IOP Conference Series: Earth and Environmental Science

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To cite this article: Chairil *et al* 2020 *IOP Conf. Ser.: Earth Environ. Sci.* **575** 012132

IOP Conf. Series: Earth and Environmental Science **575** (2020) 012132 doi:10.1088/1755-1315/575/1/012132

Land use planning for floods mitigation in Kelara Watershed, South Sulawesi Province, Indonesia

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Abstract. Indonesia has a tropical climate with high rainfall. The high rain will affect the state of hydrology until the peak discharge is a flood. Other factors that influence flooding are morphometry, topography, soil type, and land cover conditions. The Kelara watershed in South Sulawesi has been flooded. Then a flood effort in the disaster mitigation disaster watershed is needed in the form of land use planning. So, this study conducted a mapping of watershed morphometry analysis, flood vulnerability areas, and hydrological modeling to obtain debit data using the Geographic Information System method. Based on flood mapping, the land use planning for mitigation will be formulated based on flood vulnerability areas, actual land use, district space patterns, and land suitability. The results showed that the morphometry of the Kelara watershed was not identified as vulnerable to flooding, namely the watershed shape, river density, and river gradient. While the mapping of flood vulnerability areas resulting from overlapping parameters of land cover, slope, elevation, and type of soil, indicates that there are flood vulnerability areas in Kelara watershed. The flood vulnerability areas to float in flat to gentle areas (0-15%) with a height of 0-50 meters above sea level and land that have a low infiltration rate. The peak of January in a maximum discharge of 1.7268 m3 / second Kelara river. Land use planning with the forest area and development of agroforestry patterns. The reduced land use planning of the maximum discharge on the Kelara River by 0.05 m3 / sec. But land use planning has not been optimal in decreasing peak discharge. So, it needs faster effort, namely other technical activities such as dam construction and river normalization.

1. Introduction

The territory of Indonesia, including South Sulawesi, is geographically located in a tropical climate area and has two seasons, namely the dry season and the rainy season with characteristics of extreme weather changes, temperatures, and wind directions [1]. This condition can cause hydrometeorological threats such as floods and droughts. Areas with a high risk of the threat of flooding are spread throughout the area of South Sulawesi.

Rainfall conditions and temperatures in an area will affect the state of hydrology until the formation of flood discharge [2,3]. In general, flooding is caused by high above normal rainfall, so that the water drainage system (river, creek, artificial canal system) is unable to accommodate the accumulation of rainwater until it overflows [3,4]. Increased flood discharge is not only caused by rainfall but also due to changes in land use [5].

In the urban and upstream areas of the watershed as a protected area, there has been a decline in vegetation areas and an increase in residential areas [6,7]. Forest cover loss will increase annual discharge, peak discharge, and increased surface runoff [8]. Although rainfall is in the same condition, a reduction in forest cover will cause changes in soil moisture retention and surface flow [9].

Hydrological modeling is used to obtain information on discharge data [10]. Modeling for water discharge with spatial and temporal resolution uses the Soil and Water Assessment Tools (SWAT) model [10]. SWAT modeling gives good results in predicting water discharge in a watershed within a certain period of time [9] in 2009, according to the Development Statistics of Jeneberang Walanae BPDAS that in the Kelara watershed in the Jeneponto Regency area there had been a flood disaster. The flood is caused by high rainfall and topography [11]. Floods that occur will cause monetary losses and hinder development [5]

based on the flood situation that occurred, an effort was needed to reduce the impact (mitigation) of floods in the Kelara watershed. Land use planning is one of the efforts that can be done to reduce the impact of floods naturally. Land use patterns in various forms and ways will have an impact on the environment, one of which is the occurrence of floods.

This research was conducted to propose land use as an effort to reduce flood impacts on the Kelara watershed. This was started by identifying and mapping the level of flood disaster vulnerability using the Geographic Information System (GIS) method and analysis of water discharge using hydrological modeling. Therefore, it is expected to be able to provide information on flood vulnerability areas as a consideration in land use planning for flood mitigation in the Kelara River Basin, South Sulawesi.

