Parameters Cp and Ct in Snyder Synthetic Unit Hydrograph Due to Land Use Changes in Napel Sub-watershed, Bengawan Watershed

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ABSTRACT

The parameters Cp and Ct depend on the characteristics and slope of the watershed. Watershed characteristics include types of land use that are always dynamic over time. The slope of the watershed affects the smoothness and velocity of runoff flow. The development of an area will cause changes in land use which tend to become more impermeable, of course also affecting the smoothness and speed of runoff flow. This of course results in changes in Cp and Ct in a watershed. Changes in land use in the Napel watershed within 7 years starting from 2015 to 2021 have decreased in areas of jungle forest and other water catchment areas. This research was conducted to determine the influence of land use change on peak discharge and Cp and Ct parameters. The method used is the Snyder Synthetic Unit Hydrograph, which has been tested for suitability against the Measured Unit Hydrograph with validation results included in the very strong correlation category. The Ct value used in 2015 was 1.65 and in 2021 it was 0.78 while the Cp value used in 2015 was 1.4 and in 2021 it was 1.1. The results of the analysis using the Snyder method produced a discharge of 417.882 m3/s in 2015 and 619.52 m3/s in 2021. The resulting discharge shows a significant increase.

Keywords: Ct; Cp; Snyder SUH; land use change; peak flow.

INTRODUCTION

Land use affects the amount of infiltration and runoff in a watershed. Rainfall and watershed characteristics also affect the amount of peak discharge. The high peak discharge reflects a sign of damage to the watershed, namely an increase in the impermeability of the soil surface. Determination of the peak discharge requires reading the water level data at a certain time. For watersheds that do not have complete hydrological recording data, the determination of peak discharge can be done using the Synthesis Unit Hydrograph (HSS) method (Jayadi, 2005).

Changes in land use that are more impermeable are caused by population growth and the development of urban areas. This causes an increase in discharge in a watershed, so an analysis is needed regarding the increase in discharge that occurs in that watershed. The method used in calculating the peak discharge is the HSS Snyder method, which is then analyzed for correlation using the regression equation to obtain the value of the correlation coefficient (Putri, 2019).

Research on peak discharge in the Napel watershed that occurred in 2015 and 2021 used Snyder's HSS method and was tested for its suitability to the Measured Unit Hydrograph using the correlation coefficient (R) method.

Land use that changes or switches the function of the landscape, especially in the management of vegetation in a watershed, can affect the yield of water or discharge obtained. Therefore changes in land use can cause changes in the value of the surface runoff coefficient. In addition, changes in land use over some time also greatly affect the amount of peak discharge (Triatmodjo, et al, 2019).

Kristianto (2019), examines the comparison of the measured unit hydrograph model with the Snyder synthesis unit hydrograph in the Tukad Pakerisan River Basin. The HSS model is considered to provide results that are overestimated or underestimated on the unit-measured hydrograph. Therefore, it is necessary to compare the HSS models to know the magnitude of the deviation of each model so that an HSS model that approaches the measured unit hydrograph value is obtained.

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In this test the researchers used the HSS Snyder, Nakayasu, GAMA I, Limantara, ITB-1 and ITB-2 methods. From this study it was found that the HSS that approached the Measured HS was Snyder's HSS with adjustments to the coefficients of Ct = 0.800 and Cp = 1.052 with a deviation of less than 5%.

Similar research related to peak discharge analysis using the Snyder synthesis unit hydrograph method approach has also been carried out by Barid, at all (2020), who conducted research on the Katulampa watershed. This study uses the ant algorithm which is considered accurate in solving spatial and complex problems. The main objective of this study was to analyze the Snyder synthesis unit hydrograph method approach under field conditions. This research was optimized with standard deviation statistical tests and also calibration to determine the accuracy between Hss Snyder and unit hydrographs. From the analysis results, it was obtained that the most optimal Ct Cp snyder parameters in the unit hydrograph approach were 0.19 and 1.4.

