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Influence of Land Cover Type, Slope, and Soil Density of Surface Runoff

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Abstract— *One of the factors that caused flooding in Indonesia and in the world is the amount of surface runoff. And in this study, it will examine surface runoff with variations in land cover type, slope of land, and soil density using laboratory methods. Based on the results of the study, it can be seen that the effect of land cover variation on surface runoff is 75%. The variation of land slope has an effect on surface runoff with R2 maximum of 0.9643 or 96.43% and R2 minimum of 0.25 or 25%. Then, it was found that the cover of mini elephant grass land in each experiment had lower discharge compared to the cover of Japanese grass land and soil in seconds to 360. This indicates that the cover of mini elephant grass land can minimize surface runoff and can be used as a reference for grass use in a region.*

Keywords— *Hydrograph, land slope, surface runoff, rainfall simulator, land cover type.*

I. INTRODUCTION

The hydrological process is a process that must be clearly understood to support optimal utilization and preservation. Land use that is not in accordance with its carrying capacity or ignores knowledge of soil and water conservation will be damaged due to surface runoff. Surface runoff occurs when the amount of rainfall exceeds the rate of infiltration of water into the soil. This condition is influenced by various things, including rain intensity, land characteristics, soil characteristics, land slope, and soil density. Factors that influence surface runoff are divided into two groups, meteorological elements and physical properties or characteristics of the drainage area (Sosrodarsono, 1978).

Based on the problems caused by surface runoff, a study of surface runoff was carried out based on several influencing parameters, such as variations in land cover type, land slope, and soil density. Rain intensity and soil characteristics are considered constant. This study models the relationship between land cover type, land slope, and soil density with the amount of surface runoff using the Rainfall Simulator.

II. LITERATURE STUDY

A. *Surface Runoff*

Runoff is the flow that occurs on the surface of the ground as a result of rain, and then flows by the influence of gravitational forces towards the lowest places such as channels and other water bodies.

B. *Hidrograf Method*

Hydrographs can be defined as the relationship between one element of flow and time. Based on this definition there are 2 types of hydrographs, water surface hydrograph and discharge hydrograph. The hydrograph is composed of two components, namely surface flow, which comes from the direct flow of rainwater, and the base flow. The base flow comes from ground water which generally does not provide a fast response to rain. Rain can also be considered divided into two components, namely effective rain, and losses. Effective rain is part of the rain that causes surface runoff. Rainfall is part of the evaporating rain, enters the soil moisture, and stores groundwater.

C. *Surface Runoff Coefficient*

Coefficient C is defined as the ratio between the peaks of the surface flow to the intensity of rain. This factor is the variable that most determines the results of the calculation of flood discharge. Choosing the right C price requires extensive hydrological experience. The main factors that affecting C are the rate of soil infiltration or percentage of watertight land, slope of land, cover crops, and rainfall intensity. Water-resistant surfaces, such as asphalt pavement and building roofs, can produce almost 100% flow after the surface gets wet.

D. *Time of Concentration*

Time of concentration of a watershed is the time needed by falling rain water to flow from the farthest point to the place where the watershed is released (control point) after the soil becomes saturated and depression - small depression is fulfilled. In this case it is assumed that if the duration of rain is equal to the time of concentration, then each part of the watershed simultaneously contributes to the flow of the control point. One method for estimating concentration time is a formula developed by Kirpich (1940), which can be written as follows:

$$tc = \left(\frac{0.87 \times L^2}{1000 \times S}\right)^{0.385}$$

Tc is the time of concentration in hours, L is the length of the main channel from upstream to drain in km, and the average slope of the main channel in m/m.

E. *Rain Intensity*

Rainfall intensity is the amount of rain in time units (mm/hour, mm/min, mm/sec). Length of rain time is how long

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the rain takes time. Duration of rain is how long rainfall takes time in minutes or hours. In this case it can represent the total rainfall or shortened rainy period with relatively similar rainfall (Asdak, 1995). Rain intensity is interpreted as a measurement of rainfall carried out to determine the amount and duration of rainfall (Utomo, 1993).

F. *Effect of Plant Types on Surface Flow*

According to Wudianto (2000). The influence of plant species on surface flow is very dependent on several factors including:

- Plant growth rates.
- Plant height.
- The condition of plant leaves.
- Plant density.
- Root system.

Plants can reduce flow energy, increase soil roughness, thereby reducing the speed of surface flow and then cutting the surface flow ability to release and transport sedimentary particles. Rooting plants increases soil strength, granularity and porosity.

