Erosion Measurement by Using Rainfall Simulator at Grass Soil and After Harvested Soil in Wanagama

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Abstract. Erosion is a global problem, including in Wanagama. With the high risk of erosion, both naturally and due to high human activity, it is interesting and it is important to know how much erosion is in the Wanagama forest, especially in this study on kolonjono grasslands (Brachiaria mutica). The result of this study can be used as a base to avoid land degradation, while working together with the surrounding community needs to be maintained, which has recently become a trend in forest management in general to maintain the harmony of sustainable and sustainable forest management. However, the problem in measuring the erosion was faced when the rainfall happens rarely as a result of climate change. So, the development of erosion measurement tools is urgently required. The use of rainfall simulator was studied in order to find out that although during the dry season the erosion research can be carried out. The purpose of this study was to measure the erosion rate at the grass soil and after harvested soil, and to prove the use of rainfall simulator for measuring erosion. This study resulted that both the erosion and runoff have a positive correlation with the rainfall duration with the R square of 0.993 to 1. The erosion rate at the grass soil and at the post harvested soil were almost the same so there was no significant difference. However, the runoff at the grass soil was significantly different from the runoff at the post harvested soil.

1. Introduction
In general, the occurrence of erosion is determined by climatic factors (especially rainfall intensity), topography, soil characteristics, land cover vegetation, and land use. In studying erosion and soil conservation problems, two elements of the water cycle play an important role, namely the rainfall depth and surface runoff. Therefore, these two elements are factors that play a role in the destruction of the soil structure and land transportation [1]. Suggested the USLE equation to estimate the amount of erosion [2]. This equation consists of factors that are considered to play an important role in erosion, including those related to rainfall depth, soil type, slope length and slope, cropping system, and soil and water conservation measures applied [3]. Meanwhile, according to [4], the factors that influence the amount of erosion are climate, topography, soil, vegetation, and humans.

Wanagama forest, which is included in the Playen area, Gunung Kidul Regency, Yogyakarta, has a dry climate with an average rainfall between 1,500-2,000 mm / year and a number of dry months (months with a thick rain of less than 60 mm / month) of more than 6 months [5]. This has the consequence that in the rainy season, the rainfall will be very high, so that it has a great potential to cause high erosion, while in the dry season there will be drought due to the thin soil surface, which is less than 10-20 cm, especially on a high slope land, so that it cannot store water in the ground. Meanwhile, at the final destination for erosion, sediment deposits can be found that cause the thickness of the soil to several meters [6].

The lands in Wanagama have a very shallow soil depth (<10 - 20 cm) and rocky. Based on the texture of the soil in this area is dominated by the clay fraction with the Latosol type [7] so that it has...
clay soil texture class while in terms of its structure it has a lumpy structure with moderate to strong aggregate stability [8]. Carbonate sedimentary rocks are dominated by limestone and marl [7]. Wanagama forest has a hilly and sloping topography, with an altitude of about 115-205 m asl [9]. In general, the rock layers that make up the Wanagama land are sloping to the south with an average slope of up to 15°-30° [6], which will increase the high potential for erosion. These rock formations form limestone hills, which are often identified with water shortages. Rainwater that falls on rock layers that cannot be passed through by water will directly flow on the surface of the soil, while in rock layers that can be passed through, rainwater will immediately flow in large quantities through cavities formed from dissolved limestone. Land in the Wanagama forest can be categorized as rocky, even most of it is rock outcrops [6].

Wanagama forest as an educational forest is often used as a research site, so it has various types of research trees along with differences in management and treatment in them. Wanagama forest, which was built with the surrounding community in its history, also allows local people to plant and collect animal feed and food crops such as grass from Wanagama forest area [6]. In addition, there are also many visitors to the Wanagama forest who intend for nature tours or camping.

Kolonjono grass (Brachiaria mutica) was planted in plot 13 of Wanagama forest. The area has rocky land, with large stones exposed on the upper slope, but on the lower slope, the soil is thick enough, so that high erosion has occurred over time. Around this place human activities are also often carried out, not only passing by farmers and planting and harvesting forage grass, but also passing by tourists, because it is close to the main road to the Wanagama forest office. With the high risk of erosion, both naturally and due to high human activity, it is interesting and it is important to know how much erosion is in the Wanagama forest, especially in this study on kolonjono grasslands (Brachiaria mutica). The result of this study can be used as a base to avoid land degradation, while working together with the surrounding community needs to be maintained, which has recently become a trend in forest management in general to maintain the harmony of sustainable and sustainable forest management. However, the problem in measuring the erosion was faced when the rainfall happens rarely as a result of climate change. So, the development of erosion measurement tools is urgently required. In this study the use of rainfall simulator was studied in order to find out that although during the dry season the erosion research can be carried out. The purpose of this study is to measure the erosion rate at the grass soil and after harvested soil, and to prove the use of rainfall simulator for measuring erosion.

