Analysis of Surface Flow Rate (Runoff) on Land Use Case Study in Loa Bakung Sub-District

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Received:- 01 January 2023/ Revised:- 07 January 2023/ Accepted:- 16 January 2023/ Published: 31-01-2023

Abstract— *This study aimed to analyze the runoff rate on land use in the Loa Bakung Village. The results of this study are expected to be the basis for flood management in the region. The research was carried out from February - April 2021 at the Water and Soil Conservation Laboratory, Faculty of Agriculture, Mulawarman University. The object of this research is the land use of the Loa Bakung sub-district. The stages of conducting research are as follows: (1) preparation, (2) field observations, (3) data collection, (4) data processing, (5) interpretation, and (6) reporting. The data collected is in the form of; (1) an Administrative boundary map of the Loa Bakung sub-district, (2 Topographical maps, (3) Soil type maps, (4) Loa Bakung sub-watershed maps, and (5) Maximum rainfall data for the last ten years (2011-2020). This is done by calculating the surface flow rate using the rational method. The results showed that: (1) The results of the GIS analysis showed that there were five types of land use in Loa Bakung Village, namely shrubs, settlements, roads, mining, open land, and dry mixed agriculture. The use of shrubland has the largest area of 481.34 hectares, and the smallest is land without vegetation, namely 27.18 hectares; (2) The highest runoff coefficient (C) is in the use of shrubland, namely 0.13463. While the value of C or the smallest runoff coefficient is on the use of open land with a C value of 0.00493; and (3) The maximum runoff rate (Q) in the land use of Kelurahan Loa Bakung occurs in the 100-year return period (Q100) with a value of 157.4292 m3/sec and the lowest Q value appears in the five year return period (Q5) with a deal 86.1099 m3/sec*.

Keywords— ***Runoff, Land Use.***

I. INTRODUCTION

Land use (land use) is an arrangement according to existing natural conditions. Its utilization requires interpretation, provision, and designation in a planned manner for use for the welfare of society.

Changes in the use of vegetation land to non-vegetative land are increasing in number in line with the increase in population, and the land is used for residential, office, industrial, and economic needs as well as other supporting facilities, which also have an impact both on the quantity of activity and the quality of the environment.

The transition of the function of an area that can absorb water into a watertight area will cause a hydrological imbalance and adversely affect the area. An area's changes will impact the time and volume of surface runoff. In densely vegetated land, rainwater that falls will be retained on the ground, cover plants and seep into the soil through the vegetation so that surface runoff is small. In open land (without vegetation), most of the rainwater that falls will become surface runoff towards the river, so the river flow increases very quickly. An increase in surface runoff volume will cause flooding problems in the downstream watershed (Laoh, 2002).

Surface runoff is rainwater that flows over the surface of the ground. The amount of water that becomes this flow depends on the amount of rainwater per unit of time (intensity), the state of the ground cover, topography (especially the slope of the soil slope), the type of soil, and whether or not rain occurs Rahim, 2003).

The amount and speed of surface runoff depend on the catchment area and, most importantly, on the runoff coefficient and maximum rainfall intensity. Surface runoff with a high amount and speed often causes the displacement or transportation of soil masses on a large scale, causing flooding.

The amount of water that becomes a stream causes the water to overflow, so the water stagnates in the area. Areas that are inundated or flooded will disrupt human activities. Human negligence in preserving nature and inaccurate land use has resulted in floods occurring in various locations, including the Loa Bakung area.

Loa Bakung Village is located in Sungai Kunjang District, Samarinda, whose area is dominated by the Kambisol-associated soil type. Rather steep topography and open land conditions. Land use in the Loa Bakung area consists of shrubs, settlements, mining, mixed dryland agriculture, and available land with a dominant Cambisol-associated soil type and rather steep topography.

This study aimed to analyze the runoff rate in the land use of the Loa Bakung Village. The results of this study are expected to provide information regarding the runoff rate in the land use of the Loa Bakung Village so that it can become the basis for handling the flood.