III. REVIEW OF LITERATURE

Zulvyah (2013) conducted a study of the effect of variations in rain intensity and slope on vegetated soils on surface runoff. Zulvyah (2013) concludes that based on the results and discussion, it is known that the relationship between the two parameters, such as rainfall intensity and slope to the surface runoff rate, the intensity of rainfall and slope proportional to the amount of surface flow rate. The results of the Zulvyah (2013) study can be used as a reinforcement of the basic theory of research for several conditions that can affect surface runoff.

Mukarso (2005) conducted a study of the effect of the spread of rain on the concentration time on several land conditions, deforested land and vegetation land. Mukarso (2005) concluded that in general, the land covered by vegetation has a tc greater than tc on deforested land. The results of the Mukarso (2005) study can be used as a reinforcement of the basic theory of research for several conditions that can affect surface runoff.

Ziliwu (2002) conducted a study of the effect of several types of plants on surface flow and erosion. Some types plants that used; without plants, soybeans, peanuts, elephant grass, upland rice, tumpeng sari. Ziliwu (2002) concluded that the greater the growth of plants, the greater the function of catching rainwater grains so that kinetic energy is absorbed by plants, thereby reducing the occurrence of surface flow and soil erosion. Ziliwu (2002) can be used as rationale for making variations in land cover in this study.

IV. RESEARCH METHODOLOGY

This research was carried out at the Hydraulics and Coastal Laboratory of the Department of Civil Engineering, Faculty of Civil Engineering, Environment and Earth Sciences, Ten November Institute of Technology, using the Rainfall Simulator tool.

A. *Preliminary Studies and Literature Studies*

A preliminary survey was conducted to identify tools and materials that could support the research. Whereas, the literature study conducted was to obtain references that were in accordance with the research. References obtained contain solutions that have been made related to research. The literature study is conducted by looking for material from various books, journals and other sources that can support the research.

B. *Land Slope*

In this study using 3 variations of land slope, slope of 2.5°, 5°, and 7.5°. The slope affects the speed and volume of surface runoff. Basically more steeper the slope, slope percentage will get higher, the faster the runoff rate will get.

C. *Determination of Land Cover Type Variations*

For land cover types in this study using soil and grass. And for variations in type of land cover it uses 2 different types of grass, namely mini elephant grass and Japanese grass.

D. *Soil Testing*

Soil testing was carried out by testing the weight of the wet soil content, moisture content test, soil granular analysis test, and porosity test.

E. *Calibration Tool*

Before conducting the experiment, Rainfall Simulator was calibrated first. The calibration is done to get more valid data. The calibration steps are as follows:

1. The main tank is filled with water with a specified volume to facilitate the calibration to be performed.
2. After that the faucet is set in one position.
3. Then the time taken by the Rainfall Simulator is observed to spend the specified volume of water so that the volume and time are obtained.
4. From the existing data obtained the intensity of rainfall or the desired inflow volume.

F. *Running Model*

After all the tools are ready to use, the next step is to run the model. Running this research model will be carried out with 3 slope variations, 3 variations in land cover, and 2 variations in soil density. The research steps are as follows:

1. Adjust the slope of the land according to the variation of the slope of the land to be tested, namely 2.5°, 5°, and 7.5°.
2. Determine and make a plot of land cover on the land that has been prepared.
3. Regulate soil density.
4. Set the pump discharge to determine the intensity of the rain according to what will be observed in liters/minute.
5. The Rainfall Simulator tool is turned on by setting the inflow faucet according to the specified intensity.
6. Turn on the stopwatch since the tool starts operating until the discharge from the outlet reaches zero or near zero.
7. Measure the height of the water on the piezometer.
8. Measure at intervals of time.
9. Wait until the changes are consistent in certain numbers.

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10. Runoff will reach a constant when the concentration time has been reached. If these conditions have been reached, artificial rain can be stopped and show a balance between rain, discharge and loss of infiltrated water
11. After the data is obtained the engine is turned off.
12. Conduct experiments from point 1 to 13 for different land variations and slopes.

V. Determination of Land Density

In this study also used 2 variations in soil density. Soil compaction is done by pounding. For the first density, 2 rounds of collision are carried out. Obtained γd as follows:
1. At a slope of 2.5° with an average value of 1,227 kg/cm^3.
2. At a slope of 5° with an average value of 1,170 kg/cm^3.
3. At a slope of 7.5° with an average value of 1,133 kg/cm^3.

