Land Use Model To Reduce Flood at Arau Padang Watershed

Lusi Utama, Amrizal Saidi, Isril Berd, Zuherna Mizwar

Abstract— Flooding is one of the many environmental problems that occur in some watersheds (DAS) in Indonesia. Based on Lusi Utama's research (2019), is the large level of debit in SUB-watersheds Arau-the city of Padang, which is calculated based on land use that causes flooding. For this reason, it is necessary to reduce the flooding that occurred in the Arau Watershed by managing the area and land use that is ideal. Some of the results of research on floods occur as a result of human behavior, namely by changing the function of infiltration land into developed land. There was a high increase in flooding in Padang City from 2008 - 2018. This shows the condition of the Watershed (DAS) is bad, causing floods and sedimentation. By using a map of the earth and analyzed with the Argis X, obtained extensive maps and land use. Thiessen and Gumbel methods for calculating planned rainfall is used. The amount of discharge due to land use is analyzed by Rational methods. Analysis of discharge that occur due to rainfall will be compared with discharge obtained from land use. If the discharge due to rainfall is greater than the discharge due to land use, it is necessary to adjust the area and type of land use that can reduce flooding. The area and type of land use arrangement called the land use model is to reduce flood, the largest green land required is 50.21% in the Lubuk Paraku, and the smallest is 7.32% in the Sekayang.

Index Terms—Model, Land use, Discharge, Watershed, Rainfall.

1 INTRODUCTION

Run off in the Padang City Arau Watershed is an event caused by the inadequate cross-sectional capacity of the river to flow the existing discharge. Based on the research of Lusi Utama that the amount of discharge contained in the Arau sub-watershed based on land use is: The Batu Putih sub-watershed is 4.28m_3/second, Batang Arau is 17.95m_3/second, Jirak is 15.83m_3/second, Padang Idas is 6.78 m_3/ second, Lubuk Kilangan is 22.63 m_3/second, Lubuk Paraku is 13.63 m_3/second, Gadut is 13.98 m_3/ second, Indarung is 26.002 m_3/second, Aia Baringin is 9.14 m_3/second, Luwung is 12.64 m_3 /second, Gayo is 25.07 m_3/second, Sikabau Kacik is 27.18 m_3/second, and Sekayang Gadang is 11.99 m_3/second [1]–[3].

Run off is part of the rainwater that flows on the surface of the ground toward rivers, lakes, or oceans. With changes in land cover and loss of catchment areas, the chance of rainwater to be retained and seep into the ground will be smaller, resulting in increased flood discharge, which in turn will increase flooding [4]–[7]. That most urban areas that experience flooding, are areas that have flat topographic characteristics and low slope, and have physiography in the form of floodplains.

In general, the factors that cause flooding can be in the form of climatological factors, land subsidence, changes in land use and an increase in population [8]–[10]. Land use changes that often occur are the conversion of a catchment area into a built area. This cannot be avoided because most of the floodplain areas have the potential as a place / location for the development of cities, industries, economy, and settlements [11], [12]. An increase in the number of people who need space also triggers an increase in this change. All this will increase surface run off which can eventually cause flooding due to decreased drainage and infiltration capacity. In Indonesia there are estimated to be 1.96 million ha of flood area [13], [14]. The phenomenon of flooding is an indication of an error in the use of watershed land. Land use conditions often still do not pay attention to land conservation, especially its suitability for land use [15], [16]. Damage to the watershed can be seen from the reduced ability of land to absorb water when it rains, which results in disruption of the hydrological cycle [15], [17]. From studies [9], [18]–[21] that have been carried out based on the parameters of the causes of flooding in the watershed and in public spaces, that the cause of flooding that is often investigated is due to changes in land use. But how much land is used that causes flooding has not been done research. For this reason [33,40] [22], [23], it is necessary to determine the size and type of land that must be maintained to reduce flooding and sedimentation.

For the city of Padang, the SWP DAS (Watershed Management Area Unit) located in the capital of West Sumatra Province is the SWP Arau watershed, which consists of the Batang Arau watershed, Batang Kuranji watershed and Batang Air Dingin Watershed [24]–[26]. Throughout 2008 - 2018 these three watersheds showed high run off coefficient (flood). One of the efforts to tackle the spread of potential flood risks is to understand the characteristics of flood plain areas [27], [28]. The area of the floodplain can be evaluated based on land use. Furthermore, the extent of this flood plain can be overlapped by how much land use is built and the use of green land that can reduce flooding [29], [30].

