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Effectiveness of Pine Stands in Control Surface Runoff

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Abstract

This study aims to determine the effectiveness of Pine stands in controlling surface runoff, as well as the relationship between rainfall, intensity and slope with the volume of surface runoff. This study was conducted from November 2016 to February 2017. The measurement of rainfall is done by using rainfall observatory on 40 rain events, measuring the volume of surface runoff at each rainfall event, on a plot measuring 22 m x 4 m. The runoff volume on the dense pine cover was 0.006 m3, smaller than the medium and rare pine cover, ie 0.015 m3 and 0.016 m3 respectively. This shows that pine stands can minimize the impact of rainfall, rainfall intensity, and slope on the amount of surface runoff.

Keywords: Pine; surface runoff; slope; rainfall; rain intensity.

1. Introduction

Indonesia as a tropical country, during the rainy season often occurs natural disasters such as floods and landslides, this happens every year in parts of Sumatra, Java and Sulawesi. The loss of material, life, and damage to the ecosystem is inevitable. This is caused by the cover vegetation of the forest continues to decrease. Both because of fires, illegal logging, and transfer of functions into agricultural land, plantations and mines.

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The loss of forest cover decreases the ability of forests to carry out their ecological functions so that they can have serious environmental impacts such as climate change, reduced biodiversity, water regulation, increased surface runoff resulting in erosion and flooding. Forests should be more valued as a soil protection and watershed management [12] and are considered most effective in maintaining land loss and controlling surface runoff [7].

Changes in land cover to forests will alter hydrological responses [12] and evapotranspiration changes, hence it will affect the output of water stores that determine the surface flow and storage of groundwater [2].

Reforestation of critical covered areas in high rainfall areas, is now the focus of attention of many countries including Indonesia. Forest and land rehabilitation should be undertaken, with a number of considerations, particularly regarding the suitability of species to the critical land. One of the most widely used tree species for reforestation is Pinus merkusii, with a number of advantages such as interception and high evapotranspiration, proven to reduce direct runoff, peak discharge and runoff coefficient in 37 year old pine forest [10]. Pine can also increase the moisture content of the soil. The older age of the pine stands the greater its ability to absorb water into the soil, because its roots are numerous and deep. The thick litter cover acts as a protector in maintaining the physical properties of the soil and is able to reduce the occurrence of surface runoff for the same rainfall event . It is also noted that pine forest litter will reduce erosion significantly [13].

Pine forests play a role as a water regulator because it can store water during the rainy season into the soil and supply it in the dry season. Accordingly, it is important to examine more deeply the effectiveness of pine stands in controlling surface runoff.

2. Material and Methods

2.1. Study Area

This research was conducted on pine forest located in Forest Education of Hasanuddin University, Maros Regency, South Sulawesi Province. Located at an altitude of 300-800 meters mean sea level. The average annual rainfall from 2007 to 2016 is 2,863.2 mm. The soil type is axisol and inseptisol.

That Pine forests are grown since 1970 which is the result of reforestation plant area of 291.13 ha. These stands are commonly found in the northern part that spread on lands with topographic conditions varying from wavy to very steep slopes.

2.2. Observation Plot Description

The research was carried out by measuring directly in the field, among others, rainfall per rain event, surface runoff, slope level, tree cover and bottom cover, litter thickness and surface area of pine tree to calculate percentage of crown cover in each observation plot .Rainfall data is obtained from the rainfall recorder placed in the open space around the observation plot. Surface runoff data were obtained from plots mounted beneath pine stands with three types of canopy cover differentiated over rare, moderate and bushy, on three distinct slope classes that were rather steep, steep and very steep. The size of each plot is 22m x 4m. The runoff container uses

3 containers of 50 liters each installed at the bottom of each plot. The surface runoff volume for each plot is calculated by summing the runoff volume accommodated in the runoff water catchment tanks.

