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# Estimation of Surface Runoff to Support Flood Hazards Early Warning Using Landsat 8 OLI Imagery

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*Abstract* - **This study aims to determine the estimated surface runoff in the Diro sub-watershed in Kulon Progo Regency using OLI Landsat 8 imagery. Landsat images are used to determine the type of land cover which is one of the watershed characteristics. The method used to determine the surface runoff coefficient value in the Diro sub-watershed was using the cook's method. The parameters used to determine the value of surface runoff include vegetation density, flow density, soil type and slope. The results showed that the sub-watershed Diro has a surface coefficient value of 0.7999 and is in the high category.**

***Keywords— Surface runoff, flood hazard early warning, landsat 8 OLI, Diro Sub-Watershed***

## I. INTRODUCTION

Runoff is one of the hydrological cycles and also the results from the movement of the water that comes from various sources, such as agricultural systems, industry, environment, and ecological systems. An overflow cycle will produce a surface runoff [1]. Rainwater that drops to the earth surface flows in various ways, for example surface runoff which is shown by the appearance of the watershed. Watershed is a system that consists of natural resources, such as flora, fauna, and environmental elements which occupy a certain ecosystem with human activities [2]. A watershed can be said as a complex river that is connected in an interconnected system to form an outlet or a certain path [3]. The position of the watershed as a planning unit makes the existence of the watershed affect the sustainability of the ecosystem in the environment [4].

The fieldwork is one of the sub-watersheds in Kulon Progo Regency, namely the Diro sub-watershed which is a sub-watershed of the Progo watershed. As one of the Progo Watersheds, the existence of the Diro Sub-watershed is important to support the sustainability of ecosystems in the region. There are many changes in the conditions of the sub-watershed due to several reasons, such as changes in land use can cause hydrological damage to the sub-watershed. Diro watershed is one area that has potential surface runoff due to hydrological activity in it. The flow formed in the Diro sub-watershed is influenced by human activities, for example such as land use change. The changes of land functions is an activity of change or transformation carried out in an area, especially land from one function to another [5]. Land functions can be changed in more than one time of the land use because of changes in land use. This land use change can cause several impacts including negative impacts so it is important to do research on surface runoff to determine the surface runoff in the study area.

Sub-watershed is part of a natural system that is used as a planning unit which can be used for analysis. The analysis is used for hydrological activities that support the development of the Diro sub-watershed in the future. Example of the use of sub-watershed is as an early warning against the flood hazard. Runoff is a flood condition where the main source of flood is surface runoff. According to Hoyt and Langbein (1939) [6], there are many factors that influence flood, namely rainfall intensity, topography, and soil characteristics. These various factors encourage the formation of runoff flood conditions as one of the serious disasters and require treatment and mitigation. In addition, runoff floods are floods that are difficult to predict so that it is necessary to develop methods in the analysis of flood hazard management [7]. Early warning of the danger of runoff floods is carried out as an effort to prevent or minimize runoff flooding that occurs due to the amount of surface runoff in an area. This study aims to determine the



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estimated surface runoff contained in the Diro sub-watershed using raster data sourced from Landsat 8 OLI imagery. The research involved analysis of remote sensing imagery and Geographic Information Systems (GIS) to obtain information related to surface runoff.

## II. MATERIALS AND METHODS

### *A. Study Area*

Diro Sub watershed (Fig.1) is located in Kulon Progo districts, Indonesia and a part of progo watershed. The Diro sub-watershed at the topography of the watershed is dominated by hills with steep slopes.


Fig.1. Study area the Diro Sub-watershed.

### *B. Cook's Method*

The runoff coefficient is a number that shows the ratio between surface runoff and rainfall causes [8]. There are many methods that can be used to calculate the surface runoff coefficient, one of which uses the Cook's method. The cook's method is widely used in calculating surface runoff coefficients because the parameters used are able to determine the effect of land conditions and their use on the hydrological response and determine the appropriate conservation measures from the hydrological aspect [9].

### *C. Materials*

The parameters used in the Cook's method consist of slope data, soil infiltration, vegetation cover, and flow density. Data acquisition is divided into two, namely primary data and secondary data. The primary data were collected in the field survey for obtaining vegetation cover data. The secondary data were collected from satellite images (Landsat 8 OLI), Digital Elevation Model (DEM) to reduce slope, soil type data to reduce soil infiltration and flow data to reduce flow density. Each parameter was scored according to its characteristics as in Tables I, II, III and IV.