2. Methodology
2.1. Materials

Rainfall simulators have been used extensively in soil erosion studies for many years, and reviews of various designs for laboratory and field application [9]. In this study, erosion measurements were carried out using a small plot completed with rainfall simulator. The small plot is equipped with a drum to accommodate the runoff and sediment.

The data needed in this study is the rain data obtained from the running simulator rain. The tool is mounted on an erosion plot as high as 2 m and surrounded by wind shields to prevent the wind from entering the plot so that in this study the wind factor is ignored. The rain simulator used consists of 8 nozzles in 2 lanes with a distance between nozzles 30 cm and a distance between lanes 50 cm. The rain simulator is powered by a 12 V DC pump which is powered by a generator. The pump is connected to the bucket using a hose to supply rainwater. In this study, 150 plots of water were dropped in one plot with an artificial rain intensity of approximately 54.59 mm/hour.

Rainfall Simulator is a tool created to simulate natural rain. To determine the uniformity of rain distribution, 16 plastic cups were systematically arranged at the bottom of the rain simulator with a distance between glasses of 25 cm, then calculated using the Christiansen's uniformity coefficient (CU) formula [10]. Based on calculations that have been done, the uniformity of rain generated by the rain simulator is 53%.
2.2. Predicting Erosion and Runoff

Erosion data collection was done by placing a small plot in cultivated land and mixed forest. Data collection with a small plot method is done by making a small plot measuring 100 x 50 x 30 cm (Figure 1).

![Figure 1. Rainfall Simulator](image)

The small plot is equipped with a barrier in the form of a zinc plate so that there is no flow of water or sediment that exits or enters the small plot. In a small plot 1 drum is installed to accommodate the flow of water and sediment after a rain. Changes in water level in the drum are measured at intervals of 2 minutes then sediment samples are taken in the drum using a 600 ml bottle. Runoff (RO) is calculated based on the volume in the drum every 2 minutes using the following formula:

$$\text{RO (mm)} = \frac{\text{Container volume (cm}^3\text{)}}{\text{Plot area (cm}^2\text{)}} \times 10 \text{ mm}$$ (1)

Then, the amount of sediment per drum (WD) and the amount of erosion per drum (WT) are calculated using the following formula:

$$\text{WD (g)} = \frac{\text{Dry soil weight samples (g)}}{\text{Sample volume (ml)}} \times \text{Drum volume (ml)}$$ (2)

$$\text{WT (kg/ha)} = \frac{\text{WD (g)}}{\text{Plot area (m}^2\text{)}} \times 10 \text{ kg/hectare}$$ (3)

Dry soil weight samples were obtained based on the runoff filtering results. The runoff sample was filtered using filter paper so that a sediment is collected in the runoff sample. After filtering, the samples are dried in the filter paper using an oven at 80-90°C for 30 hours or when the weight of the soil sample has reached a constant weight. The weighing process of the sample is carried out after the curing process and the sample has been placed in the excavator for several hours to obtain a stable weight.

3. Result and Discussion
3.1. The Correlation of Rainfall Duration with The Erosion at the Grass Soil and Post Harvested Soil

In a tropical country like Indonesia, rain is a significant erosion agent. Therefore, rain and erosion are closely related. Figure 2. shows that both the erosion rate at the grass soil and post harvested soil has a positive correlation with the rainfall duration after 30 rainfall events were applied.
Figure 2. The correlation of rainfall duration with the erosion at the grass soil (a) and post harvested soil (b)

The higher the rainfall will result the higher erosion rate. Rainfall is the main factor influencing erosion rate. There are five rainfall characteristics: rainfall depth, duration, intensity, distribution, and size. Among them, rainfall intensity has the highest influence in resulting the erosion rate. From this study it shows that the longer the erosion happened, meaning that the rainfall depth, duration and intensity totally increase results the increasing in erosion rate.

Other factor influencing soil erosion are vegetation, soil, slopes and slopes length. Grass has a good function in helping the farmers to prevent the erosion because it covers the soil from the detachment of rainfall.

3.2. The Correlation of Rainfall Duration with the Runoff at the Grass Soil and Post Harvested Soil

Rainfall simulation is a widely used tool for investigating runoff and soil erosion processes. It offers a high methodical flexibility, as storm events with almost any desired intensity and duration can be generated. In general, rainfall simulators represent a combination of field measurements and well adjustable boundary conditions, thus allowing collecting data in-situ with simultaneously almost thoroughly controllable rainfall characteristics [11].

Figure 2 shows that both the runoff at the grass soil and post harvested soil has a positive correlation with the rainfall duration.

