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Land Use Change Effect on River Discharge of the Way Pengubuan Watershed, Sumatra_Indonesia

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Abstract. The Way Pengubuan Watershed is a tributary of the Way Seputih watershed which is administratively located in Central Lampung Regency, Lampung Province, Indonesia. Land cover changes are closely related to the hydrological characteristics of the Way Pengubuan Sub-watershed area. This study aims to determine the impact of land cover change on surface runoff coefficient and water discharge in the Way Pengubuan sub-watershed area, Indonesia. Data was collected in the form of rainfall data, river discharge data, and water level data. Land cover data were identified through the interpretation of Landsat 5.7 and 8 imagery in 2014-2017, and its contribution to surface flow coefficient was analyzed using multiple linear regression models. The results also show that the total rainfall [RAIN] has decreased from 2,921 mm/year to 2,525 mm/year. Likewise, the river discharge [DISC] which in 2014 amounted to 262.29 m³/s to 238.70 m³/s in 2017. However, it is proportional to the surface flow coefficient value which has increased from 0.031 to 0.032. For land cover in the Way Pengubuan Sub-watershed area, it is still dominated by agricultural areas which have an area of over 50% each year, compared to forest area [FRST] which are only <1% of the total area of the Way Pengubuan Sub-watershed throughout the year. By employing series data of annually rain fall, % forest cover, % shrub, and % plantation, therefore, the annual river discharge can be express : $[DISC]= 75.0 + 0.062 [RAIN] + 0.0713 [FRST] - 0.00203 [SHRB] + 0.000725 [PLTN]$ with R.Sq (adj)= 92.5%.

Keywords: River Discharge, Rainfall, Runoff, Forest Cover, Shrub, Plantation

INTRODUCTION

Environmental problems are becoming increasingly complex due to increased population growth accompanied by deforestation, and global warming as well as global ecological disturbances. The increase in population growth will always demand land needs so it has implications for changes in land cover [1]. Changes in land cover that occur quickly will indirectly have an impact on the area that is experiencing these changes and the surrounding areas [2]. Population growth will affect river water quality which can lead to ecosystem degradation, water quality degradation, and loss of biodiversity [3][4]. Change in land cover is one of the factors that greatly influence the function of water management in a watershed area [5].

One of the watersheds in Lampung Province that has good land cover is the Way Pengubuan Sub-watershed area, which is a tributary of the Way Seputih watershed in Lampung Province. Administratively, the Way Pengubuan sub-watershed location is in Central Lampung Regency, Lampung Province with an area of 210.72 km² [6]. Changes in river discharge in the watershed area will be influenced by land cover in the watershed area [7][8]. In addition, changing land cover to open areas can have an impact on increasing or decreasing the peak runoff discharge [9].

Based on the existence and function of land cover that influences river discharge, many researchers have carried out these studies such as research to determine the effect of land cover on discharge in the Way Seputih Hulu watershed area [8], a study of the impact of land use change on flow rates in the Ciujung watershed [10], as well as study in Poyang Lake Basin-China on the impact of

the multi-purpose reservoir system, land use dan climate change on runoff characteristics [11]. This study aims to determine the dynamics of land cover change and to determine the effect of changes in land cover on river discharge in the Way Pengubuan sub-watershed area, Indonesia. So it is hoped that this research can be used for related research

and is expected to be used as input for policymakers and other stakeholders, to make decisions in the rehabilitation and management of Way Pengubuan Sub-watershed in the future.

METHODS

Tools and Materials

The research study area carried out is in the Way Pengubuan Sub-watershed area of Lampung Province, Indonesia. The tools used in this research are computer devices with computer software such as statistical software, Geographic Information System (GIS) software, Microsoft Office Word, Microsoft Office Excel, Global Positioning System (GPS) tools, and stationery. The materials used in this study are rainfall data, river discharge data, water level data, and land use maps in the Way Pengubuan Sub-watershed in 2014, 2015, 2016, and 2017, as well as other supporting secondary data.

