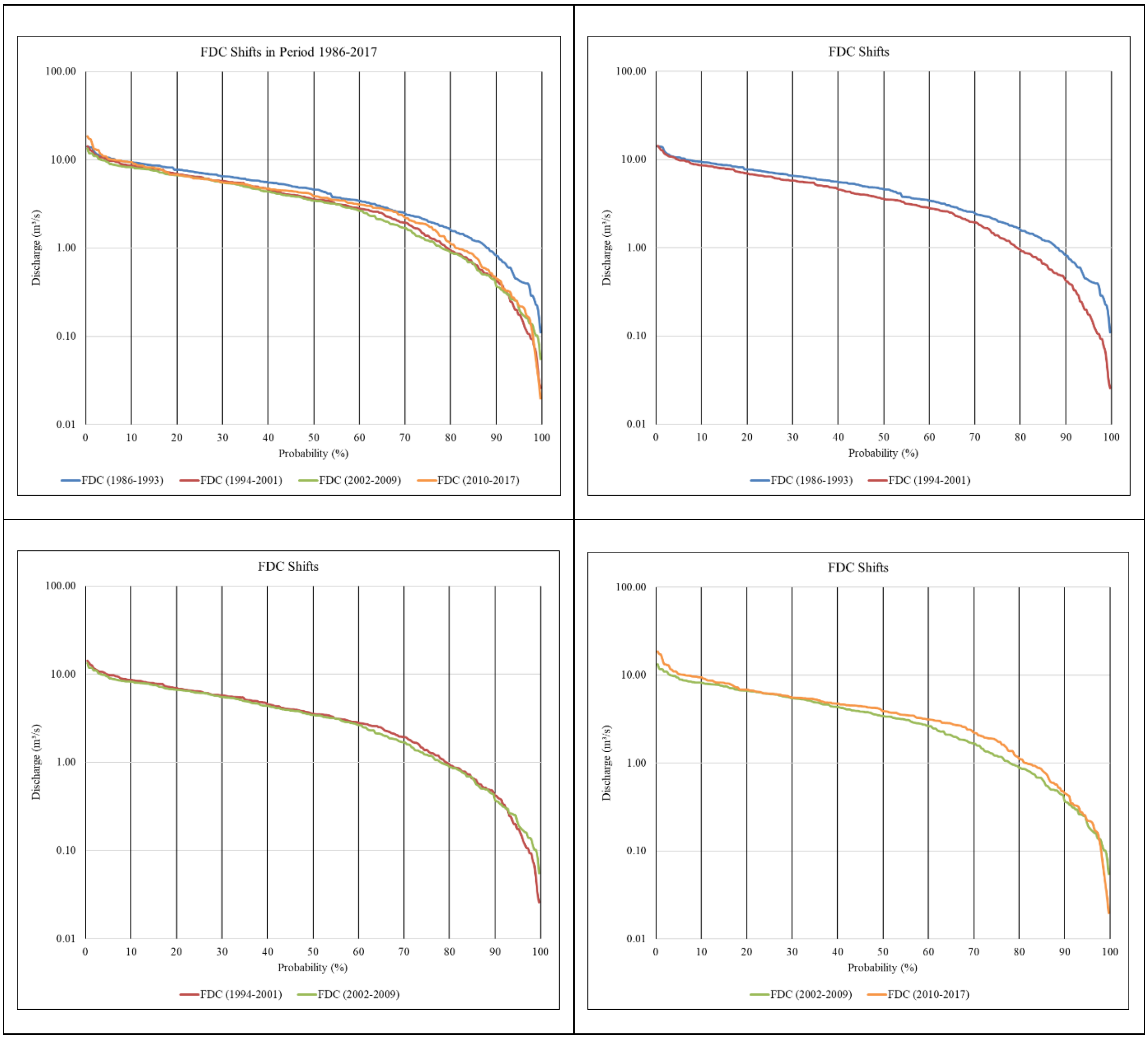

Figure 9. Logarithmic FDC shifts over four periods

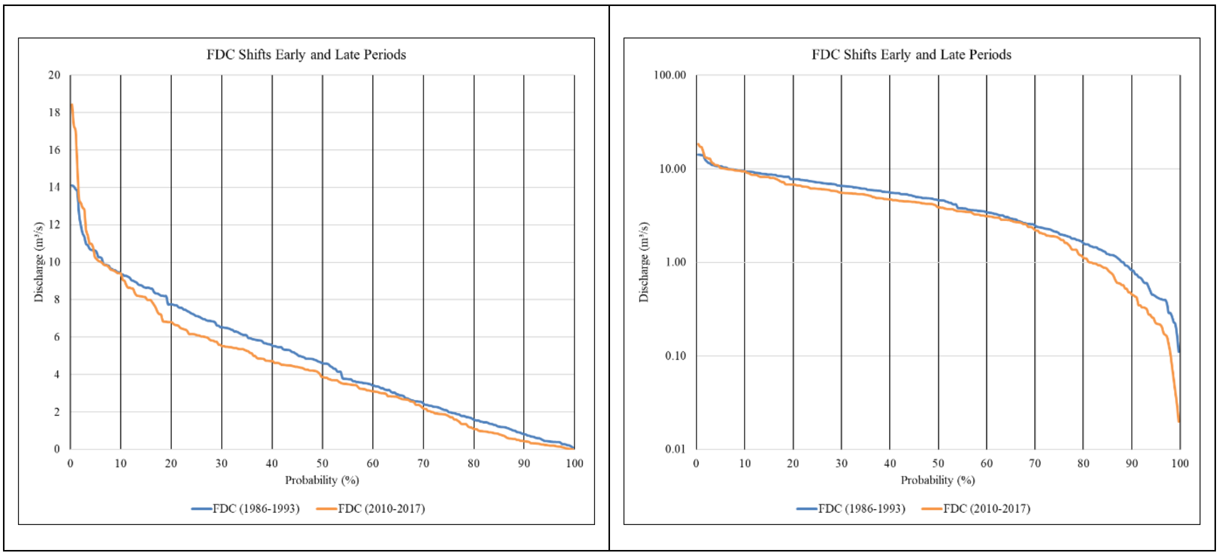

Figure 10. FDC shifts early and late periods

The FDC both normal and logarithmic curve in the early and late periods showed a higher change in ecosurplus at high flow, whereas the wet, middle, dry and low flow show ecodeficit shifting.

4. CONCLUSION

From the results of the research analysis the following conclusions can be drawn.

1) Land changes that occur are dominated by changes from mixed upland agriculture to dryland agriculture, but that does not have a major impact on changes in the value of runoff coefficient. This is because the interpretation of runoff coefficient values both mixed upland agriculture and dryland agriculture have the same value of 0.45.
2) The results of flood discharge analysis for Cikapundung-Pasirluyu sub-watersheds found that changes in flood discharge are dominated by changes in rainfall, this is indicated by changes in the runoff coefficient which tends to be constant. Then the magnitude of the effect of changes in land cover (C) to changes in flood discharge which only affects 15.9% for the Cikapundung-Pasirluyu Sub-watershed.