And for the average γd of the overall slope is 1.177 kg/cm^3. For the second compaction, collisions are carried out in 4 turns. And obtained γd as follows:
1. At a slope of 2.5° with an average value of 1,308 kg/cm^3.
2. At a slope of 5° with an average value of 1,243 kg/cm^3.
3. At a slope of 7.5° with an average value of 1,214 kg/cm^3.

And for the average γd of the overall slope is 1.255 kg/cm^3.

VI. Infiltration

In this study also carried out measurements and observations of the infiltration process that occurs in each soil condition. Infiltration observation is carried out by observing groundwater fluctuations using piezometers in the Rainfall Simulator tool.

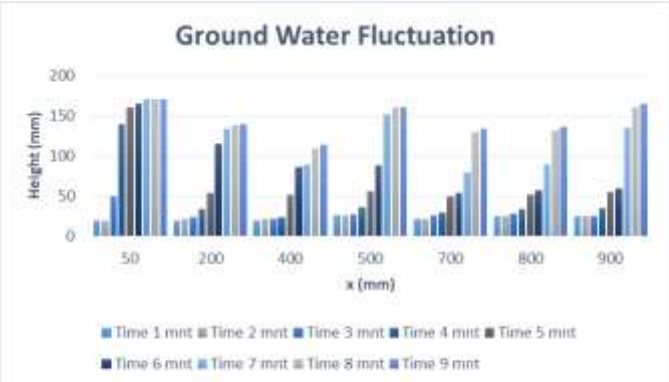

Fig. 1. Groundwater Level Fluctuation Graph in Mini Elephant Grass Slope 2.5˚ Density 1.177 kg/cm^3

The increases of groundwater level occur in the 3rd minute until the 9th minute. At point 1 is the highest increase among the other points. This is because the position of point 1 is in the downstream so that rainwater absorbed into the ground is rainwater that falls directly into the downstream and rainwater that flows from upstream to downstream. Groundwater fluctuations are influenced by land cover, land slope and soil density. In this experiment it has a varied graphical form due to the cover of mini elephant grass land. In addition to the influential slope, the cover of grass land also influences hold water from falling so that it does not immediately overflow and decreases to be absorbed into the soil. Therefore, for each point it has almost the same height, especially points 1, 4 and 7, which should be seen from the slope, the more upstream, the lower the groundwater level. And for point 3 which has the lowest groundwater level. According to the analysis, this is due to the very dense grass land cover and very dense soil conditions.

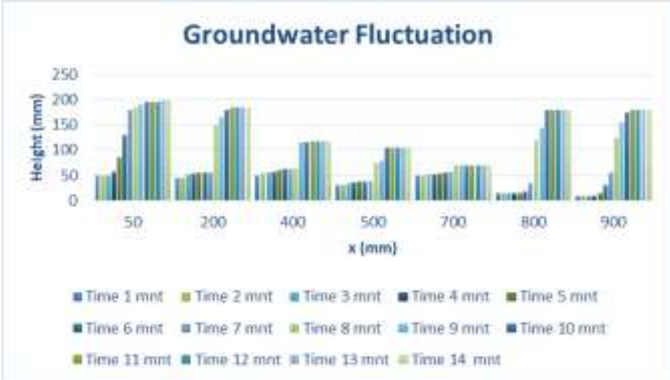

Fig. 2. Groundwater Level Fluctuation Graph in Japan Grass Slope 2.5˚ Density 1.177 kg/cm^3

The increase in ground water level occurs in the 2nd minute to the 14th minute. At point 1 is the highest increase among the other points. This is caused by land cover, land slope, and soil density. Point 1 is located downstream, so that rainwater that flows from upstream to downstream is absorbed into the ground first, and the rainwater that falls directly into the downstream is also held by the grass and absorbed into the soil. In this experiment it has a varied graphical form due to the cover of Japanese grass land. In addition to the influential slope, the cover of grass land also influences to hold rainwater from falling so that it does not immediately overflow and decreases to be absorbed into the soil. Therefore, for each point it has almost the same height, especially points 1, 2, 6, and 7, which should be seen from the slope, the more upstream, the lower the groundwater level. And the analysis results for point 5 which have the lowest groundwater level are due to very dense grassland cover and very dense soil conditions.

