The infiltration capacity and rate at the grass, building yard and green open space areas of Universitas Gadjah Mada campus

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Abstract. Land use and soil greatly determine the rate of infiltration. There are three land uses according to vegetation cover and buildings at the Universitas Gadjah Mada (UGM) campus, namely grassland, building yard and green open space area. The purpose of this study is to determine the capacity and rate of infiltration at the UGM campus area and to design the proposed land use that increases infiltration. This research uses a double-ring infiltrometer, soil samples consist of disturbed and undisturbed. Analysis of infiltration capacity using Horton's formula, then we analysed the physical and chemical properties of the soil at the laboratory. Based on the results of the study, it concludes that the infiltration capacity of grassland is 12.52 mm/hour, the building yard is 10.89 mm/hour, and the green open space area is 14.02 mm/hour. The infiltration rate of the three land uses is slightly slow. The soil texture is mostly silty clay, crumb soil structure and organic matter content ranges from 1-2.1%. The recommended land use plan for the area of UGM is planting more trees.

1. Introduction
The campus area of Gadjah Mada University (UGM) continues to grow along with the need for learning activities indicated by the increasing use of available space. Utilization of space tends to increase the area for building. In the last ten years, from 2010-2021, educational facilities and infrastructure have been built in several faculties. The increase of the built area increases the burden on the carrying capacity of the environment.

Kodoatie & Sjarief [1] stated that spatial utilization planning refers to the spatial function specified in the spatial plan. Planning is carried out by developing land use, water, and other natural resources. The availability of land to regulate the hydrological cycle and including natural boundaries is carried out to avoid the risk of disasters such as floods, landslides, and drought.

The land has a limited carrying capacity, its use needs to be maintained so that no damage or degradation occurs [2]. The increase in land requirements is calculated under the ability of the land as an environment in which humans move to avoid degradation. Degradation occurs on land that is used excessively and exceeds its natural carrying capacity and capacity [3]. Land degradation is defined as the loss of land's ability to produce [4].

The water catchment area is one of the important components that need to be considered in land use planning. It is needed to regulate the hydrological cycle in a balanced manner. Water catchment areas play an important role as flood and drought controllers. Floods and droughts can be controlled with various approaches, one of which is maximizing the catchment area. Improvement of water catchment...
areas is an important effort to do to maintain the balance of the hydrological cycle [5]. The hydrologic cycle consists of four main parts, namely evaporation, precipitation, runoff and infiltration.

Gadjah Mada University is one of the universities that is committed to being an environmentally friendly educational area or what is called a Green Campus. The form of commitment is carried out with various sustainable development efforts. Several parameters are used, one of which is the arrangement and infrastructure. Good governance and infrastructure to achieve sustainable development.

Infiltration is a complex interaction between rainfall intensity, characteristics and soil surface conditions. The intensity of rain affects the opportunity for water to enter the soil. When the intensity of rain is smaller than the infiltration capacity, so all water has the opportunity to enter the soil. On the other hand, if the rainfall intensity is higher than the infiltration capacity, then some of the water that falls on the ground does not have a chance to enter the ground, and this part will flow as surface runoff.

The use and conditions of the soil surface greatly determine the level of capacity of water to penetrate the soil surface, while the characteristics of the soil, especially its internal structure, affect the rate of water passing through the soil mass. The most important soil structural elements are pore size and pore stability. Gadjah Mada University has three (3) types of land use types according to the vegetation cover and the surrounding buildings, namely grassland, building yard and green open space area. Various types of land use in the Gadjah Mada University area that have small infiltration should be improved according to the land-use plan so that the soil infiltration can improve. Based on the problem formulation above, the purpose of this study is to determine the rate and capacity of infiltration and to design land use forms that can increase infiltration under reducing the flood potency at the Gadjah Mada University campus.

2. Materials and Methods

2.1. Geographical Location and Area

This research was conducted in the Gadjah Mada University campus area which is administratively located in Bulaksumur, Caturtunggal, Depok District, Sleman Regency, Yogyakarta Special Region. This campus has an area of 180 ha which includes 18 faculties, 1 Graduate School, and 1 Vocational School. The area also consists of various functions, including infrastructure functions, campus clusters, and other supporting functions.

The dominant soil type in this area is the Regosol soil type with soil physical properties that are included in the loamy sand soil class (sand 78.26%; dust 14.76%; and clay 6.97%) [6]. The climate in the UGM campus area includes a wet tropical climate with a rainy season between November-April and a dry season between May-October. Rainfall is the level of water that collects in a flat place, does not evaporate, does not seep, and does not flow. Based on data from BMKG observations, the rainiest days in a month are 25 days and at least 1 day. The average rainfall in this area is 2500–3500 mm per year. The average temperature at the study site is 280 C with 45–100% humidity. The average wind speed is 1.88 m/s in 1 year [7].

