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Research Article

Land Use Changes Impact Analysis to Surface Runoff in Kalibenda Village

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Abstract: The rainwater that reaches the ground will enters the soil (*infiltration*) and some water are not absorbed by the soil will become surface runoff. The regional development tends to change water catchment areas by changing land functions and affecting surface runoff. The regional development in Kalibenda Village has cause problems related to the local community water supply. In 2019 some of the local community in Kalibenda Village have experienced difficulties in accessing clean water supply which has never happened in the past . This study provides an analyze of the impact of land use changes that occur in Kalibenda Village on surface runoff. This study uses a Rational method to calculating runoff discharge by using elevation profile analysis tool from Google Earth program to calculated sloop, Approb_4.1 program to process rain data and ArcSwat Tools in the ArcMap 10.2 program to water catchment analysis. The study results shows that Kalibenda Village divided into 6 (six) catchment water. There has been increased runoff from 2000 to 2021 by 6.44%. The most influential factors are changes in land cover change from rice fields to settlements, plantations and meadow grass.

Keywords : Land use; runoff; kalibenda village; approb_4.1 .

1. Introduction

Surface runoff is rainwater that cannot retain by soil, vegetation, or basins and eventually flows directly into rivers or the sea. Runoff occurs because the intensity of rain falling in an area exceeds the infiltration capacity. After the infiltration rate collects, the water will fill the hollows on the soil surface. After the basins are complete, the water will overflow to the soil surface. The amount of surface runoff is influenced by rainfall, vegetation (land cover/land use), the presence of water storage buildings (Rohyanti *et al.*, 2015), slope, soil water storage capacity, and infiltration rate (Hahn *et al.*, 2012). The regional development tends to change the catchment area by changing the land use and affecting the increased runoff and a decrease in the level of infiltration of rainwater into the ground.

The regional development in Banjarnegara Regency has changed the land use, especially forests and rice fields. In 2001-2015, the dynamics of land-use change in Banjarnegara regency at 10:02% dominated by forest change into plantations, fields, and shrubs, and the rice fields into settlements (Ramadhan *et al.*, 2016). That also happened in Kalibenda Village, an administrative area at the boundaries of Banjarnegara City. Kalibenda Village has developed by constructing the public gas station, industries, shopping centers, and residences in the last two decades. Analyze result on Environmental Impacts Assessment (EIA) the construction of Waterparks and Hotels in Kalibenda Village has raised the issue of water sources. In the dry season of 2019, some of the local communities of Kalibenda Village have experienced difficulties accessing clean water supply, which has never happened in the past (PT. Cipta Kreasi Wisata, 2021). One of the factors for this to occur is the change in land use in the water catchment area as a result of development in this area.

Several studies conducted land-use changes to surface runoff. Bedog watershed in Yogyakarta, an increase type of land use "settlements", from 15.29% in 2004 to 16.94% in 2008 and 17.72% in 2010, resulted in a difference in runoff of 4% from 2010 (Yudha, 2013). From 2005 to 2010 and 2011-2015, in subwatershed Samin, there was a decrease in the average annual river flow (-117.42 m^3/s) and the value of runoff coefficient (-0.11) (Rahayu *et al.*, 2017). Cerucuk watershed on Belitung Island in the period 1994 - 2013 showed an increase in maximum daily rainfall at both stations as well as changes in forest land cover and dryland agriculture into oil palm plantations and settlements, which resulted in an increase in the volume of runoff discharge by 6.5% (Narulita and Marganingrum, 2017). Changes in land elevation at the construction site of the Simpang Patal Palembang Underpass have resulted in changes to the catchment area limit, which causes a difference in the runoff amount of 0.159%-90.022% (Muharomah, 2014).

The Rational Method has been widely used to estimate the peak of runoff discharge caused by heavy rain in small catchment areas (watershed). A watershed is categorized as small if the distribution of rainfall can be considered uniform in space and time, and usually, the duration of rain exceeds the concentration-time (Rohyanti *et al*., 2015). According to data from the Central Statistics Agency of Banjarnegara Regency in 2019, the area of Kalibenda Village is 1.02 km^2. The rational method can be used to estimate the peak discharge of surface runoff. In evaluating the runoff discharge, it is necessary to know the rainfall intensity obtained from the analysis of the planned rainfall for a certain period. To calculate the annual rain forecast, the Gumbel distribution, Log Pearson Type III, Normal Probability, and Log-Normal Probability method have been adopted in the Approb_4.1 program made by Istiarto.