2. RESEARCH METHOD

This problem [17] will be investigated by conducting surveys in the form of interviews with village officials and residents, directly observing existing conditions, obtaining information from the newspaper and television media, collecting rain data, obtaining situation maps and topographic maps and maps of the earth (picture) to obtain land area and land use existing [4], [31]. Conducting a literature review related to the function and use of land that can cause flooding. Rainfall data is used from measuring the daily rainfall height using a cylindrical shape with a height and diameter of 14 cm which is placed in all Arau Watershed, by observing from 1 March 2019 to 1 April 2019. Rainfall data will be analyzed into rainfall plans using the Thiessen formula. In the calculating discharge, Rational method is used [32], [33], To get a map of land use and land area, the Argis X quantum program is used. Determination of sediment concentration is by means of filtering and using the following formula [34]:

Cs = (b-a)/V

3.RESULTS AND DISCUSSION

A cylindrical rainfall gauge with a diameter and height of 14 cm is used. Measured rainfall for 30 days, and obtained average rainfall (mm). The amount of discharge is calculated according to average rainfall multiplied by land area and is calculated based on the length of rain. Determine the discharge from rainfall in each SUB-Watersheds:

Sub Watershed Area of Jirak = 323.3 ha. The average height of rainfall measured in the field is 1.89 cm. Volume = 323.3 x 1.89 = 611.04 ha. Length of rain 1 hour = 3600 seconds. The amount of Discharge = volume / duration of rain = 611.04 ha cm / 3600 seconds = 16.97 m3/second. Furthermore, to calculate the discharge due to rainfall in 12 sub-watershed is tabulated in table 1 as follows.

Table 1. Discharge for SUB Watershed Arau from rainfall

Sub Watershed	Average height of rainfall (cm)	Area (ha)	Volume (ha cm)	Duration of rain (second)	Discharge (m_3/second)
Batang Jirak	1.89	323.3	611.04	3600	16.97
Aia Baringin	0.96	565.12	542.52	3600	15.07
Lubuk Kilangan	0.87	3161.34	2750.37	7200	38.20
S.Gadut	1.76	741.97	1305.87	5400	24.18
S. Indarung	1.01	2566.5	2592.17	7200	36
S. Sekayang Gadang	3.15	338.1	1065.02	5400	19.72
A. Luwung	1.6	749.97	1124.96	5400	20.83
Batu Putih	0.96	132.44	127.14	3600	3.53
A. Padang Idas	1.05	819.68	860.66	7200	11.95
Batang Arau	0.93	1913.62	1779.67	7200	24.71
Sikabau Kacik	0.5	899.06	449.53	1800	24.97
S. Gayo	1.75	1810.16	3167.78	7200	44
Lubuk Paraku	0.5	2881.84	1440.92	7200	20.01

Table 2. Table for comparison of discharges due to land use and rainfall

SubWatershed	Discharge based on land use (m_3/second)	Discharge based on field rainfall (m_3/second)	Difference in discharge(m_3/second)
Batu Putih	4.28	3.53	0.75
Batang Arau	17.95	24.71	-6.76
Batang Jirak	15.83	16.97	-1.14
A. Padang Idas	6.78	11.95	-5.17
Lubuk Kilangan	22.63	38.2	-15.57
Lubuk Paraku	13.63	20.01	-6.38
S. Gadut	13.98	24.18	-10.20
S. Indarung	26.00	36	-10.00
Aia Baringin	9.14	15.07	-5.93
A. Luwung	12.64	20.83	-8.19
S. Gayo	25.07	44	-18.93