Kahfi (2021) also analyzed peak discharge using the HSS Snyder method and also the HSS SCS, the research location is on the Poso River which is located in Poso Regency, Central Sulawesi Province. The Poso River has a river length of 74,580 km2 and a watershed area of 1092,810 km2. The river flow has a large water discharge which will later be used for hydroelectric power (PLTA). Thus the maximum flood discharge data is needed for the security preventive measures for the Poso hydropower plant.

Research on the effect of land use on discharge has also been carried out by Heriyanto (2018), who researched the upstream Ciujung Watershed, Lebak Regency, Banten Province. The overflow of Ciujung River water causes Lebak Regency to frequently experience flooding, this is caused by an increase in discharge. To find out the amount of discharge, secondary data is needed in the form of rainfall data, discharge, watershed maps, land use maps, soil type maps, and topography as well as primary data by conducting surveys and field observations as supporting data. This research was carried out to study the effect of changes in land use in the upstream Ciujung watershed on river flow discharge.

Ilmi (2019), also examines the effect of changes in land use on the hydrological conditions of the Dodokan River basin, West Nusa Tenggara Province. It is known that in the past the Dodokan Watershed was dominated by land with permanent vegetation cover which also served as a water catchment area. However, due to the high rate of population growth, the vegetation land has changed its function to become residential land. The main objective of this study is to determine the effect of land use change on peak discharge and Cp and Ct generated using Snyder's HSS method.

RESEARCH METHODS

The research carried out is quantitative research in which this research includes explaining the relationship between variables, testing theories and generalizing the social phenomena studied to know the correlation or suitability of discharge in the field as well as with data from synthesis calculations. The synthetic calculation method used is the Snyder Synthetic Unit Hydrograph method.

Research sites

The location of this research is in the Napel watershed, which is also one of the sub-watersheds of the upstream Bengawan Solo watershed. Geographically it is located at 7°22'29.92"S South Latitude and 111°27'52.66"E East Longitude. This location was determined based on the availability of data obtained from the Bengawan Solo River Basin Center. After the daily rainfall data is obtained, then determine the stations that have complete rainfall in 2015 and 2021 and then plot them on Google Earth along with the map of the Upper Bengawan Solo Watershed. From the station plotting results, it was found that the Napel watershed as the object of the research, with a watershed area of 9662.76 km2 and a length of the main river of 190.41 km. The location and shape of the Napel watershed is clarified in Figure 1 below.

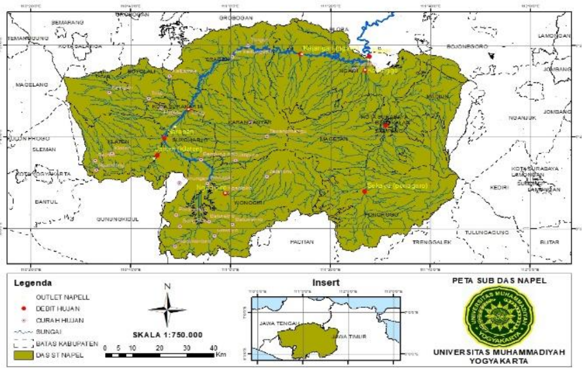

Figure 1. Napel watershed

The research stages are described in the following flowchart:

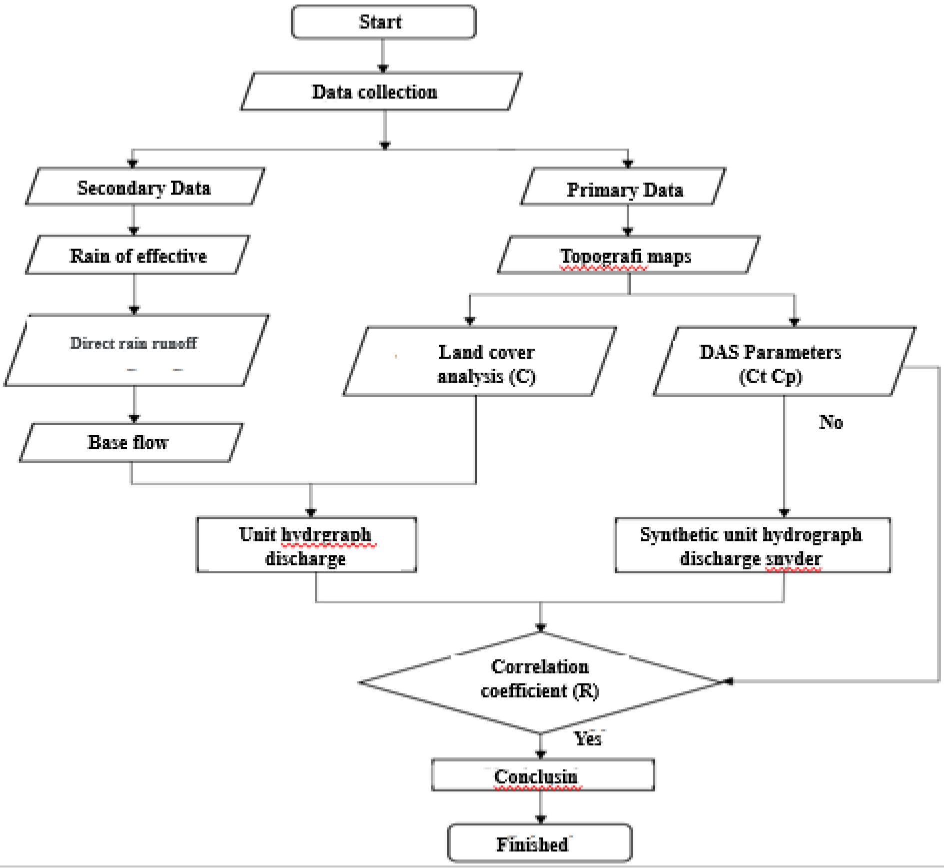

Figure 2. Research flowchart

This research requires several data that are considered related to the research being carried out. The secondary data used such as rainfall and water flow rate in this research are sourced from the official website of the Bengawan Solo River Basin Center in Sukoharjo Regency, Central Java. Meanwhile, the watershed data and land use distribution maps were obtained from topographical maps in the form of Google Earth and ArcGIS (Arc-map).

The satellite imagery data used in this study were obtained from existing satellite imagery data provider sites. One of the existing satellite image data providers is https://tanahair.indonesia.go.id. Downloaded satellite imagery data, namely data that corresponds to the location of the research object and in the period according to the research criteria, namely 2015 and 2021.

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Land Use

In this study, land use data were obtained from topographical maps in the form of Google Earth and ArcGIS (Arc-map). Meanwhile, satellite imagery data was obtained from one of the data provider sites, namely https://tanahair.indonesia.go.id.

The data on the downloaded satellite imagery is data that corresponds to the location of the research object and in the period according to the research criteria, namely 2015 and 2021.

The results of the data obtained from satellite imagery were then analyzed for changes in land use that occurred during the 2015 and 2021 periods. The analysis of land use changes classifies land cover types into several groups, and then a runoff coefficient value (C) is generated which is used in calculating effective rainfall so that produces discharge on a measured unit hydrograph.

Rainfall data

The rainfall data used in this study is sourced from the official website of the Bengawan Solo River Basin. Calculation of the average rainfall in this study using the Thiessen method,

Rain Intensity

The average/planned rainfall value that has been obtained is the daily rainfall value, therefore it is necessary to have a distribution so that it becomes an hourly rainfall value, the calculation can be calculated using the mononobe formula.