II. RESEARCH METHODS

2.1 Time and Place

The research was carried out from February - April 2021 at the Water and Soil Conservation Laboratory, Faculty of Agriculture, Mulawarman University. The object of this research is the land use of the Loa Bakung sub-district.

2.2 Materials and Tools

The materials used are administrative boundary maps of the Loa Bakung sub-district, land use maps of the Loa Bakung Sub-district, topographical maps of the Loa Bakung Sub-district, soil type maps of Loa Bakung Sub-district, sub-watershed maps in Loa Bakung Sub-district and maximum daily rainfall data for the last ten years (2011- 2020) Loa Bakung. The tools used in this study were laptops and ArcGIS 10.4.

2.3 Research Design

This research is a quantitative analysis research that aims to analyze the runoff rate on different land uses in the Loa Bakung area.

2.4 Research Procedures

The stages of conducting research are as follows: (1) preparation, (2) field observations, (3) data collection, (4) data processing, (5) interpretation, and (6) reporting.

2.5 Data Collection

Data collection was obtained from several related agencies, consisting of:

1) Administrative boundary map of the Loa Bakung sub-district obtained from the Cartography and Geographic Information System Laboratory, Faculty of Agriculture, Mulawarman University.
2) Topographic map of the Loa Bakung sub-district obtained from the Cartography and Geographic Information System Laboratory, Faculty of Agriculture, Mulawarman University.
3) Map of Soil Types for the Loa Bakung sub-district obtained from the Cartography and Geographic Information System Laboratory, Faculty of Agriculture, Mulawarman University.
4) The map of the Loa Bakung sub-watershed was obtained from the Cartography and Geographic Information System Laboratory, Faculty of Agriculture, Mulawarman University.
5) Maximum rainfall data for the last ten years (2011-2020) for the Loa Bakung subdistrict obtained from BMKG Samarinda.

2.6 Data Processing

Data processing is done by calculating the surface flow rate using the rational method. The results obtained are presented in the form of a histogram graph anabld tabular form. The value of C is obtained through the surface runoff coefficient price table while considering land use, soil type, and topography of the study area. The average rain intensity value (I) is obtained by processing maximum rainfall data for Loa Bakung Village for the last ten years (2011-2020). In contrast, the value of A is obtained by processing administrative boundary data for the Loa Bakung Village to get the area of the catchment area through the ArcGIS application.

III. RESULTS AND DISCUSSION

3.1 Overview of the Region

Loa Bakung Sub-district is one of the sub-districts in Sungai Kunjang District, Samarinda City, with an area of 11.83 km2. Soil is dominantly associated with Iutrudepts and Hapludalfs, with predominantly sloping topography in residential areas (8% - 15%) and rather steep in other regions (15% - 25%).

Types of land use in Loa Bakung Village are presented in Table 1 and Figure 1 below:

TABLE 1
TYPES OF LAND USE IN LOA BAKUNG VILLAGE 2021

No	Type of Land Use	Area (Ha)	Percentage (%)
1	Thicket	**481,34**	**43,60**
2	Settlement	**430,81**	**39,06**
3	**Land Without Vegetation**	**27,20**	**2,46**
4	**Mining**	**115,34**	**10,45**
5	Mixed Dryland Agriculture	**48,03**	**4,35**

Source; Calculation Results (2021)

