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Surface Runoff Under Pine Stands on Slopes Below and Above 40%

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Abstract. The study aimed to analyze the effectiveness of pine stands in controlling surface runoff on land with a slope >40%, comparing surface runoff on slope >40% by slopes <40%. This research was conducted from November 2016 - March 2017. It was carried out under the Pine stands on UNHAS Education Forest in Maros Regency. Surface runoff measurements were carried out by installing plots measuring 22 x 4 m on slopes <40% and >40% respectively for 3 replications. The bottom of the plot is installed with 3 pieces of 50 liter capacity storage. Observation of surface runoff is taken every time of rain, as many as 39 times rain. The average surface runoff volume (m³/plot) is obtained by summing the volume collected in 3 reservoirs. The results showed that the average surface runoff on slopes <40%, ie, 0.012 m³/plot and 0.014 m³/plot on slope >40%. The results of the difference test were 2 on average with a 95% confidence interval; there was no difference in the average runoff on slopes <40% and >40%. Regression analysis results show that canopy cover can control surface runoff.

1. Introduction

Deforestation of forests that continues to occur in Indonesia causes a decrease in the quality and quantity of land cover. In 1950 the Indonesian mainland was covered with primary and secondary forests including all types of plantations of 162 million ha. In 1985 the forest cover was 119 million ha. There was a decrease of 27 percent. When the government and the World Bank in 1999 collaborated to re-map, the average deforestation rate from 1985-1997 reached 1.7 million ha. During this period Sulawesi, Sumatra, and Kalimantan experienced the largest deforestation. Overall this area lost more than 20 percent of its forest cover. Indonesia is a country that has the fastest rate of forest destruction, equivalent to 300 football fields every hour; this is recorded in the Guinness World Record book [1]. Indonesia is one of 10 countries that experience the fastest loss of tropical forests in the world [11].

The loss of forest cover has resulted in a decline in the ability of the forest to carry out its ecological functions [9]. This will have a serious impact on the environment. Among them are climate change, reduced biodiversity, availability of water resources, increased surface runoff which results in flooding.

The size of surface runoff is closely related to the condition of land cover or land use. States that surface runoff in non-forest land use forms is much higher and can even reach four times higher than surface runoff that occurs in forest cover land [8]. Changes in land cover to the forest will change the hydrological response [29], in addition to high evapotranspiration, forests will also infiltrate precipitation in more portions. Tree canopy (forest) can reduce the kinetic energy of rainwater that falls



to the surface of the soil, while tree roots can increase soil resistance to destructive power in the form of rainwater blows.

Aside from vegetation, the slope factor is also the cause of increased surface runoff [18]. If the slope buckling is greater, the flow coefficient and carrying capacity increase, soil stability and slope stability decrease [32]. The slope factor does not have a significant effect on the amount of surface runoff if the vegetation cover becomes more dominant [14].

The reality in the field shows that the rate of increase in critical land tends not to be offset by the success rate of forest development again, as a result of the high level of land needs for various interests. The fulfillment of the intended land needs makes the forest area its primary target, including protected forest areas. The area that should be maintained as a forest with its function as a regulator of water systems, prevention of erosion and flooding. This area according to the applicable provisions is on the slopes starting at 40%. However, on this slope, it has been penetrated to be converted into other uses such as plantations and industrial plantations. Starting from these problems, does the determination of a protected area starting from a 40% slope will continue to be a reference? Or will we be realistic enough to say that the establishment of protected forest areas needs to be reviewed? Given that the forest field on the 40% slope has run out.

Based on the answers to these questions, there is a need for data and information support that can prove whether there is a difference between runoff on land that has a slope below 40% and those above 40%. The data and information are not only affected by slope but also influenced by the closure. Therefore, further information is needed about the significance of differences in surface runoff levels in the two categories of the slope with the type of vegetation cover identified.

One type of forest cover that deserves consideration for this purpose is *Pinus merkusii*. This is based on the consideration that since the early 70s this type has been widely developed as a reforestation plant. Since the days of Dutch colonial rule, especially in Java. This species is noted to have the potential to control erosion and landslides because it has a high interception, deep roots, high evapotranspiration, binding to the soil, and the trees are not too heavy or light, and the main products which are not wood [6].

Starting from the description, further research is needed to explain the role of pines in reducing surface runoff. Specific research is specifically needed on lands that have slopes above 40%. This is based on the consideration that on lands which according to the applicable provisions should be managed as protected areas, pine trees are found, especially in the South Sulawesi region.