Research methods

This research was conducted using secondary data. The stages in the research carried out were preparing data, analyzing digital maps, analyzing data on monthly rainfall data and monthly discharge, and regression analysis. In this study the data used were rainfall data, river discharge data, and land cover data for the period 2014, 2015, 2016, and 2017 in the Way Pengubuan Sub-watershed, Indonesia.

Data analysis

Data analysis for river flow uses the calculation of flow rate fluctuation or Flow Regim Coefficient (FRC) which aims to determine whether or not land use in the watershed area is good [12]. The FRC equation uses the comparison formula between the maximum debit and the minimum debit set by [24], the FRC value table can be seen in Table 1 below.

TABLE 1. Watershed Quality Criteria based on FRC scores

Category	FRC
Very low	<20
Low	20-50
Moderate	50-80
High	80-110
Very high	>110

The next data analysis is the Annual Flow Coefficient (AFC) using the comparison formula between annual river discharge and annual rainfall stipulated by [24], the table of AFC values can be seen in Table 2 below.

TABLE 2. Watershed Quality Criteria based on AFC scores

Category	AFC
Very low	<0.2
Low	0.2-0.3
Moderate	0.3-0.4
High	0.4-0.5
Very high	>0.5

Then perform an analysis to see the effect of land cover on river discharge using a linear regression equation. Linear regression is a statistical technique used to test the effect of two or more independent variables on one dependent variable [13]. In general, the model used in this study refers to Hosmer and Lemeshow [14].

RESULTS

Rainfall

Indonesia has a large rainfall value which is generally relatively different. The average rainfall value in Indonesia is in the range of 2000-3000 mm/year [15]. In Lampung Province, the amount of rainfall for the highlands is 2314 mm/year, while for the coastal area is 1830 mm/year [16]. Rainfall in the Way Pengubuan Sub-watershed area is obtained from the Way Seputih-Sekampung River Basin Management Agency (BPDAS-WSS). Rainfall in the Way Pengubuan Sub-watershed area can be seen in Table 3 below.

TABLE 3. Monthly rainfall in Way Pengubuan Sub-watershed 2014-2017

Month	Rainfall (mm)			
	2014	2015	2016	2017
January	421.0	636.0	328.5	283.5
February	372.5	383.0	398.0	265.0
March	396.0	432.0	393.0	271.2
April	346.0	327.0	273.0	302.0
May	245.0	153.5	157.5	58.0
June	124.5	57.5	124.5	120.0
July	145.5	41.5	98.5	47.0
August	168.5	25.0	83.0	101.3
September	0.0	0.0	156.5	98.0
October	126.0	8.0	232.0	144.0
November	131.0	251.0	284.0	323.0
December	445.0	383.5	375.0	512.0
Total	2,921.0	2,698.0	2,903.5	2,525.0
Average	243.4	224.8	241.9	210.4
Max	445.0	636.0	398.0	512.0
Min	0.0	0.0	83.0	47.0

Based on Table 3, it can be seen that the total rainfall has decreased, namely 2921 mm in 2014 and decreased to 2525 mm in 2017. Based on the Schmidt-Ferguson climate classification measured from 2014-2017, Sub-watershed rainfall Way Pengubuan humid climate type. Large rainfall intensity in a short time can describe the value of the total rainfall with a few rainy days in a year [17]. In general, the high amount of rainfall affects the increase in river discharge and vice versa, but the increase in rainfall does not affect of water discharge coefficient. This is because the large value of the water discharge coefficient is influenced by land cover in the Way Pengubuan Sub-watershed area of Lampung Province.

Land cover

Changes in land cover are caused by many factors that influence it, one of which is a human intervention to make ends meet [25]. The Way Pengubuan sub-watershed area has an area of 128,528 ha consisting of seven land covers. Based on the results of image interpretation, the land cover in the Way Pengubuan Sub-watershed area can be seen in the following Table 4 below.