2. Materials and Method

This research focuses on reducing the impact (mitigation) of flood disasters, which begins with the identification of morphometry of watersheds, flood vulnerability areas, and flood discharge. The hydrological boundary used is in the Kelara watershed area. This study included:

2.1. Determining the Boundary of Research Location

The boundary of the Kelara watershed is the outer boundary of all types of data used for the purpose of analyzing the research location. Administratively, the Kelara boundary is in two regencies, namely Gowa district and Jeneponto Regency, South Sulawesi Province, which can be seen in Figure 1.

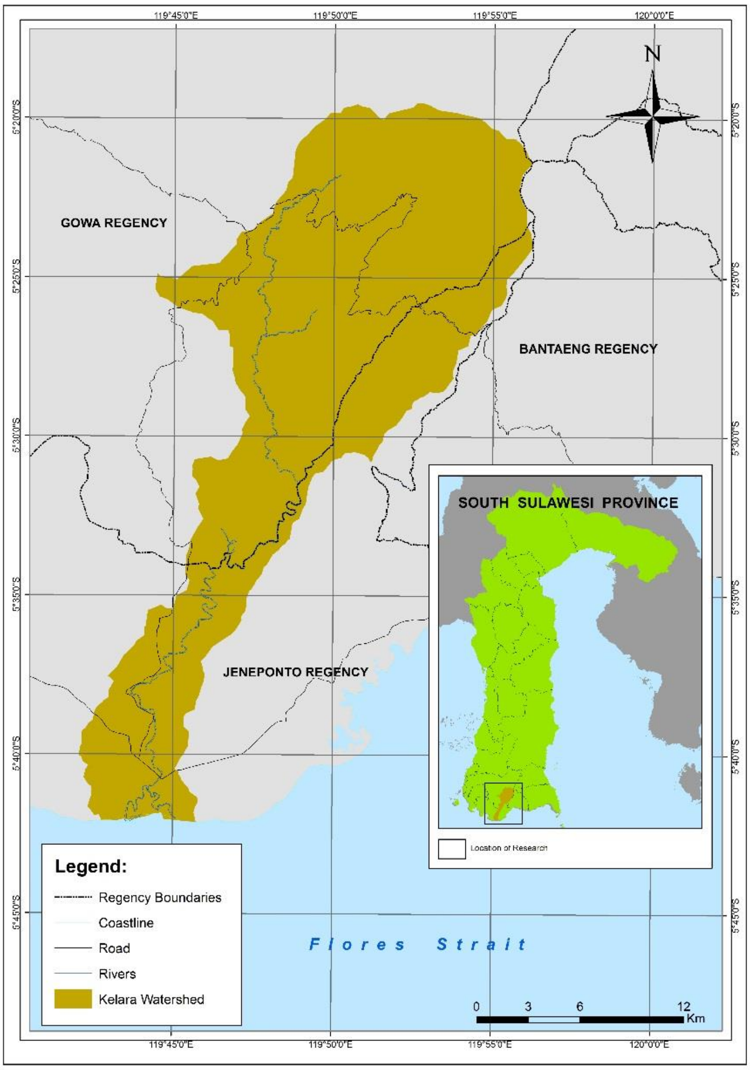

Figure 1. Location of Research Map

2.2. Collecting Research Data

To describe morphometry, flood vulnerability areas, and hydrological modeling analysis in this study using the geographic information system (GIS) method. Data collected in this study consisted of primary data and secondary data. Primary data collected is an image of the 2017 Landsat 8 OLI recording for analysis of image interpretation that issues a land cover map. Secondary data includes boundary watershed data, 30 meters DEM daisies, river network maps, soil type maps, and climate data.