2. Material and Method

This research was conducted under the forest stands of *Pinus merkusii* located in the Hasanuddin University Educational Forest, Maros Regency, South Sulawesi Province. This location is located at an altitude of 300-800 meters above sea level. Total annual average rainfall from 2007 to 2016 was 2,863.2 mm.

The pine forest was planted since 1970 which is the result of reforestation covering 291.13 ha. This stand is generally found in the northern part which spreads on land with topographic conditions that vary from wavy to very steep slopes.

This research was conducted through measurements of rainfall, duration of rain, rain, volume, slope level, understory, litter thickness, canopy cover of each plot, and soil physical properties. Rain intensity is classified into 4, namely light (1-5mm / hour), medium (5-10mm / hour), heavy (10-20mm/ hour) and very thick (> 20mm / hour) [16,24].

Rainfall data is obtained from rainfall measurements placed in an open area around the observation plot. Observations were made of each rainfall event with a total of 39 rain events. The surface runoff measurement plot is placed on the slope of > 40% and <40% which is 22 m long and 4 m wide. The same plot length in the study conducted [20-22]. Surface runoff plots are installed on slopes between 15-30% for slope classes <40% and slopes between 45-75% for slope classes > 40% and 3 replications for each slope class.

The plot is made of tarpaulin made from rubber. To prevent the possible flow of water entering or exiting the plot, the plot boundary tarpaulin is immersed in the soil as deep as ± 5 cm, the height of the side of the tarpaulin is 20 cm. On the outer side of the test, plot is made a groove to direct the flow of water and prevent the possibility of entry of water into the test plot. Each plot is described as a percentage of canopy cover which is classified into 3 categories: rare (10% -40%), medium (41% -70%) and dense (> 70%) [17]. The surface runoff container uses 3 buckets of each plot with a capacity of 50 liters. The volume of surface runoff can be calculated by adding rainwater collected in the bucket of each plot. Surface runoff plots can be seen in Figure 1.



Figure 1. Surface runoff plot

2.1. Data Analysis

This study uses 2 analyzes, namely linear regression analysis to determine the relationship between rainfall intensity and pine canopy cover with surface runoff and Independent Samples T-Test to compare the average values of surface runoff on slopes below and above 40%.

Test the effect of rain intensity and closure on surface runoff using the following regression equation model;

$$Y = \beta_0 + \alpha_0 Z + \beta_1 INT - \beta_2 PNT + \alpha_1 Z.INT - \alpha_2 Z.PNT$$

Where;

Y = dependent variable (runoff and erosion)

β_0 = Constanta

Z = Dummy, using the number 0 for slopes <40%; 1 for slopes > 40%

β_1 = Coefficient variable independent of rain intensity

β_2 = Coefficient is the independent variable covering the header

α_0 = dummy coefficient variable

α_1 = dummy slope coefficient on rain intensity

α_2 = coefficient dummy slope against canopy cover.

3. Results and discussion

3.1. The relationship between Surface Runoff Volume and Rainfall Intensity and Closure on Slopes Below and Above 40%

The regression analysis of surface runoff volume with independent variables namely rainfall intensity, closure and slope using dummy variables are shown in Table 1.

Table 1. Regression analysis of the relationship between intensity, closure, and slope with surface runoff.

ANOVA ^a					
Model	Sum of Squares	df	Mean Square	F	Sig.
Regression	0,004	3	0,001	8,107	0,000 ^b
Residual	0,04	230	0,000		
Total	0,045	233			

a. Dependent Variable: surface runoff

b. Predictors: (Constant), cover, intensity, slope

The results of the regression analysis as shown in Table 1 that the intensity of rain, canopy cover and slope together have a significant relationship to surface runoff. Next in Table 2 shows the relationship of each independent variable with surface runoff.

Table 2. Regression analysis of the relationship of rainfall intensity, canopy cover, Z. intensity, Z. canopy cover with a surface runoff on slopes below and above 40%

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	0,014	0,005		2,874	0,004
Intensity	0,004	0,002	0,203	2,282	0,023
Canopy Cover	-0,005	0,002	-0,193	-3,073	0,002
Z.Intensity	0,001	0,002	0,087	0,443	0,658
Z.Canopy Cover	-0,0001	0,003	-0,006	-0,030	0,976

a. Dependent variable: Surface runoff

Remarks: Z = dummy slope

Regression analysis results in Table 2 show that rainfall intensity, the closure has a significant relationship with runoff, while other variables (Z. Intensity, Z. canopy cover) do not have a real relationship with surface runoff. The variables Z.INT and Z.PNT showed a coefficient value that was

not significant at 5% significance level, which means that the slope did not contribute to the effect of rain intensity and canopy cover of runoff on slopes above 40%. This happens because of the dominant vegetation factors [12].