TABLE 4. Land cover changes in the Way Pengubuan Sub-watershed area

Land Cover	Year (ha)							
	2014	%	2015	%	2016	%	2017	%
Forest	1,195.89	0.93	1,195.89	0.93	1,092.39	0.85	1,070.46	0.83
Scrub	9,131.96	7.11	6,053.91	4.71	6,134.67	4.77	6,156.59	4.79
Plantation	7,490.07	5.83	7,355.56	5.72	9,731.66	7.57	12,346.45	9.61
Settlement	13,597.27	10.58	18,206.96	14.17	24,003.94	18.68	16,483.98	12.83
Dryland farming	83,078.46	64.64	48,480.30	37.72	40,671.07	31.64	44,996.84	35.01
Mixed Dry Land Farming	13,308.28	10.35	46,217.51	35.96	45,878.13	35.69	42,960.18	33.42

Land Cover	Year (ha)							
	2014	%	2015	%	2016	%	2017	%
Rice fields	726.51	0.57	1,019.37	0.79	1,016.61	0.79	4,513.95	3.51
Total	128,528.4		128,529.5		128,528.5		128,528.4	

Based on table 4 above, it can be seen that the land cover in the Way Pengubuan Sub-watershed area in the 2014-2017 period was dominated by dry agricultural land cover every year. In 2014, the area of dry agricultural land covered was 64.64%, and 35.01% in 2017 of the total area. The large area of land cover which is dominated by dry land agriculture indicates that the fulfillment of the living needs of the population around the Way Pengubuan Sub-watershed area is very dependent on the agricultural sector to meet their daily needs.

