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Analysis of infiltration and surface runoff using rainfall simulator with variation of rain intensity and vegetation

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Abstract. Changes in watershed land use are a concern due to the increase of flood from year to year which can harm the community both material and non-material. Meanwhile, during the dry season there was a significant decrease and causes irrigation water supply and clean water for daily needs to decrease and even to dry. Surface runoff and infiltration in a watershed area becomes an inseparable unit, with increasing surface runoff causing big flooding, flash floods and reducing infiltration, causing less groundwater supply to maintain river availability tend to decrease. The testing of vegetation effect on watershed areas on surface runoff and infiltration with a rainfall simulator was to analyze the extent of the role of vegetation in rainfall intensity with surface runoff and infiltration on rainfall intensity. Tests were carried out using a rain fall simulator using intensities I2 and I5 on two types of vegetation selected at the location of Maros watershed, namely mango and bamboo vegetation. The results show that changes in land cover increase surface runoff and reduce infiltration. So that land use should not be carried out carelessly and still have to pay attention to the sustainability of the function of the forest as river water retention. Land damage will be responded to by unexpected flooding and disruption of the land ecosystem, causing the extinction of flora and fauna habitat to become an indicator of increasingly critical land damage.

1. Introduction

Utilization of watershed land into residential, agricultural, industrial areas is inevitable in line with the increasing human needs to fulfill their welfare. Land use must use the concept of conservation or restoration, so that the impact can be minimized. Excessive land use causes changes in the vegetation of the watershed to become uncritical or reduced. This change will be responded to by various problems that can occur in watershed areas.

The response to changes in watershed land use will have an impact on changes in the ecosystem in the watershed area causing a decrease in infiltration capacity [1] and an increase in surface runoff [2] [3], changes in flow coefficient [4], increased sedimentation transport [5], it can increase the peak flood discharger [2] [6] [7], climate change [8] [9], and lack of groundwater availability and hydrological drought [10]. There is a correlation between infiltration and surface runoff [11], infiltration rates were high and decreased with time up to constant infiltration rate [12], conservation based empowerment [13], so that it greatly affects the groundwater protection area. At his time, the decrease of infiltration and the increase of surface runoff due to land change are the biggest problems,



because they can significantly affect the decrease in river water discharge along with decreasing ground water supply, reducing river base flow. Therefore, it is necessary to restore land and agricultural areas in the watershed by eco-engineering, conservation ponds, artificial recharge, river side polder method. This issue is a concern, so that the testing of variant models that can respond negatively to land changes is an interesting object for further studies.

Testing will be carried out with variations in land cover changes by arranging land cover using 2 (two) types of vegetation, namely; Mango and Bamboo in rainfall intensity with rainfall simulator test. The objectives of research were: 1) to analyze the effect of intensity on land surface runoff; (2) to analyze the effect of intensity on infiltration on land, (3) the effect of changes in land cover with an increase in surface runoff and a decrease in land infiltration.

2. Methodology

2.1 Time and Research Site

The research will be conducted during 5 (five) months, starting from June - October 2020, in the laboratory of rainfall simulator of Muhammadiyah University of Makassar.

2.2 Tools and Materials

a. Rainfall simulator tool

The picture of Rainfall simulator tool at the laboratory of hydrology of Muhammadiyah University of Makassar with initial running conditions of Mango and Bamboo vegetation.

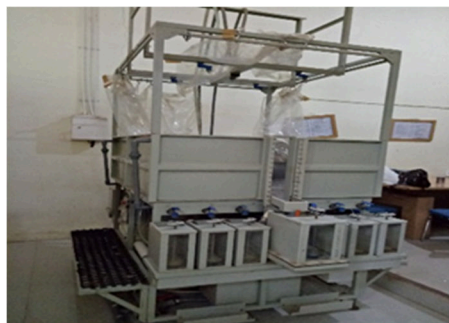


Figure 1. Tools Rainfall Simulator



Figure 2. Preliminary running preparation with Mango (left) and Bamboo (right) vegetation

b. Testing Material

- (1) Soil samples taken from Maros watershed area (Subdistricts of Simbang, Tanralili and Tompobulu)
- (2) Vegetation of cover is selected in the area of Maros watershed, namely vegetation (such as Mango and Bamboo vegetation).

c. Rainfall Data

For rainfall intensity analysis, we use data from 3 (three) station namely Batu Bessi, Tanralili and Tompobulu in Maros watershed area with each data about 18 years.

2.3 Data Analysis

Material for test media in the rainfall simulator was obtained from Maros River in areas with Bamboo and Mango vegetation with the type of soil as follows:

- Soil samples are taken from Maros watershed as test material in the laboratory to obtain texture classification, soil classification and filter analysis.
- The approach to surface runoff and infiltration with rain fall simulator method by using soil samples in Maros watershed.
- Calculation of rainfall intensity uses Mononobe equation approach
- Validation of rainfall simulator infiltration using the empirical method approach, namely Horton and Holtan' equation.
- Validation of surface runoff of rainfall simulator uses rational equation.

