The reduction of infiltration capacity at various tourist attraction areas in Wanagama I education forest

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Abstract. Wanagama is a rehabilitation forest and it was stated as an Education Forest continues to grow and develop so that it has some tourist attractions visited by people, however impacted to the infiltration capacity. This research aimed to determine infiltration capacity in each tourist attraction area. Infiltration capacity and soil samples measurements were carried out at each tourist attraction areas with 3 replications for every slopes unit. Infiltration data was taken by using a double ring infiltrometer, whereas soil samples were taken by using soil ring samples. Then, Horton method was used for analyzing the infiltration data. The physical and chemical analysis of soil was conducted in the Soil Laboratory in Universitas Gadjah Mada. It was concluded that the infiltration capacity at all areas were lower than that of control: in Wanagama 1000 Selfies was 112 mm / hour, WanagamaPaksi was 76 mm / hour, around Wanagama Bridge was 52 mm / hour, Camping Ground was 36 mm / hour, and control was 368 mm / hour in average. Furthermore, the infiltration capacity of the tourist activities areas in Wanagama and the control area were significantly different. However, the soil properties do not significantly influence the infiltration capacity.

Keywords: capacity, infiltration, soil, tourism, Wanagama

1. Introduction

Wanagama is an education forest located in Gunung Kidul Regency, Yogyakarta Province. Wanagama was used to be a critical land that could not be utilized but this area had been successfully rehabilitated into a forest that provided direct and indirect benefits for the surrounding community. The success of Wanagama I has invited many visitors both individuals and groups from various places. They want to see closely the Wanagama I as a forest that was built in a critical area [1].

The main function of Wanagama forest is as an education forest for Universitas Gadjah Mada forestry students in conducting learning in the form of practical activities. In addition, Wanagama forest also has a role in maintaining the hydrological cycle. In the water cycle, Wanagama forest serves as a buffer for the water needs of the community around the forest. Recently, Wanagama forest continues to grow and become a unique icon for Gunung Kidul Regency. This caused many people to be interested in visiting Wanagama forest. The most visited tourist objects by the public are: Wanagama1000 Selfies, Wanagama Paksi, Wanagama Bridge, and Camping Ground.

The large number of visitors who come to Wanagama forest causes a change in soil compaction which impacts on infiltration. Infiltration is the term applied to the process of water entry into the soil,
generally by downward flow through all or part of the soil surface [2]. The longer the infiltration rate will decrease over a period of time to constant and reach infiltration capacity. Infiltration capacity is dynamic which can change in response to changes in vegetation cover, temperature, and water in the soil or as a result of land management and forest management (Lee, 1990 in [3]).

Infiltration is related to soil properties such as structure, texture, volume weight, density, porosity and organic matter. Among the physical properties of the soil that are closely related to infiltration are the texture and structure of the soil. Both physical properties of this soil determine the proportion of micro and macro pores in the soil [3]. Soil pores are parts that are not filled with solid soil material (filled with air or water). Soil pores can be differentiated into macro pore and micro pore. Macro pore contains air or gravity water while micro pore contains capillary water or air [4].

Wanagama which has a hydrological and educational function must be managed with proper hydrological management. Visitors who come to Wanagama affect the existing hydrological system, marked by the presence of tourism activities that affect land density and environmental destruction. In recent years there has also been an overflow of river water from the Oyo River which is adjacent to Wanagama. The most important hydrological cycle is infiltration so infiltration measurements are carried out in this study. Research on infiltration is needed to better understanding and implement effects of the dynamic nature of the soil surface structure on infiltration [5]. The purpose of this study is: a. to find out the infiltration capacity of attractions in Wanagama I Education Forest, and b. analyze the relationship of soil characteristics (particle bulk density (BJ), bulk density (BV), porosity, structure, texture, and organic matter) to infiltration capacity.

2. Material and methods

2.1. Location
This research was conducted at the Wanagama I Education Forest located in GunungKidul Regency. Data retrieval is carried out at 4 tourist sites and 1 control location i.e.: Wanagama 1000 Selfi, Wanagama Paksi, Wanagama Suspension Bridge, Camping Ground Plots 5 and Location of Control.

2.2. Material
The materials used in this study are:

1. Water to be inserted into the Double ring infiltrometer
2. Land on various tourist attractions in Wanagama I Education Forest

The equipment used in this study are double ring infiltrometer, soil ring sample, stopwatch, tally sheet, plastic, bucket, dipper, ruler, analytical scales, oven, clinometers, roll meter, hag meter, tape meter, camera.

