Flood debit analysis based on land use: A case of Batang Arau Watershed, Padang

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Flood debit analysis based on land use: A case of Batang Arau Watershed, Padang

L Utama[1], Amrizal[2], I Berd[2], and Zuherna[3]
[1]Department of Civil Engineering, Universitas Andalas, Padang, Indonesia
[2]Department of Agriculture, Universitas Andalas, Padang, Indonesia
[3]Department of Civil Engineering, Universitas Bung Hatta, Padang, Indonesia

Email: lusi_utamaindo115@yahoo.co.id

Abstract. A flood may occur for both climatology and human action factors. The climatology factors can be in the form of land degradation, land-use changes, and population increase. The land-use changes can identify when there is a conversion of recharge area into a built area. The conversion may happen because there is potency for a flood area to transform into a place of cities development and settlements. When the population increases, space needed also enlarges. Consequently, the surface flow increase and can cause a flood. Padang - Indonesia, has high rainfall intensity around 3,329 to 4,296 mm/year, which results in a frequent flood. The worst flood occurred on 26 September 2018 and 2 November 2018, which washed away a bridge and caused a 3-meter high puddle. In analyzing those phenomena, this study applied a descriptive qualitative method. The image used in the map was analyzed with Argis X quantum program to get a flood-prone map. The rainfall was calculated by using methods of Thiesen, Gumbel, and Log Pearson III, while the debt calculated using the rational method. The difference debit between these was 42,030m^3/second. The results, the amount of land used to discharge was higher than due to the rainfall.

1. Introduction

In Indonesia, a flood is one of the problems that often occur in a watershed (known as *daerah aliran sungai* or DAS). The flood defines as an overflowing of a large amount of water beyond its normal confines that creates damages. Generally, a flood occurs for natural or human action factors [1]. Some of these factors include land degradation, land-use changes, and population increase. The land-use change can be identified when there is a conversion of recharge area into a built area. The conversion may happen because there is potency for a flood area to transform into an area of cities development, industrial, economics, and settlements. Besides, when the population increases, space needed also enlarges. Consequently, the surface flow increase and causes a flood.

DAS in Batang Arau refers to Batang Arau River, which its river flow comes from several rivers, named Lubuk Paraku, Padang Idas, and Lubuk Sarik. In the headwaters part of DAS of Batang Arau, the water capacity area is around 174.30 hectares (174.30 km^2), covering conservation area, protected forest, and private lands [2]. Meanwhile, states that there are flood, droughts, lack of water, and land (as the effect of population increase) found in Batang Arau DAS every month [3]. Therefore, the river flow of the Batang Arau River needs to fix due to siltation. It also needs to have vegetation to keep more water under the soil. Lastly, it needs to be analyzed the use of the land to prevent the flood. Batang Arau DAS located in the height of height 1,915 m above sea level, the area of water catch capacity is 174.30 km², and the river length is 216.27 km [2]. Based on the previous study, it also found that the main factors of the flood are the sharp topography and the change of land use [4].

The availability of water in Batang Arau DAS cannot meet the need of the DAS so that it must be supplied from other DAS. For example, to fulfill the need of water for PDAM in the area of Batang Arau DAS, half of it is supplied from PDAM in the area of Batang Kuranji DAS and Batang Air Dingin DAS. Besides, the lack of this water supply causes conflict with farmers since they need water for their field and with other society who need water for their work. On the other hand, the water debit is excess in certain months. As the effect of this inefficient management, the excess water cannot be accommodated by the river, and the flood occurs. The water excess and shortage caused by a morphometric factor, which is due to population growth, more settlement is needed, and it affects the change of the use of land and the type of land cover [5]. Based on observations, flashes flood incident in Padang on 24 July 2013 caused by forest conversion to a population field as well as illegal logging. Besides the high rainfall factor, the steep slope conditions with an average slope of 45-55% and small cracks in the soil, so that the slope is filled with water and saturated causes the thick soil solum to be unstable, were the main suspect. So far, from the results of previous studies, the amount of discharge was determined based on rainfall, rainfall intensity, and extent of rain catchment. This research determined the amount of discharge based on land use.

2. Methods

The problem identified by conducting surveys in the form of interviews to officials and residents, observing the area, getting information from mass media, related government departments (to obtain the data of rain and map of DAS), and getting information from Provincial Statistical Bureau. Later, reviewing the literature related to the debit of the land use. In this phase, the data needed were rainfall from 2005-2017, map (image). The rainfall calculated with the Thiessen method and the debit measured by using ration formula.

3. Result and discussion

The maps of land use and Batang Arau DAS presented in figure 1 and figure 2.