3. Result and Discussion

3.1 Infiltration of Rainfall Simulator Method, Horton and Holtan with Vegetation

The results of infiltration observations with a rainfall simulator and infiltration analysis by using Horton and Holtan' method on variations in rainfall intensity against infiltration rates with Mango and Bamboo tree vegetation are shown in Table 1 as follows.

Table 1. Infiltration Rate Rainfall Simulator, Horton and Holtan' Method

Vegetation Type	Permeability	Infiltration rate Rainfall simulator (mm/jam)		Infiltration method (mm/jam)		Horton Infiltration method (mm/jam)	
		I ₂	I ₅	I ₂	I ₅	I ₂	I ₅
without vegetation	0.000151	18.539	22.004	19.271	22.887	18.479	22.009
vegetation mango	0.000141	18.737	22.346	19.291	23.089	18.664	22.336
vegetation bamboo	0.000121	18.678	22.238	19.395	23.042	18.674	22.242

3.2 Surface Runoff with Rainfall Simulator and Rational

Analysis of surface runoff by using rainfall simulator method with rational on variations in rainfall intensity (I₂) and (I₅) on Mango, Bamboo vegetation and without vegetation is described in Table 2 below. This table shows the change in the reduction in surface runoff, if using vegetation both the rainfall simulator test and rational empirical equation method. This change shows that the role of vegetation in a land is very significant in reducing surface runoff.

Table 2. Surface Runoff by Rainfall Simulator and Rational On Mango And Bamboo Vegetation

Rainfall Intensity (mm/jam)	q _t Tveg Rain fall Simulator (m3/dt)	q _t Tveg Rational (m3/dt)	q _t Vmgo Rainfall (m3/dt)	q _t Vbmb Rainfall (m3/dt)	q _t Vmgo Rational (m3/dt)	q _t Vbmb Rational (m3/dt)
I ₂ = 287.631	0.0000652	0.0000533	0.0000560	0.0000572	0.0000465	0.0000522
I ₅ = 343.204	0.0000818	0.0000696	0.0000669	0.0000676	0.0000524	0.0000544

3.3 Effect of rainfall intensity with infiltration and surface runoff

Changes in infiltration and surface runoff in a watershed area are influenced by factors such as rainfall intensity, topography, soil structure, vegetation and cropping patterns. The effect of rainfall intensity on infiltration on variations of Mango and Bamboo vegetation is shown in Figures 3 and 4, while surface runoff in Figures 5 and 6 can be shown as follows:

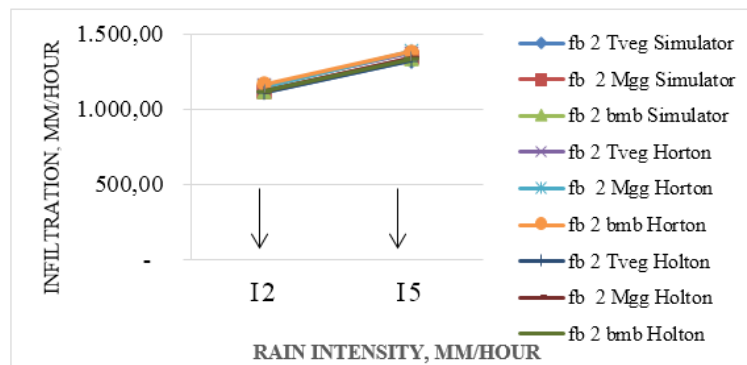


Figure 3. Relationship between rainfall intensity with infiltration on variations of Bamboo and Mango vegetation

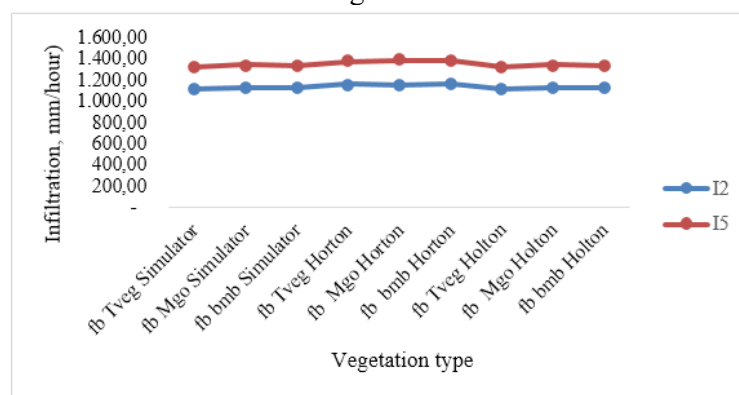


Figure 4. Relationship Between Rainfall Intensity with Infiltration On Variations of Bamboo and Mango Vegetation

Figures 3 and 4 show changes in increased infiltration due to land cover with Bamboo and Mango vegetation. The increase of this infiltration is caused by the resistance of surface runoff at tree roots and triggers an increase in infiltration capacity [14] [15] through tree root media. The land cover factor is quite influencing infiltration and surface runoff in a watershed or other land. The role of vegetation has an important role in increasing the infiltration capacity and groundwater supply of watersheds. Vegetation affects watershed ecosystem changes because correlation between infiltration and surface runoff [11]. To reduce surface runoff, an eco-concrete infiltration approach is required [16] and rainfall intensity also plays an important role in increasing infiltration capacity.