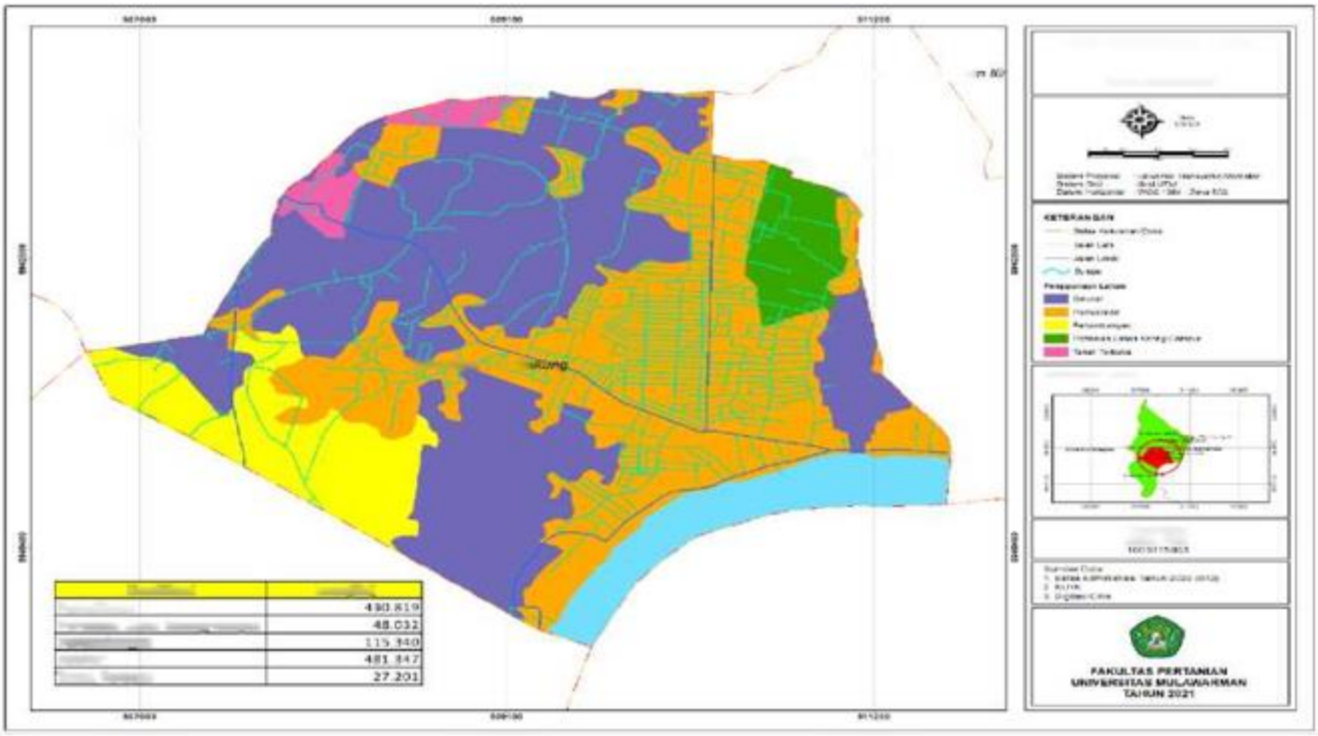

FIGURE 1: Land Use Map of Loa Bakung Village

3.2 Condition of Soil Type

Loa Bakung Village has four types of land, namely: (1) gleysol covering an area of 281.54 hectares, (2) endowments covering an area of 281.54 hectares, (3) cambisol covering an area of 527.85 hectares, (3) podzolic covering an area of 237.68 hectares. The soil type map is presented in Figure 2 below:

