JOURNAL OF APPLIED GEOSPATIAL INFORMATION

Vol 6 No 2 2022

http://jurnal.polibatam.ac.id/index.php/JAGI
ISSN Online: 2579-3608

Analysis of Land Cover Changes On Rainwater Runoff In Ciapus Sub-Watershed

Alimuddin[1], Feril Hariati[1]*, Fachruddin[2], Muhamad Lutfi[1], Muhamad Rizki[1]
[1]Study Program of Civil Engineering – Faculty of Engineering and Science – Ibn Khaldun University
[2]Department of Civil Engineering – Faculty of Engineering – Teuku Umar University
Corresponding author e-mail: ferilh2k@gmail.com

Received: June 26, 2022
Accepted: August 15, 2022
Published: August 15 , 2022

Abstract

Ciapus Sub Watershed is part of the Cisadane watershed which passes through 3 (three) sub-districts in Bogor Regency, namely Dramaga District, Ciomas District, and Tamansari District. From 2011 to 2020 housing construction in Dramaga, Ciomas and Tamansari sub-districts increased. High enough rainfall and continuous land changes will result in water infiltration not functioning properly and will cause an increase in surface runoff. Therefore, it is necessary to know how much influence changes in land cover have on the runoff discharge of rainwater in the Ciapus sub-watershed. The purpose of this study was to identify changes in land cover in the Ciapus sub-watershed and to determine the magnitude of the increase in runoff due to changes in land cover in the Ciapus sub-watershed. The results of the analysis of the Ciapus sub-watershed have 8 types of land cover, namely water bodies, primary dry land forest, secondary dry land forest, gardens, dry land agriculture, mixed dry land agriculture, rice fields and settlements. The biggest change in land cover area between 2011 and 2020 is the increase in residential area of 2441.59 ha. Meanwhile, dry land agriculture experienced the largest reduction in area of 1288.68 ha. Based on the calculation of runoff discharge using the rational method, the amount of discharge that occurred in 2011 was 153.31 mm/second while in 2020 it was 214.99 mm/second.

Keywords: Land Cover Change, Runoff discharge, Ciapus Sub-Watershed.

1. Introduction

Watersheds are ecosystem entities that play an important role in life and must be managed and conserved (Halengkara et al., 2012). One of the main functions of the watershed is as a supplier of water with good quantity and quality, especially for people who live in downstream areas (Fachruddin et al., 2021). Watershed is an ecosystem consisting of upstream, middle and downstream. The upstream watershed ecosystem is an important part because it has a protection function for all parts of the watershed (Asdak, 2014).

Changes in land cover on a large scale can be seen from changes in the hydrological function of the watershed which begins with a decrease in regional rainfall and is followed by watershed yields (Pawitan, 2010). Changes in land use also cause changes in soil structure due to human management, thus affecting the infiltration capacity of the soil (Hariati et al., 2020). Watershed management being a serious problem because of the increasing number of critical lands and changes in land use patterns that exceed the environmental capacity (Nurdin et al., 2014).

The Ciapus sub-watershed is part of the Cisadane watershed which passes in 3 (three) districts in Bogor Regency, namely Dramaga District, Ciomas District, and Tamansari District. From 2011 to 2020 housing construction in Dramaga, Ciomas and Tamansari Districts was increased. The impact of this condition can cause changes in soil structure due to human management, thus affecting the infiltration ability of the soil. Research results Pratiwi & Agustina (2017) show that the Dramaga higher education area also experienced an increase in land use change, which was lower than the Jatinangor education area by 23% in 2007-2016.

The change in land use causes a change in the surface runoff coefficient (C). The results of the research Kusumastuti et al., (2018) these changes lead to an increase in the coefficient of surface runoff (C) which causes an increase in flood discharge by 1.75% in all watersheds. High enough rainfall and continuous land changes will result in water infiltration not functioning properly and will cause an increase in surface runoff. The results of the research Fachruddin et al. (2015) also show that there is a relationship between rainfall and surface runoff. With regard to surface runoff, the type of cover will be a measure of the amount of runoff that will occur. Excessive conversion and not paying attention to environmental balance causes environmental degradation that affects the productivity of the area (Alimuddin & Aryanti, 2020). Therefore, it is necessary to know how much influence changes in land cover have on the runoff discharge of rainwater in the Ciapus watershed.