The arrangement of green/landscape elements on the UGM campus is directed at efforts to overcome problems that interfere with academic activities through ecological engineering. The green system concept applied is the Green Way which consists of two kinds of systems, namely closed systems and Open systems. Closed systems are intended as water catchment areas and air conditioning and in the long term should be able to replace the function of air conditioners in lecturer rooms, lectures and laboratories or meeting places with wild forests and various types of plants. The open system is intended as a parking lot or other activity area shaded by tall, large and diverse trees. The selection of plant species is adjusted to the character of the microclimate. This system is located along major roads, cluster boundaries, and UGM valleys.

2.2. Sampling Points
The research was conducted on the campus of Gadjah Mada University, Yogyakarta. The research location is divided into three types of land use types, namely: grass area, building yard area, and green open space area. At each of the three types of land uses, the samples were taken at three different locations and each location data were collected at three different points. In this study, 27 sample points were obtained. The map of the research location can be seen in Figure 1 below.

Figure 1. Map of Data Collection Points at the Research Site.

The details of the location of each data collection point are described as follows.

a. Grass area, including UGM Hall (grass section around the building), Boulevard Path to GSP (grass section in the middle of the lane) and GSP parking lot with 3 points each.

b. Building yard area includes 1. Three points in the north (1 point at the UGM Faculty of Mathematics and Natural Sciences, 1 point at the UGM Fisheries Department, and 1 point at the UGM Faculty of Veterinary Medicine). 2. Three points in the centre (1 point at UGM Central Library, 1 point at Bulaksumur Residence UGM, and 1 point at UGM Valley Sports Centre Building) and 3. Three points in the south (1 point on the UGM Faculty of Dentistry, 1 point on the UGM Faculty of Mathematics and Natural Sciences, and the UGM Campus Mosque).

c. Green open space area, covering the Arboretum of the Faculty of Forestry, Arboretum of the Faculty of Biology, and the UGM Valley (the part covered by tree vegetation) with 3 points each.

2.3. Tools and Materials

Research Tools and Materials consists of tools for field research as well as laboratory research. Global Positioning System (GPS), to determine the location of data collection through coordinate points and to know water catchment areas. Double Ring Infiltrometer, to measure the infiltration capacity. Soil rings were used to take the soil samples. Stopwatch, for measuring the length of time during the infiltration process. Ruler, to measure the drop of water that seeps into the ground. Plastic, to store soil samples. Buckets and jerry cans, for water containers. Compass, to determine the cardinal directions in the field.
Roll meter, to make a square plot. Label paper, to provide information on each soil sample. Shovel, to obtain the required soil sample. Cutter, to clean the remaining soil on the soil ring infiltrometer. Stationery and tally sheet, to record the required data. Laptop, to process data. Camera, to document research activities. The materials used in this study were water and soil samples collected from 27 observation points spread across the UGM campus area.

There are two types of data taken in this study, namely primary data and secondary data.

a. Primary data
The primary data taken in this study include infiltration data, soil physical properties data, soil chemical properties data, and vegetation data. Infiltration data in the form of infiltration capacity. Soil physical properties data in the form of soil texture and soil structure. The data on the chemical properties of the soil used in this study was in the form of soil organic matter (SOM).

b. Secondary data
Secondary data is data obtained from previous studies and obtained from certain institutions or agencies. Secondary data taken in this study is a map of the location. The research location map was made using ArcGIS 10.3 software with RBI Sheet Yogyakarta base map and Google Earth satellite imagery.

2.4. Data Analysis Method
The data obtained from the infiltration capacity measurement were then tabulated and data processing with Ms Excel, then the data was analysed using the Horton equation. The Horton equation is as follows:

\[ f = f_c + (f_0 - f_c) e^{kt} \]  

Where,
\[ f \] : Infiltration rate (mm/hour)
\[ f_0 \] : Initial infiltration rate (mm/hour)
\[ f_c \] : Infiltration capacity (mm/hour)
\[ k \] : Constant (k value = 2.75)
\[ t \] : Time (hours)

Soil texture shows the ratio of grains of sand, dust and clay [8]. The laboratory analysis results in the percentage of each fraction which was then entered into the USDA soil texture class triangle, from the soil texture class triangle the soil texture class obtained. Soil structure shows the combination or arrangement of primary soil particles (sand, dust and clay) to secondary particles or also called aggregates [9]. The soil structure was analysed descriptively to explain the relationship between soil structure and infiltration capacity [10].