Geographic Information Systems (GIS) are used as a basis for determining the runoff coefficient to estimate surface runoff. The analysis study of the Surface Flow Coefficient (C) due to changes in land use in the Watershed of Ular River using GIS described flow patterns from 2000 – to 2015 (Irmayanti, 2018). GIS for estimating runoff discharge was used, but not many articles use the Approb_4.1 program for calculating rain plans. The Google Earth program has provided an elevation profile analysis tool that makes it possible to obtain a sloop used to calculate rainfall concentration. This tool is also not widely used in previous studies. This study was conducted to analyze the impact of land-use change on runoff in Kalibenda Village using GIS, Approb_4.1 program, and elevation profile analysis tool from Google Earth program.

2. Material and Methods

The impact of land-use change on runoff in Kalibenda Village is conducted by comparing the runoff discharge under current conditions with the runoff discharge in the past. The runoff discharge of surface water that enters drainage is calculated using a rational method (Kamiana, 2011)

$$Q = 0{,}278 \cdot C \cdot I \cdot A \quad (1)$$

Where:
Q = Runoff discharge (m^3/s)
C = Rational method runoff coefficient
I = Rainfall intensity (mm/hour)
A = Catchment area (km^2)

The rational method runoff coefficient (C) was determined based on the type of land cover in the catchment area (Kodoatie and Syarief, 2005 in Hani et al., 2021). The current condition's delineation type of land cover is based on Google Map Satellite Imagery. In contrast, the past delineation type of land cover based on the Peta Rupa Bumi Digital Indonesia (Indonesian Digital Earth Map) 1:25,000 Sheet

1408-412 Banajarnegara I-2000 edition. The rational method runoff coefficient values based on the type of land cover are presented in the following table:

Table 1. Runoff coefficient values by type of land cover

Types of Land Cover	Runoff Coefficient (C)
Primary Dryland Forest	0.02
Secondary Dryland Forest	0.03
Secondary Mangrove Forest	0.05
Secondary Swamp Forest	0.15
Industrial forest	0.05
Plantation	0.40
Settlement	0.60
Dryland farming	0.10
Dryland Mixed Bush Farming	0.10
Swamp	0.20
Ricefield	0.15
Meadow	0.30
Scrub	0.07
Swamp Scrub	0.20
pond	0.05
open ground	0.20
waters	0.05

Rainfall intensity (I) is obtained using the Mononobe formula (Kamiana, 2011) as follows:

$$I = \frac{X}{24} \cdot \left(\frac{24}{t_c}\right)^{2/3} \quad (2)$$

Where:
I = Rainfall intensity (mm/hour)
X = Daily rainfall planned (mm)
t_c = Rainfall concentration time (hour)

Rainfall data were obtained from the http://openweathermap.org website. The rainfall data used is the average rainfall from 2011 to 2020. The rainfall data is processed using the Approb_4.1 program to get the daily rain planned (X). This Approb_4.1 program was created by Istiarto - Departement of Civil and Environmental Engineering, Faculty of Engineering, UGM (http://istiarto.staff.ugm.ac.id/). The Approb_4.1 program performs probability analysis of extreme hydrological data (rain, discharge), better known as frequency analysis of excessive hydrological data, and plots the data according to the distributions: Gumbel, Normal Log, Pearson Type III, and Normal logs. The test of the suitability of the data distribution against the theoretical distribution in the Approb_4.1 Program is carried out by:

1) Chi-square test, confidence level 1-α=90%.
2) Smirnov-Kolmogorov test, α=10%.