S. Sekayang Gadang	11.99	19.72	-7.73
Sikabau Kacik	27.18	24.97	2.21

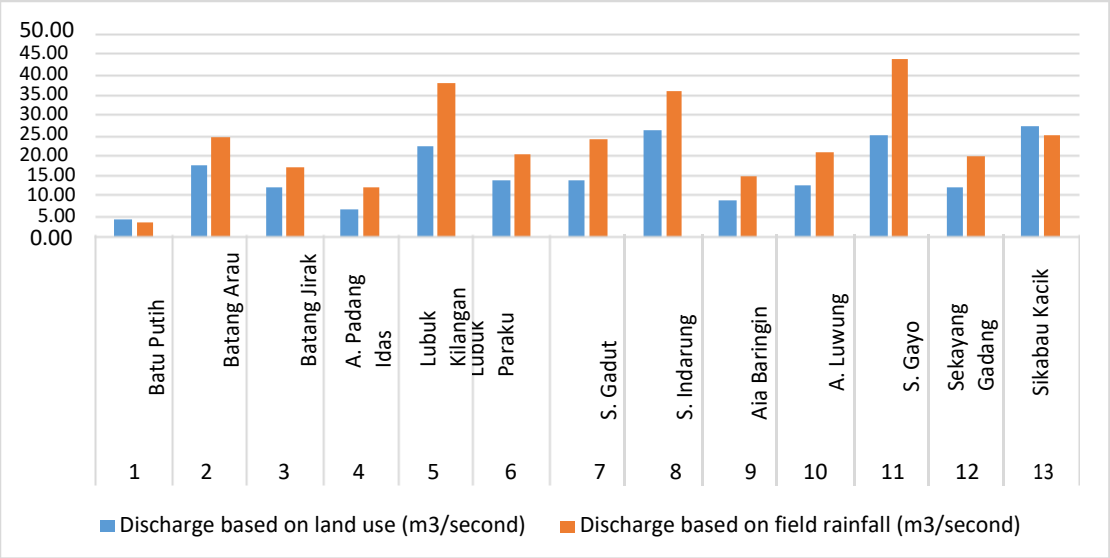

Figure 1. Comparison graph of land use discharge with rainfall

3.1 DETERMINING THE SEDIMENT DISCHARGE FROM THE ARAU SUB-WATERSHED

To determine the sediment debit, water samples were taken and tested in the Bung Hatta University laboratory in Padang. From the laboratory results obtained the value of Cs (sediment concentration) using the formula Cs = (b-a) /, where a = filter paper weight (grams), b = weight of filter paper and sediment that has been in oven, V = volume of water (ml).

Determination of the amount of sediment debit Qs = Cs.Q (Q = debit due to rainfall) (table 3)

SubWatershed	Os (gram/second)
Lubuk Kilangan	3820
Aia Baringin	4521
S. Gadut	8463
S. Indarung	5400
S. Sekayang Gadang	2958
A. Luwung	4166
Batu Putih	953.1
A. Padang Idas	1195
Batang Jirak	8145.6
Batang Arau	8154.3
Sikabau Kacik	6741.9
S. Gayo	6160
Lubuk Paraku	2201.1

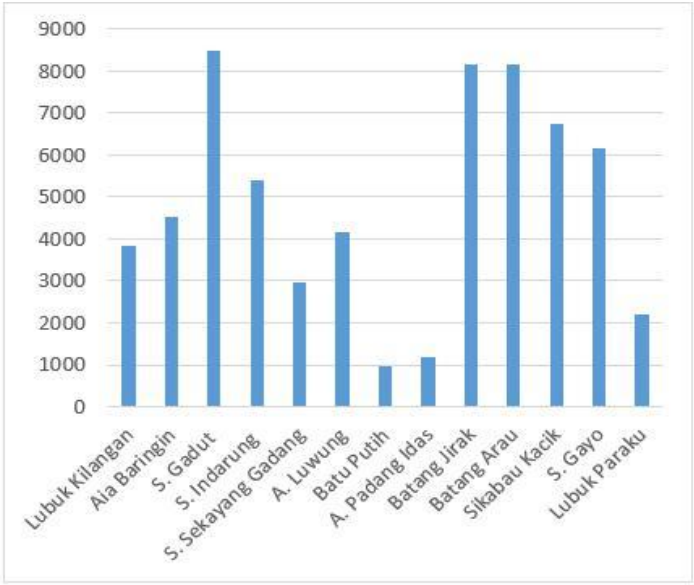

Figure 2. Graph of sediment discharge values in the Arau SUB watershed

3.2 DETERMINE THE MODEL OF LAND USE TO REDUCE FLOODING

To determine the land use model, land types and land area will be planned that can reduce flooding in each sub-watershed