Soil organic matter has a fairly complex structure, but its composition is relatively constant. Carbon (C) is the main “building” element of soil organic matter, accounting for 48 – 58% of the total weight of BO. To determine the amount of % organic matter in the soil, the Walkley and Black methods were used.

3. Result and discussion

3.1 Infiltration Capacity and Rates
The infiltration rate is determined by the amount of infiltration capacity and the rate of water supply (rain intensity). As long as the rainfall intensity is less than the infiltration capacity, the infiltration rate is the same as the rainfall intensity. If the rainfall intensity exceeds the infiltration capacity, there will be inundation on the surface or runoff. Thus, the infiltration rate varies according to variations in rainfall intensity. Infiltration that occurs in one place is different from other places and at other times, one of which is determined by the type of land use [11]. The infiltration rates at various land use vary depending on the type of land use and several factors affecting the properties of the soil, including soil texture, organic matter, bulk density, porosity, aggregate stability/stability and water content. However, to ascertain the rate of infiltration, research is needed on these various land uses. According to Agustina et al. [12] different land uses result in different infiltration rates.
3.1.1. Grass Area

Land use with grass plants can provide a good texture form on the soil surface. Grass plants have characteristics that give a smooth or rough impression on the soil surface. In addition, grass plants as ground cover are useful for protecting the soil from the threat of damage due to erosion and for improving the chemical and physical properties of the soil [13].

Figure 2 shows that the infiltration capacity on grassland ranges from 7.25 to 21.05 mm/hour with a slightly slow to moderate class. From 9 sample points, there is only 1 sample point that has a moderate infiltration rate classification located on the UGM Boulevard 2 (G2). The other eight sample points show a rather slow infiltration rate classification. This is because the existing infiltration is getting smaller on land uses that have vegetation with short roots compared to vegetated land. The absence of stands or ground cover automatically has a direct effect on the organic matter content.

![Figure 2. The infiltration capacity of the grass area.](image)

3.1.2. Building Yard

The land suitability analysis only considers the physical factors of the soil. These considerations are based on the suitability of building construction to the bearing capacity of the soil as its foundation [14].
One of the construction failures that often occurs is land subsidence caused by the consolidation process. Consolidation is the process of reducing the pore voids of low-permeability saturated soil due to loading, where the process is influenced by the speed at which water is squeezed out of the soil cavity [15].

In Figure 4 we can see that the infiltration capacity of the yard building ranges from 3.56 to 26.32 mm/hour or slow to moderate class. This figure also shows that there is a significant difference in infiltration rates, especially at the sample points at the Faculty of Veterinary Medicine UGM (B3) with a moderate infiltration rate and the UGM Faculty of Dentist yard (B7) with a slow infiltration rate. This can be explained by the density of the soil which is influenced by the presence of buildings, so the infiltration rate tends to be slow. The infiltration rate of the building yard can be seen in the figure below.

![Figure 4](image)

B1 = Fac. of Mathematics and Nature; B2 = Department of Fisheries UGM; B3 = Faculty of Veterinary Medicine UGM; B4 = UGM Central Library; B5 = Bulaksumur Residence; B6 = UGM Valley Sports Center Building; B7 = Fac. of Dentist; B8 = Wisma FMIPA UGM; B9 = UGM Campus Mosque Courtyard

**Figure 4.** The infiltration capacity of the building yard.
3.1.3. The Green Open Space Area

According to Morgan [16], the effectiveness of vegetation in suppressing runoff and erosion is influenced by canopy height, canopy area, and vegetation density. Trees have a canopy that can withstand the kinetic energy of rainwater, litter covers the soil surface to protect the soil surface, and the tree root system is also able to improve soil porosity and soil infiltration [17]. From Figure 5, the infiltration rate obtained is mostly rather slow, however, there are 2 sample points with moderate infiltration rates, namely UGM Lake 3 (S6) and the Arboretum of the Faculty of Forestry 3 (S9). The presence of high plant density in this type of land use tends to increase the rate of soil infiltration. First, because the roots help the formation of macropores and secondly the existence of transpiration makes the soil drier and absorbs water faster. The canopy of vegetation prevents the soil surface from hitting raindrops and with the occurrence of plant transpiration so that water absorption from the soil can provide room for the infiltration process [18].

Figure 5. Infiltration rate of building yard.