Rainfall concentration time (t_c) was calculated using the Kirpich formula (Kamiana, 2011) as follows:

$$t_c = \left(\frac{0{,}87 \times L^2}{1000 \times S}\right)^{0.385} \quad (3)$$

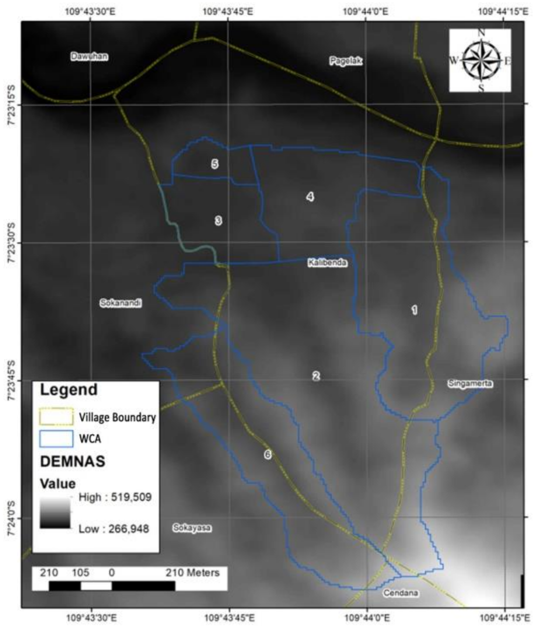
Where:
t_c = Rainfall concentration time (hour)
L = The length of the water path from the farthest point to the point under consideration (km)
S = average sloop of water path (%)

The water path length from the farthest point to the point under consideration (L) and average sloop of water path (S) was obtained by using the elevation profile analyses of the Google Earth program. The catchment area (A) was obtained using the ArcSwat Tools in the ArcMap 10.2 Program. It's accepted by analysis of water catchments using Digital Elevation Model Nasional (Demnas) 1408-41 2020 published by the Badan Informasi Geospatial (BIG) (Geospatial Information Departement) within https://tanahair.indonesia.go.id/demnas/#/ website.

3. Result and Discussion

3.1. Catchment Area

The results of Demnas data analysis using ArcSwat Tools in the ArcMap 10.2 Program obtained 6 water catchment areas (WCA) in Kalibenda Village. The catchment area of the most widespread is the WCA2 (337,112.15 m^2), and the smallest is the WCA5 (30,176.51 m^2)—the results of the ArcSwat Tools analysis in the ArcMap 10.2 program presented in Figure 1. The area north of the Kalibenda Village is not included in this study's water catchment area because the land use is rice fields and bordered by two water paths, Daerah Irigasi (DI) (Irrigation Drainage), Singomerto, and Serayu River.



Catchment number	Area (m^2)
WCA1	174,374.77
WCA2	337,112.15
WCA3	84,092.64
WCA4	135,213.03
WCA5	30,176.51
WCA6	73,587.59
Total Area (m^2)	**834,556.68**

Figure 1. Analysis of arcswat tools on the arcmap 10.2 program in kalibenda village

3.2. Rain Intensity

The Approb_4.1 program plots rainfall data from the http://openweathermap.org website for each distribution then estimates the planned daily rainfall with a specific return period for each type of data distribution. The Approb_4.1 Program plot of rainfall data is presented in Figure 2, while the result of planned annual rainfall peak analysis according to each type of distribution is presented in Table 2.