2.3. Methods
The data was collected in Wanagama 1000 Selfie, Wanagama Paksi, Camping Ground, around Wanagama Bridge and Control Site. The four locations of tourist attractions are determined based on the point of interest, which is interesting places for visitors to come [6] states that the results of the interpretation will be the main source of information that can be packaged into a point of interest in an area that presents unique and distinctive attractions and carries a conservation mission.

Sampling was carried out at each location of a tourist attraction with 3 replications so that 15 soil samples were obtained. The soil samples used are disturbed and not disturbed. Taking samples of uninterrupted soil is done by using a soil ring sample [7]. Disturbed soil samples are used for texture determination, BJ, and Organic Materials analysis. Undisturbed soil is needed for analysis of determination of bulk density (BV). Furthermore, the infiltration capacity measurements were carried out with a double ring infiltrometer at the 15 sampling points.
Then, the soil samples were brought to the laboratory for analysis of texture, structure, BV, BJ, porosity, organic matter. Soil texture was analyzed by piping method, soil structure was observed with a microscope, BV was obtained gravimetrically, BJ was measured using piknometer, while organic matter was measured using the Walkley and Black method.

2.4. Analysis
The infiltration measurement technique carried out in the field is by means of a double ring infiltrometer. After infiltration measurements, the actual infiltration rate is calculated. Then plotting the time (h) as the x axis with the actual infiltration rate (cmh⁻¹) as the y axis, so that the graph of the actual infiltration rate relationship with time is obtained. After the actual infiltration rate is known, the next step is to calculate the rate of Horton infiltration [8] and [9].

Based on the data obtained at each tourist attraction, analysis was carried out with One Way ANOVA. This analysis is carried out to explain the value of infiltration capacity according to the conditions of tourist attractions. After that, a statistical analysis was performed with multiple regression on volume weight, specific gravity, porosity, and organic matter against infiltration. The analysis carried out on the structure and soil texture is descriptive analysis.

3. Result and Discussion

3.1. Infiltration Capacity
Infiltration measurements were carried out on several tourism objects in the Wanagama I Education Forest, namely Wanagama 1000 Selfie, Wanagama Paksi, around Wanagama Bridge, and Camping Ground Plots 5 and Control by random sampling. The results of measuring infiltration capacity in the five locations are presented in the figure 1 as follows:

![Figure 1. Infiltration Capacity at each Tourism Object](image-url)
Infiltration Capacity in Wanagama 1000 Selfie. The location of Wanagama 1000 Selfie has an area of about 1.35 Ha. This location is used by visitors to relax, camp and outbound. This location has a wooden museum that is used for education related to wood. The results of measuring infiltration capacity are presented in figure 2 as follows:

![Infiltration Rate in Wanagama 1000 Selfie](image)

**Figure 2. Infiltration Rate in Wanagama 1000 Selfie**

Figure 2 shows that the infiltration capacity in the upper Wanagama 1000 Selfie is 12 mm / hour. This figure shows that infiltration in this area is classified as rather slow according to [10]. The infiltration capacity in the middle area is 120 mm / hour, categorized as rather fast and at the lower area has 204 mm / hour (fast category).

Based on the results of soil analysis, it can be seen that the soil texture in the upper Wanagama 1000 Selfie is clay. This dominant clay fraction makes it difficult for water to enter the soil. Clay-textured soils have the ability to hold water and provide high nutrients. The infiltration capacity at the upper area is small. The BV at the upper area is 1.14 g/cm³ higher than that of the lower area. This is because the location of the upper part is close to the entrance to the Wood Museum which becomes a visitor passing by so that the compaction of the land is greater. The BJ at the upper area is 2.08 g/cm³. The value of the BJ determines the magnitude of porosity. The porosity of the land at the upper area is 45.29%, this is lower compared to the middle and lower area. This happens because of intense soil compaction. Soil compaction results in shrinking the soil pore so that it impacts on the difficulty of air and water entering the soil. Although the organic material at the upper area is higher than the middle and lower parts, but it does not significantly reduce soil compaction because the sampling location is close to the path.

In the middle part of the location of Wanagama 1000 selfies have a clay soil texture. This clay texture affects the speed of water entering the soil so that the value of infiltration capacity in the middle is lower than the lower area. The BV in the middle area is 1.23 g/cm³ and the BJ is 2.18 g/cm³. The porosity in this middle section is 54.72% higher than the upper but lower compared to the lower area, resulted the infiltration capacity value is in the middle between the upper and lower area. The organic material
content is 2.83%. Organic material in this section is small but the infiltration is rather fast due to other factors, which are large porosity which makes water easier to enter.

