Analysis of The Potential for Surface Runoff on Land Use Changes in Leuwi Padjadjaran II Reservoir Using the Cook Method

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Abstract. The micro watershed area of the Leuwi Padjadjaran II reservoir has undergone land use changes, and the analysis about land use changes is carried out based on 2011 map and 2021 map of land use. Changes occur as a result of increasing open and closed land at the same time, and changes in research land use can have an impact on the hydrological cycle. The surface runoff value is one of the hydrological cycles studied in this research. The purpose of this research was to determine the presentage surface runoff in 2011 and 2021 based on land use change. The runoff value was calculate using the Cook method. Cook's method has four different factors, such as topography, soil infiltration, surface storage, and land cover vegetation. Based on the results of research conducted, it was found that the micro watershed area of the Leuwi Padjadjaran II reservoir experienced an increase in land use change and resulted in the predicted value of surface runoff increasing in 2021 when compared to 2011, which had a lower predictive value of surface runoff . The runoff prediction in the micro watershed area of the Leuwi Padjadjaran II are 66,3% from water discharge in 2011 and 66,8% from water discharge in 2021 which has an increase in runoff prediction of 0,5%.

Keywords: Cook's Method, Land Use Change, Micro Watershed Area, Runoff

1 Introduction

Watershed is a land area bounded by mountain ridges that collect and store rainwater to then drain it to the sea through the main river[1]. Increased growth can have an impact on the use of land use in a watershed, with an increase in population that can lead to land use and utilization in various activities and can cause changes in land cover or land use change [2]. Proper water management is needed to reduce excess or runoff water. Runoff water generated from rainfall needs to be collected to become water storage or reserves [3]. Within the watershed, there are water structures that are used as rainwater reservoirs to minimize the potential for excess water.

The construction of reservoirs in the Unpad Jatinangor Campus area is a step taken in dealing with the problem of water availability. The soil texture in the Jatinangor Campus Unpad Catchment Area is clay, based on Kamilan's research [4], Jatinangor Campus Unpad has good potential in the construction of rainwater harvesting ponds

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with a total area of 60,1 ha or 16,9% of the total area of Jatinangor Campus Unpad Catchment Area with a good location for rainwater harvesting in dryland agricultural areas. The construction of Leuwi Padjadjaran Reservoir is the first step in controlling water availability problems. Leuwi Padjadjaran Reservoir was built with the aim of water conservation [5]. Small reservoirs can be used as a solution to accommodate water because small reservoirs can increase the water holding capacity in the micro watershed [6].

Still, the reservoir has different catchment area characteristics in various aspects such as land cover, slope and others[7]. Land use change in the watershed can affect the hydrological conditions of the watershed such as erosion, land degradation, flooding and result in a decrease in land quality and potential productivity of land in the area, either naturally or caused by human intervention, so that land cannot be used optimally and sustainable [8]. Runoff occurs due to the intensity of the rain that falls beyond the infiltration capacity, when the infiltration rate is met, the water will fill the basins on the soil surface [1]Excessive runoff conditions need to be resolved, namely with natural water harvesting areas owned by the watershed and artificial harvesting areas, one of which is a small reservoir. Runoff occurs due to the intensity of rain that falls exceeding infiltration capacity, when the infiltration rate is met, the water will fill the basin on the ground surface. Runoff water can be divided into two, namely sheet and rill surface runoff, but if the flow has entered the waterway system or river, it is called stream flow runoff [9].

On previous research, [10] identified the Cikeruh watershed experiencing land use changes. Between 1983-2002, the Cikeruh watershed experienced changes in land use, namely a decrease in the area of paddy fields by 20,51%, forest land by 9,75%, grass bushes 2,79%, and mooring 1,21%. Reduced land area due to changes in land use into urban, sub-urban, industrial, and open land areas. The land change tends to increase. Land use changes in the Cikeruh watershed affect the micro watershed area of the Leuwi Padjadjaran reservoir, because the catchment area of the reservoir is inside the Cikeruh Watershed.