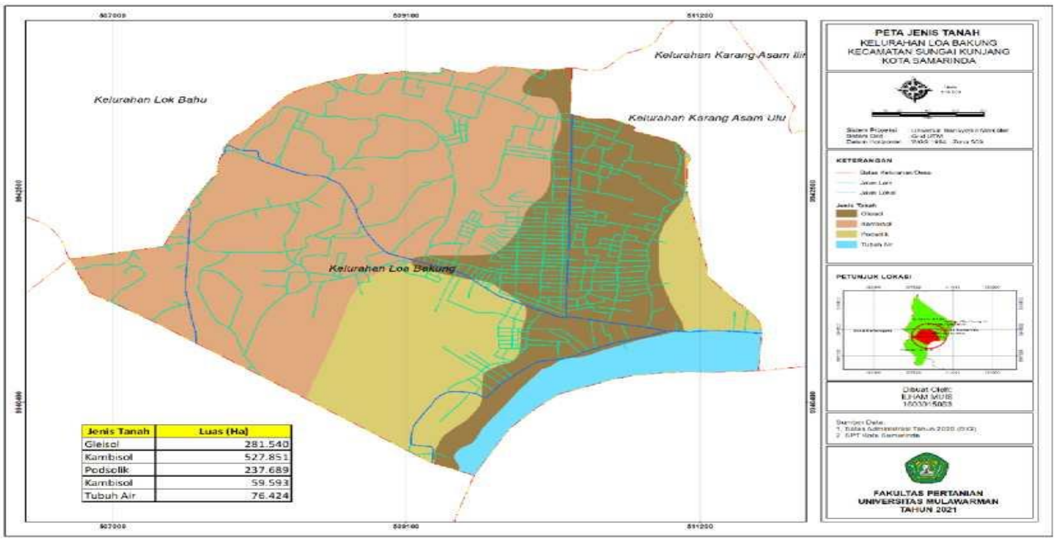

FIGURE 2. Map of Soil Types in Loa Bakung Village

3.3 Topography

Loa Bakung Village has topography with slope class in the study area generally dominated by type III or rather steep slopes (15% -25%) with an area of 553.72 hectares. Data on the distribution of the gradient of the slopes of the Loa Bakung Village are presented in Table 2 and Figure 3 below:

TABLE 2
LAND SLOPE CONDITIONS

No	Slope Class	Area (hectares)
1	Flat (0-8%)	548,72
2	Ramp (8%-15%)	237,40
3	Slightly Steep (15%-25%)	267,24
4	Steep (25%-45%)	127,62
5	Very Steep (>45%)	2,09

Source: Calculation Results (2021)

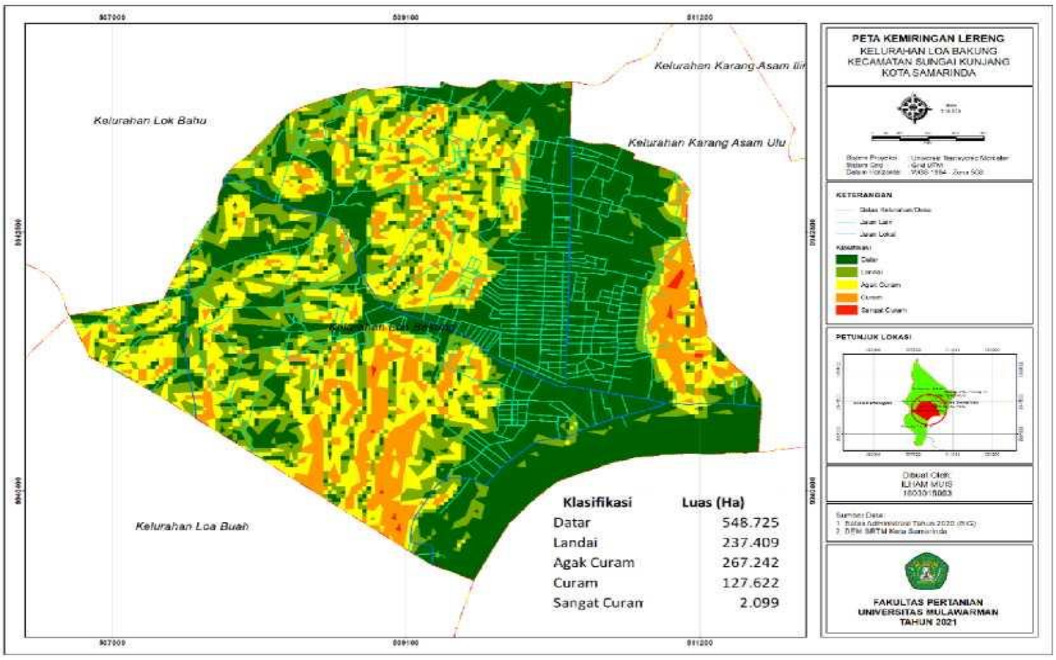

FIGURE 3: Slope Map of Loa Bakung Village

3.4 Rainfall

The maximum daily rainfall data for the Loa Bakung sub-district for 2011-2020 obtained from the BMKG Samarinda were processed to get the amount of rain intensity. The method used in calculating the average rainfall in the study area is the average algebraic method:

$$P = (Pl+P2+P3+..+Pn)/n \quad (1)$$

Where P1, P2, P3...., Pn is the rainfall recorded at the rain measuring post, and n is the number of rainfall measuring posts. The results of calculating the maximum daily rainfall data are presented in Table 3 below:

TABLE 3
MAXIMUM DAILY RAINFALL DATA PROCESSING

Year	Rainfall (mm)	$(Xi-X)^2$
2011	105,5	15,7609
2012	98,9	6,9169
2013	84,3	296,8729
2014	102,5	0,9409
2015	67,1	1185,425
2016	80	463,5409
2017	87	211,1209
2018	187	7305,121
2019	72	872,0209
2020	131	868,4809
Jumlah	1015,3	11226,2
Average (x)	101,53	1122,62
Standard Deviation	35,31792274	

Source: Calculation Results (2021)

After obtaining the maximum daily rainfall for 2011-2020 using the average algebraic method, it is necessary to carry out a frequency analysis. Frequency analysis aims to predict a certain amount of rainfall or discharge within a certain anniversary period. The frequency distribution in this study uses the Gumbel distribution.

$$R24 = X + [Sx/Sn]x[Yt - Yn] \quad (2)$$

Note: R24 = maximum daily rainfall for 24 hours (mm/24 hours); X = average rainfall (mm); Sx = standard deviation; Yn = reduced mean; Sn = reduced standard deviation; Yt = reduced variation as return period.

The results of calculating the Gumbel distribution are presented in Table 4

TABLE 4
CALCULATION RESULTS OF R24 GUMBEL

No	Repeat Period (Year)	R24 (mm)
1	5	138,897
2	10	166,803
3	25	202,072
4	50	228,234
5	100	254,202

Source: Calculation Results (2021)

Based on the data above, the planned rainfall intensity with an annual return period is calculated using the Mononobe formula. The statement of Loebis (1992) and Suroso (2006) that rain intensity (mm/hour) can be derived from empirical daily rainfall data using Mononobe.

$$I = [R24 : 24] \times [24 : t]^{2/3} \quad (3)$$

Description: I = rain intensity (mm/hour); R24 = maximum daily rainfall (for 24 hours) (mm); and t = duration of rain (hours)

The results of the analysis of rain intensity based on a specific return period can be seen in Table 5 below.

TABLE 5
MONONOBE RAINFALL INTENSITY VALUES

Duration (minute)	Mononobe Rainfall Intensity (mm)				
	5 years	10 years	25 years	50 years	100 years
5	243,0416	291,8715	353,5851	399,3633	444,802
10	153,8158	184,7191	223,7763	252,7484	281,5056
15	117,7011	141,3486	171,2355	193,4052	215,4104
30	74,49049	89,45649	108,3713	122,4019	136,3286
45	57,00076	68,45286	82,9266	93,663	104,3198
60	47,14342	56,61507	68,58582	77,46553	86,2794
120	29,83604	35,83045	43,40648	49,02626	86,2794
180	22,83604	27,41776	33,215	37,5131	41,78372
360	9,144531	17,35211	21,02105	23,74262	26,44401
720	5,787375	10,98177	13,30377	15,02619	16,73584

Source: Calculation Results (2021)

Based on the calculation results, the planned rain intensity shows an increased value compared to previous years. The highest rainfall intensity value occurs in the 100-year return period with rainfall of 86.2794 (mm/hour), and the minor rainfall intensity occurs in the five-year return period with the rain of 47.1434 (mm/hour).

3.5 Surface Flow Coefficient (C)

Loa Bakung Village has five types of land use from the results of ArcGIS data processing and Google map satellite imagery in the form of shrubs, settlements, mixed dry land agriculture, mining, and open land. Furthermore, with the help of the ArcGIS overlay from land use data, soil type, and topography, the runoff coefficient (C) can be input by adjusting it in Tables 1, 2, and 3.