Figure 3. The correlation of rainfall duration with the runoff at the grass soil (a) and post harvested soil (b)

The higher the rainfall will result the higher runoff. More rainfall results the higher runoff. From this study it shows that the longer the rainfall happened, there will be more water becomes runoff so, the runoff increases.
3.3. Statistical Analysis

The statistical analysis of this study can be seen in Table 1.

| N         | Normality test | Mann-Whitney Rank Sum test | Statement                  |
|-----------|----------------|----------------------------|----------------------------|
| Erosion at the grass soil | 90 0.664       | P = 0.649                  | There is no significant difference |
| Erosion at the post harvesting soil | 90 0.889  |                               |                             |
| Run off at the grass soil | 90 0.961       | P < 0.001                  | There is significant difference |
| Run off at the post harvesting soil | 90 0.927  |                               |                             |

Table 1 shows that the erosion rate at the grass soil and at the post harvested soil is almost the same so there is no significant difference. It means that the grass harvesting do not influence the erosion rate. However, the runoff at the grass soil was significantly different from the runoff at the post harvested soil. So, the harvesting process influence the runoff. The erosion rate between grass soil and post-harvest soil, which did not differ significantly between the two, was thought to be caused by the root system of the grass remaining on the soil surface. Grass residues can reduce erosion rates and improve soil characteristics, both physical, chemical, and biological [12], [13], [14]. Grass can slow runoff and increase infiltration into the soil [15], [16], [17]. The grass that has been harvested loses this ability. Therefore there is a significant difference between the two plots.

4. Conclusions

This study resulted that both the erosion and runoff have a positive correlation with the rainfall duration with the R square of 0.993 to 1. The erosion rate at the grass soil and at the post harvested soil were almost the same so there was no significant difference. However, the runoff at the grass soil was significantly different from the runoff at the post harvested soil.

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References

[1] Arsyad S 2010 *Konservasi Tanah dan Air* (Bogor: Institut Pertanian Bogor)
[2] Wischmeier WH and Smith DD 1978 Predicting rainfall erosion losses. A guide to conservation planning, United States Department of Agriculture, Washington, D.C. https://models.pbl.nl/image/index.php/Wischmeier_and_Smith_1978
[3] Asdak C 2010 *Hidrologi dan Pengelolaan Daerah Aliran Sungai* (Yogyakarta: Gadjah Mada University Press)
[4] Hardjowigeno S 2011 *Evaluasi Kesesuaian Lahan dan Perencanaan Tataguna Lahan* (Yogyakarta: Gadjah Mada University Press)
[5] Suseno OHH 2004 *Sejarah Wanagama I. Dalam: Pramudyo, RIS., OH Suseno, H. Supriyo, Soekotjo, M. Naiem, U Iskandar. Dari Bukit-Bukit Gundul sampai ke Wanagama-I.* Yogyakarta: Yayasan Sarana Wana Jaya
[6] Ernawati J 2016 *Jejak Hutan Wanagama* (Jakarta: Deutsche Gesellschaft Fur Internationale Zusammenarbeit (GIZ) GmbH Forest and Climate Change Programme (Forclime))
[7] Ratmaningrum Y W N and Indrioko S 2014 Variation on Genotypes and Flowering Characters Affecting Pollination Mechanisms of Sandalwood (Santalum album Linn, Santalaceae) Planted on exsitu Gene Conservation in Yogyakarta, Indonesia. *Eurasean J. For Res, VI* 167–179
[8] Supriyo H, Faridah E, Atmanto WD, Figyantika A and Fajri AK 2009 *Kandungan C-Organik dan N Total pada Seresah dan Tanah pada 3 Tipe Fisiognomi (Studi Kasus di Wanagama I, Gunung Kidul, DIY)* Jurnal Ilmu Tanah Dan Lingkungan 9(1) 49–57

[9] Chevone B I, Yang Y S, Storks-Cotter I W E and Long S J 1984 A Rainfall Simulator for Laboratory Use in Acidic Precipitation Studies *Journal of the Air Pollution Control Association* 34:4 355-359

[10] Christiansen J E 1942: Irrigation by Sprinkling. California Agriculture Experiment Station Bulletin, No. 670

[11] Zemke J J 2016 Runoff and Soil Erosion Assessment on Forest Roads Using a Small Scale Rainfall Simulator. *Hydrology* 3, 25: 1-21 www.mdpi.com/journal/hydrology

[12] Turmel M, Speratti A, Baudron F, Verhulst N, and Govaerts B. 2015. Crop residue management and soil health: A systems analysis *Agricultural Systems* 134 pp 6-16

[13] Blanco-Canqui H, Stalker A L, Rasby R, Shaver T M, Drewnoski M E, Donk S V, Kibet L 2016 Does Cattle Grazing and Baling of Corn Residue Increase Water Erosion? *Soil & Water Management Conserv.* 80 pp 168-177

[14] Rakkar MK and Blanco-Canqui 2018 Grazing of crop residues: Impacts on soils and crop production. *Agriculture. Ecosystems & Env.* 258 pp 71-90

[15] Bissonnais Y L, Lecomte V and Cerdan O 2004 *HAL*. 24 3 pp 129-136

[16] Zhang X, Li P, Li Z, Yu G, Li C 2018 Effects of precipitation and different distributions of grass strips on runoff and sediment in the loess convex hillslope *Catena* 162 pp 130-140

[17] Li C and Pan C 2018 The relative importance of different grass components in controlling runoff and erosion on a hillslope under simulated rainfall *J. of Hydr.* 558 pp 90-103