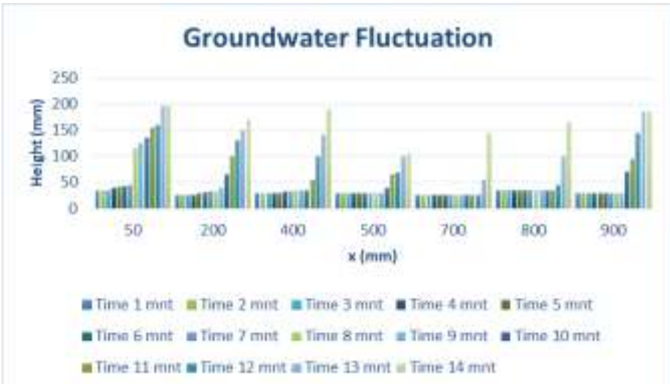

Fig. 3. Groundwater Level Fluctuation Graph in Soil Slope 2.5˚ Density 1.177 kg/cm^3

The increase in ground water level occurs in the 5th minute until the 13th minute. At point 1 the highest increase is among the other points. And point 7 has the lowest increase. This is because the position of point 1 is in the downstream so that rainwater absorbed into the ground is rainwater that falls directly into the downstream and rainwater that flows from upstream to downstream. It can be seen that the graph form decreases from point 1 to point 7, because in this experiment there is no cover of grass land, only using land. Therefore, for each point it has a decreasing altitude, the more upstream, the lower groundwater level will get. Rainwater that falls to downstream mostly flows towards downstream before it seeps into the ground.

VII. Analysis of Surface Runoff

This research uses inflow of 5 liters / minute or 0.083 liters / second. Based on these conditions, runoff was found and the runoff time began as follows:

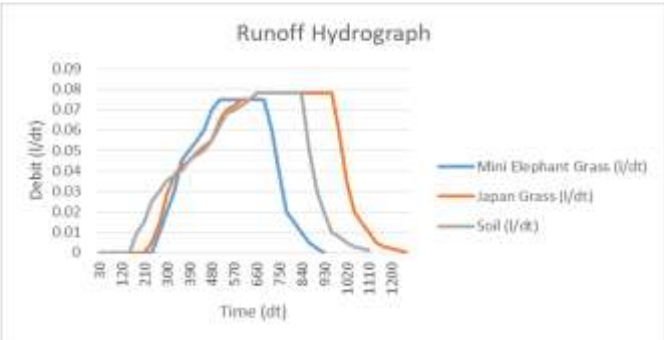

Fig. 4. Hydrograph of the Relationship of Land Cover to Runoff at a Slope of 2.5 ° and Density (1.) 1,177 kg / cm^3

In the hydrograph it can be seen that in experiments using mini elephant grass land cover has the lowest maximal discharge between Japanese grass land cover and 2.5° slope and density (γ) 1.177 kg/cm^3. In addition, for the time to start runoff in the use of mini elephant grass land cover and Japanese grass has a longer time compared to the soil. However, to achieve maximum discharge, mini elephant grass takes more time.

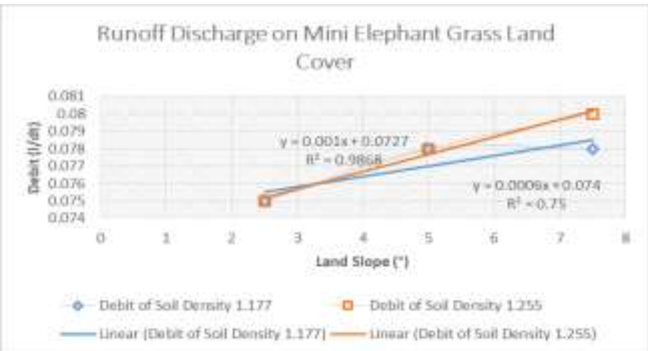

Fig. 5. Effect Chart of Slope Against Debit on Density of 1.177 kg / cm^3 and Density of 1.255 kg / cm^3 at Cover of Mini Elephant Grass Land

To get the equation as shown above, the cover of mini elephant grass land is determined with a density of 1,177 kg/cm^3 and a density of 1,255 kg/cm^3 and changing the slope. Based on the linear regression line approach, the equation is as follows:

1. $y = 0.0006x + 0.074$ dan $R^2 = 0.75$. It can be interpreted that 75% of the maximum discharge runoff is influenced by slope parameters and 25% is influenced by other parameters. This condition is due to the experiments using mini elephant grass land cover and density of 1.177 kg/cm^3 on a slope of 5° and 7.5° having the same maximum discharge rate.
2. $y = 0.001x + 0.0727$ dan $R^2 = 0.9868$. It can be interpreted that 98.68% of maximum runoff is affected by slope parameters and 1.32% is influenced by other parameters. It shows the effect of slope on the maximum discharge surface runoff on mini elephant grass land cover and density of 1255 kg/cm^3 is very influential because it has a very largeR^2.