2. Methods

2.1. Time and Location Of Research

Time for data collection, data processing, data processing, report generation and data analysis was carried out for three months, starting in January 2022. Location of research was carried out in the Ciapus watershed.

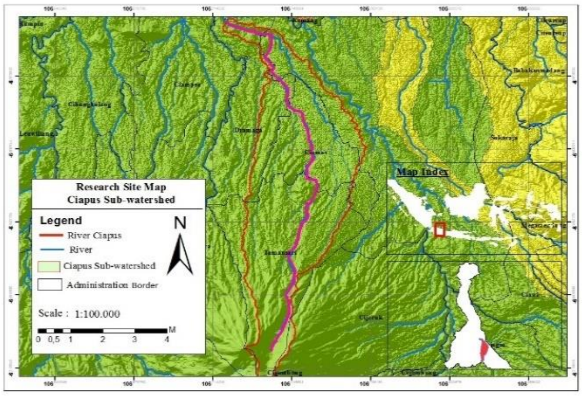

Figure 1. Location of research

2.2. Tools and Material Of Reseacrh

The tools used in this research are laptop, ArcGis 10.5, and GPS. The materials used in this research are 10-year rainfall recording data (2011-2020), Indonesian Earth Map, Landsat satellite imagery in 2011 and Google Earth in 2020.

2.3. Data Collection

Data collection uses a quantitative descriptive method in the form of test results data.

2.3. Data Analysis

2.3.1. Land Cover and Runoff Coefficient Value

Land cover is a watershed element that greatly determines the amount of water flow from rainfall which results in flooding. The condition of land cover in the drainage area will affect the flow of the river. With regard to surface runoff, the type of land cover will be a measure of how much surface runoff will occur, as the area will have small surface runoff due to its large infiltration capacity.

Runoff coefficient is the percentage of the amount of water that can run off/flow through the soil surface from the total rainwater that falls on an area. The C coefficient value is obtained from each type of land cover, the correlation between land cover and C value is determined based on the equation table 1, To find out the runoff coefficient value, using the formula below:

$$C=\frac{C1.A1+C2.A2.......CN.AN}{A1+A2..........AN} \quad ....(1)$$

Table 1. Land Cover Runoff Coefficient Value

Land Cover	C Value
Dry Land Forest	0.03
Shrubs	0.07
Primery Forest	0.02
Secondary Swamp Forest	0.15
Industrial Park Forest	0.05
Plantation	0.4
Dryland Farming	0.1
Mix Dry Land Farming and Shrubs	0.1
Settlement	0.6
Ricefield	0.15
Embankment	0.05
Open Land	0.2
Waters	0.05

Source: (Suripin, 2004) *in* (Sugiyanto & Kodoatie, 2022)

2.3.2. Average Rainfall

Rain data obtained from a rain gauge is rain that occurs only in one place or point (point rainfall). Considering that rain varies greatly with space, for a large area, a rain gauge has not been able to describe the rain in the area.

2.3.3 Rain Frequency Analysis

Rain frequency analysis is used to determine the probability of the occurrence of maximum daily rain in a certain return period, the amount of rain is equaled or exceeded. Rain frequency analysis can be used with frequency distribution method below:

1. Distribution of Log Person III

Calculate the average value, shown in the equation (2):

$$LogX = \frac{\sum_{i=1}^{n} LogX_i}{n} \quad ....(2)$$

Calculate the standard deviation, shown in the equation (3):

$$s = \left[\frac{\sum_{i=1}^{n}(LogX_i - logX)^2}{n-1}\right]^{0.5} \quad ....(3)$$

Calculate the coefficient of shearing, shown in the equation (4):

$$G = \frac{n\sum_{i=1}^{n}(logX_i - logX)^3}{(n-1)(n-2)s^3} \quad ....(4)$$

Calculate the logarithm of rain or flood with the return period T shown in the equation (5):

$$LogX_T = LogX + K.s \quad ....(5)$$

Description:

K = Standard variable
X = Average value
s = Standard deviation
G = Swelling coefficient
Log X = Average value of variant
X_T = Estimated value expected to occur in return period T.