Figure 6. The infiltration capacity of green open space area.
Figure 6 shows that the infiltration capacity at the green open space area ranges from 7.19 to 21.04 mm/hour with a rather slow to moderate class. The type of land use of green open space area has the largest infiltration capacity. However, the rate of infiltration in this area is slightly slow. This is because the area has more variety of stands.

The infiltration rate is influenced by the condition of the physical and chemical properties of the soil. This effect shows that the physical properties of the soil on the green open space area are very supportive of the infiltration process compared to other types of land use. The infiltration process is highly dependent on soil structure at the surface layer and various layers in the soil profile, while soil structure is influenced by soil organic matter and biota activity whose energy sources depend on organic matter (surface litter, organic exudation by dead roots and roots). The availability of high organic matter for biota (especially earthworms) plays a very important role in anticipating the process of clogging of soil macropores which greatly determines the rate of infiltration [19], therefore the high infiltration of the green open space area is caused by better soil physical quality, especially higher soil porosity due to the high C-organic content of the soil.

The high soil organic matter in the land can increase the activity of soil organisms and improve soil structure. According to [20], one of the important roles of organic matter is to reduce the bulk density of the soil and increase the rate of soil infiltration. In addition, the presence of various forms of a canopy, and tree density are other supporting factors in the infiltration process.

3.2. Soil Characteristics
Soil physical properties are environmental elements that greatly affect the availability of water, soil air and indirectly affect the availability of plant nutrients. This property will also affect the potential of the soil to produce optimally [21]. The physical properties of the soil are related to the shape or condition of the original soil, which includes texture, structure, soil density, porosity, stability, consistency, colour and temperature of the soil and others. In this study, observations were made on the texture, structure and permeability of the soil in the UGM campus environment.

Soil texture is closely related to the movement of water and solutes, air, heat movement, soil volume weight, specific surface area, the ease of compaction (compressibility), and others [22]. Soil texture is the relative ratio between the fractions of sand, silt and clay, namely soil particles whose effective diameter is 2 mm.

The soil analysis of the soil texture can be seen in table 1. Based on the laboratory analysis, the soil texture in the UGM campus area has three soil textures, namely loam/clay, sandy loam / sandy clay, and silt loam / dusty clay.
The laboratory analysis shows that at 8 points the sample had a loam texture. The texture is slightly coarse soil and has almost equal fractions of sand, silt, and clay. The soil will also be more porous than soil with high fine content. This means that such soil will be easily penetrated by plant roots, the amount of water and air retained in the soil will be balanced for plant growth [23]. Two observation points that have a soil texture in the form of sandy loam are on Boulevard 3 and Arboretum of the Faculty of Forestry 1. According to Bhardwaj [24], the characteristics of sandy textured soil are low water holding capacity and excessive drainage so that the availability of water and fertilizers can be used.

Soil with a silt loam/dusty clay texture dominates the UGM campus area. Toknok et al. [25] stated that dusty clay soil is soil that when dry clumps but breaks easily and when wet feels soft and floury, sticks to form hard lumps. Soil structure is one of the physical properties of soil that can affect soil loss in the land. Soil structure is the soil fraction that forms soil aggregates [26]. The soil structure in the UGM campus area is crumb with the consistency of dry and slightly hard to hard conditions. This relates to the texture of the soil that is clay. The structure is the interlocking arrangement of soil grains. [27] explained that crumb soil structure is a soil structure that is good at passing water and has nutrients that are more easily available to plants. In contrast to the single grain, structure which can pass water faster but is poor in nutrients.

The content of organic matter in the soil affects the soil quality. Although the organic matter content in most soils is only 2-10%, it has a very important role [28]. Based on the table above, it is known that most of the soil in the UGM campus area has low organic matter content. This is because the lands in the area rarely receive treatment in the form of composting. In addition, most areas do have not too

| Sample | Texture | Soil structure | SOM |
|--------|---------|---------------|-----|
| S1     | loam    | crumb         | 7.19|
| S2     | loam    | crumb         | 13.39|
| S3     | loam    | crumb         | 8.56|
| S4     | loam    | crumb         | 17.13|
| S5     | loam    | crumb         | 19.67|
| S6     | silt loam | crumb     | 21.04|
| S7     | sandy loam | crumb     | 9.98|
| S8     | loam    | crumb         | 8.81|
| S9     | loam    | crumb         | 20.38|

Table 1. Soil characteristics.
much vegetation. Building factors and human activities also contribute to the development of soil organic matter in the area.

The physical properties and chemical properties of the soil on the UGM campus has a slight difference. It depends on the land use. On the grassland, the soil has a texture of silt loam/dusty clay with a crumb structure and is a bit hard. The use of grassland has little deep-rooted vegetation, so the soil has quite a bit of organic matter. With low organic matter content, the soil has low porosity and results in low permeability.