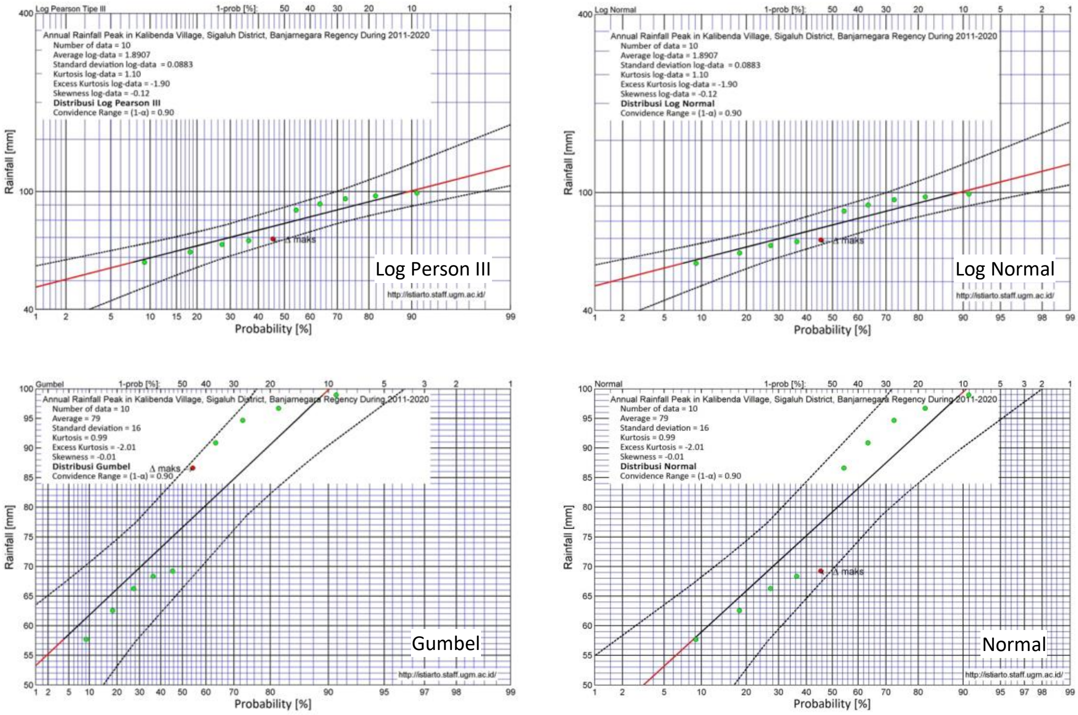


Figure 2. Plot of rainfall data for each distribution using the approb_4.1 program

Table 2. Planned annual rainfall based on return period

Return period (years)	Gumbel	Log Normal	Log Pearson III	Normal
2	77	78	78	79
5	91	92	92	93
10	100	101	101	99
20	109	109	108	105
50	120	118	116	112
100	129	125	122	116
200	137	131	128	120
500	149	140	135	125
1000	157	146	141	128

The data distribution suitability test was conducted to determine the annual rainfall distribution table plan used to calculate runoff discharge—the suitability test was conducted with chi-square test (1-α=90%) and Smirnov-Kolmogorov Test (α=10%). The data distribution test is presented in Table 3.

Table 3. Test the suitability of each distribution

Match Test	Gumbel	Log Normal	Log Pearson II	Normal
Smirnov-Kolmogorov	*Graduated*	*Graduated*	*Graduated*	*Graduated*
Maximum difference	0.190	0.171	0.175	0.190
Chi-Square	failed	*Graduated*	*Graduated*	failed
Chi-Square maximum	8.200	5.400	5.400	8.200

Based on the suitability test results in table 3, the planned rainfall used to calculate runoff discharge using the Log-Normal Distribution is determined cause it has a more negligible Maximum difference than Log Pearson II Distribution. The catchment area based Tools ArcSwat at 10.2 ArcMap Program was 834,556.68 m^2 or 0.835 km^2, daily rainfall planned (X) used return period of 5 years, which is 92 mm.