The Diro sub-watershed has two types of soils, namely andisol and alfisol soils. Andisol soil is a land that has a very high binding capacity, always saturated with vegetation, very loose but has a low degree of structural resistance so it is easy to process, and has a moderate level of infiltration [10]. Alfisol soils are generally located in areas that have formed marginal soils and have a slow infiltration rate.

The percentage of vegetation density score is determined by looking at the vegetation conditions in the image. The classification of vegetation cover was carried out on Landsat 8 OLI images using vegetation index. Vegetation index is used to find the relationship between pixel values and vegetation cover density. This study uses NDVI as a vegetation index. To obtain the actual vegetation cover, vegetation density measurements were taken using a sample and a regression was performed to obtain the actual state of the vegetation cover.

Table I. Slope.

| Slope | Configuration Relief | Score |
|---|---|---|
| 0 – 5 % | Flat (Datar) | 10 |
| 5 – 10 % | Corrugated (Bergelombang) | 20 |
| 10 – 30 % | Hills (Perbukitan) | 30 |
| > 30 % | Rough Terrain (Medan Terjal dan Kasar) | 40 |

Source: Gunawan, 1991[11]

Table II. Soil infiltration.

| Infiltration Level | Characteristics of Field | Scores |
|---|---|---|
| Fast | Deep sand or other soil that is able to absorb faster | 10 |
| Medium | clay with infiltration is about the same type as prairie land | 20 |
| Slow | Clay / other soil material with low infiltration capacity | 30 |
| Very Slow (ignored) | No effective soil cover, thin layer | 40 |

Source: Gunawan, 1991

Table III. Vegetation cover.

| Landcover | Vegetation cover | Score |
|---|---|---|
| Forests, Mangroves, Plantations | 90 % covered either, by timber or the like | 5 |
| Shrub Bush | About 50 % is covered both by trees and grasses | 10 |
| Irrigated fields | Cover crops are small, no agricultural crops and natural cover is little | 15 |
| Farm / pond, river, built up land, open land | There is no effective or similar cover | 20 |

Source: Gunawan, 1991

The flow density score is determined using the formula:

$$D_{Sub\ DAS} = \frac{\sum L_{Sub\ DAS}}{A_{Sub\ DAS}} \qquad (1)$$

*Information:*
$D_{Sub\ DAS}$ = density per unit of land (miles / miles)
$\Sigma L_{Sub}$ DAS = Amount of flow length per land unit (miles)
$A_{Sub}$ DAS = Area of land unit ($mil^2$)

Table IV. Flow density.

| Criteria | Surface Deposit | Score |
|---|---|---|
| High | < 1 | 3 |
| Normal | 1-2 | 10 |
| Low | 2-5 | 15 |
| Ignored | 5 | 20 |

Source: Gunawan, 1991

All parameters are given a score and can be count by adding all of the parameters score to get the total score. To get a C value, we need a weighting factor for each unit of land (pixel based). The weighting factor can be obtained by the formula:

$$F = A_{Sub}\ DAS/A \quad (2)$$

*Information:*
F = Weighting factor for each unit of land
$A_{Sub}$ DAS = Land area
A = watershed area

The formula used to determine the mean watershed coefficient:

$$C = F\ x \sum S \quad (3)$$

*Information:*
C = Flow coefficient resulting from the Cook method estimation
F = Weighting factor for each unit of land
ΣS = Total score

Related to the problem of flood hazard, the surface runoff coefficient or often abbreviated as C becomes important to know. This C value is one of the indicators to assess if a watershed is experiencing physical disturbance or not. In another sense the value of C is a watershed response to rainfall, which is getting closer to number 1 means that more rainwater becomes runoff water or shows the condition of the watershed getting disturbed [12].

## III. RESULTS AND DISCUSSION

### *A. Analysis of Surface Runoff Potential Parameters*

#### *A1. Topographic parameters*

Topography reflects the height of the area from sea level (*dpal*), length, and slope at certain stretches of land. In this study, the topography of the area is grouped into 4 classes, namely flat (0-5 %), bumpy (5-10 %), hills (10- 30 %), and steep terrain (> 30 %) with their respective digits/ weightings. The magnitude of the scale indicates the size of the effect of the slope on the surface runoff. The more steep the slope means that it will have a greater value which will also cause the runoff coefficient value to be greater. The steep and hilly terrain class dominates the slope of the Diro Sub-watershed (Fig. 2).