2. Distribution of Gumbel

Calculation of the planned rainfall according to the Gumbel method is shown in equation (6) (Suripin, 2004):

$$X = \bar{X} + s.K \quad (6)$$

Description:

$\bar{X}$ = Sample average value

S = Standard deviation of the sample

$\bar{X}$ value is shown in equation (7):

$$\bar{X}=\frac{\sum X_i}{N} \quad (7)$$

Standard deviation (S) is shown in equation (8):

$$S_x=\sqrt{\frac{\sum(X_i-\bar{X})^2}{N-1}} \quad (8)$$

Description:

$\sum X_i$ = Total maximum rainfall value, and

N = Maximum amount of rainfall data.

The probability factor K for Gumbel's extreme values is shown in equation (9):

$$K = \frac{Y_{T_r}-Y_n}{S_n} \quad (9)$$

Description:

K = Probability factor

Y_n = Reduced mean which depends on the number of samples/data

S_n = Reduced standard deviation which also depends on the number of samples/data,

Y_{Tr} = *Reduced variate*

Reduced variate is shown in equation (10):

$$Y_{Tr} = -In\left\{-In\frac{T_r-1}{T_r}\right\} \quad (10)$$

2.3.4 Chi-Square Test

Chi-square test is used to test the distribution of observations, whether the sample meets the distribution requirements being tested or not. The procedure for calculating chi-square test according to Limantara (2008) is as follows:

1. Counting the number of classes shown in the equation (11):

   K = 1+3.3222 log.n .... (11)

   Description:

   K = Number of classes, dan

   n = Amount of data.

2. 2. Calculating the calculated chi-square parameter is shown in equation (12).

   $$X^2 = \sum_{i-1}^{k}\frac{(Oi-Ei)^2}{Ei} \quad (12)$$

   Description:

   X^2 = Calculated chi-square parameter

   K = Number of classes

   Oi = Frequency of class observations

   Ei = Class theoretical frequency

3. Determine the critical X2 from by determining the significant level (α) and degrees of freedom with the equation (13).

   Dk = K – (p+1) ....(13)

   Description:

   Dk = Degrees of freedom,

   K = Number of classes, dan

   P = The number of parameters for the chi-square test is 2.

Concluding the results from the calculation table X^2 count < X^2 critical then the distribution is fulfilled and if the value X2 count > X^2 is critical then the distribution is not fulfilled (Limantara, 2008).

2.3.5. Rain Intensity

Rain intensity is the amount of rain expressed in height of rain or volume of rain per unit time. Rain intensity is usually associated with short-term rain duration, for example 5 minutes, 30 minutes, 60 minutes and hours. If only daily rainfall data is available, then the rainfall intensity can be estimated as shown in the Mononobe equation (14):

$$I = \frac{R_{24}}{24}\left(\frac{24}{t}\right)^{2/3} \quad (14)$$

Description

I = Rainfall intensity [mm/hour],

R_{24} = Maximum Rainfall in 24 hours [mm],

t = The duration of the rainfall [hour]

2.3.6 Surface Runoff

Surface runoff is the amount of water flow or inundation that occurs on the surface when it rains and at certain times the Rational Method is widely used for ordinary rivers with large drainage areas and for planning drainage of narrow drainage areas (Wesli, 2008). The general equation for the Rational Method is as follows:

Q = 0.00278 x C x I x A ....(15)

Q = Runoff discharge [m^3/second],

C = Surface runoff Coefficient,

I = Rainfall intensity [mm/hour],

A = surface area (m^3)

3. Discussion Results

3.1. Identifikasi Perubahan Tutupan Lahan

Based on the results of data processing using the Arcgis 10.3 obtained from Landsat Imagery in 2011 and Google Earth in 2020, the Ciapus sub-watershed has 8 types of land cover, namely water bodies, primary dryland forest, secondary dryland forest, gardens, dryland agriculture, agriculture. mixed dry land, rice fields and settlements. Results of data processing is shown in Figure 2, Figure 3 and Table 2 below.