2.3. The Processing and Analyzing Research Data

2.3.1. Watershed Morphometry. Watershed morphometry is a quantitative description of the physical condition of a watershed with a geographic information system [12]. Morphometry will affect the output of a watershed, such as the output of water discharge, which will affect the occurrence of flooding [13]. The morphometry analysis of the watershed is based on the Director-General of BPDAS and Social Forestry Regulation with No: P.3 / V-SET / 2013 concerning guidelines for Identifying the Characteristics of Watersheds [14]. The measured morphometry of watershed to identify floods in the watershed is the form of the watershed (circularity ratio / Rc), river network (bifurcation ratio / Rb), river density (Dd) and river gradient (Su).

*2.3.2. Mapping of Flood vulnerability Areas.*The mapping of flood vulnerability areas is done by overlapping the factors that influence flood events through the Geographic Information System [14]. Factors that influence the vulnerability of floods are chosen as parameters. The mapping parameters of flood vulnerability areas include land cover, slope, elevation, and soil type. Next, determine the classification of flood parameter values and weighting for each parameter. Granting values and weights is based on how much influence these parameters have on the occurrence of flooding.

The flood hazard value of an area is determined by the number of values of all parameters that affect flood. The value of flood hazard is determined by using the following equation:

$$K = \sum_{i=1}^{n} (Wi \ x \ Xi) \qquad 1$$

Explanation:
K : Vulnerability Value
Wi : weights for the parameter of i
Xi : Parameter class value of i

Determining the level of flood vulnerability is done by dividing the vulnerability values equally by the number of class intervals, as shown in Table 1. using the following equation:

$$i = \frac{T}{n} \qquad 2$$

Explanation:
i : Interval Class
T : Maximum score difference with the minimum score
n : Number of classes of flood vulnerability

Table 1. Flood Vulnerability Level Classification

No.	Flood Vulnerability Level	Value
1	Not Vulnerable to flooding	80 – 220
2	less Vulnerable to flooding	220 – 360
3	Vulnerable to flooding	360– 500

2.3.4. Modeling River Water Discharge. River water discharge data is obtained using the Soil Water Assessment Tools (SWAT) model. Input data used in SWAT models include land cover, topography, soil type, and daily climate data (rainfall, temperature, wind speed, sunlight intensity, and air humidity). The Soil Water Assessment Tools are able to estimate peak discharge and flood volume with spatial and temporal input [15]

2.4. Landuse Planning for Floods Mitigation

Mapping the level of flood vulnerability as a basis in formulating land use planning in the Kelara watershed. Land use planning to mitigate flooding with flood vulnerability areas, actual land use, district space patterns, and land suitability.

3. Result and discussion

3.1. Watershed Morphometry

The shape of the Kelara watershed is elongated because it has a value of Rc = 0.3, which indicates that Rc is smaller than 1 (one). The longer the shape of a watershed indicates the concentration of water flow will be longer so that the occurrence of flooding will be lower. Most of the Kelara watershed (Rb) index value is below three. River branching below three (Rb <3) indicates a rapid rise in water level, while a slow decline. The flow/river density value of the Kelara watershed is 1.59 Km / Km2. river density value is smaller than 0.62 km / km2, the watershed will experience flooding, whereas if the value of river flow density is greater than 3.1 km / km2, the watershed will often experience drought. The river gradient of the Kelara watershed is 0.61%. The river gradient with a value of 0.5% - 1% occurs rather slowly.

Based on the morphometry analysis of the Kelara watershed, that there is only one variable that shows that the Kelara watershed is identified as vulnerable to flooding, which is the river branching variable. While variables such as the shape of the watershed, river density, and river gradients indicate that the Kelara watershed is not vulnerable to flooding. So that in terms of morphometry, the Kelara watershed is not identified as vulnerable to flooding. The details of the results of the Kelara Watershed morphometric analysis to identify flood vulnerability are presented in Table 2.

Table 2. Morphometry of the Kelara Watershed for Identification of Flood Vulnerability

Identification of Flood Vulnerability	Watershed Morphometry			
	Rc (km/km)	Rb	Dd (km/km)	Su (%)
Not Vulnerable to flooding	< 1	> 5	> 3.1	< 1
Vulnerable to Floods	> 1	< 3	< 0.62	< 2
Kelara Watershed	0,3	2	1.56	0.61

Source: GIS Analysis, 2018.