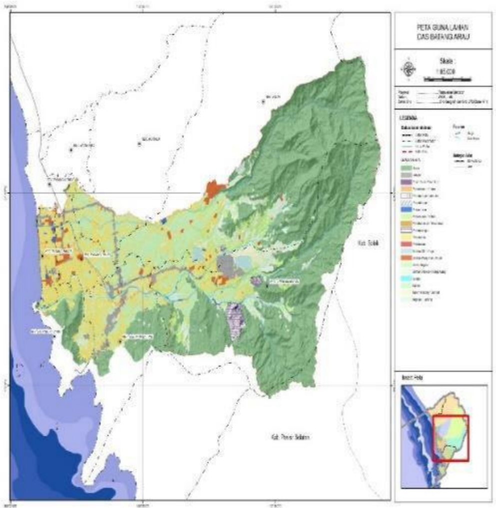

Figure 1. Map of land use

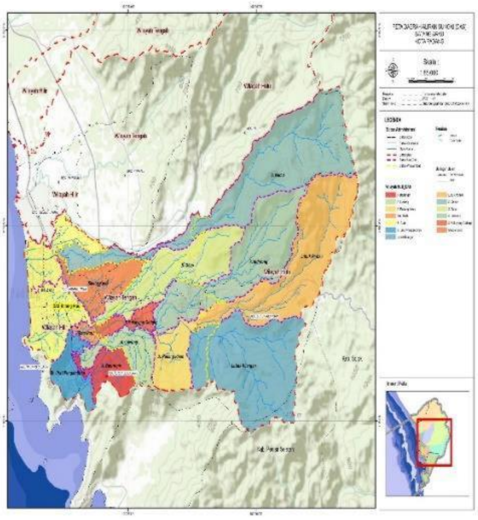

Figure 2. Map of Batang Arau DAS

The calculation of the debit amount occurred as the effect of land use and land types in the Batang Arau DAS consisting of 13 sub-DAS are presented in table 1.

Table 1. Discharge upstream part of Batang Arau DAS

Lubuk Kilangan				
No	**Vegetation**	**Area (Ha)**	**Coefficient (C)**	**Discharge (m^3/second)**
1	Forest	2,561.22	0.20	14.661
2	Industry	6.93	0.10	0.020
3	Plantation	63.24	0.15	0.271
4	Mining	186.76	0.60	3.207
5	Housing	48.13	0.70	0.964
6	Sport facilities	0.55	0.50	0.008
7	Public service facilities	88.69	0.60	1.523
8	Rice field irrigation	139.59	0.30	1.199
9	Shrubbery	22.42	0.70	0.449
10	River	15.56	0.20	0.089
11	Wasteland	28.25	0.30	0.243
	Total	3,161.34		22.634
	Intensity	10.295 mm/hour		

The calculation of upstream areas at Lubuk Pakaku, Air Beringin, and Gadut Hulu is presented in table 2.

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Table 2. Calculation discharge for upstream areas

Upstream Areas	Total Discharge (m^3/second)	Intensity (mm/hour)
Lubuk Paraku	2,881.84	7.603
Air Beringin	565.12	13.822
Gadut Hulu	3,104.70	11.572

The calculation of middle areas at Sekayang Gadang, Gadut Tengah, Luwung, Indarung Hulu, Batu Putih, Padang Idans, and Batang Jirak/Pengambiran is presented in table 3.

Table 3. Calculation discharge for middle areas

Middle Areas	Total Discharge (m^3/second)	Intensity (mm/hour)
Sekayang Gadang	11.991	22.774
Gadut Tengah	13.749	11.572
Luwung	12.636	14.674
Indarung Hulu	26.002	12.171
Batu Putih	4.282	19.196
Padang Idas	6.777	10.316
Batang Jirak / Pengambiran	15.826	22.487

The calculation of downstream areas at Arau, Sikabau Kacik, and Gayo River presented in table 4.

Table 4. Calculation discharge for downstream areas

Upstream Areas	Total Discharge (m^3/second)	Intensity (mm/hour)
Arau	17.945	5.688
Sikabau Kacik	27.180	17.198
Gayo River	25.067	10.702

The summary of all discharges is presented in table 5.

Table 5. Resume of all discharge

No	Sub-DAS	Discharge (m^3/second)
1	Batu Putih	4.282
2	Bt. Arau	17.945
3	Bt. Jirak/Pengambiran	15.826
4	Padang Idas	6.777
5	Lubuk Kilangan	22.634
6	Lubuk Paraku	13.633
7	Gadut Hulu + Tengah	33.983
8	Indarung Hulu	26.002
9	Air Baringin	9.144
10	Luwung	12.636
11	S. Gayo	25.067
12	Sikabau Kacik	27.180
13	Sekayang Gadang	11.991
	Total	**230.100**

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4. Conclusion

There was a very significant debit deviation occurs when the debit calculation was measured based on rainfall intensity and ignoring the land use in each part of sub-DAS. Therefore, it was necessary to deliberate the land type and used that influence the debit. The debit for each sub-DAS based on the land use and type was 230.100 m^3/second, while the debit based on rainfall intensity was 272.13 m^3/second. The difference between these is 42.030 m^3/second. There were four sub-watersheds, namely Gadut, Indarung, Sikabu Kacik, and Gayo, which produced the most significant discharge. For this reason, it was necessary to take into account the extensive use and type of green land to reduce flooding. Due to higher land use debits, it is necessary to change the land use from the land to build into green land.

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