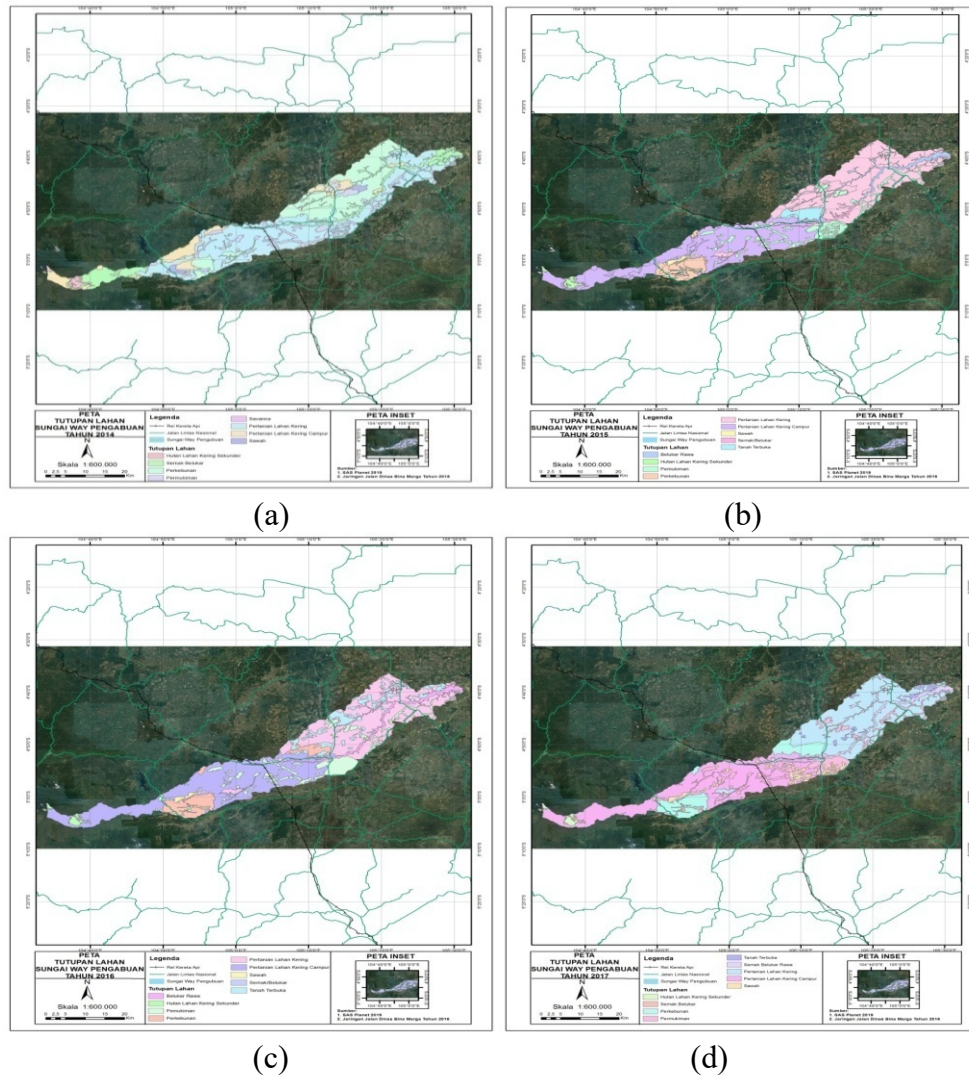


FIGURE 1. Land cover change in the Way Pengubuan Sub-watershed in (a) 2014, (b) 2015, (c) 2016 and (d) 2017.

Forest land cover in the Way Pengubuan Sub-watershed area has a very small area because it has an area of <1% each year. It should be noted that forest areas have enormous potential to be exploited [18], where the role of forest areas is quite important in regulating water management which affects water runoff or river discharge in the Way Pengubuan Sub-watershed area. The following is a map of land cover changes obtained from the results of image interpretation in the Way Pengubuan Indonesia Sub-watershed area which can be seen in Fig 1 below.

River discharge

River discharge is the amount of river runoff that flows per unit of time or the amount of water stored in a place which is influenced by several factors, such as land cover, soil conditions, topography, and changes in rainfall [19][8]. River discharge data in the Way Pengubuan Sub-watershed area can be seen in the following Table 5 below.

TABLE 5. River discharge in Way Pengubuan Sub-watershed, Indonesia

Month	River Discharge (m ³ /s)			
	2014	2015	2016	2017
January	67.75	44.74	27.24	41.86
February	54.68	36.39	34.5	42.45
March	38.47	33.39	25.14	58.95
April	26.37	23.54	32.24	32.34
May	12.25	17.46	17.94	18.70
June	6.31	7.13	9.53	5.72
July	3.60	4.40	4.49	5.56
August	6.71	3.78	3.37	3.68
September	2.08	3.19	4.76	3.34
October	1.13	3.44	10.23	4.37
November	3.91	3.23	19.29	6.86
December	39.03	9.46	18.70	14.87
Total	262.29	190.15	207.43	238.70
Average	21.86	15.85	17.29	19.89
Max	67.75	44.74	34.5	58.95
Min	1.13	3.19	3.37	3.34

It can be seen in the table above that the total river discharge in the Way Pengubuan Sub-watershed has decreased from 2014-2017. Where in 2014 the river discharge value in the area was 262.29 m³/s and decreased to 190.15 m³/s in 2015. The decrease in river discharge value during 2014-2017 in the Way Pengubuan Sub-watershed was in line with the decline of the value of rainfall in the watershed area. This indicates that the land cover in the area is increasingly critical, where more rainwater falls into surface runoff [8]. However, this is inversely related to the research conducted by [26], who in his research concluded that an increase in the value of river discharge will affect the increase in the coefficient of runoff.

Hydrological characteristics of Way Pengubuan Watershed

One indicator to determine whether the area of a river basin is good or not is by knowing the value of flow rate fluctuation/water discharge coefficient (FRC) and the value of the runoff coefficient (AFC) in the study area. The surface flow coefficient value is an indicator in determining whether or not there is a physical disturbance in a watershed [20]. The values of FRC and AFC in the Way Pengubuan Sub-watershed area can be seen in the following Table 6 below.