3) In the Cikapundung-Pasirluyu Sub Watershed, the FDC (1986-1993) and FDC (1994-2001) Normal Curve shifts and the FDC (1994-2001) and FDC (2002-2009) shifts showed ecodeficit shifts in high flow at 6.1%, wet flow at 8.1% and middle flow at 9.0%. When viewed from the shift in the FDC (2002-2009) and the FDC (2010-2017) showed the opposite condition, they were ecosurplus shifts in high, wet and middle flow at 18.5%, 4.0% and 9.8% respectively.
4) The shifts of FDC Normal Curve in the period 1986-2009 showed a fairly thin level of change or can be said to not show a large level of difference, but the FDC period 2002-2017 showed a fairly high change as indicated by ecosurplus symptoms at high flow where this can be an indicator of flooding.
5) The shift in Logarithmic Curves of FDC (1986-1993) and FDC (1994-2001) showed ecodeficit shifts in dry flow at 32.9% and low flow at 61.7%. When viewed from a shift in FDC (1994-2001) and FDC (2002-2009) showed ecodeficit shift in dry flow at 9.9% and ecosurplus shift in low flow at 30.9%. Whereas based on shifts in FDC (2002-2009) and FDC (2010-2017) showed the opposite condition which shows ecosurplus shifting in dry flow at 31.4% and ecodeficit shifting in low flow at 2.0% where this can be an indicator of reduced base flow.