Unit Measured Hydrograph

Unit hydrograph or direct runoff hydrograph originating from effective rain that occurs evenly in a watershed with a fixed intensity with a rain unit of 1 mm/hour. The unit hydrograph can be calculated if the parameters that have been determined are complete. The required data parameters are AWLR (Automatic Water Level Recorder), discharge, and rainfall measurement data (Gustama, et al, 2018).

Calculation of direct runoff discharge is obtained from the settlement of the hydrograph based on effective rain. In this study, the decrease in unit hydrographs comes from measured hydrographs generated by effective rain which has been distributed into several different intensities.

Snyder Synthetic Unit Hydrograph

Triatmodjo, (2008) states that the Snyder Unit Hydrograph has 4 parameters consisting of lag time, peak flow, bottom time, and standard duration of effective rain then the hydrograph is associated with the physical geometry of the watershed. To make it easier to draw the Snyder chart, $W50$ and $W75$ apply

With $W50$ and $W75$ as a reference where the width of the hydrograph unit is at a discharge of 50% and 75% of the peak discharge (hours). The width of $W50$ and $W75$ is made with a ratio of 1:2; with a short side on the left (Triatmodjo, 2008).

Table 1. Variation of Ct Cp (Siswoyo, 2012)

Parameter	Min	Max
Ct	0,75	3
Cp	0,9	1,4

Correlation Between Hydrographs

To determine the suitability and accuracy of the results of the measured unit hydrograph peak discharge and also the Snyder unit hydrograph, suitability validation was carried out. In this study using the method of correlation coefficient (R)

RESULTS AND DISCUSSION

Land Use Change

From the results of the analysis carried out, the changes in land use that occurred from 2015 to 2021 are described in the following table.

Table 2. Land Use of the Napel Watershed

No	Land Use Jungle	Wide (km)	
		2015	2021
1	Plantation/garden	1415,1007	165,6685
2	Settlements and Places of Activity	93,8180	171,8668
3	Ricefield	2251,3549	3988,9905
4	Farm Field	4506,3796	3806,3913
5	Other	436,9827	1222,3921
6	Land Use	959,1245	307,4512
	Amount	9662,7604	9662,7604

Land changes that occur in the Napel watershed are in line with the increasing needs of the population every year. Evidenced by an increase in the area of residential land use types and places of activity, which in 2015 was 23.2993%, increasing to 41.2821%. Meanwhile, significant land degradation occurred in forest land types, with a land decline of 12.9304%.

Land use changes also affect the flow coefficient values in the watershed, changes in the flow coefficient values of the Napel watershed are described in table 3 below.

Table 3. Napel Watershed Flow Coefficient

No	Land Use	C 2015	C 2021
1	Jungle	0,0366	0,0043
2	Plantation/garden	0,0038	0,0072
3	Settlements and Places of Activity	0,0698	0,3303
4	Ricefield	0,0932	0,0788
5	Farm Field	0,0271	0,0760
6	Other	0,0893	0,0287
Amount		0,32014	0,5251

Land use change has an impact on decreasing the value of the flow coefficient, from the analysis results show that the coefficient value has increased by 0.2048. The decrease in forest land affects the hydrological conditions of the Napel watershed, this is because forest land affects slowing the runoff rate and increasing the time for water to infiltrate the ground surface so that forest sustainability indirectly influences the hydrology of a Napel watershed.

Unit Measured Hydrograph

The measured unit hydrograph requires rainfall data and area data from each station. Rainfall data and station area are described in Tables 4 and 5 below.