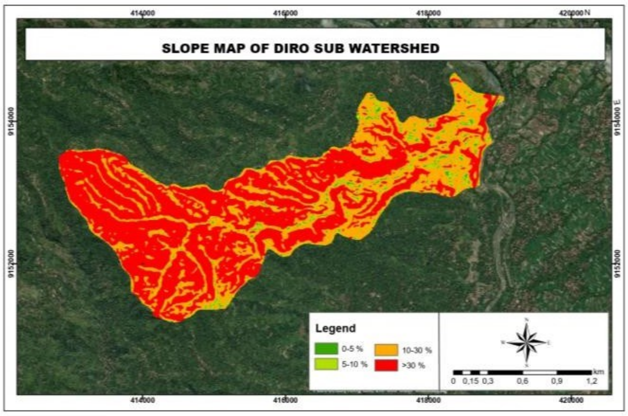


Fig. 2. Slope map.

#### *A2. Soil type parameter*

The parameter of soil type in determining runoff coefficient is the parameter that decides if the water becomes runoff or not. The response of physical properties to water qualitatively ranges from easy-seep to hard-seep into the soil. Water that is easily absorbed will produce surface water that is smaller than the water that is difficult to seep. Based on the soil texture in each soil type (Fig. 3), andisol soils have a higher infiltration rate than alfisol so andisol are able to absorb water better. Water that seeps into the soil will reduce the formation of surface runoff. In surface runoff studies, locations with andisol soils have a faster rate of infiltration so water flowing on the surface move more quickly seeps into the soil.

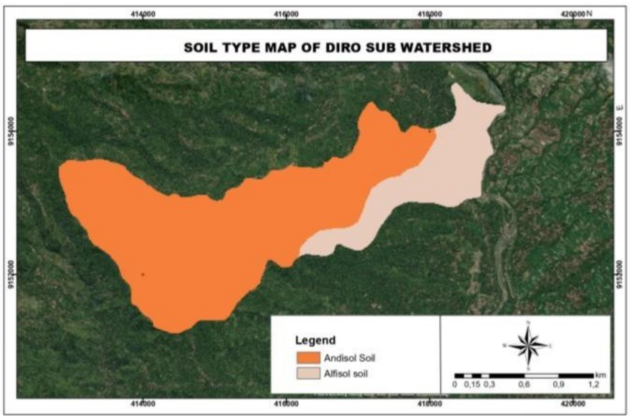


Fig. 3. Soil type map.

#### *A3. Vegetation density parameter*

Areas that have high vegetation density have low scores. This is due to the presence of vegetation as land cover in an area affecting the flow of water that moves on the earth surface. Covered vegetation can intercept rainwater and reduce the energy of rain falling to the ground, thus giving the soil an opportunity to absorb water.

Based on field data, the majority of vegetation density in the study area was 50 % covered both by trees and grass (Fig. 4). There are several locations that have a class of 90 % wood, 25 % covered well, and no vegetation. Class locations are scattered in the study area but don't dominate the density of vegetation in the Diro Sub-watershed. Field results provide a correlation value of 0.7826 between field density and NDVI values which can be seen in Fig. 5.

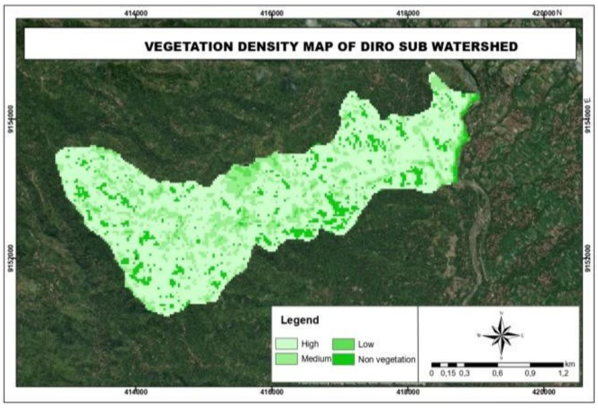


Fig. 4. Vegetation density map.