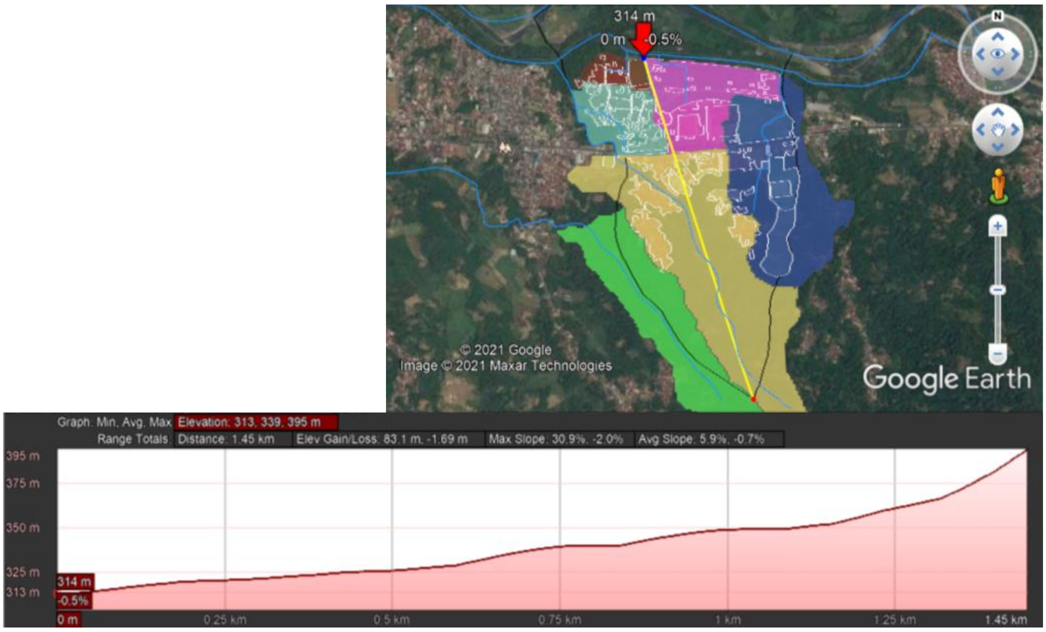


Figure 3. Elevation profile analysis in Google Earth Program

The results of the analysis of the elevation profile are in Figure 3. The obtained water path length from the furthest point to point consideration (L) 1.45 km and an average slope of water path (S) of 5.9%. Rainfall concentrations time (tc) is calculated using Formula (3), obtained the value of 0.263 hours. Then the rain intensity (I) is calculated by Equation (2), the value is 77.79 mm/hour.

3.3. Runoff Discharge

The runoff discharge in Kalibenda Village is calculated using Formula (1). Surface runoff is calculated for each catchment area number that has been determined using the ArcSwat Tools in the ArcMap 10.2 Program. The rational method runoff coefficient (C) was determined based on the type of land cover delineation. The impact of land-use change on surface runoff discharge in Kalibenda Village is conducted by comparing runoff discharge with land cover current conditions with surface cover in the past. The map of land cover types in the year 2021 is presented in Figure 4, while the land cover in the year 2000 is shown in Figure 5.

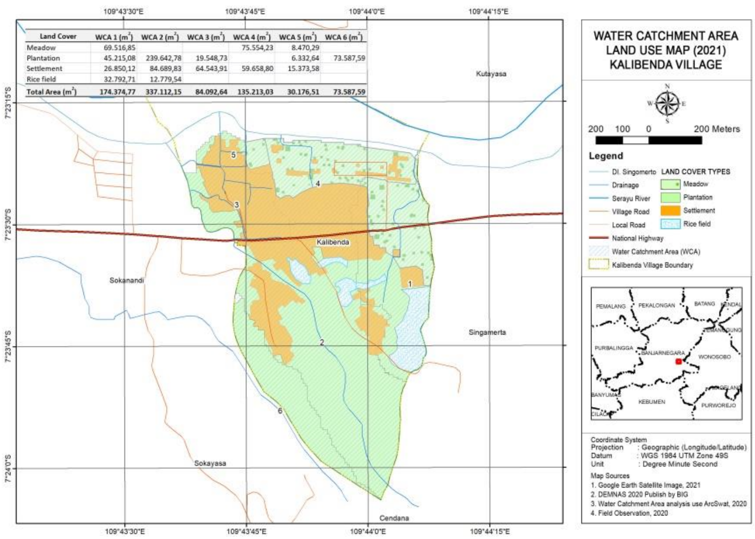


Figure 4. Map of land cover in water catchment areas in Kalibenda Village in 2021