The value of the regression coefficient variable of positive intensity is 0.004; that means that each increase in one unit of intensity will increase the surface runoff by 0.004 m³ / plot assuming other variables are of fixed value. The higher the intensity of the rain, the higher the surface runoff [4]. The regression coefficient value of the canopy cover variable is negative, which is -0.005; this means that each increase in one unit of canopy cover will decrease the surface runoff by 0.005 m³ / plot assuming other variables are of fixed value.

Based on the regression test of the equation in the method, it can be explained that the intensity of rain and canopy cover are significantly related to surface runoff on slopes below above 40%.

3.2. Effect of Rain Intensity on Surface Runoff

The relationship of rainfall intensity with the volume of surface runoff on slopes <40% and > 40% can be seen in Figure 2.

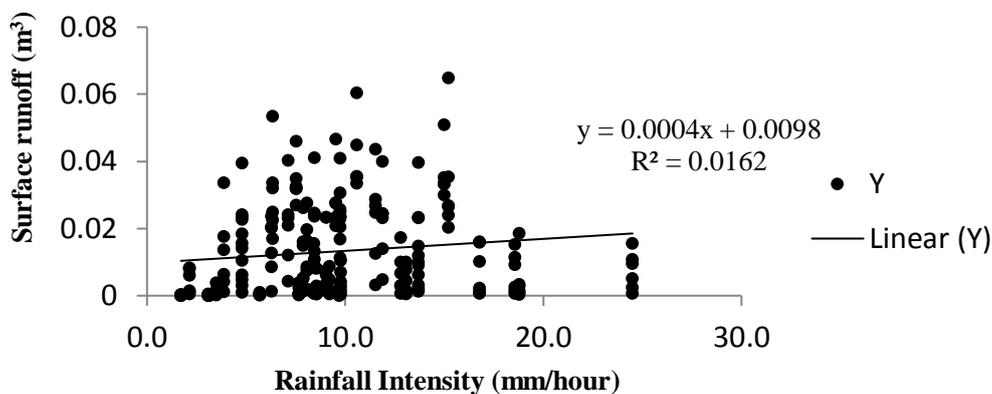


Figure 2. Graph of the relationship of intensity with a surface runoff on slopes <40% and > 40%

Figure 2 shows the relationship of rainfall intensity with surface runoff of 1.62% and the remaining 98.38% is another factor. This relationship shows that there is minimal influence on the amount of surface runoff. This happened because of the influence of thick pine canopy cover.

The results of further tests of the relationship of intensity with a surface runoff on slopes below and above 40% can be seen in Figure 3.

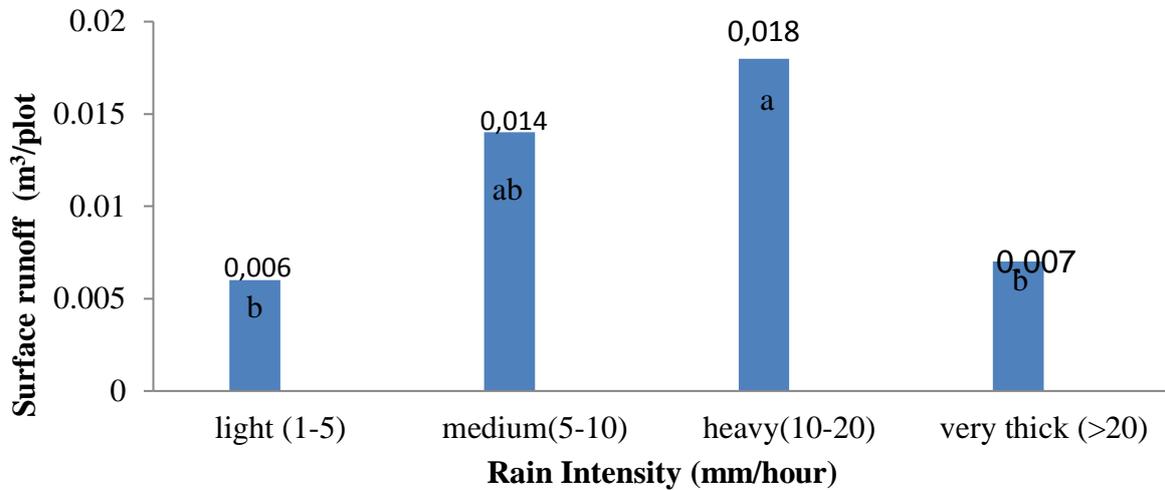


Figure 3. Graph of test results and the relationship of intensity with the runoff on slopes <40% and> 40%.