3.2. Areas Vulnerable to Flooding

3.2.1. Land Cover. Land cover in the watershed will play an important role in increasing or reducing the magnitude of floods [16]. Land cover data were obtained from the interpretation of Landsat 8 Path 114 and Row 64 imagery in October 2017. The results of image interpretation in the form of land use classification in 2017 will be tested for accuracy. This is to find out the percentage level of trust from the results of image interpretation. The data in this accuracy test are predetermined sample points compared to the results of field observations related to the specified sample points. Classification of Kelara watershed cover from 135 points shows 120 points according to the sample and the conditions in the field, while 15 points are not suitable. Seeing the level of accuracy of the interpretation made is 88.89%. This shows that the results of the interpretation of the images made can be accepted, that image classification can be accepted, namely with a minimum level of accuracy of 85% [17]. The classification of land cover values as a parameter of flood hazard is presented in Table 3.

Table 3. Classification of land cover values as a parameter of flood Vulnerability

No.	Land Cover	Value	Weight	Value of The Flood	Area (ha)
1	Secondary forest	1	35	35	5.862,84
2	Plantation Forest	1		35	736,51
3	Plantation	2		105	11.569,99
4	Dryland Agriculture	3		105	11.120,09
5	Rice fields	3		105	8.240,55
6	Water	3		105	179,57
7	Ponds	3		105	204,66
8	Settlement	4		140	1.197,64
		Total			39.111,85

Source: GIS Analysis, 2018.

Closure of land in the form of forest in the Kelara watershed is only about 17 percent of the watershed area. While the land used by the community is very broad, about 83 percent of the watershed area is dominated by dryland agriculture and plantations. Changes in land use to agricultural land is a choice for the community to meet future demand [18]. The same thing was also revealed, namely changes in land use to agricultural land due to increased food demand and population growth [19].

3.2.2. Slope. The slope is one of the properties that affect surface runoff, which will cause flooding [13]. The steeper the land, the more water that will be forwarded to the flat to the sloping area. The slope classification in the Kelara watershed was obtained from Aster DEM 30 meters data with GIS analysis. The classification of slope values as parameters of flood hazard is presented in Table 4.

Table 4. The classification of slope values as a parameter vulnerable to flooding

No.	Slope	Value	Weight	Value of The Flood	Area (ha)
1	>40%	1	25	25	12.711,43
2	25-40%	2		50	5.909,38
3	15-25%	3		75	4.844,77
4	8-15%	4		100	2.158,75
5	<8%	5		125	13.487,53
		Total			39.111,85

Source: GIS Analysis, 2018.

3.2.3. Elevation. The elevation or height of a place has an effect on flood vulnerability areas. Areas that have a low elevation have a high potential for flooding because the nature of water flows following the gravitational force that flows from a high place to a lower place. Elevation data obtained from Aster DEM 30 meters data with GIS analysis for elevation classification in the Kelara watershed. The classification of elevation values as parameters of flood hazard is presented in Table 5.

Table 5. Classification of elevation values as a parameter of flood Vulnerability

No.	Elevation Class	Value	Weight	Value of The Flood	Area (ha)
1	<12.5m	5	20	100	1.677,77
2	12.5-25m	4		80	1.378,82
3	25-50m	3		60	1.524,64
4	50-75m	2		40	758,25
5	75-100m	1		20	1.285,70
6	>100m	0		0	32.486,67
		Total			39.111,85

Source: GIS Analysis, 2018.

3.2.4. Type of Soil. Flood vulnerability areas are also influenced by the type of soil which is located at the level of infiltration. The slower the land infiltrates, the greater the surface flow that will result in flooding. Maps of soil types were obtained from the land system data system Regional Physical Project for Transmigration (RePPProt) National Coordinating Survey and Mapping Agency in 1987. The classification of soil type values as flood hazard parameters is presented in Table 6.