REFERENSI

Adzhani, M. D., & Tayubi, Y. R. (2019). Analisis Curah Hujan Terhadap Debit Air Sungai Di Daerah Aliran Sungai Citarum. *Prosiding Seminar Nasional Fisika 5.0*, *0*, 1–4.

Bachrein, S. (2012). Pengembangan Daerah Aliran Sungai (DAS) Cikapundung: Diagnostik Wilayah. *Jurnal Bina Praja*, *04*(04), 227–236. https://doi.org/10.21787/jbp.04.2012.227-236

Krisnayanti, D. S., Chandra, C., Made Udiana, I., Bunganaen, W., & Damayanti, A. C. (2022). Penenatuan Parameter Model NRECA Untuk Debit Pada DAS Temef. *Media Komunikasi Teknik Sipil*, *28*(1), 145–152.

Legowo, S., Hadihardaja, I. K., Haji, T. S., & Enung. (2019). Application of digital elevation method (DEM) for flood estimation on upstream Ciliwung river, West Java, Indonesia. *International Journal of GEOMATE*, *17*(59), 154–165. https://doi.org/10.21660/2019.59.30379

Maria, R., & Lestiana, H. (2014). Pengaruh Penggunaan Lahan Terhadap Fungsi Konservasi Air Tanah Di Sub Das Cikapundung. *Jurnal RISET Geologi Dan Pertambangan*, *24*(2), 77. https://doi.org/10.14203/risetgeotam2014.v24.85

Marsim, S., & Yudianto, D. (2017). Analisis Debit Andal Pada Das Cikapundung Hulu Dengan Menggunakan Model NRECA. *Jurnal Teknik Sumber Daya Air*, *3*(2), 121–126.

Megariansyah, T. S., Enung, & Suryadi, C. (2022). Pengembangan Aplikasi Pengolahan Data Hujan Berbasis Web.

Pertemuan Ilmiah Tahunan Ke-39 HATHI, 2297–2308.

Permatasari, R., Natakusumah, D. K., & Sabar, A. (2017). Determining peak discharge factor using synthetic unit hydrograph modelling (case study: Upper komering South Sumatera, Indonesia). *International Journal of GEOMATE*, *13*(36), 1–5. https://doi.org/10.21660/2017.36.2744

Rahayu, Y., Juwana, I., Marganingrum, D., & Lingkungan, J. T. (2018). Kajian Perhitungan Beban Pencemaran Air Sungai Di Daerah Aliran Sungai (DAS) Cikapundung dari Sektor DomestikSm. *Jurnal Rekayasa Hijau*, *2*(1), 61–71.

Rizaldi, A. (2018). *Analisa Trend Curah Hujan, Tutupan Lahan, dan Debit Limpasan di Wilayah DAS Citarum Hulu-Majalaya*.

Ruminta. (2008). *Karakteristik, Mekanisme, dan Model Temporal Hidrometeorologi Daerah Aliran Sungai Citarum Hulu dan Tengah*. Institut Teknologi Bandung.

Suntari, L. (2017). *Dinamika Pengelolaan Sumber Daya Air Di Desa Pudak Kulon Kecamatan Pudak Kabupaten Ponorogo*. Universitas Muhammadiyah Ponorogo.

Suryadi, C., Miharti, I., Putri, M., & Georgen, R. J. (2021). Analisis Perbandingan Temporal Debit Andalan Maksimum Dan Minimum (Studi Kasus: DAS Cikapundung). *Jurnal Teknik Sipil*, *1*(1), 11–16.

Suryadi, C., & Nurkhaerani, F. (2023). Comparative Analysis of Observational Rainfall with Satellite Rainfall Chrs Data Portal on The Dependable Flow. *Journal of Civil Engineering, Building and Transportation*, *7*(2), 88–97. https://doi.org/10.31289/jcebt.v7i2.9799

Utari, R., & Martini, S. (2022). Analisa Debit Bangkitan Menggunakan Model Arima (Autoregresif Integrated Moving Average). *Bearing : Jurnal Penelitian Dan Kajian Teknik Sipil*, *7*(3), 159. https://doi.org/10.32502/jbearing.4645202273