Figure 3 shows the highest volume of surface runoff occurring in the intensity of heavy rainfall that is 0.018 m³ / plot, not significantly different from the volume of surface runoff at moderate rainfall intensity which is 0.014 m³ / plot, and both are significantly different compared to the surface runoff volume at rain intensity. Thick and light, each of which produced a surface runoff volume of 0.007 m³/plot and 0.006 m³ / plot.

The intensity of the rain was very heavy in this study resulting in a small surface runoff volume compared to the intensity of heavy and medium rainfall, due to the shorter rainfall intensity and the meager amount of rainfall which is 9.8 mm. Intensity, amount and duration of rain greatly affect the magnitude of surface runoff [26]. The intensity of very heavy rain in a short time will not cause high surface runoff. Rainwater that falls above the surface of the soil almost all will penetrate into the soil through the soil pores. Conversely, if the amount of rainfall is high, there will be a high potential for surface runoff because rainwater will fill the soil pores until they are saturated. When the soil becomes saturated, rainwater will be more concentrated above the soil surface. The relationship of rainfall with surface runoff can be seen in Figure 4.

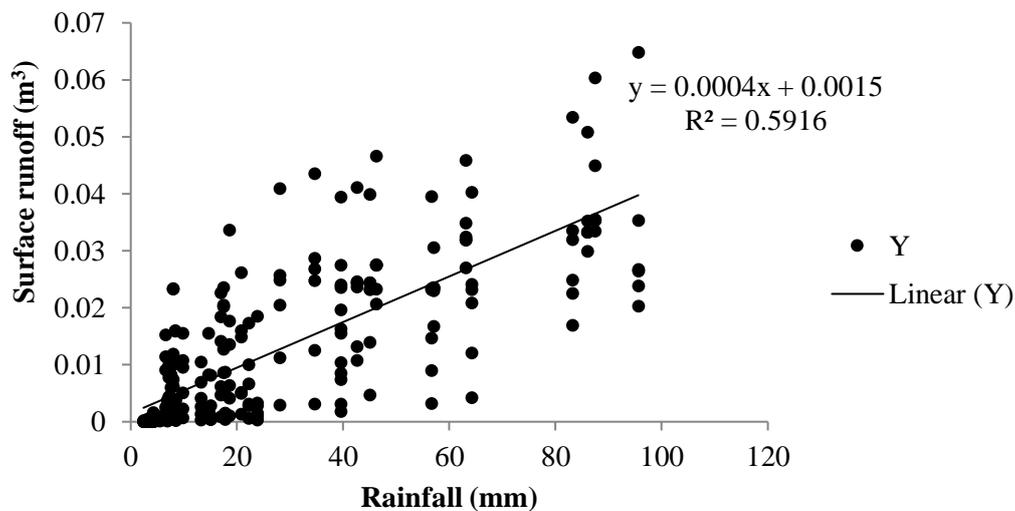


Figure 4. Graph of rainfall relations with the surface runoff on slopes <40% and> 40%

Figure 4 shows the influence of rainfall with surface runoff of 59.16% and the remaining 40.84% is another factor. The relationship between rainfall and surface runoff is linear, i.e. the higher the rainfall, the higher the surface runoff volume. Therefore, rainfall factors play an essential role in determining the amount of surface runoff [13].

3.3. Effect of Pine Stand on Surface

The relationship of canopy cover with the volume of surface runoff on slopes <40% and > 40% can be seen in Figure 4.