Table 6. Classification of soil type values as a parameter vulnerable to flooding

No.	Type of Soil	Value	Weight	Value of The Flood	Area (ha)
1	Dystrandepts	4	20	80	10.814,61
2	Dystropepts	4		80	21.738,93
3	Haplustalfs	3		60	318,30
4	Haplustults	3		60	15,80
5	Tropudalfs	3		60	1.178,41
6	Ustropepts	3		60	5.045,81

No.	Type of Soil	Value	Weight	Value of The Flood	Area (ha)
			Total		39.111,85

Source: GIS Analysis, 2018.

3.2.5. Mapping of Flood vulnerability Areas. The level of flood vulnerability areas in the Kelara watershed was analyzed by the Gegrafis Information System method spatially by overlaying (overlapping) four flood parameters, namely land cover, slope, elevation and soil type based on the classification of values and weights of each flood vulnerability parameter and level classification flood vulnerability. Based on the results of the analysis, data obtained on the classification of flood vulnerability in the Kelara watershed area are presented in Figure 2.

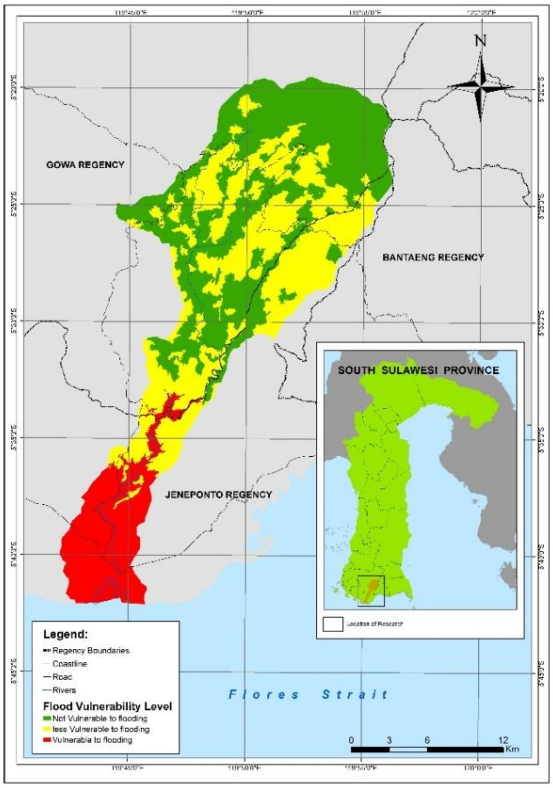

Figure 2. Map of The Flood Vulnerability Level

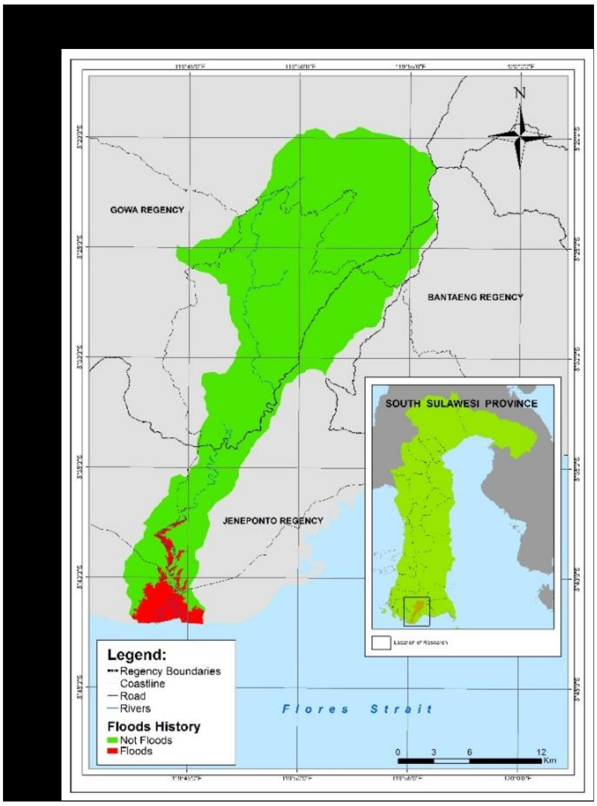

Figure 3. Map of Flooding

Based on the level mapping of the flood area in the Kelara watershed in Figure 2, it can be seen in the area that will be flooded. Mapping flood vulnerability areas provide information about flood areas. Areas experiencing flooding starting from land use consisting of settlements, ponds, and rice fields, have a gentle slope (0-15%) with a height of 0-50 meters above sea level and land which has a low infiltration rate. The flood vulnerability area in the central area is biogeophysical, middle flood areas [20]. So the flood level mapping that shows flood vulnerability areas in the middle of the watershed only consists of puddles in areas where the relief forms a basin, and the land contains fields that can be excavated by air. In Figure 3, it can be seen areas that have been affected by floods.

3.3. Water Flow

SWAT modeling analysis was used to determine the water flow of the Kelara river for the calculation of flood discharge using land acquisition as a result of interpretation of Landsat imagery 8 Path 114

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and Line 64 in October 2016, ASTER DEM data 30 meters, data collected from the National Global Center for Environmental Prediction (NCEP), Climate Forecast System Analysis (CFSR) for the past 10 years, and land types obtained from land system data (land system), Regional Physical Project for Transmigration (RePPProt) 1987 National Survey and Mapping Coordinating Board. Data can be obtained from rainfall data, temperature, wind speed, sunlight intensity, and air humidity. The maximum discharge data every month in Sungai Kelara is presented in Table 7.