Padjadjaran University currently has two small reservoirs, one of which is the Leuwi Padjadjaran two small reservoir. Padjadjaran two small reservoir was built because water problems still occur in the amount of water reservoirs that have not been met where during the dry season the water runs dry and during the rainy season the water overflows which can cause flooding and landslides due to changes in land use. On previous research, [11] identified that changes in the runoff coefficient value are soil infiltration and vegetation cover. In order to maintain the hydrological function of the watershed, it is necessary to know the runoff coefficient value that occurs in the micro watershed area.

There are several ways to identify surface runoff including the SCS-CN, Hassing, U.S Forecast, Rational and Cook methods and other methods. The cook method is widely used to determine the coefficient of surface runoff because the cook method is easier to use in the field qualitatively by directly relating the physical properties of the soil including the determinants of the coefficient of surface runoff [12]. This research will be useful in determining the amount of surface runoff in the micro watershed of Leuwi Padjadjaran II Reservoir, Padjadjaran University, Sumedang Regency, West

Java. Surface runoff estimation can help in determining the required drainage capacity and evaluating the impact of land use change on surface runoff [13]

2 Material and Methods

2.1 Study Area

Leuwi Padjadjaran II is a small reservoir located in Padjadjaran University, Jatinangor, Sumedang Regency, Indonesia. The reservoir is a new reservoir that build after the government build highway above the campus. That land changes from field to highway must have and affect for that area. This leads to increase in the size of surface runoff area, which in turn affect the waterhsed's ability to store water and ultimately, transforms a large proportion of the rain that falls in the area into runoff. Hopefully that new reservoir can help that area from the affect of surface runoff because of land changes.

2.2 Data Analysis

Slope Gradient Calculation
The gradient of the slope is important in runoff and soil erosion. Runoff drops as the slope gradient increases, yet soil erosion rates increase, resulting in more acute soil erosion when the slope angle surpasses a threshold point[14]. Elevation data using some tools to get the value. As such, the slope variation in micro watershed Leuwi Padjadjaran II were categorized in three classes: 5-10%, 10-30% and >30%. Each class was assigned a score based on the criteria in the Cook method. The Slope was created using software ArcMap 10.8.1.

Drainage Density Calculation
A higher drainage density indicates a more developed channel system, leading to a larger contribution of surface runoff to stream discharge and a smaller contribution from baseflow[15]. The Drainage density was calculated using the equation below [16]:

$$DD = \frac{L}{A} \qquad (1)$$

Where:
DD = Drainage Density (km/km^2)
L = Stream Length (km)
A = Sub Watershed Area (km^2)

The Cook Method Was Used to Generate Runoff Coefficient Layers of Physical
The Cook method incorporates plant cover into runoff coefficients as part of the land use element. In a watershed, vegetation cover has a significant impact on runoff and infiltration[17]. The parameters are: slope maps, infiltration maps, drainage density

maps and land use maps [18]. These four maps were scored according to the requirements present in table 1 and then overlaid to produce and predicted runoff coefficient (C) in the watershed observed. There were two sets of land use maps, for the two years of 2011 and 2021; hence there were two runoff coefficients, one for each of 2011 and 2021.

Table 1. Parameter of Cook Method Analysis for Surface Runoff [19]

Parameter	Level, Score dan C (%)			
Relief/Slope	Steep (>30%) (C = 40%)	Hilly (10-30%) (C = 30%)	Bumpy (5-10%) (C = 20%)	Flat (0-5%) (C = 10%)
Density Drainage (km/km^2)	High (> 8) (C = 20%)	Moderate (3,2 – 8) (C = 15 %)	Low (1,6 – 3,2) (C = 10%)	Very Low (< 1,6) (C = 5%)
Soil Infiltration Capacity	No effective ground cover, thin soil layer (C = 20 %)	Low, smooth, clay (C = 15 %)	Medium, groggy (C = 10 %)	High, rough, sand (C = 5 %)
Vegetation/ Land Use	Open Land, Rare Vegetation (C = 20 %)	bad, moderate, non agriculture area, 10% Watershed area covered by vegetation (C = 15 %)	moderate to good, 50% watershed area covered by vegetation (C = 10 %)	Very Good, 90 % watershed area covered by vegetation (C = 5 %)