Table 4. Rainfall at each station

Rain station	Rainfall (mm)	
	2015	2021
Pracimantoro	20	50
Song Putri	9	85
Parangjoho	6	81
Giriwoyo	12	79
Baturetno	6	122
Batuwarno	12	65
Jatisrono	65	9
Wonogiri	38	29
Jatipuro	120	10
Bendungcolo	28	11
Klaten	16	46

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Tritis	29	17
Kalijambe	71	5
Tawangmangu	54	42
Pabelan	77	10
Karangpandan	82	6
Jururejo	40	8

Table 5. Area of each Station

Rain station	Station area (Ha)	Area percentage (%)
Pracimantoro	10277.3050	1.0636%
Song Putri	7764.3370	0.8035%
Parangjoho	10687.3190	1.1060%
Giriwoyo	12858.8488	1.3308%
Baturetno	11159.5635	1.1549%
Batuwarno	27429.1243	2.8386%
Jatisrono	162998.6923	16.8687%
Wonogiri	20488.9497	2.1204%
Jatipuro	20404.8786	2.1117%
Bendungcolo	28223.8543	2.9209%
Klaten	63016.1415	6.5215%
Tritis	70422.7177	7.2880%
Kalijambe	64936.4903	6.7203%
Tawangmangu	60118.3760	6.2217%
Pabelan	31432.0376	3.2529%
Karangpandan	84040.3884	8.6973%
Jururejo	280017.8064	28.9790%
Total area	966276,8304	100%

From the results of the analysis based on the equation previously described, the effective rain mala is obtained as follows

$\overline{P}2015$ = 48.56mm
$\overline{P}2021$ = 19.44mm

With a large rain intensity of
It2015 = 6.6808 mm
It2021 = 2.6739 mm

With the results of the baseflow analysis of
Qb = 125.94 m3/second
With duration of rain occurred for 4 hours. Then the debit is obtained as follows:

2015:
Qpeak = 450.3965 m3/s
Tp = 36th hour

2015:
Qpeak = 619.3041 m3/s
Tp = 18th hour

Graphs of the Unit Hydrograph calculations can be seen in Figures 2 and 3 below

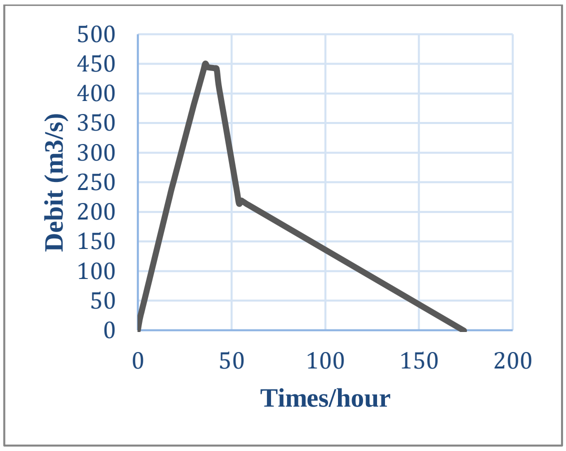

Figure 3. HS Chart for 2015

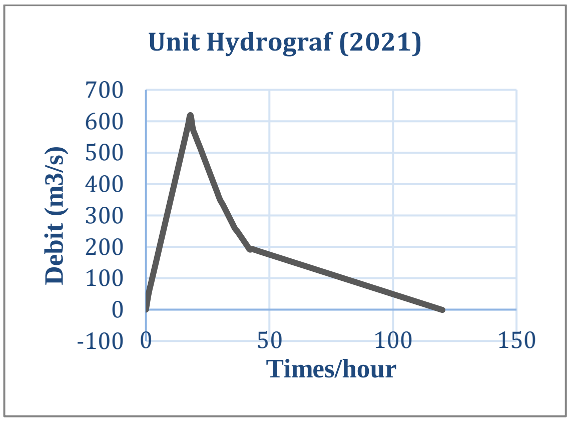

Figure 4. HS Chart for 2021

Unit Measured Hydrograph

With DAS parameters as follows:

Watershed area (A) = 9662.76 km^2

River Length (L) = 190.41 km

Center of Weight (Lc) = 126.94 km

Effective Rain Duration (Tr) = 4 Hours

As well as non-physical parameters as in table 6 below:

Table 6. Parameters ct Cp Optimal

Parameters	2015	2021
Ct	1,65	0,78
Cp	01,4	1,1

Then it produces a peak discharge as described in the following table.