Table 7. Maximum Debit Data for Each Month on the Kelara River

Month	January	February	March	April	May	June
Discharge	1,7268	1,1979	0,7587	1,0527	0,9152	0,7220
Month	July	August	September	October	November	December
Discharge	0,4977	0,2224	0,0943	0,0634	0,2444	1,0639

Source: SWAT Analysis, 2018.

The highest debit of the Kelara River occurred in January, which was 1.7268 m3 / second. River discharge will follow rainfall conditions in each region. So that the highest discharge that occurred in January was marked by high rainfall during the month. Debit data will also describe the flood events that occur during high rainfall. [4] states that one of the flood events is caused by rainfall that is high above normal, causing rivers and drainage channels to not be able to accommodate the amount of rainwater that falls.

Data from Karajae watershed land is mostly used by the community, starting from rice fields and dryland farming and plantations. While forest land cover is only 17 percent of the Kelara watershed. This will have an impact on the flow of the Kelara river, which will accumulate into a flood. Lack of forest cover in a watershed will increase surface runoff, peak discharge, and increase annual discharge.

3.4. Land Use Planning

Mapping the level of flood vulnerability that shows the Kelara watershed that is vulnerable to flooding in a particular month. Then efforts need to be made in order to overcome the risk of flooding. Land use planning is one of the concepts that can be done for natural flood prevention. Plan land use not only in the downstream areas that are vulnerable to flooding but the entire Kelara watershed area as a single hydrological area. Land use planning is based on flood vulnerability areas, actual land use, district space patterns, and land suitability. Based on the results of the analysis, land use planning data is obtained for flood mitigation in the Kelara watershed presented in Table 8.

Table 8. Land use planning for flood mitigation in the Kelara watershed

No.	Land Use	Area (ha)
1	Secondary Dryland Forest	4.114,91
2	Forest Plantation	3.168,77
3	Industrial forest	1.101,45
4	Agroforestry	16.273,12
5	Meadow	1.732,30
6	Dryland Agriculture	2.156,55
7	Wetland Agriculture	8.786,29
8	Settlement	1.267,56
9	Ponds	193,86
10	Water	317,03
	Total	39.111,85

Source: GIS Analysis, 2018.