Intensity (mm / hour)	10.32		

Table 4. Land Use Discharge (Sub Watershed : Padang Idas)

Vegetation	Area(Ha)	Coeffisient (C)	Discharge (m_3/second)
Forest	479.93	0.2	2.75
Sand Dunes	2.62	0.1	0.01
Office space	1.36	0.5	0.02
Plantation	93.95	0.15	0.40
Housing	51.87	0.7	1.02
Public Service Facilities	8.07	0.5	0.12
Irrigated fields	84.74	0.6	1.46
Shrubs	65.31	0.3	0.56
River	12.52	0.7	0.25
Empty land	0.33	0.2	0.00
Field	18.98	0.3	0.16
Total	819.68		6.78

In order to flood can be reduced; land use in SUB-Watershed, Padang Idas is as follows:

Land area for green land use is = 103.95 / 819.68 = 12.68%, housing area is = 120.87 / 819.68 = 14.75% and the minimum

Table 5. Discharge after changes in land type and area that can reduce flooding (Sub Watershed : Padang Idas)

Vegetation	Area (Ha)	Coefficient (C)	Discharge (m_3/second)
Forest	400.93	0.2	2.30
Sand Dunes	2.62	0.1	0.01
Office space	1.36	0.5	0.02
Plantation	103.95	0.15	0.45
Housing	120.87	0.7	2.42
Public Service Facilities	8.07	0.5	0.12
Irrigated fields	84.74	0.6	1.46
Shrubs	65.31	0.3	0.56
River	12.52	0.7	0.25
Empty land	0.33	0.2	0.00
Field	18.98	0.3	0.16
Total	819.68		6.78
Intensity (mm / hour)	10.32		

Forest area is = 400.93 / 819.68 = 48.91%. For 12 sub-watershed is tabulated in table 6.

Table 6. Land Use Models to reduce flood discharge in the Arau

SubWatershed	% Green Land	% Housing	% Forest	% irrigated fields
A. Baringin	14.53	25.88	35.26	0
A. Luwung	28.37	28.13	13.8	0
A. Padang Idas	12.68	14.75	48.91	0
Bt. Arau	34.94	27.55	0	0
Lubuk Kilangan	9.91	1.52	73.11	0
Lubuk Paraku	50.21	4.16	36.89	0
S. Gadut	32.69	32.87	0	19.37
S. Gayo	16.46	18.08	0	33.37
S. Indarung	19.34	12.31	0	0
S.Sekayang Gadang	7.32	42.29	0	8.92
Jirak	43.76	24.44	0	0

4. CONCLUSSION

The largest sediment occurs in the watershed of:Arau, Jirak, Gadut, Sikabau Kacik, Gayo, Indarung, A.

Baringin, Lubuk Kilangan, Lubuk Paraku, Luwung, Sekayang Gadang, Padang Idas, Batu Putih. The largest green land is needed in the SUB-watershed of: Lubuk Paraku, Jirak, Arau, Gadut, Luwung, Indarung, Gayo, Baringin, Padang Idas, Lubuk Kilangan and Sekayang Gadang. The biggest use of green land in the SUB Watershed is Lubuk Paraku, and the smallest in the Watershed Sekayang Gadang. For SUB-watershed Padang Idas, Lubuk Kilangan, A, Baringin, and Luwung, and Lubuk Paraku, the forest must be maintained. Sub-watersheds that do not have forests are expected to maintain the use of irrigated, namely SUB-watersheds Gadut, Gayo and Sekayang Gadang. It appears that the need for green land is directly proportional to the occurrence of sedimen

References

[1] L. Utama, ―Study Charge the Floods Evaluated From Morphometry and Mitigasi Arau Padang City,‖ *Int. J. Sci. Tech. Res. Eng. www.ijstre.com*, vol. 2, no. 11, pp. 1–8, 2017.

[2] U. Lusi, A. Saidi, I. Berd, and Z. Mizwar, ―Mitigation Disaster at Drainage Basin of Air Dingin Padang City,‖ 2019, doi: 10.2991/icoma-18.2019.83.