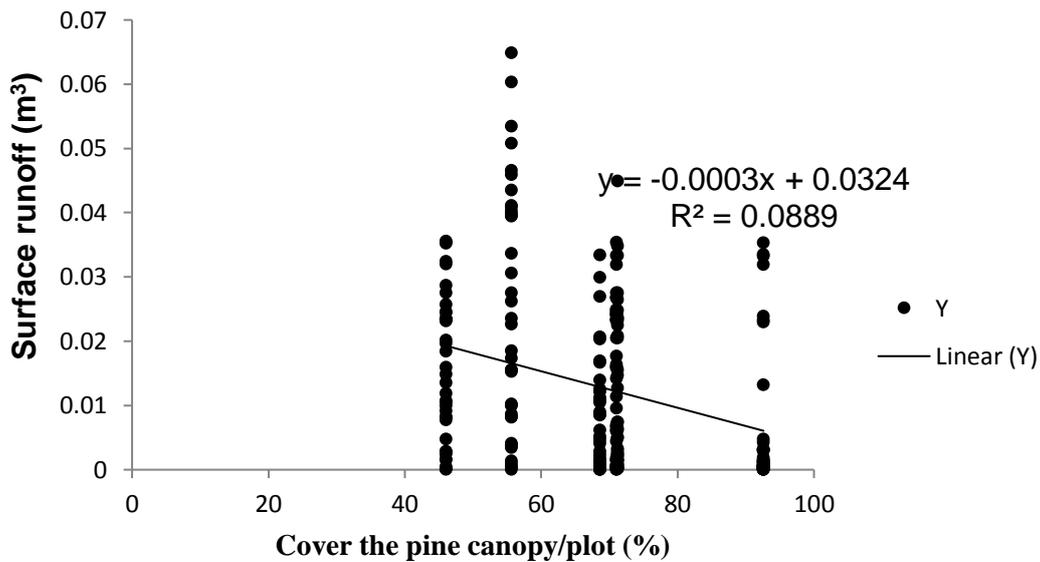


Figure 5. Graph of canopy cover relationships with a surface runoff on slopes <40% and > 40% 40%

Figure 4 shows the relationship of canopy cover with surface runoff of 8.89% and the remaining 91.11% is another factor. The higher the canopy cover, the smaller the surface runoff will be. The thick cover of pine canopy can reduce surface runoff volume. Lands covered by forest vegetation will produce smaller surface runoff than land that is not covered by forests. Vegetation cover would have a significant effect on the size of the surface runoff [7].

The results of further testing of the relationship between canopy cover and surface runoff on slopes below and above 40% can be seen in Figure 5.

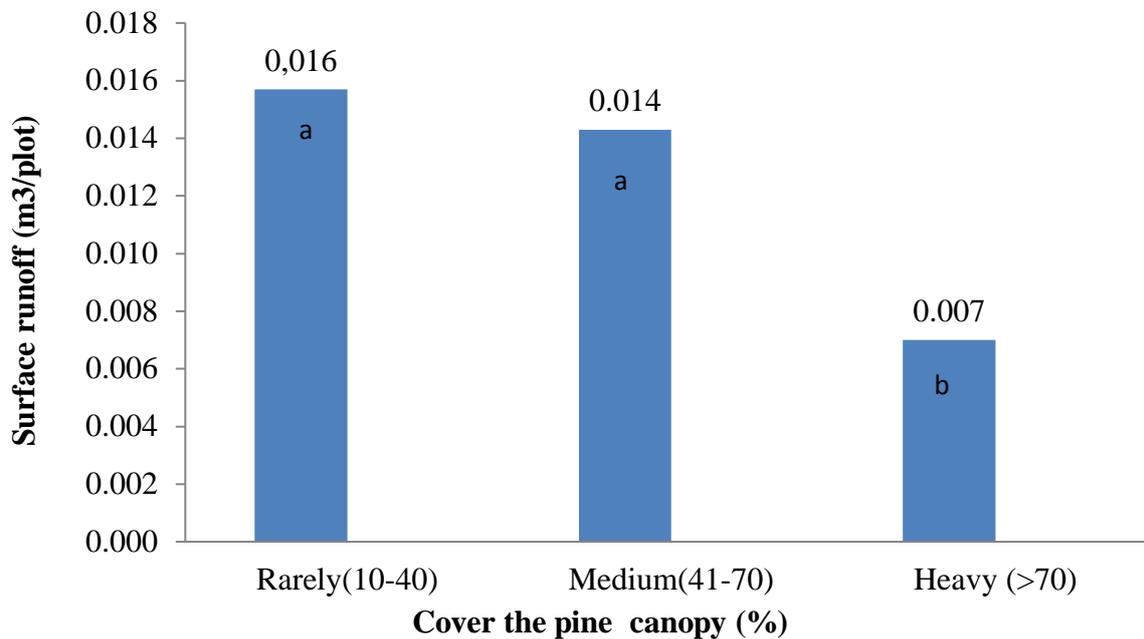


Figure 6. Graph of test results and the relationship between canopy cover and surface runoff on slopes <40% and > 40%.

Pine canopy cover category per plot consists of 3, which are rare, medium and dense [17]. Figure 6 shows that the pine canopy cover rarely produces an average surface runoff of $0.016 \text{ m}^3 / \text{plot}$. It was not significantly different from the medium closure with an average runoff of $0.014 \text{ m}^3 / \text{plot}$ and both were significantly higher with thick closure which resulted in a smaller average runoff of $0.007 \text{ m}^3 / \text{plot}$.

There is a significant effect of canopy cover on surface runoff volume. The results of the regression analysis showed a significant effect on the level of 5%, with a negative regression coefficient which means that canopy cover can reduce surface runoff. Land covered with forest produces smaller surface runoff than non-forest [8]. Land with dense forest cover is difficult to surface because of the large interception, transpiration and percolation. Forest stands are considered effective for reducing surface runoff.