VIII. Effectiveness of Land Cover Variations

TABLE I. The table results of runoff discharge in seconds to 360 based on variations in land cover

Name of Experiments	Time (Second)	Debit (l/sc)
G1a	360	0.05
G1b	360	0.05
J1a	360	0.045
J1b	360	0.06
T1a	360	0.045
T1b	360	0.05
G2a	360	0.05
G2b	360	0.05
J2a	360	0.055
J2b	360	0.06
T2a	360	0.065
T2b	360	0.058
G3a	360	0.05
G3b	360	0.055
J3a	360	0.057
J3b	360	0.07
T3a	360	0.065
T3b	360	0.077

It can be seen in the table above that the cover of mini elephant grass in each experiment has a low discharge compared to the cover of Japanese grass land and soil in seconds to 360. This shows that the cover of mini elephant grass land can minimize surface runoff and can be used as a reference in certain region. Even though the cover of Japanese grass land and land on a slope of 2.5° and a soil density of 1,177 kg/cm^3 has a low discharge of 0.045 l/sc. However, the results are not always low on land slope and other soil densities. In fact, the debit results tend to increase.

XI. Conclusions

Based on the results of calculations and analysis described in Chapter IV, it can be concluded that:

1. Based on the results of the study it can be seen that the effect of land cover variation on surface runoff is 75%. However, if the land has reached saturation, the maximum discharge in each type of land cover will produce almost the same value and close to the rain inflow. The variation of land slope has an influence on surface runoff with R2 maximum of

1 or 100% and minimum R2 of 0.75 or 75%. In each experiment in addition to variations in land cover and slope of the land that have a large influence, soil density also has an influence on surface runoff. In 25% the influence of other parameters is the effect of soil density.

2. Based on the results of the study it can be seen that the effect of land cover variation on the concentration time with R2 is a maximum of 0.9868 or 98.68% and the minimum R2 is 0.4286 or 42.86%. The variation of land slope has an influence on surface runoff with R2 maximum of 0.9643 or 96.43% and R2 minimum of 0.25 or 25%. When an experiment using mini elephant grass land cover occurs an error, the discharge time reaches the peak has a faster time compared to the cover of Japanese grass land and soil, because the soil used at the time of the experiment has high soil moisture, so it saturates faster. In each experiment in addition to variations in land cover and slope of the land that have a large influence, soil density also has an influence on the concentration time. About 57.14% in land cover and around 75% in land slope which means that the influence of other parameters is the effecting soil density.

3. The hydrograph produced in each experiment shows that mini elephant grass land cover has a low peak discharge and a long concentration time compared to the cover of Japanese grass land and soil. Then followed by Japanese grass, and then the soil. Because land does not have land cover such as grass, experiments using only land have higher peak discharge and faster concentration times. From the hydrograph it can also be concluded that the higher the slope the higher the discharge and the faster the concentration time. Likewise with soil density, the higher the density of the soil, the higher the discharge and the faster the concentration time. The maximum peak discharge is 0.082 l/sc in the soil experiment, slope of 7.5°, and density of 1.255 kg/cm^3 and minimum peak discharge is 0.075 l/sc in the experiment of mini elephant grass land cover, slope of 2.5°, and density of 1,177 kg/cm^3 and 1,255 kg/cm^3. For the shortest concentration time of 6.5 minutes in the Japanese grass cover and soil, 7.5° slope, and density of 1,255 kg/cm^3 and the longest concentration time of 11 minutes in the experiment of mini elephant grass land cover, slope of 5°, and density of 1,255 kg/cm^3.

4. From the results of the research that has been done, it can be seen that land cover variations have low runoff yields. To find out this, it can be done by looking at the runoff discharge values for each experiment at the same time. Then, it was found that the cover of mini elephant grass land in each experiment had a low discharge compared to the cover of Japanese grass land and soil in seconds to 360. This indicates that the cover of mini elephant grass land can minimize surface runoff and can be used as a reference to be used in a region.

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