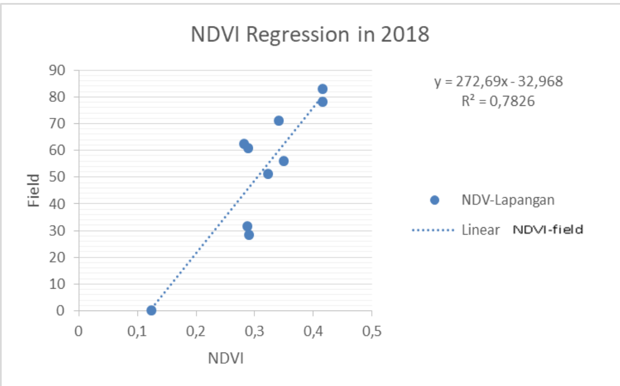


Fig. 5. Regression of NDVI.

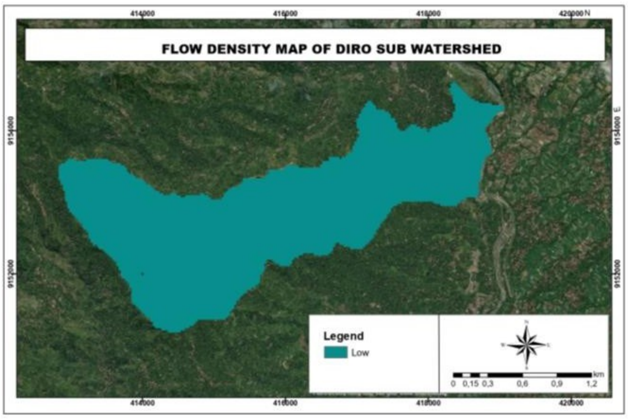


Fig. 6. Flow density map.

*A4. Flow density parameters*

Flow density is used to determine the surface storage area of the study (Fig. 6). The flow density is calculated using the river flow length per kilometer divided by the watershed area. Based on the calculation, the value of the flow density of the Diro Sub watershed is obtained:

| | |
|---|---|
| Total river length | : 36.622912 km |
| Sub-watershed area | : 9,729 $km^2$ |

Overall, it has a low density class, which is 3,764 km / $km^2$, causing the chance of water to be absorbed into the ground getting higher and the reduced surface storage.

*B. Analysis of Surface Runoff Coefficient*

The surface runoff coefficient value can be used as anindicator to determine the physical disturbance of the watershed. The higher the C value indicates most of the rainwater becomes runoff causing the threat of erosion. That higher C values can cause higher potential of flood may happen. The runoff coefficient is calculated using the cook method by adding all the parameters. The overall surface runoff coefficient in the sub-watershed is 0.79943364, which means that runoff occurs 79 % of the falling rainwater and 21 % stored in the soil. The results of this runoff value can be reviewed using the coefficient constituent parameters. Based on topography, the Diro sub-watershed is dominated by hills with 50 % vegetation well covered and has low flow density with smooth river body flow. Runoff coefficient obtained can be used as input for flood modelling in the study area. The existence of flood modelling can be obtained information related to making a zone of flood-prone areas, especially flood caused by runoff. One of the modeling of runoff flooding is by calculating the peak discharge.

## IV. CONCLUSION

Estimation of the surface runoff in Diro sub-watershed can be done by a certain method, such Cook's method and the help of the remote sensing application. Landsat 8 OLI is used to know the parameters that are used in Cook's method. Cook's method is used to estimate the surface runoff in the field area and has four parameters, which are topographic, soil type, vegetation density, and flow density. Topographic parameters show that most of the area is categorized as hills and rough terrains so it is given a high score. Soil type parameters show that there are 2 types of soils, namely andisols that have binding capacity and alfisols that have slow infiltration rate. Vegetation density parameter shows that most of the area is categorized as high vegetation density so it is given a low score. Flow density parameter shows that based on the calculation, the area has a good surface storage. Overall calculation in Diro sub-watershed has a surface runoff coefficient of 0.7999 based on the calculation of all of the parameters. That result is included as the high category. The surface runoff coefficient value can be used to support early warning of flood hazards, such as the flood modelling and modelling of the zone of flood-prone areas, especially when the flood is caused by the surface runoff or is categorized as a runoff flooding.

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