Calculation and Result Analysis

The Runoff calculation was estimated using on Cook method by examining the infiltration, vegetation, cover, slope, and drainage density [20]. The results were present in table maps and analysed using the descriptive qualitative method. The runoff coefficient change was depicted in maps.

3 Results

3.1 Slope

Cook's method is suitable for use because it has a better peak discharge estimation value than other methods[12]. Land use factors act as a barrier or accelerate surface runoff, depending on the condition of the land cover. The slope was calculated using the RBI (Rupa Bumi Indonesia) map. It is possible to utilize the Slope tool in Arc Map, which is part of the Spatial Analyst extension. The Slope tool determines the steepness of a raster surface at each cell. A third-order finite difference estimator is used to compute the slope value[21]. The results were classified into four classes according to the slope classification in the Cook method. The coefficient value of flat slope (0-5%) is 10%, slope (5-10%) is 20%, slope (10-30%) is 30% and slope (> 30%) is 40%.

Topography, especially the shape and slope of the slope, affects the length of time rainwater flows through the land surface to the river and the intensity of flooding[22]. Steeper and longer slopes will increase surface flow velocity and surface water volume so that objects or soil particles will be lifted more and more[23]. The difference in slope is due to the different elevations in the Leuwi Padjadjaran II Catchment Area. This slope information can then be included in the classification for % C in the Cook method so that the coefficient value in the Leuwi Padjadjaran II Catchment Area can be known.

Based on the results of slope data processing with the National DEM source classified by the cook method, the Leuwi Padjadjaran II Catchment Area is dominated by slopes with a slope classification of 82.68% with a steep classification (>30%), and 15.68% with a hilly classification (10-30%). The area with wavy classification (5-10%) is the smallest area with a percentage of 0.64% and the (Catchment Area) Leuwi Padjadjaran II reservoir area does not have land with flat calcification.

The slope values in the Leuwi Padjadjaran II Catchment Area have coefficient values of 20%, 30% and 40%, the runoff coefficient of 40% dominates with the largest area distribution in the Leuwi Padjadjaran II Catchment Area with a percentage of by 82.68%. Based on the classification, it can be determined that the Leuwi Padjadjaran II Catchment Area is dominated by the steep slope class, with a large runoff coefficient percentage value of 40%, based on the results of the overlay map of the runoff coefficient weight according to the slope has a large surface runoff coefficient, with the largest land use dominated by fields, mixed crops and forests.

3.2 Infiltration

Soil infiltration rate is influenced by soil type and texture[24]. Infiltration rate is defined as the ability of soil to absorb water into and retain it[25]. The research area in the Micro Watershed Embung (Catchment Area) Leuwi Padjadjaran II has a slow soil infiltration rate. The value of the coefficient classification in the region has a value of 15% or later. Slow soil infiltration in the study area does not have a bad impact on the amount of surface runoff that occurs, because the research area is more than 50% covered by forest land, paddy fields and mixed crops, so that the runoff that occurs does not have a bad impact on the research area. The slow rate of soil infiltration can be conserved by cultivating the soil with vegetative, chemical, or mechanical conservation.

3.3 Drainage Density

The surface storage value uses a flow density approach which is the ratio between the total length of the river and the area of the region[26]. Surface water storage is one of the parameters in determining the coefficient of surface runoff. Flow density is a surrogate variable for surface deposits. Flow density aims to provide information related to surface water storage. Based on the results of data processing obtained from the RBI map with the help of Google Earth Images in July 2021, the overall length of the river in the Leuwi Padjadjaran II Micro Watershed (Catchment Area) is 2.745 km with an area of 93,99 Ha or 0,9399 km^2 Micro Watershed Reservoir, can be generated for a flow density value of 2.9205 km/km^2 and is included in the flow density class, the flow pattern is quite good, the water flows smoothly, with a C value of 15%.