Meanwhile, if the area consists of various land uses with different runoff coefficients, then C is modified. The modified value of C is presented in Table 6.

TABLE 6
RUNOFF COEFFICIENT VALUE (C)

No	Land Use	Area (A)	C-Value	C x A	Ci.Ai/Ai
1	Thicket	481,3419441	0,31	148,37	0,13463
2	Mixed Dryland Agriculture	48,0324791	0,65	31,29	0,02839
3	Settlement	430,8016428	0,75	323,10	0,29319
4	**Land Without Vegetation**	27,18482407	0,20	5,44	0,00493
5	Mining	114,6443601	0,90	103,18	0,09363
6	Total	1102,00525	2,80	611,38	0,55478

Source: Calculation Results (2021)

Based on the analysis results, the highest surface runoff coefficient (C) is found in shrub land use because shrubs have the largest area of other land uses. The surface runoff coefficient (C) for scrub land use is 0.13463, which means that the soil absorbs rainwater that falls to the surface, and some of it becomes surface runoff. While the smallest surface runoff coefficient is found in open land use with a C value of 0.00493. The value of the runoff coefficient depends on land use and area; the larger the size, the greater the runoff coefficient (C) (Delmar, 2006).

3.6 The Rational Method

The Loa Bakung Subdistrict's catchment area was obtained by processing administrative boundary data for the Loa Bakung Subdistrict, which has a water catchment area of 11.83 Km2. After all the data needed to analyze runoff rates, such as land use data, rainfall data, and others. Then the next step is to calculate the runoff rate to obtain the runoff value for the return period using the modified rational method (Suripin, 2004), with the formula:

$$QT = 0.278 \text{ x } C \text{ x } IT \text{ x } A \tag{4}$$

Description: QT = maximum surface runoff with a return period of T years (m3/second); C = Surface runoff coefficient value (dimensionally); IT = Rainfall intensity with return period T (years) (mm/hour; and A = catchment area (Km2).

Based on the calculation results, the maximum runoff value is obtained in the return period as presented in Table 7 below:

TABLE 7.
CALCULATION RESULTS OF THE MAXIMUM RUNOFF VALUE IN THE RETURN PERIOD

Land Use Lahan	Wide Catchment Area (Km2)	Coefficient Flow (C) (C)	Qmaks (m^3/second)				
			T (5)	T (10)	T (25)	T (50)	T (100)
Thicket	11,8309	0,1346	20,8750	25,0691	30,36976	34,3016	38,20447
Mixed Dryland Agriculture	11,8309	0,2931	45,4606	54,5941	66,1376	74,7003	83,19964
Settlement	11,8309	0,2931	4,40201	5,28643	6,4042	7,2333	8,056338
Land Without Vegetation	11,8309	0,0049	14,5178	17,4346	21,1210	23,8555	26,569774
Mining	11,8309	0,0936	0,7644	0,91800	1,1121	1,25608	1,399005
Total	0,5547	86,1099	103,3023	125,1447	141,347	157,4292	

Source: Calculation Results (2021

The surface runoff discharge value calculated using the rational method to obtain the maximum surface flow rate (Qt) for the return period of 5, 10, 25, 50, and 100 years can be seen in Table 7. The Q value for the 5-year return period has a value of 86,1099 m3/sec, the Q value for the 10-year return period is 103.3023 m3/sec, and the Q value for the 100-year return period is 157.4292 m3/sec. This shows that the intensity of rainfall influences surface runoff discharge with a specific return period. The higher the rainfall intensity, the higher the Q value or surface runoff discharge. The calculation of the maximum surface runoff discharge results also shows that it is heavily influenced by rain intensity and vegetation or watertight areas along with the site.

Control of surface runoff as a result of development needs to be done with development planning that pays more attention to the aspects and conditions of an area's hydrology. Hydrological functions such as storage, infiltration, and groundwater filling or the volume and frequency of surface runoff discharge can be maintained by handling rainwater flows on a small scale that is thorough and integrated both in terms of retention and detention areas. A Map of the distribution of Runoff Coefficients for Loa Bakung Village is presented in Figure 4.