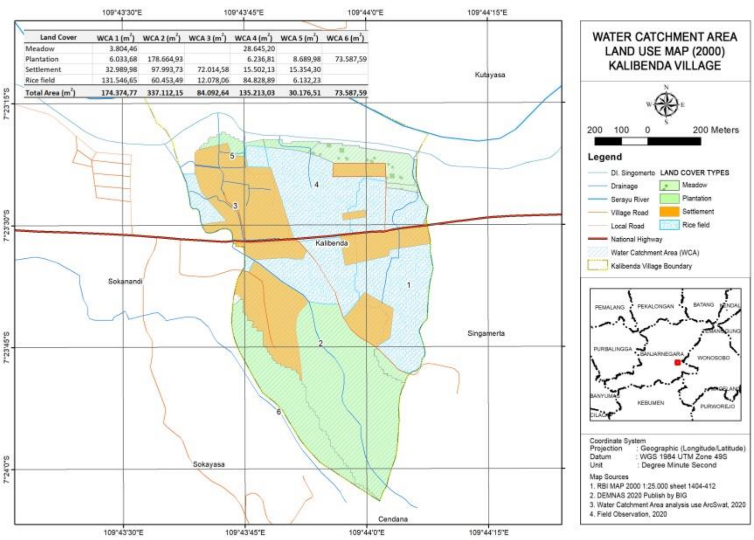


Figure 5. Map of land cover in water catchment areas in Kalibenda Village in 2000

Based on Figure 4, Figure 5, and the information that has been obtained before the comparison of the runoff discharge for each surface water catchment area in 2021 and 2000 at present as follows:

Table 4. Comparison of runoff discharge in 2021 and 2000

Year	Runoff Discharge (m^3/s)						
	WCA1	WCA2	WCA3	WCA4	WCA5	WCA6	Total
2021	1.297	3.213	1.007	1.264	0.309	0.637	7.727
2000	0.932	3.013	0.974	0.716	0.294	0.637	6.565
Difference	**0.365**	**0.200**	**0.033**	**0.548**	**0.015**	**0.000**	**1.162**

Table 4 shows that the WCA2 produces the most significant surface runoff discharge rate in 2021 or 2020, with 3.213 m^3/s and 3.013 m^3/s. WCA5 has the lowest surface runoff discharge rate of 0.309 m^3/s in 2021 and 0.294 m^3/s in 2000. In total discharge runoff in the catchment area number in the Kalibenda Village in 2021 amounted to 7.727 m^3/s, while in 2000, it was 6.565 m^3/s. An increased discharge of runoff in 2021 compared to 2000 amounted to 1.162 m^3/s.

3.4. Discussion

Based on the results of the calculation of surface runoff discharge in 2021 and 2000, it has been found that there has been an increase in surface runoff discharge in Kalibenda Village. When viewed in more detail in Table 4, it is found that the increase in runoff discharge occurred in all water catchments numbers except in WCA6, where there was no change in land use. Changes in land-use change the runoff coefficient value; the peak runoff discharge is higher, and the time of occurrence is faster because the land surface is more impermeable (Kamiana, 2018). The environmental impact analysis study results on the planned hotel and waterpark development related to runoff water in WCA1 show an estimated 8.77% increase in runoff from conditions in 2021 (PT. Cipta Kreasi Wisata, 2021). It is estimated that surface runoff in WCA1 will be 1.411 m^3/sec. With the construction of a Hotel and Waterpark in Kalibenda Village, it is possible to trigger regional development so that changes in land use can increase runoff in the future.

How to determine the impact of land-use changes on surface runoff by comparing the percentage of land use and runoff for each water catchment area in the year under study presented in Table 5.

Table 5. Comparison of p ersentase land cover and surface streams each catchment area

Year	Comparison Parameters	WCA1	WCA2	WCA3	WCA4	WCA5	WCA6	Total WCA
2000	Meadow	2.18%			21.19%			3.89%
	Plantation	3.46%	53.00%		4.61%	28.80%	100.00%	32.74%
	Settlement	18.92%	29.07%	85.64%	11.46%	50.88%		28.02%
	rice field	75.44%	17.93%	14.36%	62.74%	20.32%		35.35%
	Surface flow	24.71%	41.33%	53.54%	24.49%	45.10%	40.00%	36.38%
2021	Meadow	39.87%			55.88%	28.07%		18.40%
	Plantation	25.93%	71.09%	23.25%		20.99%	100.00%	46.05%
	Settlement	15.40%	25.12%	76.75%	44.12%	50.95%		30.09%
	rice field	18.81%	3.79%					5.46%
	Surface flow	34.39%	44.08%	55.35%	43.24%	47.38%	40.00%	42.81%