Table 2. Coefisien C Value

Land Cover	Coefiesien	Area (ha)		Composite C	
	C	2011	2020	2011	2020
River	0.05	37.03	37.03	1.85	1.85
Primery dry land forest	0.2	120.16	120.16	24.03	24.03
Secondary dry land forest	0.15	718.61	718.61	107.79	107.79
Garden	0.4	93.32	832.65	37.33	333.06
Dry land farm	0.1	2178.57	1288.68	217.85	128.86
Mixed	0.1	623.56	182.19	62.35	18.21
Ricefield	0.15	718.61	500.68	107.79	75.10
Settlement	0.6	1631.70	2441.59	979.02	1464.95
	Total	6121.62	6121.62	1538.04	2153.88
		Composite C		0.251	0.352

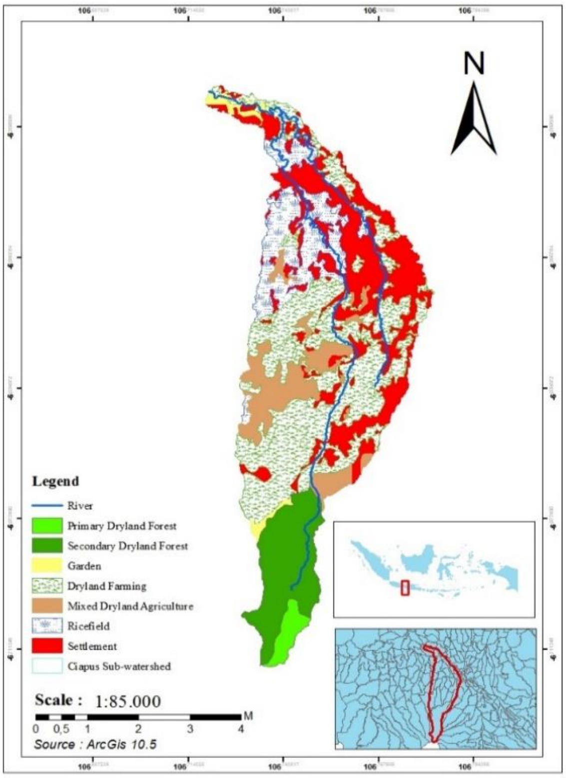

Figure 2. Land Cover Maps, Year 2011

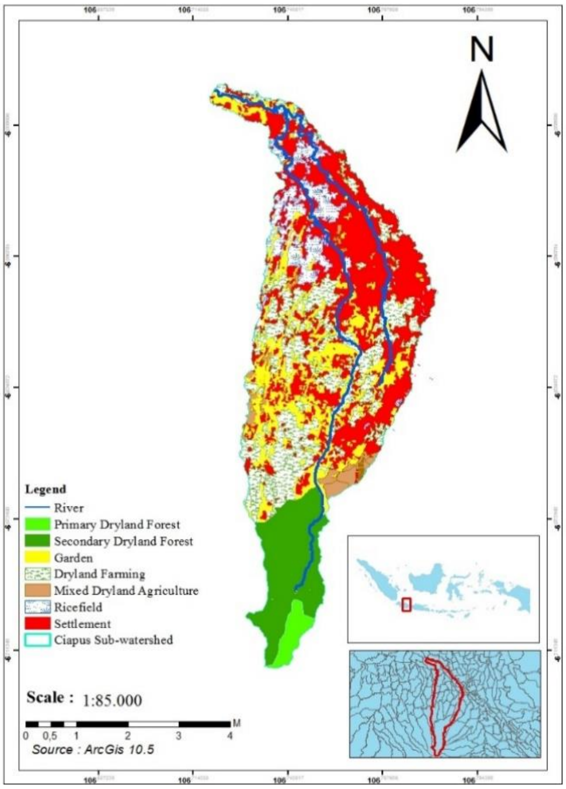

Figure 2. Land Cover Maps, Year 2020

Table 2 explained that in 2011 the Ciapus sub-watershed had a surface runoff coefficient of 0.251 and in 2020 the Ciapus sub-watershed had a surface runoff coefficient of 0.352.