3.4 Land Use in 2011 and 2021

Land Use in 2011

The Leuwi Padjadjaran II Micro Watershed (Catchment Area) is located in the Sumedang Regency area and is only a few kilometers from the city of Bandung, causing the distribution of land use types in the Leuwi Padjadjaran II Micro Waterhsed (Catchment Area) to vary widely. Based by the classification of the Cook method, the land use area of the Leuwi Padjadjaran II Micro Watershed (Catchment Area) in 2011 can be described with the coefficient value for land with closed vegetation, a C value of 5% with an area of 14,09% of the total land area, for land with medium/good vegetation the C coefficient value is 10% with an area of 32,05% of the total land area, for bad/less covered land the C coefficient value is 15% with an area of 42.01% of the total land area, for open/poor land the value is coefficient C of 20% with an area of 11,81% of the total area.

Land Use in 2021

Based on the classification of the Cook method, the land use area of the Leuwi Padjadjaran II Micro Watershed (Catchment Area) in 2021 can be described with the coefficient value for land with closed vegetation, a C value of 5% with an area of 21,5% of the total land area, for land with vegetation. medium/good the C coefficient value is 10% with an area of 22,64% of the total land area, for bad/less closed land the C coefficient value is 15% with an area of 30,02% of the total land area, for open/poor land the coefficient value is C by 20% with an area of 25,83% of the total area. Based on the results per land cover vegetation classification, poor/less covered land dominates the research area. These results show that in 2021 there will be an increase in open and poor land, where if the total land area exceeds > 50%, the open land will increase due to the construction of toll roads.

4 Discussion

Land Use Change in 2011 and 2021

Land use Change presented in Table 2. below shows that each type of land use in the Leuwi Padjadjaran II (Catchment Area) has changed, either increasing or decreasing land area. The type of land use that experienced the highest decline based on the Cook method classification was found in medium-good vegetation with a change of 42%, in addition to poor-moderate vegetated land it decreased by 40%, while the highest increase in land use occurred in open land with an increase in land change by 54,2%, in addition to other vegetation that experienced an increase in changes was closed vegetation by 34.4%. The increase in open land use changes occurred due to the conversion of land functions in the research area, such as toll roads which were previously farm areas. Land use change may have a substantial impact on runoff because it affects the features of the land surface, reducing its ability to absorb water and determining the quantity of runoff that reaches streams and rivers[27].

Table 2. Land Use Change in 2011 and 2021

Vegetation Cover	C %	2011		2021		Change Score	
		Area (Ha)	%	Area (Ha)	%	Area (Ha)	%
Open Land	20%	11,12	11,83	24,28	25,83	13,16	54,201
Bad - Moderate	15%	39,49	42,02	28,22	30,02	-11,27	-39,936
Moderate - Good	10%	30,13	32,06	21,28	22,64	-8,85	- 41,588
Close Land	5%	13,25	14,10	20,21	21,50	6,96	34,4384
Total		93,99	100,00	93,99	100,00		