[3] L. Utama, Amrizal, I. Berd, and Zuherna, ―Flood debit analysis based on land use: A case of Batang Arau Watershed, Padang,‖ *IOP Conf. Ser. Earth Environ. Sci.*, vol. 343, no. 1, 2019, doi: 10.1088/1755-1315/343/1/012003.

[4] C. Asdak, *Hidrologi dan Pengelolaan Daerah Aliran Sungai*. UGM Press, 2014.

[5] M. C. Acreman and C. D. Sinclair, ―Classification of drainage basins according to their physical characteristics; an application for flood frequency analysis in Scotland,‖ *J. Hydrol.*, vol. 84, no. 3, pp. 365–380, 1986, doi: https://doi.org/10.1016/0022-1694(86)90134-4.

[6] Q. Yao, J. Xie, L. Guo, X. Zhang, and R. Liu, ―Analysis and Evaluation of Flash Flood Disasters: A Case of Lingbao County of Henan Province in China,‖ *Procedia Eng.*, vol. 154, pp. 835–843, 2016, doi: 10.1016/j.proeng.2016.07.444.

[7] Paimin, ―Teknik Mitigasi Banjir dan Tanah Longsor, Balai Penelitian Teknologi Kehutanan Pengelolaan DAS Surakarta,‖ 2009.

[8] K. N. Brooks, S. P. (USA). F. for S. D. P. eng Minnesota Univ., H. M. Gregersen, A. L. Lundgren, R. M. Quinn, and D. W. Rose, ―Watershed management project planning, monitoring, and evaluation: a manual for the ASEAN region.‖ St. Paul, MN (USA) University of Minnesota, College of Natural Resources, 1989.

[9] B. Hidayat, ―Memahami Bencana Banjir di Kota Padang dengan Content Analysis Artikel Berita (Understanding Flood in Padang City with...,‖ *Researchgate*, no. August 2014, 2014.

[10] H. Pawitan, ―PERUBAHAN PENGGUNAAN LAHAN DAN PENGARUHNYA TERHADAP HIDROLOGI DAERAH ALIRAN SUNGAI Land Use Changes and Their Impacts on Watershed Hydrology,‖ 2020.

[11] F. Halim, ―Pengaruh Hubungan Tata Guna Lahan Dengan Debit Banjir Pada Daerah Aliran Sungai Malalayang,‖ *J. Ilm. Media Eng.*, vol. 4, no. 1, pp. 45–54, 2014.

[12] S. Rahayu, I. N. Piarsa, and P. W. Buana, ―Sistem Informasi Geografis Pemetaan Daerah Aliran Sungai Berbasis Web,‖ *Lontar Komput. J. Ilm. Teknol. Inf.*, vol. 7, no. 2, p. 71, 2016, doi: 10.24843/lkjiti.2016.v07.i02.p01.

[13] L. K. Katherina, ―Banjir sebagai Respon terhadap Urbanisasi dan Perubahan Guna Lahan,‖ *Lembaga Ilmu Pengetahuan Indonesia*, 2016. [Online]. Available: http://kependudukan.lipi.go.id/id/kajian-kependudukan/ekologi-manusia/360-banjir-sebagai-respon-terhadap-urbanisasi-dan-perubahan-guna-lahan.

[14] S. O. Putri, ―Pengaruh Penggunaan Lahan terhadap Debit Aliran Sungai di Sub DAS Batang Arau Hulu Kota Padang,‖ IPB, 2011.

[15] A. Supriyo, ―Aspek Vegetasi dan Tata Guna Lahan dalam Proses Erosi di Daerah Tampung Waduk Jati Luhur, Jawa Barat,‖ Universitas Padjajaran Bandung, 1986.

[16] Farida and M. van Noordwijk, ―Analisis Debit Sungai Akibat Alih Guna Lahan dan Aplikasi Model GenRiver Pada DAS Way Besai, Sumberjaya (River Discharge Analysis due to Land Use Changes and GenRiver Model Application in Way Besai catchment, Sumberjaya,‖ *Agrivita*, vol. 26, no. 1, pp. 39–47, 2004.