3.2. Average Rainfall

In this study, the maximum daily rainfall data was obtained from 1 observation post with the location of the BMKG Dramaga station. From the observation post, data on daily rainfall observations for 10 (ten) years in the period 2011 to 2020. Then the highest maximum daily rainfall value is taken every year.

Table 3. Maximum Rainfall Value

No	Year	Observation Place
		BMKG Dramaga station (mm)
1	2011	118
2	2012	63
3	2013	130
4	2014	192.8
5	2015	86.8
6	2016	78.4
7	2017	90
8	2018	164.1
9	2019	87.4
10	2020	118.7

3.3. Rainfall Frequency Analysis

Frequency analysis requires a series of rain data obtained from the rain gauge post. There are several methods of frequency analysis to obtain the magnitude of the return period, in this study used calculations using Log Person III Distribution Method and Gumbel Method.

Table 4. Combination of rainfall in the return period (mm)

Return Peroid (T)	Gumbel	Log Pearson III
2 Year	106.18	103.53
5 Year	155.55	139.48
10 Year	187.62	164.14

3.4. Chi-Square Method Compatibility Test

The distribution compatibility test is used to test whether the selected distribution matches the empirical distribution

Table 5. Chi-Square Test

Class	Probability	Amount		Oj - Ej	$X^2 = \frac{(O_i - E_i)^2}{Ei}$
		Oj	Ej		
1	42<x<85	2.5	5	-2.5	2.50
2	85<x<128	2.5	2.0	0.5	0.13
3	128<x<171	2.5	2.0	0.5	0.13
4	171<x<214	2.5	1.0	1.5	2.25
Jumlah		10	10		5.00

The value of X2 uses Dk = 1 and the degree of confidence is 2.5% with a value of 5.042. then the critical X2 value is compared with the calculated X2 value which can be seen in the table with the conditions that must be met, namely X2 < X2 critical. Judging from the results of these calculations that the value of X2 = 5.00 < X2 critical = 5.042 then the sample can be accepted in this study.

3.5. Rainfall Intensity

To calculate the amount of rainfall intensity is obtained from the maximum rainfall data (mm). From the rainfall data, it can be calculated the amount of rainfall intensity by changing the amount. The unit of rainfall in mm is changed to mm/hour (units of rainfall intensity).

Table 6. Calculation of return period rainfall

Rainfall Duration (minute)	Return Period Rainfall (mm)		
	2 Year	**5 Year**	**10 Year**
	103.53	139.48	164.12
1	550.09	741.10	872.02
2	346.53	466.86	549.34
3	264.45	356.28	419.22
4	218.30	294.10	346.06
5	188.13	253.45	298.23
10	118.51	159.66	187.87
20	74.66	100.58	118.35
25	64.34	86.68	101.99
50	40.53	54.60	64.25
60	35.89	48.36	56.90
120	22.61	30.46	35.84
180	17.26	23.25	27.35
240	14.24	19.19	22.58

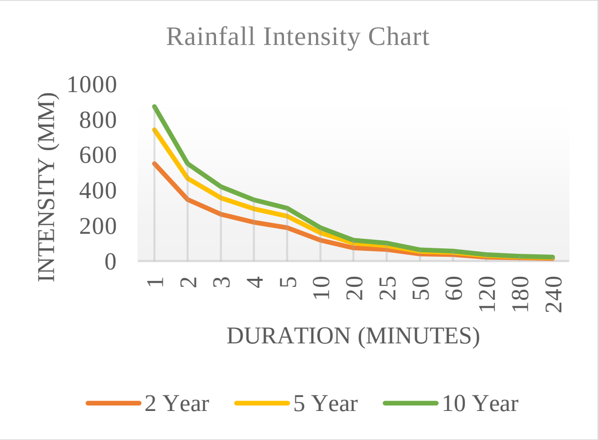

Figure 3. Rainfall Intensity Graph

Figure 3 describes a graph of the intensity of rain within 60 minutes on return periods of 2 years (35.89 mm), 5 years (48.36 mm) and 10 years (56.90 mm). Generally, the whole is above 20 mm. Based on Triatmodjo (2009) a value of > 20 mm with a rain intensity of 60 minutes is included in very heavy rain conditions. Meanwhile, according to the results of research by Syafira et al., (2016) in the city of Dramaga, it is included in the high-intensity category.