Pine with a number of advantages including from the shape of needle leaves and canopy cans can reduce the beads of rainwater. The granules are smaller before they arrive above the surface of the soil, and will even evaporate back into the atmosphere. In addition, interception and transpiration are high so that the catchment area of pine forests has the lowest annual average flow [5]. The rate of evaporation of rainwater through interception by pine forests is several times greater than the value of transpiration [23]. High interception in pine due to more and more canopy branches. In addition to the high interception of pine leaves, there are many stomata so that transpiration is high. Hard woody plants When rain falls the proportion of intercepted leaves and surface of the stem is between 10 and 20% [23]. *Pinus merkusii* evapotranspiration values of $1,971.12 \text{ mm} / \text{year}$ or 64.5% of the total rainfall of $3,056 \text{ mm} / \text{year}$ [15]. Pine interception that we found in this study was 42.92% of the total rainfall of 904.50 mm . Greater than what was found by another researcher namely 16-20% [25], and 15-39.7% [21]. Pine interception was greater than the interception of aga this forest 14.7% and up 13.7% [19]

Pine also has a lot of litter. Litter cover acts as a protective layer to maintain the physical properties of the soil. Litter layer and wood debris will increase the surface roughness which can inhibit the amount of flow to reduce the rate of surface runoff [13]. The thickness of litter in pine stands will increase soil organic matter thereby reducing bulk density and increasing soil porosity so that the litter will significantly reduce surface runoff [27]. Soil with high porosity has high infiltration capacity and can

stabilize the soil surface [3], with this stability the surface runoff will decrease [2]. The old pine age has many and long roots so that it can infiltrate more precipitation in parts [29] causes smaller surface runoff.

The study for 4 years of observation, namely the opening of mixed forest cover land, replanting until the closed canopy is perfect, suggesting that conversion of mixed forests to pine forests with harvesting systems of hauler is logged, annual average water catch reaches 90% almost equal to the average yearly yield on natural conditions of mixed forests [10]. It can be explained that pine stands can maintain and maintain the physical properties of the soil so that they are not degraded due to harvesting.

The study found that runoff under old black pine stands (*Pinus nigra* A r n.) with preserved humus accumulations covered with thick grass cover, at a slope of 32 ° (62.49%) amounting to 16.17 mm / m² (161.7 m³ / ha) [31]. This figure is still greater than what we found in *Pinus merkusii* with an average stand age above 40 years on slopes above 40% with an average surface runoff volume of 0.014 m³ / plot or 1.59 m³ / ha. Another research results also found that runoff coefficients will decrease in pine trees aged 37 years compared to 7-year-old mixed plantations. This means that the older the pine age, the more it will reduce the rainwater that falls to the ground [30].

Statistical test results of the average value of runoff on slopes below and above 40% whether different or not different can be seen in Table 3.

Table 3. Independent Samples T-Test table (difference test 2 mean) runoff on slopes <40% and > 40%

		Levene's Test for Equality of Variances		t-test for Equality of Means					95% Confidence Interval of the Difference	
		F	Sig.	T	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Runoff	Equal variances assumed	4,229	0,041	1,155	232	0,249	0,0021	0,0018	-0,0015	0,0057
	Equal variances not assumed			1,155	216,591	0,250	0,0021	0,0018	-0,0015	0,0057

Different test results 2 average (Independent Samples T-Test), obtained the value of T count = 1.155 smaller than T table is 1.970 at a significant test level of 0.025 (test 2 sides), then H₀ is accepted. This means that with a 95% confidence interval there is no difference in the average surface runoff on the slopes below and above 40%. The average value of surface runoff volume on slopes below and above 40% is shown in Figure 6.