[17] A. Suharsimi, ―Prosedur penelitian suatu pendekatan praktik,‖ *Jakarta: Rineka Cipta*, 2006.

[18] M. C. Acreman and C. D. Sinclair, ―Classification of drainage basins according to their physical characteristics; an application for flood frequency analysis in Scotland,‖ *J. Hydrol.*, vol. 84, no. 3–4, pp. 365–380, May 1986, doi: 10.1016/0022-1694(86)90134-4.

[19] T. K. E. Trimarwanti, ―Evaluasi Perubahan Penggunaan Lahan Kecamatan di Daerah Aliran Sungai Cisadane Kabupaten Bogor,‖ *J. Pembang. Wil. Kota*, vol. 10, no. 1, p. 43, 2014, doi: 10.14710/pwk.v10i1.7632.

[20] H. A. Lubis, ―NoPengaruh Perubahan Penggunaan Lahan terhadap Koefisien Aliran Permukaan (Runoff) DAS Betung Provinsi Lampung,‖ Universitas Lampung, 2011.

[21] B. Latuamury and K. Resesi, ―Pengaruh Kerapatan Vegetasi Penutup Lahan terhadap Karakteristik Resesi Hidrograf pada Beberapa Subdas di Propinsi Jawa Tengah Dan Propinsi DIY,‖ *Maj. Geogr.*

Indones., vol. 26, no. 2, pp. 98–118, 2016, doi: 10.22146/mgi.13418.

[22] P. P. R. I. N. 37 T. 2012, *PENGELOLAAN DAERAH ALIRAN SUNGAI DENGAN RAHMAT TUHAN YANG MAHA ESA PRESIDEN REPUBLIK INDONESIA*. INDONESIA, 2012.

[23] U.-U. R. INDONESIA and N. 26 T. 2007, *UNDANG-UNDANG REPUBLIK INDONESIA NOMOR 26 TAHUN 2007 TENTANG PENATAAN RUANG*. INDONESIA, 2007.

[24] A. A. Komolafe, S. A. A. Adegboyega, and F. O. Akinluyi, ―A review of flood risk analysis in Nigeria,‖ *Am. J. Environ. Sci.*, vol. 11, no. 3, pp. 157–166, 2015, doi: 10.3844/ajessp.2015.157.166.

[25] S. Arsyad, *Konservasi Tanah & Air*. Bandung: IPB Press, 2010.

[26] J. D. M. Cindy Jeane Supit, ―Prediksi Perubahan Karakteristik Hidrologi akibat Perubahan Penggunaan Lahan sebagai Usaha Mitigasi Banjir di Manado,‖ *TEKNO*, vol. 14, no. 66, 2016.

[27] T. V Cech, ―Principles of water resources.‖ pp. XXVI, 546 S., 2010.

[28] J. M. H. Cockburn and J. I. Garver, ―Abrupt change in runoff on the north slope of the Catskill Mountains, NY, USA: Above average discharge in the last two decades,‖ *J. Hydrol. Reg. Stud.*, vol. 3, pp. 199–210, 2015, doi: https://doi.org/10.1016/j.ejrh.2014.11.006.

[29] J. Musau, J. Sang, J. Gathenya, and E. Luedeling, ―Hydrological responses to climate change in Mt. Elgon watersheds,‖ *J. Hydrol. Reg. Stud.*, vol. 3, no. September, pp. 233–246, 2015, doi: 10.1016/j.ejrh.2014.12.001.

[30] R. J. Kodoatie, *Rekayasa dan Manjemen Banjir Kota*. Yogyakarta: Andi Publisher, 2013.

[31] L. Richard, *Hidrologi Hutan*. Yogyakarta: Gajah Mada University Pres, 1990.

[32] Indarto, *Dasar Teori dan Contoh Aplikasi Model Hidrologi*. Jakarta: Bumi Aksara, 2014.

[33] S. Loebis Joesron, Soewarno, *Hidrologi Sungai*. Jakarta: Badan Penerbit PU, 1993.

[34] U.S Army Corps of Engineers-Hydrologic Engineering Center (HEC), ―Hydraulic Reference Manual HEC-RAS 3.1.3,‖ California, 2001.