3.6. Surface Runoff

The method for estimating runoff discharge which is commonly used is the rational method. This method is very simple and easy to use, but its use is limited to watersheds (DAS) with a small area, where the use of the Rational Method can be used in an area of more than 5000 ha. The presentation of surface runoff results can be seen in Table 7, Table 8 and Figure 4.

Table 7. Surface runoff discharge in 2011

No	Period (year)	R24mm	C 2011	I (mm/hour)	A (ha)	Qr (m/second)
1	2	103.53	0.251	35.89	6121.62	153.31
2	5	139.48	0.251	48.56	6121.62	207.43
3	10	164.12	0.251	56.9	6121.62	243.05

Table 8. Surface runoff discharge in 2020

No	Period (year)	R24mm	C 2011	I (mm/hour)	A (ha)	Qr (m/second)
1	2	103.53	0.251	35.89	6121.62	214.99
2	5	139.48	0.251	48.56	6121.62	290.89
3	10	164.12	0.251	56.9	6121.62	340.85

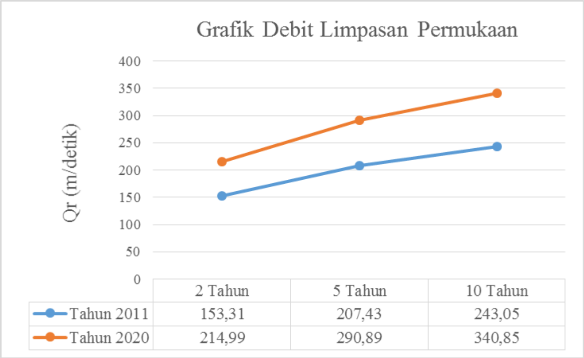

Figure 4. Surface runoff graph

Figure 4. describes the surface runoff discharge in 2011 using return periods of 2, 5 and 10 years. Included in the high category is the range from 153.31 to 243.05. Meanwhile, in 2020 the return period of 2, 5 and 10 years experienced a higher increase from 214.99 to 340.85. Of course, this change occurred because there was a change in land use in 2011 and 2020. Thus changing the value of the flow coefficient C changed which increased the surface discharge value. The results of the study (Permatasari et al., 2016) there was a trend of increasing the value of c and decreasing the value of b throughout the year in the Komering Watershed.

4. Conclusion

The types of land cover in the Ciapus sub-watershed are rivers, primary dry land forest, secondary dry land forest, gardens, dry land agriculture, mixed dry land agriculture, rice fields, settlements. Identification of the largest change in land cover between 2011 and 2020 is the increase in residential area of 2441,599 ha. Meanwhile, dry land agriculture experienced the largest reduction in area of 1288,680 ha. Based on the calculation of runoff discharge using the rational method, the amount of discharge that occurred in 2011 was 153.31 mm/second while in 2020 it was 214.99 mm/second.

5. References

Alimuddin, A., & Aryanti, D. (2020). *Kajian Perubahan Garis Pantai Muara Gembong, Bekasi*. *13*(2), 71–83.

Asdak, C. (2014). *Hidrologi dan Pengelolaan Daerah Aliran Sungai*. Gadjah Mada University Press.

Fachruddin, F., Setiawan, B. I., Mustafril, M., & Prastowo, P. (2015). Pemanenan Air Hujan Mengunakan Konsep Zero Runoff System (ZROS) Dalam Pengelolaan Lahan Pala Berkelanjutan. *Jurnal Teknik Sipil ITB*, *22*(2), 127–136.

Fachruddin, F., Sirait, S., Alimuddin, A., & Ramli, I. (2021). Kajian Tingkat Bahaya Erosi dan Kekritisan Pada DAS Krueng Raya, Provinsi Aceh Menggunakan Sistem Informasi Geografis. *Jurnal Keteknikan Pertanian Tropis Dan Biosistem*, *9*(2), 154–164. https://doi.org/10.21776/ub.jkptb.2021.009.02.06

Halengkara, L., Gunawan, T., & Purnama, S. (2012). Analisis Kerusakan Lahan Untuk Pengelolaan Daerah Aliran Sungai Melalui Integrasi Teknik Penginderaan Jauh dan Sistem Informasi Geografis. *Majalah Geografi Indonesia*, *26*(2), 149–173.