In the building yard, the physical and chemical properties of the soil are almost the same as the conditions on the grassland. The organic matter content is higher than grassland. This is because the amount of vegetation in the building yard is more.

Of the three land uses, land under the stands had better physical and chemical soil properties to support infiltration. The amount of vegetation that is more diverse makes the soil richer in organic matter. Soil permeability also increases, making it easier for water to escape into the soil.

3.3 Infiltration at Different Land Use and Soil Characteristics
The spatial development of the Gadjah Mada University (UGM) campus area that occurs from year to year as an effort to meet the needs of the area for learning activities indicates an increase in the use of available space. The rapid development of buildings allows the reduction of rainwater catchment areas [29]. The water catchment area is an area where rainwater seeps into the ground which then becomes groundwater [30]. In this study, the mechanism of rainwater infiltration was observed in the form of an infiltration process.

The use and condition of the soil surface, the characteristics of the soil and the conditions above the soil surface will affect the rate of water passing through the soil mass. Gadjah Mada University's land has various types of land use, which show different infiltration capabilities in each type of land use. Based on the type of land use according to the vegetation cover and the surrounding buildings, the Gadjah Mada University area has three (3) types of land use types, namely the type under the stands, the type of grass, and the type of building that has a yard. The results of the research that have been carried out for the three types of land use observed show that the infiltration capacity of each land use is different, with the highest to lowest average infiltration capacity, respectively, on land under the stands of 14.02 mm/hour., grassland 12.52 mm/hour, and building with yard 10.90 mm/hour. This shows that differences in use and conditions on the soil surface allow differences in infiltration rates that occur in the area.

Each land use shows the differences in the vegetation community that compose it as well. Vegetation plays a role in increasing the infiltration capacity of the soil and protecting the soil from raindrops that can damage the soil structure so that it can reflect the ability of the soil to absorb rainwater, maintain or increase the infiltration rate, and show the ability to hold water or infiltration capacity [31].

In general, soils on land with dense vegetation will tend to be better able to support the infiltration process through increasing organic matter content, amount and thickness of litter and soil biota that support the infiltration process [32]. The results show that the green open space area has a higher infiltration capacity than the other two types of use. This is because the existing vegetation cover forms a layered canopy stratification consisting of various levels of constituent tree growth thereby reducing the rate of rainwater falling to the ground and the ability of transpiration by trees to provide room for the infiltration process, the layer of litter that accumulates on the forest floor avoids the surface. The soil from the blows of raindrops, as well as the plant roots that make up the formation of macropores and the presence of transpiration, makes the soil drier and absorbs water quickly.

On the grassland, the presence of vegetation in the form of trees is not found, more understorey grows. The trees are planted with a certain pattern to add aesthetic value. Grass as a ground cover is useful to protect the soil from the threat of damage due to erosion and to improve the chemical and physical properties of the soil, besides that, land use with grass plants can provide a good texture form on the soil surface [13].
Differences in land use indicate differences in the composition of the vegetation found growing above the soil surface. In addition to these differences, the condition of the physical and chemical properties of the soil is also another factor that determines the characteristics of soil infiltration. Texture and structure affect the distribution of soil pores which in turn affects the rate of infiltration, the ability of the soil to hold water and other hydrological processes [33]. Based on the observed soil texture of each land use, the overgrown land use withstands has a soil texture that is dominated by loam/clay texture which is characterized by almost balanced fractions of sand, silt, and clay so that it is more porous which allows water to enter will be faster [23]. On the grassland, the observed soil texture shows three textures that compose it, namely silt loam or silty clay that is the most dominant, loam, and sandy loam / sandy loam. In the type of building land with a yard, there are only two soil textures that make up the soil on the land, namely silt loam/dusty clay that is the most dominant and loam or clay, which is only found at one observation point. Toknok et al. [25] stated dusty clay soil as soil which when dry clumps but breaks easily and when wet feels soft and floury, sticks to form hard lumps.

4. Conclusions
The infiltration capacity on grassland ranged from 7.25 – 21.05 mm/hour, on building yards it ranged from 3.56 – 26.32 mm/hour, and on green open space areas ranging from 7, 19 – 21.04 mm/hour. The average infiltration capacity for each type of land use was obtained, namely grassland 12.52 mm/hour, building yard of 10.89 mm/hour, and green open space areas of 14.02 mm/hour. The infiltration rate in the green open space area was higher than the other two land uses. This is because the tree's root system enlarges the pores of the soil so that it is easier to pass water.

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