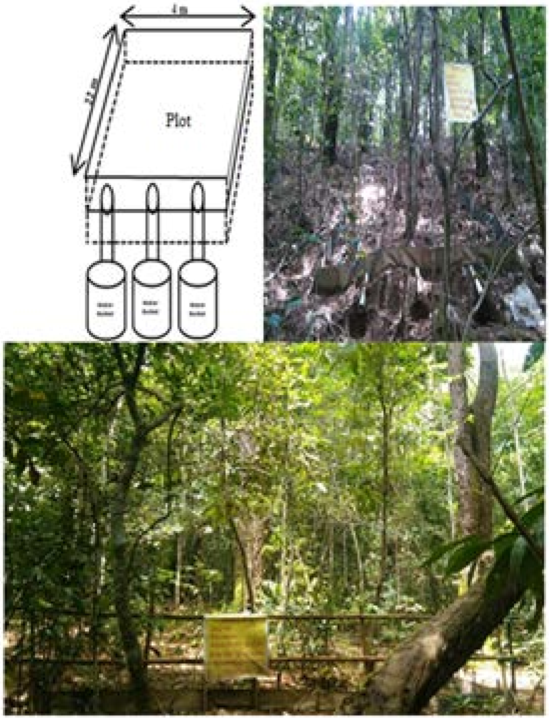

Figure1: Surface run off plot

2.3. Data Analysis

The surface runoff volume is obtained by observation every time the rains occur in cubic meters per rainfall event, per plot. The average number of surface runoff volumes is the total water stored in the three container shelters in each plot and then divided into three, calculated immediately after the event of rain. Rainfall is also measured every rain event in mellimeter unit.The percentage of pine canopy cover per plot was obtained by first calculating the area of the pine tree heading using the formula πr2 in units (cm2).

Where r is the radius. The r value is obtained from ½ times the crown diameter or (D/2), D is the crown diameter. How to calculate the crown diameter by defining a point as the center of the canopy on the ground, from that point drawn lines to the north, south, east and west to the crown edge drops.

The average length of the line is the same as the crown diameter. After obtaining the surface area of headings per plot then calculated the percentage of cover per plot area with 3 categories of coverage of the cover is rare, medium and dense.Data were analyzed by using regression analysis, to know the relationship of rainfall, slope and pine stand as independent variable with surface runoff volume as dependent variable.

3. Result and Discussion

3.1. Result

Table 1: Table coefficient of regression analysis

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	-0,002	0,003		-0,514	0,608
Rainfall	0,006	0,000	0,683	15,747	0,000
Slope	0,003	0,001	0,193	4,520	0,000
Pine Cover	-0,005	0,001	-0,197	-4,628	0,000
Rain intensity	0,002	0,001	0,092	2,114	0,036

a. Dependent Variable: Volume of Surface Runoff

Table 1 shows the significance value for rainfall, slope, closure and rainfall intensity variables is very small ($P < 0.05$). It means that the independent variables of rainfall, slope, pine cover and rainfall intensity have a significant relationship with surface runoff volume. The alleged regression equation is:

$$Y = -0{,}002 + 0{,}006\,X1 + 0{,}003\,X2 - 0{,}005\,X3 + 0{,}002\,X4$$

The variable regression coefficient of X1 is 0.006 indicates that if it is assumed that other independent variables are constant, then an increase of one rainfall unit (mm) will cause an increase in surface runoff volume of 0.006 m3.The regression coefficient of variable X2 of 0.003 indicates that if it is assumed that other independent variables are constant, then an increase of one unit of slope will cause an increase in surface runoff volume of 0.003 m3.The coefficient of X3 variable regression of -0.005 indicates that if other independent variables are constant, then an increase of one unit of closure will cause a decrease in surface runoff volume of 0.005m3. The extent of surface runoff is closely related to land cover conditions or land use forms. Surface runoff on forest-covered lands will be smaller than non-forest land use which tends to result in higher surface runoff [6].The regression coefficient of variable X4 of 0.002 y means that if it is assumed that other independent variables are constant, then an increase of one unit of rainfall intensity (mm / h) will cause an increase in surface runoff volume of 0.002 m3Based on the results of regression analysis using stepwise method can be explained that rainfall, rainfall intensity and slope correlated positively with the amount of surface runoff. Meanwhile, the closure is negatively correlated with the volume of surface runoff. This means that the cover of pine stands can decrease the amount of rainwater that will flow above the soil surface.

Table 2: Duncan test result of rainfall relationship with surface runoff volume

Rainfall	Surface runoff volume	
	1	2
Very light	0,004	
Moderate	0,008	
Light	0,008	
heavy		0,022
Very heavy		0,027

Duncan test results show that the average lowest runoff volume of 0.004 m3 occurs in very low rainfall and the highest in very heavy rainfall of 0.027 m3.

Table 3: Duncan Test Result of Rainfall Intensity relationshipwith surface runoff volume

Rain Intensity	Surface runoff volume (m^3)	
	1	2
Light	0,006	
Very heavy	0,007	
Moderate		0,015
Heavy		0,018

Duncan test results showed that on the light intensity of light rainfall obtained the average of the lowest surface runoff volume of 0.006 m3 and the highest of 0.018 m3 occurred in heavy rainfall intensity.

Table 4: Correlation between the slope to the surface runoff volume

Slope	Surface runoff volume (m^3)		
	1	2	3
Steep	0,008		
Rather steep		0,012	
Very steep			0,019

Duncan test results showed that there is a significant difference in the average volume of runoff on the slopes rather steep, steep and very steep.