TABLE 6. Hydrological characteristics in Way Pengubuan Sub-watershed, Indonesia

Hydrological Characteristics	2014	2015	2016	2017
Total rainfall (mm)	2,921.00	2,698.00	2,903.50	2,525.00
Total discharge (m ³ /s)	262.29	190.15	207.43	238.70
Max discharge (m ³ /s)	67.75	44.74	34.5	58.95
Min discharge (m ³ /s)	1.13	3.19	3.37	3.34
FRC	59.96	14.03	10.24	17.64
AFC	0.09	0.07	0.071	0.094
Runoff	0.030	0.024	0.024	0.032

Based on Table 6 above, it can be seen that the KRA value in the Way Pengubuan Sub-watershed has decreased very drastically, whereas the KRA value in the area in 2014 was 59.96, which means that the area has watershed

quality in the medium category. However, in 2017 the KRA value became 17.64, which means that the quality of the watershed in the area is in the very low category. The increase in the KAT value in the Way Pengubuan Sub-watershed area shows that the land's ability to hold and store rainwater that falls to the surface is decreasing. Increasing KAT values indicate that the hydrological characteristics of the watershed are getting worse [21]. In addition, the increase in the KAT value in the Way Pengubuan Sub-watershed area was influenced by changes in land cover from forest to dry land agriculture [22] and rice fields. Changes in forest land use increased the surface runoff coefficient so that the resulting discharge was getting bigger [23].

The relationship between of land cover and river discharge

Based on the results of image interpretation, it is found that the land cover in the Way Pengubuan sub-watershed area consists of forests, swamps/shrubs, plantations, settlements, dry land agriculture, mixed dryland agriculture, and rice fields. From the land cover, it is then regressed with the hydrological characteristics of a watershed by using a regression test.

TABLE 7. Results of regression test analysis

Variable	Coefficient	Std. Error	T	P
Constant	-75.02	41.82	-1.79	0.085
Rainfall [RAIN]	0.066162	0.003789	17.42	0.000
Forest [FRST]	0.071350	0.030510	2.340	0.028
Scrub [SHRB]	-0.0020346	0.0004674	-4.35	0.000
Plantation [PLTN]	0.0007251	0.0008926	0.81	0.424
S = 2.92860	R.Sq= 93.5%	R.Sq (adj)= 92.5%		

Based on the table above, it can be concluded that the correlation between the effect of river discharge toward rainfall and land use change effect can be seen in the following regression results:

$$[DISC]= 75.0 + 0.062 [RAIN] + 0.0713 [FRST] - 0.00203 [SHRB] + 0.000725 [PLTN].$$

Based on Table 7, it can be seen that the coefficient determination between the independent variables and the dependent variable [DISC] has a value of R-Sq (adj) = 93.5%. This indicates that the dependent variable [DISC] can be explained well by the four independent variables of rainfall forest cover, shrub, and plantation area. Based on the results of the tests carried out, there was a significant relationship between rainfall [RAIN] 0.066162 (p = 0.0000), forest cover [FRST] 0.07135 (p = 0.028), and scrub [SHRB]-0.0020346 (p = 0.0000) to river discharge at the Way Pengubuan Sub-watershed area.

CONCLUSIONS

This research concludes that it can be proven that 93.5% of the independent variables used can explain the dependent variable in the Way Pengubuan Sub-watershed area, while 6.5% there is a significant relationship between river discharge and rainfall and land cover in the Sub-watershed area. -DAS Way Pengubuan, Indonesia. The model can be expressed: $[Y]= 75.0 + 0.062 [RAIN] + 0.0713 [FRST] - 0.00203 [SHRB] + 0.000725 [PLTN]$. Changes in land cover in the Way Pengubuan Sub-watershed area were dominated by agricultural land and at least forest areas in the 2014-2017 period. Rainfall has decreased from 2921 mm/year in 2014 to 2525 mm/year in 2017. The decrease in rainfall is in line with decreasing river discharge in the Way Pengubuan Sub-watershed area, in 2014 the amount of river discharge in the area was 262.29 m³/s and decreased to 238.70 m³/s in 2017. However, this is inversely proportional to the surface flow coefficient which has increased from 0.031 to 0.032, also with the AFC value which has increased from 0.090 to 0.094.

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CONFLICT OF INTEREST DECLARATION

We do not have any conflict of interest with this research result.

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