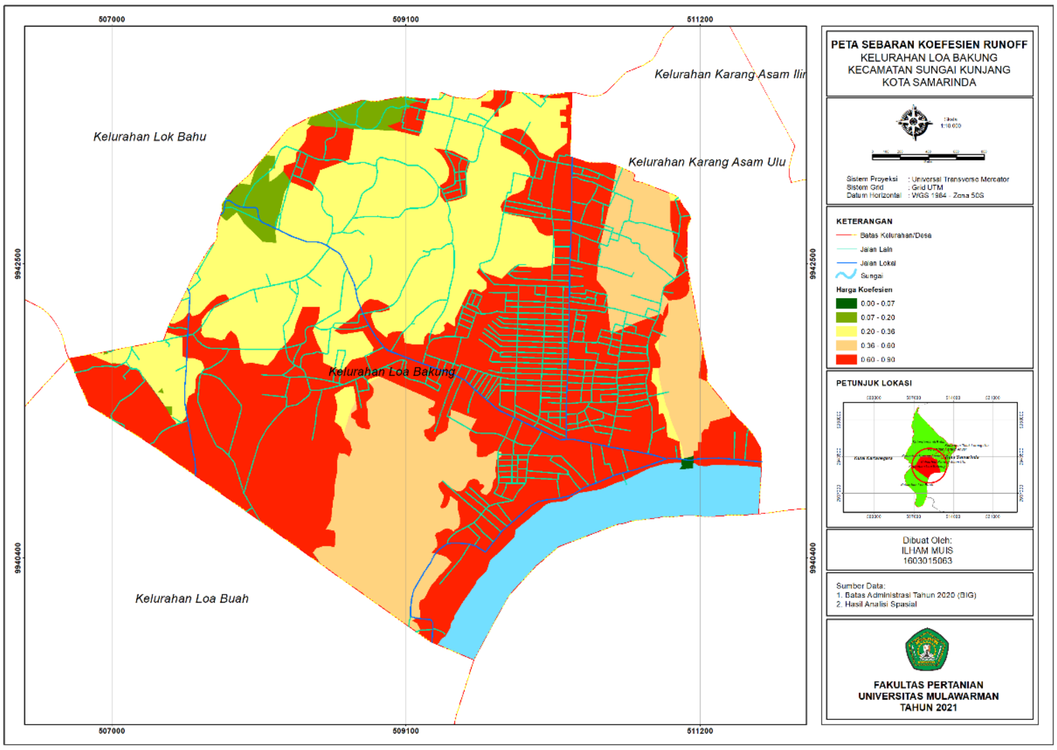

FIGURE 4: Runoff Coefficient Distribution Map of Loa Bakung Village

IV. CONCLUSIONS AND SUGGESTIONS

4.1 Conclusion

Based on the results of research and discussion, it can be concluded as follows.

1) The results of the GIS analysis show that there are five types of land use in Loa Bakung Village: shrubs, settlements, roads, mining, open land, and dry mixed agriculture. The land use of shrubs has the largest area of 481.34 hectares and the smallest on land without vegetation, with an area of 27.18 hectares.

2) The highest runoff coefficient (C) is in shrubland, 0.13463. At the same time, the value of C, or the smallest runoff coefficient, is on the use of open land with a C value of 0.00493.

3) The highest surface runoff rate (Q) in the land use of Loa Bakung Village occurs in the 100-year return period (Q100) with a value of 157.4292 m3/sec, and the lowest Q value appears in the 5-year return period (Q5) with a value of 86, 1099 m3/sec.

4.2 Suggestion

Based on this research, suggestions can be put forward, namely as follows:

1) Comparing land use in previous years to the surface runoff rate value is necessary.

2) It is necessary to carry out further research to reduce the value of C or runoff coefficient, and it is necessary to carry out approaches in controlling surface runoff rates such as bioretention, infiltration wells, and others.

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