Land use planning was prepared as a flood mitigation effort in the Kelara watershed. Forest land use planning has increased to 20 percent of the Kelara watershed. However, this area is not enough based on Law Number 41 of 1999 concerning Forestry, which implies a minimum forest area of 30 percent of a watershed. Natural flood mitigation does not mean that rain has to be reduced, but manages to stop forest conversion [3]. In addition to increasing forest area, it encourages the development of agroforestry patterns on land owned by communities that have high topographic conditions and steep slope. Agroforestry can be one of the applications of land use that can be a solution to overcome ecological problems and also to overcome food problems [21]. Whereas other land uses require soil and water conservation efforts. Land use in the form of rice fields needs to improve irrigation channels. The use of land in the form of water bodies, ponds and settlements improve drainage channels and the making of infiltration wells. as well as flood mitigation on agricultural land by applying soil conservation [4].
Debit simulation in looking at the effectiveness of land use planning as a flood mitigation effort is carried out after conducting land use planning based on flood vulnerability areas, obtaining actual land cover, district space patterns, and land suitability. The maximum discharge every month after conducting land use planning in the Kelara watershed is shown in Table 9.

Table 9. Discharged Simulated of the Kelara River

Months	January	February	March	April	May	June
Actual Discharge	1,7268	1,1979	0,7587	1,0527	0,9152	0,7220
Plan Discharge	1,6768	1,2082	0,7748	1,0573	0,9177	0,7303
Difference	0,0500	-,0104	-0,0161	-0,0047	-0,0026	-0,0083
Months	July	August	September	October	November	December
Actual Discharge	0,4977	0,2224	0,0943	0,0634	0,2444	1,0639
Plan Discharge	0,5135	0,2333	0,1005	0,0644	0,2399	1,0271
Difference	-0,0158	-0,0110	-0,0062	-0,0010	0,0045	0,0368

Source: SWAT Analysis, 2018.

Simulations of the Kelara river discharge with land use planning decreased the maximum discharge in January by 0.05 m3 / second so that the Kelara river discharge was 1.6768 m3 / second. The maximum debit in December also decreased by 0.0368 m3 / second. The maximum debit in February to October is the addition of debit at a number below 0.017 m3 / second. This illustrates that land use planning with the addition of forest cover reduces the maximum discharge in January, which is understood as a flood discharge. Increasing land cover to the forest will reduce surface runoff, peak discharge, and annual discharge [8,9]. The addition of forests will have an impact on increasing canopy cover and vertical strata of cover. a decrease in peak discharge is also one of the outputs of the addition of forested land.

Efforts to deal with flooding can be made by improving the causes of flooding, namely land use planning. this plan will increase the capacity of water capacity and increase infiltration so that it impacts on the condition of the discharge that will decrease. However, based on a land use planning simulation, it was found that it was not optimal in reducing river discharge. Then there needs to be other efforts with faster results. One of the efforts that can be done is other technical activities such as dam construction and river normalization. technically one of the flood mitigation efforts is by creating a shortcut from meandering, dredging deposits, and building retaining walls [4].

4. Conclusions

The conclusion of this study is morphometry of the Kelara watershed identified as vulnerable to flooding is the river branching variable. however, based on the shape of the watershed, the density of

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the river, and the river gradient shows that the Kelara watershed is not vulnerable to flooding. The mapping of flood vulnerability areas of flooding from several parameters shows that there are flood vulnerability areas in the Kelara watershed. The flood vulnerability area to flooding starts from land use in the form of settlements, ponds, and paddy fields, areas that have a flat to the gentle slope (0-15%) with a height of 0-50 meters above sea level and land that has a low infiltration rate. The peak of the flood event occurred in January with a maximum discharge of 1.7268 m3 / sec on the Kelara river. Land use planning uses the basis of flood vulnerability areas, actual land cover, regency space patterns, and land suitability that will experience an increase in forest area and the development of agroforestry patterns. The land use planning reduced the maximum discharge on the Kelara river by 0.05 m3 / sec. However, land use planning has not been optimal in reducing peak discharge. So it needs a faster effort, namely other technical activities such as dam construction and river normalization.

Acknowledgment
The author would like to thank Hasanuddin University for the support of facilities and for the Education Fund Management Institute for the assistance of research scholarships so that the authors can complete this research.

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