At the lower area of Wanagama 1000 selfies has a clayey soil texture. This high sand fraction makes it easy to pass water into the soil so that the infiltration capacity at the lower area is greater than the other parts. The texture at the lower area is different from the other parts because the lower area is close to the Oyo river in Wanagama. The BV is 1.01 g/cm³ and BJ is 2.37 g/cm³. The porosity is 57.31%, bigger than the other parts so that it can pass a lot of water. The organic matter at the lower area is 1.12%, although the organic matter is small but the soil texture class in this section is clay loam which is dominated by the sand fraction making it easy to lose the water. Moreover, landslides in residual soil slopes are commonly induced by rainfall infiltration [11].

3.1.2. Infiltration Capacity in WanagamaPaksi. The Wanagama Paksi site has an area of about 0.24 ha. This location is used for relaxing, refreshing, and educating about bird species in the dome. The results of measuring infiltration capacity are presented in figure 3 as follows:

![Figure 3. Infiltration Rate in WanagamaPaksi](image)
proportional to the infiltration capacity which is also small. The organic matter content at this section is classified as high category (3.74%).

At the lower area of WanagamaPaksi has the clay soil texture. The soil BV is 1.12 g/cm³ and the BJ is 2.21 g/cm³. The porosity of this section is 49.12%, greater than the value of porosity in other parts. This is proportional to the magnitude of the infiltration capacity at the lower area which is also greater than the other parts. Organic material in this section is high category (3.54%).

3.1.3. Infiltration Capacity in the Bridge Area. The location around the Wanagama bridge has an area of 0.26 ha. This location is used for just relaxing, taking pictures, playing canoeing, swimming in the river and fishing. The results of measuring infiltration capacity are presented in the graph as follows. figure 4. shows the infiltration capacity around the upper area of Wanagama Bridge at 48 mm/hour. This figure shows that this region is in the medium class category. In the middle part it has 96 mm/hour (rather quickly). At the lower area, has the infiltration capacity of 12 mm/hour (rather slowly). The measurement results that the soil texture of the upper area is clay with a BV of 1.25 g/cm³ and BJ of 2.30 g/cm³. The porosity in this section is 45.77%. Infiltration capacity in this section is the second largest after the middle area. The organic matter content at the upper area is categorized as high class (3.39%), and it results the infiltration capacity is also in the medium category.

In the middle part of the location it has a turbulent texture. This large sand fraction (71.53%) affects the amount of soil infiltration in this section, so the value of infiltration capacity in this section is greater than the other parts. The volume weight ranges from 1.25 g/cm³ and the specific gravity ranges from 2.37 g/cm³. The porosity in this section is 47.40%. Organic material in this section includes the medium class category (1.12%). It is influenced by a high porosity factor and the texture class in the middle is sandy loam which are dominated by the sand fraction making it easy to loose the water from the soil surface.

At the lower area of the location it has sandy clay texture, dominated by the clay fraction which causes the slowly flow of water due to the micro pore. The BV of this section is 1.46 g/cm³. This means that the land in this section is denser than others. Solid soil has small pores so that the infiltration capacity is small. The BJ in this section is 2.37 g/cm³ and its porosity is 30.86%, small porosity is directly results in the small infiltration capacity. Organic material at the lower area is so small that the infiltration capacity is small.

Figure 4. Infiltration Rate in the bridge
3.1.4. **Infiltration Capacity in Camping Ground.** This location has an area of about 0.28 Ha. This location is used for just relaxing, camping and is equipped with a pavilion that is commonly used for gatherings. The results of measuring infiltration capacity are presented in figure 5 as follows.

![Figure 5. Infiltration Rate in Camping Ground.](image)

Figure 5. shows that the infiltration capacity of the upper area of Camping Ground is 24 mm/hour. This figure shows that this region belongs to the middle class category based on Kohnke's classification (1968) in [10]. In the middle part of 12 mm/hour, the rather slow category while at the lower area is 72 mm/hour, categorized as a rather fast class.

The soil texture at the top of the Camping Ground is loamy sand. The large percentage of dust and sand in this section is due to the large amount of limestone in this location. The dust fraction dominates (50.56%). The BV is 1.01 g/cm³ and the BJ is 1.88 g/cm³. The porosity is 46.49% and the organic material content is included in the category of very high (6.76%).