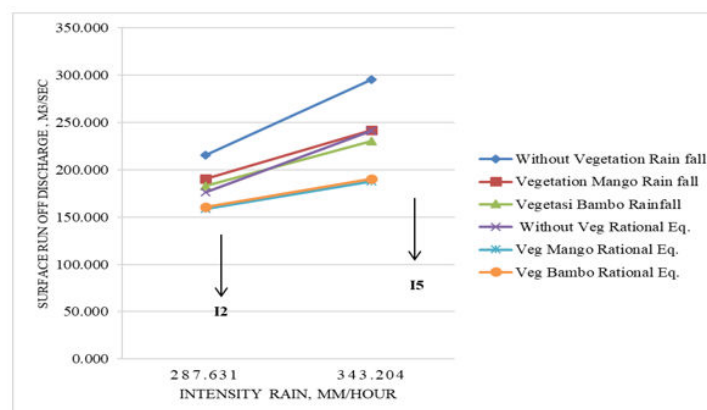


Figure 5. Relationship between rainfall intensity and surface runoff on variations of Bamboo and Mango vegetation

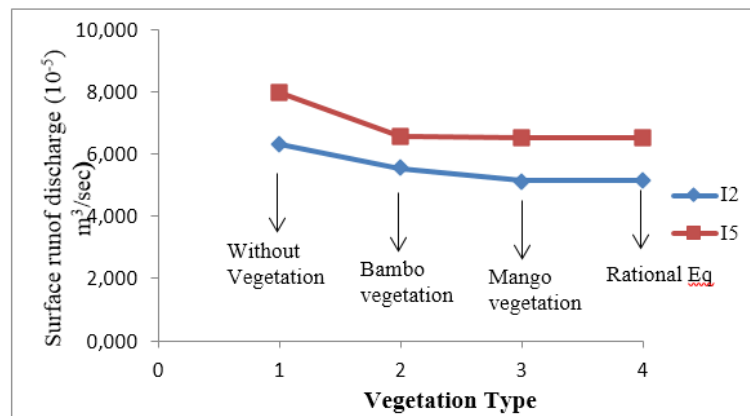


Figure 6. Relationship between rainfall intensity and surface runoff on variations in Bamboo and Mango vegetation

Vegetation on land plays a role in restraining runoff rates and strengthening the surface soil structure, as well as increasing infiltration as base groundwater watershed for river water retention in the dry season. Surface runoff with infiltration becomes an integral parameter of river flow which is inseparable because it has a correlation between infiltration and surface runoff [11]. Arrangement of watershed land vegetation is an absolute must to increase infiltration and reduce surface runoff. Response of land use change can influence climate change [8] [9] and promote a longer dry season, allowing the accumulation of detritus, algae, and vegetation, and the development of higher temperatures and lower levels of dissolved oxygen, leading to species extinction. Certain species [8] and exotic species often thrive in med-rivers will disappear, causing low river dynamics. The impact is too big is to break the cycle chain of water hydrological or be a disaster for human life.

Changes in use by logging, agricultural use, and settlements in watershed areas mean the beginning of changes in the hydrological cycle and the function of forests as the main buffer for river flows. Forests are very vital in human life because they are main source of clean water. The quality of clean water is very much influenced by the natural forest system. To prevent prolonged water crisis and unpredictable flooding is to maintain and restore natural forest functions.

4. Conclusion

4.1 Conclusion

As discussed above can be concluded as follows:

- Activities in the watershed area have a significant effect on changes in land use causing various changes in the watershed, such as changes in hydrology, river morphology, river ecosystems, etc.
- Changes in land use cause high surface runoff, change in flow coefficient, decreased infiltration, shorter peak discharge periods and sedimentation.
- Changes in land use can cause degradation of the resilience of watershed areas as a buffer for water supply in rivers.

4.2 Recommendations

As conclusion above, there are some recommendations including:

- It is necessary variation the type of vegetation to increase the infiltration value and reduce runoff.
- It is necessary variation the slope and type of soil in Maros watershed as soil samples to increase infiltration value and reduce surface runoff.
- It is necessary variation the density of vegetation to increase infiltration value and reduce runoff.
- It is necessary to study watershed restoration efforts to restore the function of watershed as a source of river water.

e. Massive government intervention is needed to maintain the flora and fauna habitat of Maros watershed as a more economical natural balance ecosystem.

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