Runoff Change in 2011 and 2021

The results that have been obtained from the comparison 2 different years and with 4 factors that are owned the runoff coefficient value (C) as a whole, namely the runoff coefficient (C) in 2011 of 0,663 or equal to 66,3% of the total rainfall which will be runoff water and in 2021 the runoff coefficient (C) obtained is 0.668 or equal to 66,8% of the total rainfall that will become runoff water. There is a change in the runoff coefficient value of 0,005 or 0,5% of the total rainfall which will become runoff. The value of the runoff coefficient (C) changes due to land use factors. In detail, the table of Analysis of the Runoff Coefficient Value (C) in 2011 and 2021 in the Leuwi Padjadjaran II (Catchment Area) is presented in the table 3. Based on the table 3. The change in the runoff coefficient value that occurs is bigger in 2021 compared to 2011, based on the runoff coefficient factor (C), land use affects changes that occur in the research area, where if the land use used from time-to-time changes, then the runoff coefficient value will also change, land with open vegetation will give a greater runoff coefficient (C), while land with closed vegetation will decrease the runoff coefficient (C) on the land used. Based on the 4 factors of surface runoff analysis (C) using the Cook method, the runoff value that has the greatest influence is the slope or relief, in 2011 around 57,66% of 100% of the runoff coefficient value is influenced by slope, and in 2021 around 57,21% of 100% of the runoff coefficient value is influenced by the slope factor, so based on the Cook method, the slope will have a greater impact.

Based on the results of research, runoff water that becomes surface runoff (C) in 2011 is predicted to be 70,5% and in 2021 the predicted value (C) in the study area is 71% with a total land area of 93,99 ha or 0,9399 km^2. The use of the Cook method in research in the Micro Watershed (Catchment Area) Leuwi Padjadjaran II provides a simpler approach, but the use of the cook method can give a large runoff coefficient (C) at large rainfall intensity. According to the results of interviews with farmers who were in the research area, the change in land use did not have too great a negative impact on the Leuwi Padjadjaran II micro-watershed reservoir (Catchment Area) research. Land use that is used as forest, mixed cropping, paddy fields, mixed cropping and other vegetated land helps the reservoir micro-watershed land with a large runoff coefficient flow value, so that land changes that occur in the study area do not have too large an impact, but when dry season in 2021 the water will dry up a little faster when compared to 2011 resulting in a change in the use of closed land or into open land.

Table 3. Change Coefficient Runoff Between 2011 and 2021

Factor	**Factor Condition**	**C%**	**C**	
			2011	**2021**
Slope	Flat	10	0	0
	Bumpy	20	0,001	0,001
	Hilly	30	0,05	0,05
	Steep	40	0,331	0,331
Soil Infiltration	High	5	0	0
	Normal	10	0	0
	Low	15	0,15	0,15
	Very Low	20	0	0
Drainage Density	Ekstrem, No Puddle	20	0	0
	Good System	15	0,005	0,005
	Normal	10	0	0
	Bad Drainage	5	0	0
Vegetation Cover	Extrem	20	0,024	0,052
	High	15	0,063	0,045
	Moderate	10	0,032	0,023
	Very Low	5	0,007	0,011
Total			0,663	0,668