In the middle part of the texture is sandy loam with a very dominant sand fraction (63.39%). Sand and dust dominate the part marked with the chalk chunks when sampling. The BV is 1.14g/cm³ and the BJ is 2.29 g/cm³. The porosity in this section is 50.24%. Very large porosity is inversely proportional to the small infiltration capacity, this is because at the middle there is a pavilion so that previously there was intense development that resulted in the soil compaction. The organic matter content in this section includes the excessive class category (7.93%).

At the lower area has the soil texture of the sandy loam. The sand fraction is very dominating (57.19%). The BV is 1.08 g/cm³ and the BJ is 2.05 g/cm³. The porosity is 47.07% and the organic content is included in the category of excessive class (7.62%).

3.1.4. **Infiltration Capacity in Control Location.** The control location in this study has an area of 2.74 ha. This location is located between Wanagama 1000 Selfies and Wanagama Paksi which are not accessed by tourist visitors. This location is very green and has tight vegetation cover. This location was taken as a comparison with the tourist sites in Wanagama I Educational Forest. The results of measuring infiltration capacity are presented in figure 6 as follows.
Figure 6 shows that the infiltration capacity in the upper area of control location is 264 mm / hour (very fast class). The middle part has 480 mm / hour (very quickly) and at the lower area has 360 mm/hour (very fast). The results of the soil analysis showed that the upper area of control location had a soil texture of loam, consist of sand fraction (38.38%), silt (34.83%) and clay (26.79%). The BV is 1.13 g/cm³ and the BJ is 1.99 g/cm³. Its porosity is 43.08% and organic matter in this section belongs to the very excessive class category (8.37%). Organic material at the upper area has a high percentage and has a large infiltration capacity but is not greater than the middle and lower parts, this is because in this part the porosity is smaller and the soil density is greater than the other parts.

In the middle part it has a clay texture because the clay fraction dominates (46.22%). The BV is 1.04 g/cm³ and the BJ is 1.96 g/cm³. The porosity in this section is 47.02% and organic matter in its part is included in the high class category (2.23%). The organic matter is smaller than the other parts but it has a very large infiltration capacity because in this section its porosity is greater than the other parts and also small soil compaction shown by the value of the BV is smaller than the upper and lower area.

At the lower area has a clay texture with a BV of 1.03 g/cm³ and the BJ is 1.91 g/cm³. The porosity in this section is 46.31%. The content of organic matter in this section belongs to the category of excessive class (7.69%). High organic matter and the second highest porosity than other parts results in very fast infiltration capacity.

3.1.5. One Way ANOVA Test Results. Data of infiltration was analysed by using One Way ANOVA test to find out variables that are significant in some tourist objects. From the results of this test showed that the significant value was 0.001. The level will be significant if <0.05 (5%). Further test by using Duncan's was applied and resulted that Control area has a significant value to four tourist areas that are Wanagama 1000 Selfie, Wanagama Paksi, Camping Ground and the Bridges area. It has to be understood that infiltration process is one of the most important components of the hydrological cycle. Then, the ability to quantify infiltration is of great importance in watershed management [13].

4. Conclusion and recommendation
Based on this research, it can be concluded that:
1. The average infiltration capacity in various tourist attractions in Wanagama I Education Forest is 112 mm/hour (rather fast) in Wanagama 1000 Selfies, 76 mm/hour (rather fast) in Paksi Wanagama, 52 mm/hour (medium) at Bridge, 36 mm/hour (medium) on Camping Ground, They are significantly different to control area which has the rate of 368 mm/hour (very fast).

2. a. Soil structure conditions in the Wanagama I Education Forest in all locations are sub angular blocky, soil texture is mostly dominated by clay. The average value of BV varies, the highest value is on the bridge is 1.32 g/cm³ and the smallest value is in Camping Ground (1.03 g/cm³). The highest average density is found on the bridge, which is 2.26 g/cm³ and the smallest one on the Camping Ground (2.07 g/cm³). The highest average porosity values were found in Wanagama 1000 Selfie, which were 52.44% and the smallest on the Bridge (41.34%). The average value of the highest percentage of organic matter is found in Camping Ground, which is around 7.44% and the smallest is around the Wanagama Bridge, which is around 1.70%.

b. There is no significant relationship between structure, texture, BV, BJ, porosity and soil organic matter to infiltration capacity because many other factors influence infiltration.

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Acknowledgement
We would like to thank to Universitas Gadjah Mada (UGM) for facilitating this research through UGM Final Project Recognition 2019.