In total, there has been a decrease in rice field cover in 2000 (35.35%) to 5.46% in 2021. On the other side, in 2021 has been an increase in different types of land cover. Thus, it can be stated that there has been a change in rice field cover of -29.89%. This change is more significant than the study conducted by Ramadhan et al. (2016) in landslide-prone areas in Banjarnegara Regency with changes in rice field cover of -10.4% during the period 2001-2015. The percentage of rice field cover in the studied area is much lower than the 2014 land use analysis results of 16.18% (Bahri, 2015).

The relationship between land-use changes and increased runoff described as follows:

1. WCA1; in 2000, the highest percentage of land cover was Rice fields (75.44%). In 2021 there has been a land cover change from rice fields to meadow grass (39.87%) and plantations (25.93%). In 2021 rice field land cover on WCA1 has been reduced to 18.81%. The land cover changes have provided an increase in surface runoff from 24.71 % to 34.39% or an increase by 9.69%. The waterpark and hotel development plan is located in this area (PT. Cipta Kreasi Wisata, 2021). There may be changes in higher runoff discharge in the future.
2. WCA2; Has occurred changes of plantations land cover increased from 53.00% in 2000 to 71.09% in 2021. On the other side appears rice field land cover reduction from 17.93% in 2000 to 3.79% in 2021. In this area has built a public gas station and a plywood industry. The land cover change provides a change of surface runoff from 41.33% in 2000 to 44.08% in 2021 or by 2.75%.
3. WCA3; There has been a land cover change from rice fields to plantations. Changes in surface runoff of WCA 3 from 53.54% in 2000 to 55.35% or increased by 1.81%. Although the increase in the percentage of runoff in 2021 is not significant, the rate of runoff in this WCA3 is the highest compared to other catchments area numbers.
4. WCA4; there has been a significant change in land cover where plantations and rice fields have become meadow grass and development land or settlements. In 2000, the most considerable land cover in this area was rice fields (62.74%), while in 2021, the land became settlement (44.12%) and meadow grass (55.88%). The most visible developments in WCA4 are industrial, shopping centers, and modern residences. Most of the meadow grassland cover in WCA4 has been included in the residential development project, which until 2021, has not yet been built. Land cover changes on this WCA4 provide surface runoff changes from 24.49% in 2000 to 43.24% in 2021, an increase of 18.75%.
5. WCA5; has land cover change from rice fields to meadow grass. Rice field land cover types in 2000, at 20.32%, were transformed into a football arena identified as meadow grass in 2021. The land cover change provided runoff discharge changes from 45.10% in 2000 to 47.38% in 2021, increasing 2.29%.
6. WCA6; there is no change of land cover type in WCA6. The runoff discharge in 2021 is relatively unchanged from 2000.

There has been a total change in surface runoff from 36.38% in 2000 to 42.81 % in 2021. There is an increase of 6.44%. Considering the elevation profile analysis from the Google Earth Program in Figure 3, WCA1, WCA2, and WCA6 become the upstream water catchment areas and have a higher role in the infiltration of water into the water ground. WCA3, WCA4, and WCA5 are downstream areas with reasonably high development. Even in WCA4, the entire area is a residential development area because the land cover has been included in the modern residential development project.

4. Conclusion

Kalibenda Village can be divided into 6 (six) catchment area numbers. There has been a change in the magnitude of surface runoff caused by changes in land use during 2000-2021. The results of the surface runoff analysis show an increase of 6.44% in 2021 compared to 2000 due to changes in land use in Kalibenda Village. The most significant runoff discharge change occurs in WCA4 caused by industrial, shopping centers, and settlement or residence developments. In WCA1, the increase in runoff will appear in the coming year with the construction of Hotels and Waterparks. The results of this study are limited to the analysis of changes in surface runoff due to changes in land use with the development in Kalibenda Village, which has been quite significant in recent years. Further studies related to control runoff discharge need to be conducted as input for stakeholders in better environmental management policies.

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