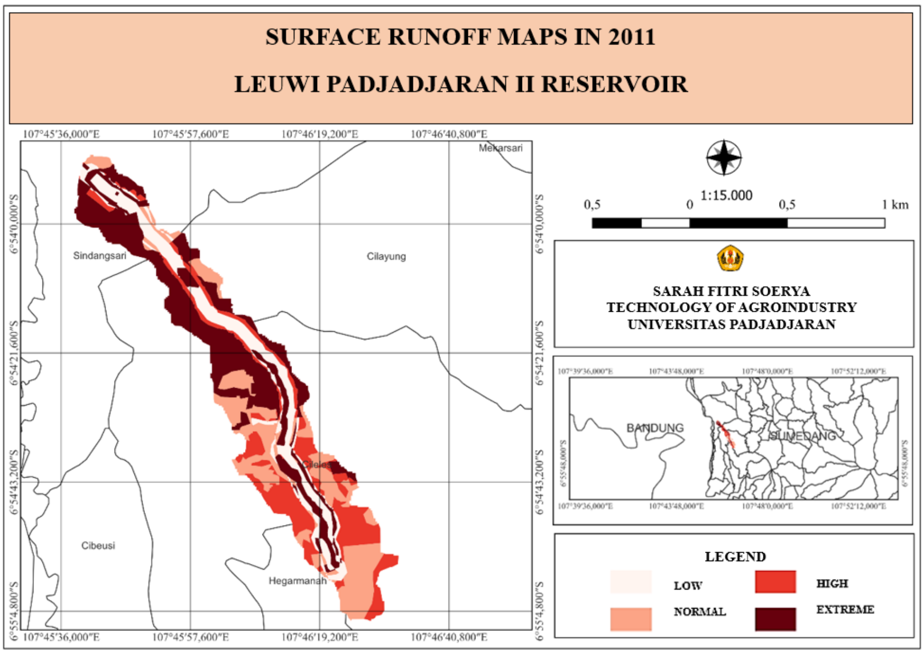

Figure 1. Embung Leuwi Padjadjaran Reservoir Runoff Analysis in 2021

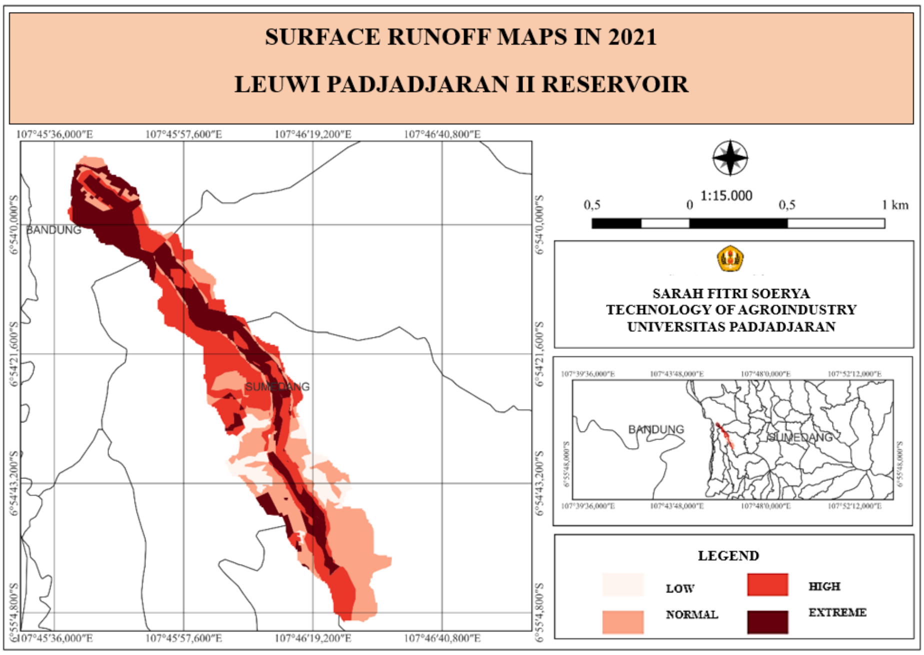

Figure 2. Embung Leuwi Padjadjaran Reservoir Runoff Analysis in 2011

Increased runoff in catchment areas can have a variety of negative repercussions, including as floods, water quality impacts, erosion, and changes to the natural hydrological cycle [28].Understanding the effects of runoff change on catchment areas is crucial for managing water resources and mitigating potential negative impacts on the environment and human activities[29]. there are several measures that can be taken to mitigate the effects of increased runoff in catchment areas such as increasing infiltration and evapotranspiration, retaining rainwater, reducing impervious surfaces, improving soil health and managing land use[30] [31].

5 Conclucion

The conclusions that can be drawn from this research are:
Analysis of the coefficient of surface runoff on land use changes in the Leuwi Padjadjaran II (Catchment Area) with a comparison in 2011 and 2021 and the use of the Cook method is 66,3% from water discharge in 2011 and 66,8% from water discharge in 2021 of the total rainfall which will become runoff water with an increase in % runoff coefficient of 0,5%. Land use such as forest, mixed cropping, paddy fields, mixed cropping, and other vegetated land helps the reservoir micro-watershed land with a high runoff coefficient flow value, so that land changes in the study area have little impact, but during the dry season in 2021, the water will dry up a little faster than in 2011, resulting in a change in the use of closed land or open land.

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