Table 5: Correlation between pine cover with surface runoff volume in Tukey's test

Pine Cover	Volume of survace runoff (m^3)	
	1	2
Dense	0,006	
Medium		0,015
Rare		0,016

Duncan test results show that dense coverage pine obtain smallest of surface runoff ie 0,006 m3, while rare coverage pine obtained average surface runoff ie 0,016 m^3.

3.2. Discussion

3.2.1. Correlation between rainfall and rain intensity to surface runoff volume

Rainfall and intensity significantly affected the surface runoff volume at $P < 0.05$. The amount of runoff depends on rainfall and rainfall intensity [9,10]. The more rainfall the more rain that will fall to the soil surface and then will become the flow of the surface.

Similarly, with high rainfall intensity the surface runoff from the forest base is also high [4]. Because the soil pores are saturated with rain water causing high surface runoff volumes.

3.2.2. Correlation between Slope to Surface Runoff Volume

Hilly land or slopes are considered most susceptible to surface runoff [5]. The higher slopes cause the volume of water to fall more and more of which will become surface runoff. If slope buckling is greater then flow coefficient and carrying capacity increases, soil stability and slope stability decreases. Table 4 shows more high slope will increase average surface runoff volume. The same result is stated by [1] that the length and slope of the slope have a significant influence on the runoff volume. In addition, the increase in slope length can lead to increased runoff volume. Therefore it can be explained that there is a linear relationship between surface runoff volume, slope length and slope it self.

In addition, the effect of slope to runoff volume is also highly dependent on rainfall and intensity [4]. The result of variance analysis shows that there is interaction between rainfall with slope (see table 2) that is significant at level $P < 0{,}05$. In addition, Table 5 shows the average difference in runoff volume for each slope class. Where the average highest runoff volume on the slopes is very steep and the lowest occurs on steep slopes. This is because on the steep slopes there is an influential vegetation factor so that the average value of the runoff volume is lower than on the steeper slope.

3.2.3. Effect of Pine Cover on Surface Runoff Volume

Table 5 shows dense pine cover obtained surface runoff volume was $0{,}006 m^3$, smaller than rare and medium pine cover. Surface flow is difficult in forest lands that have dense cover due to the magnitude of interception, evaporation, transpiration and percolation. Forest stands, therefore, are considered effective for reducing surface runoff, although on steep slopes.

Results above show that on very steep slope obtain smaller volume of surface runoff was 0,007905 than rather steep, see table 4 of runoff volume on each slope, this is because the vegetation structure is more complex and the layered strata are stratified. The highest canopy layer is Pinus merkusii, second layer is Alstonia scholaris, third layer Cinnamomon Sp and Sapindaceae. This complex vegetation can suppress the influence of the slopes. The canopy layers can minimize rainwater particles falling on each layer so that before it reaches the soil surface, the rainwater particles will evaporate again. Forest vegetation can cut raindrops so that they do not fall to the earth and allow for direct evaporation of leaves, twigs that will not increase the amount of water flowing above the soil surface.

In general surface runoff will increase with increasing slope and slope length. The longer slopes tends more and more surface water that accumulates, so that the surface becomes higher runoff depth and speed. However, this factor does not have a significant effect on the extent of surface runoff when the cover is thick. Conversely, if the closure is rare (see Table 4), the runoff remains high even on a sloping slopes [4].

Pine has many advantages such as from the shape of the needle leaf and canopy berdusun so as to minimize rain grains. The grains are smaller before they reach the surface of the soil, the rain particles will evaporate back into the atmosphere. Because of the high interception and evapotranspiration in the pine forest catchment areas, it has the lowest annual average flow [3]. The rate of rainwater evaporation through interception by pine forest is several times more than the value of transpiration, when rain occurs, the intercepted proportions of leaves and stem surfaces are between 10% and 20% in hardwoody plants [15].

Pine also has a lot of litter. Lid cover acts as a protective layer to maintain the physical properties of the soil. Layers of litter and wood debris will increase the surface roughness of the soil, thus lowering the rate of surface runoff [9]. Litter thickness on the pine stand will add soil organic matter so as to reduce the bulk density and increase soil porosity so that the litter will significantly reduce surface runoff and also erosion [13]. High porosity soil, has a high infiltration capacity that will decrease the runoff volume [1]. Proven in this research location found infiltration under pine stand including fast. Namely 148 mm / h on slope> 40% (steep to very steep) and 200 mm / h on slope <40% (steeper slope).

The soil on pine stands infiltrate more water into the soil. According to [2] this is because the forest can stabilize the soil surface so that it will reduce surface runoff. The research of [8] during 4 years of observation that is starting the clearing of mixed forest cover, replanting until completely closed canopy, suggests that the conversion of mixed forest to pine forest with hauler logged harvesting system, annual water catchment reach 90 % is almost equal to the annual average yield on natural conditions of mixed forests. Can be explained that the pine stands can maintain and maintain the physical properties of the soil is not degraded due to harvesting.

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