Table 7. Snyder's HSS Debit in 2015

Hours	Debit Hidrograf Snyder (m^3/s)
0	0

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18	208,9409
24	313,4115
36	417,8819
39	313,4114
42	208,9409
174	0

Table 8. Snyder's HSS Debit for 2021

Hours	Debit Hidrograf Snyder (m3/s)
0	0
9,18858	309,7575
12,2514	464,6363
18,3772	619,5151
20,9032	464,6363
22,8463	309,7575
120,328	0

Hydrograph Validation Test

From the results of the measured unit hydrograph and the snyder synthetic unit hydrograph obtained, suitability was tested using the correlation coefficient (R) method. The results obtained are as follows.

2015 year

$$R = \frac{1.220.975.671,4066}{\sqrt{1.277.872.348,8196 \; x \; 1.491.327.536,4813}}$$

= 0,8845

From the R value obtained, the suitability of the Snyder Unit Hydrograph and Synthetic Unit Hydrograph for 2021 falls into the very strong correlation category. So that the Ct value of 0.78 and Cp of 1.1 is considered optimal.

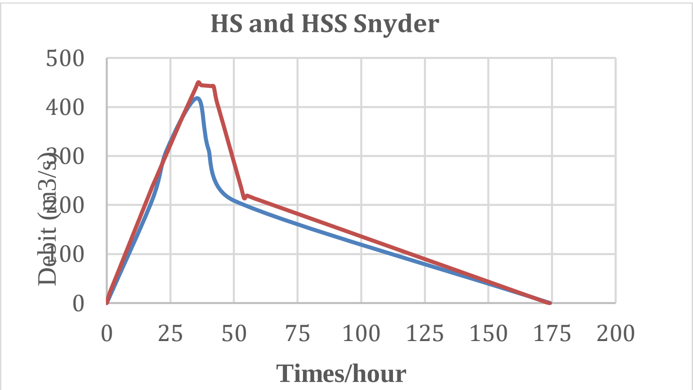

Figure 5. Snyder 205 HS and HSS Graphs

Year 2021

$$R = \frac{3283047511,0246}{\sqrt{4312837386,4725 \; x \; 2694637781,6013}}$$

= 0,9510

From the R value obtained, the suitability of the Snyder Unit Hydrograph and Synthetic Unit Hydrograph for 2015 falls into the category of very strong correlation. So that the Ct value of 1.65 and Cp of 1.4 is considered optimal and can be recognized.

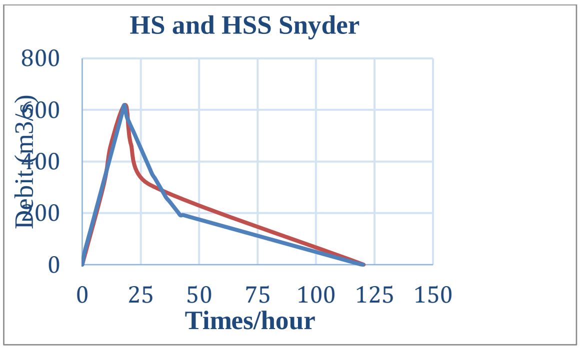

Figure 6. Snyder 205 HS and HSS Graphs

CONCLUSION

From the research results regarding the peak discharge on the synthetic snyder unit hydrograph due to changes in land use are 1). changes in land use in 2015 and 2021 experienced an increase in the flow coefficient. The flow coefficient value in 2015 was 0.321 and in 2021 it was 0.525, 2). the results of the peak discharge analysis with Snyder's HSS produced a peak discharge in 2015 of 417.882 m3/s while in 2021 the resulting peak discharge was 619.52 m3/s, 3). the Ct parameter value used in 2015 was 1.65 and in 2021 it was 0.78. Meanwhile, the Cp parameter in 2015 was 1.4 and in 2021 it was 1.1.

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