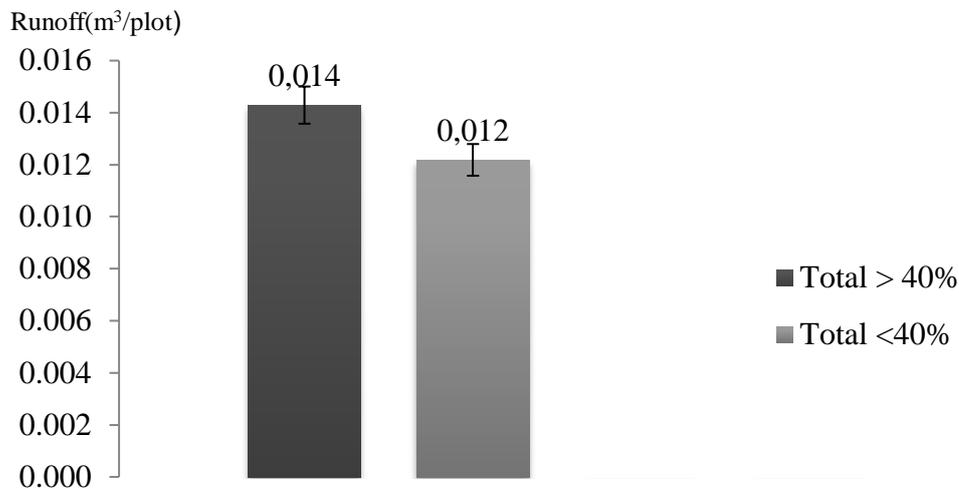


Figure 7. Average value of surface runoff volume on slopes <40% and> 40%

Based on Figure 6 shows the total average value of the below and above 40% slope runoff volume of 0.012 m³ / plot and 0.014 m³ / plot. This figure shows no significant difference in the average volume of surface runoff of both slope levels. This proves that pine stands can minimize the influence of slopes. The slope factor does not have a significant effect on the amount of surface runoff if the vegetation cover becomes more dominant [14]. Pine merkusii is a forest stand that is very effective in controlling surface runoff. In line with that stated that runoff would decrease or be smaller in forest land than in cultivated lands [7]. The use of Pinus Markus as a reforestation plant for critical lands is very appropriate to reduce the occurrence of floods and erosion by high runoff water.

4. Conclusion

Based on the results of the research conclusions can be formulated as follows:

1. Pine closure can significantly control or decrease the surface runoff volume, both on the slope below and above 40%.
2. Surface runoff on the slopes below and above 40% has a real relationship with rain intensity and closure, but there is no significant difference between the two.

It is advisable to research the measurement of surface runoff under pine merkusii stands carried out on the same slope length, the same litter thickness, the same number of trees per plot. Buckets that are used to hold runoff water must have a capacity of more than 50 liters which aims to overcome the occurrence of water spills, especially when rainfall is very high. Rainfall measurements should be taken in different periods. It's just that this will have consequences for the length of the study.

The results of this study will have implications for the review of the determination of the protected forest area of 40% slope. This number limit according to if it is associated with the results of this study then the number 40% has not become an absolute number. It was found that there was no difference in a surface runoff on slopes below and above 40%. Based on these results, the determination of the limit of protected forest on a 40% slope can still be raised. Regarding what percentage of slope, further research is needed.

References

- [1] Anggilia, M. and A Djazuli 2011 An Overview Forest Carbon Accounting (Case Study Ulu Masen Ecosystem Aceh Province, Indonesia *Tazkia Islamic Business and Finance Review* 20-35
- [2] Akbarimehr M, and R. Naghdi 2012 Assessing the Relationship of Slope and runoff volume on skid trails Case study: Nav 3 district *Journal of Forest Science* **58** 357–362