Hariati, F., Saputra, D., Alimuddin, A., & Yanuarsyah, I. (2020). Dampak Peningkatan Intensitas Hujan dan Tutupan Lahan Terhadap Debit Banjir Puncak Sungai Ciseel. *Jurnal Komposit*, *4*(1), 13–18. https://doi.org/10.32832/komposit.v4i1.3748

Kusumastuti, C., Djajadi, R., Winarko, E. A., & Richard, E. A. (2018). Dampak Perubahan Tata Guna Lahan Terhadap Besarnya Debit Banjir di Kabupaten Probolinggo. *Dampak Perubahan Tata Guna Lahan Terhadap Besarnya Debit Banjir Di Kabupaten Probolinggo*, 1–10. http://www.hathi-pusat.org/blog/detail/pit-ke-35-hathi-medan

Limantara, L. M. (2008). *Pengaruh perubahan cuaca terhadap optimasi irigasi dengan program linier (Studi kasus daerah irigasi Pamotan)*. Malang Citra Malang. https://onesearch.id/Record/IOS2847.INLIS000000000008278

Nurdin, F. A., Bisri, M., Rispiningtati, R., & Priyantoro, D. (2014). Studi Pemulihan Fungsi Das Berdasarkan Tingkat Kekritisan Lahan Dan Potensi Kelongsoran Di Sub Das Jeneberang Hulu. *Jurnal Teknik Pengairan: Journal of Water Resources Engineering*, *5*(1), 29–41.

Pawitan, H. (2010). Arti Perubahan Iklim Global dan Pengaruhnya Terhadap Pengelolaan Daerah Aliran Sungai di Indonesia. *Arti Perubahan Iklim Global Dan Pengaruhnya Terhadap Pengelolaan Daerah Aliran Sungai Di Indonesia.*

Permatasari, R., Arwin, & Natakusumah, D. K. (2016). *Pengaruh Perubahan Penggunaan Lahan terhadap Rezim Hidrologi DAS (Studi Kasus: DAS Komering)*. 8.

Pratiwi, R. I., & Agustina, I. H. (2017). Identifikasi Perubahan Penggunaan Lahan di Kawasan Pendidikan Tinggi (Studi Kasus di Kecamatan Dramaga Kabupaten Bogor dan Kecamatan Jatinangor Kabupaten Sumedang). *Prosiding Perencanaan Wilayah dan Kota*, *0*, 361–368. https://doi.org/10.29313/pwk.v0i0.6926.

Sugiyanto, S., & Kodoatie, R. J. (2022). *Banjir: Beberapa Penyebab dan Metode Pengendaliannya Dalam Perspektif Lingkungan*. Pustaka Belajar. https://opac.lib.ugm.ac.id/index.php?mod=book_detail&sub=BookDetail&act=view&typ=htmlext&buku_id=5926&obyek_id=1

Suripin, S. (2004). *Sistem Drainase Perkotaan Yang Berkelanjutan*. Andi.

Syafira, S. A., Syaifullah, D., & Renggono, F. (2016). Karakteristik Hujan Dan Awan Penghasil Curah Hujan Harian Tinggi Berdasarkan Data Micro Rain Radar (Studi Kasus: Wilayah Dramaga, Bogor). *Jurnal Sains & Teknologi Modifikasi Cuaca*, *17*(1), 27–35. https://doi.org/10.29122/jstmc.v17i1.535.

Triatmodjo, B. (2009). *Hidrologi Terapan* (Yokyakarta). Beta Offset. perpustakaan.ft.unram.ac.id%2Findex.php%3Fp%3Dshow_detail%26id%3D1489.

Wesli. (2008). *Drainase Perkotaan*. Graha Ilmu. https://opac.perpusnas.go.id/DetailOpac.aspx?id=351891.