- [3] Baharuddin, K., Mokhtaruddin, A.M., Nik Muhammad, M. 1995 Surface Runoff and Soil Loss from Skid Trail and a Logging Road in a Tropical Forest *Jurnal of Tropical Forest Science* **7** 568-569
- [4] Cao Longxi, Yin Liang, Yi Wang, Huizhong Lu 2015 Runoff and Soil Loss from Pinus Massoniana Forest in Southern China after Simulated Rainfall *Catena* **129** 1-8
- [5] Dons A 1987 Hidrology and Sediment Regime of Apasture Native Forest, and Pine Forest Catchment in the Central North Island, New Zealand *New Zealand Journal of Forestry Science* **17** 161-78
- [6] Daniel, T.W 1995 Prinsip-Prinsip Silvikultur *terjemahan* (Yogyakarta:Gadjah Mada University Press) p 89-90
- [7] EI-Hassanin, A.S, Labib, T.M. and Gaber, E I 1993 Effect of Vegetation Cover and Land Slope on Runoff and Soil Losses from the Watersheds of Burundi *Agric. Ecosystems Environ* **43** 301-308
- [8] El Kateb. H 2013 Soil Erosion and Surface Runoff on Different Vegetation Covers and Slope Gradients: A field experiment in Southern Shaanxi Province, China *Catena* **105** 1-10
- [9] Foley, J.A., R. De Fries, G.P. Asner, C. Barford, G. Bonan and S.R. Carpenter 2005 Global Consequences of Land Use *Science Journal* **309** 570-574
- [10] Fahey B, Rick Jackson 1997 Hydrological Impact Converting Native Forest and Grasslands to Pine Plantation, South Island, New Zealand *Agricultural and Forest Meteorology* **84** 69-82
- [11] Forest Watch Indonesia 2011 Portrait of Indonesia's Forest Condition for the Period of 2000-2009 (First Edition) p 89
- [12] Gunawan G dan Kusminingrum N 2015 Handling of Vetiver's Gravel Slope and Road Dumps Erosion (Bandung : Research and Development Center for Bandung Bridge Road) p 66
- [13] Hartanto H, Ravi Prabhu, Anggoro S.E. Widayat, Chay Asdak 2003 Factors Affecting Runoff and Soil Erosion: Plot Level Soil Loss Monitoring for Assessing Sustainability of Forest Management *Forest Ecology and Management* **180** 361-374
- [14] Ispriyanto R, Nana M.A, Hendrayanto 2001 Surface Run-off and Erosion from the Logged over Pinus merkusii Jungh Et de Vriese Forest Plantation under Tumpangsari System Management *Journal of Tropical Forest Management* **8** 37-47
- [15] Indrajaya Y, Wuri H 2008 Potency of merkus pine pinus merkusii jungh. et de vriese forest as landslide control in java Ciamis Forestry *Research Center Forest Info* **5** 231-240
- [16] Meteorology, Climatology and Geophysics Agency 2010 Criteria for Rainfall Intensity in Indonesia p 89
- [17] National Standardization Agency 2010 Classification of Land Cover (Jakarta: NSA) p 66-70
- [18] Nanko, K., N. Hotta and Suzuki M 2005 Evaluating The Influence of Canopy Species and Meteorological Factors and Throughfall Drop Size Distribution *Journal of Hydrology* **329** 422-431
- [19] Perhutani Forest Resource Development Center 2002 Pine Forests and Water Products Perhutani *Cepu* **1** 12-13
- [20] Paimin, Sukresno dan Mashudi 2003 The Dynamics Of Vegetation Community Of Mahogany (*Swietenia macrophylla*) Plantation Forest On Its Role In Controlling Runoff And Erosion *Journal of Watershed Management* **9** 12-15
- [21] Pudjiharta, Ag 2005 Precious Hydrological Aspect Problems and Efforts to Overcome them. *Journal of Forestry Analysis Forestry Research and Development Agency* **2** 129-144
- [22] Pramono Irfan. B and Nining W 2009 Run-off and Erosion Control Model with Vegetative Method (Dungwot Sub-watershed case study) *Solo Forestry Research Center* p 56-60
- [23] Rutter, A. J., Kershaw, K. A., Romns, P. C. and Morton, A. J 1971 A Predictive Model of Rainfall Interception in Forests Derivation of the model from observations in a plantation of Corsican pine *Agric. Meteorol.* **9** 367-384
- [24] Ramadhan M.M, Teguh H 2014 Rainfall Comparative Analysis Based on NOAA AVHRR Image Data with Rainfall Data in the Field *GEOID Journal* **10** 34-45

- [25] Sudjoko S.A Suyono and Darmadi 1998 Study of Pine Forest Water Balance at KPH Banyumas Timur (Yogyakarta : Research Summary) p 89
- [26] Suripin 2004 Preservation of Land and Water Resources (Yogyakarta: ANDI Press) p 56-60
- [27] Sidle RC, Hirano T, Gomi T, Terajima T 2007 Hartonian Overland Flow from Japanese Forest Plantation-on Aberration, the Real Thing, or Something in Between? *Hydrological Processes* **21** 3237-3247
- [28] Suwana U, Harnios A, Mohammad R 2009 Soil Erosion Caused by Forest Harvesting *Operations JMHT* **15** 61-65
- [29] Suryatmojo H 2013 Impacts of the Intensive Forest Management System on Runoff and Erosion Characteristics (Dissertation : Kyoto University) p 78-80
- [30] Suryatmojo H, M.Fujimoto, K.Kosugi dan T Mizuyama 2014 Runoff and soil erosion characteristics in different periods of an intensive forest management system in a tropical Indonesia rainforest. *Int. J. Sus. Dev. Plann* **9** 830–846
- [31] Topić Vlado, Igor Anić, Butorac Lukrecija 2008 Effects of Stands of Black Pine (*Pinus nigra* a r n.) and Aleppo pine *Pinus halepensis* on the Protection of Soil from Erosion **27** 287–299
- [32] Zachar, D 1982 *Soil Erosion* Elsevier Scientific Publishing Company (Forest Research Institute, Zvolen,Czechoslovakia) p 78-80
- [33] Zuazo, P H D and C R R. Pleguezuelo 2009 Soil Erosion and Runoff Prevention by Plant Covers A Review *Sustainable Agriculture Journal* **9** 785-811