Soil properties under four different land uses in relation to soil erosion and conservation in Wanagama

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Abstract. Although the parent material of the study area is the same at all land uses, but when the plantation is different will result the different processes and development. In Wanagama where it was used to be highly degraded land, then it was rehabilitated. This research aimed to analyze the soil properties under Gliricida, teak, crops and grass plantation. Also, aimed to relate the soil properties with soil erosion. Soil samples were taken from the field randomly at the four land use types with 3 replications, in addition for the grass land the soil samples were taken from the 3 location. Then, they were brought to the laboratory to analyze. This research shows that: the soil organic content varies from 2.61 to 9.78%; the permeability were classified as slow to very rapid; the bulk density and bulk particle density are also varies, that are 0.50 – 1.15 and 1.86 – 2, 20 respectively. Soil porosity ranges from 46.75 to 76.97 % which is considered as moderate to high. The soil texture are mostly clay with the clay content varies from 32.79 to 61.85%. The soil erodibility is considered as low to moderate with the K factor of 0.07 to 0.26. Soil properties has a very close relationship with the process inside the soil, especially related to the psychological processes or other process including erosion process.

1. Introduction
Soil characteristics, both chemical and physical reflects its fertility and will influence the development process of the soil. It relates to soil function as plant growth media also to other process such as erosion. Research of soil characteristics is absolutely important to achieve sustainable forest management [1].

Wanagama is an education forest located in Gunung Kidul Regency, Yogyakarta Province. Wanagama was used to be critical land that could not be utilized but this area had been successfully rehabilitated into a forest that provided direct and indirect benefits by 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 form of Wanagama I as a forest which was built in a critical area [2].

Wanagama is used to be highly degraded land where the soil was extremely shallow and unfertile. In rehabilitating the land, several species were planted such as teak, ebony, gliricida, also grass and in such area was planted by the farmer for agricultural land. According to [3] there were six variables, i.e. rainfall, soil type, slope, populations, populations density, and distance to urban area were significantly affecting the land use and cover changes for the watershed.

Soil, water and vegetation resources are nature’s gift to mankind. These are the basic resources continuing to exert over-riding impact on agricultural production. Twenty per cent of land sustains 60% world’s population that exploited the natural resources (soil, water and vegetation) and that disturbed ecological balance. Therefore, efficient utilization of water resource and conservation of soil are
important for sustainable agricultural production [4]. The purpose of this study are: a. to evaluate the soil chemical and physical characteristics, and b. to relate the soil characteristics to erosion.

2. Methods

2.1. Location
This research was conducted at the Wanagama I Education Forest. Wanagama I administratively is located in Playen district, Gunung Kidul Regency, Province of Yogyakarta. This forest is about 35 km South East of Yogyakarta city, at 7°53’ - 7°54’ South Latitude and 110°30’ – 110°33’West Longitude. Wanagama I Forest was divided into 8 blocks: 5,6,7,13,14,17 and 18 (Suseno, 2004). Data retrieval is carried out at 4 land uses, includes teak forest, gliricidea, crops land, and grass plantation.

2.2. Material
The materials used in this study are:
1. Soil samples taken from 4 land use types
2. Land with 4 variation land uses in Wanagama I Education Forest
   The equipment used in this study are soil ring sample, tally sheet, plastic, ruler, analytical scales, oven, clinometer, roll meter, hagameter, tape meter, camera, and tools for laboratory analysis.

2.3. Methods
The data was collected in Wanagama at four different land uses that were highlighted includes: teak, gliricidea, crops land and grass plantation. Except for grass plantation, the samples consists of 3 areas (upper, middle, and lower areas) with 3 replications, so totally there were 18 soil samples. The soil samples consists of disturbed and undisturbed. Undisturbed soil samples were taken using soil ring sample [5]. Disturbed soil samples are used for texture determination, BJ, and organic materials analysis. Undisturbed soil is required for soil bulk density (BV) analysis.

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 picnometer, while organic matter was measured using the Walkley and Black method.

2.4. Data analysis
After completing the data collected from the field and the result of laboratory analysis, then data analysis was carried out. The K factor (soil erodibility index) was analysed by using the equation [6]. Data required for calculating the K factor includes: soil structure, soil texture, soil permeability and soil organic matter content.

3. Results and Discussion

3.1. Soil characteristics
The table below consists the result of soil analysis and the K factor (soil erodibility index). Table 1 shows that the soil organic matter content ranges from 2.61% to 9.78%. The soil permeability varies from 0.21 to 55.45 mm/hr. The soil bulk density (BV) ranges from 0.5 to 1.15 g/cm3 and the specific density (BJ) varies from 1.86 to 2.18 g/cm3, so the porosity is between 44.51% until 76.97%. The soil texture reflected from the clay content (32.79% - 62.15%), silt (21.96% - 46.97%), and sand (3.4% - 32.14%). The K ranges from 0.07 to 0.25 and classified as very low to moderate. In general the soil structure is sub angular blocky.

According to [7] soil organic carbon maintains soil health and productivity of plant resources. At least there are two advantages of the existence of soil organic matter in the soil includes: increasing the water absorbance and the soil aggregate stability. Furthermore, research done by [8] showed that the
coefficient correlation for the relationship between aggregate stability and organic matter content was highly significant (P<0.01%) which is in agreement with the findings of [9]. Furthermore, the soil organic matter is driven by the soil texture [10]. Other research done by [11] showed that overall mean soil organic carbon stock was higher under natural and mixed forest land use compared with other land use types and at all depths.

The distribution of soil organic matter can be seen in Figure 1 as follows.

![Figure 1. Soil organic matter content](image_url)
The highest soil organic content was in the gliricidea area (7.92%) and the lowest was in the crops land (3.18%). This finding is similar to the research resulted by [12] the highest OM content was found in the forestland, while the lowest OM content was found in the cultivated land. In the forestland tree leaves, stems, barks, flowers, logs and fruits increase OM. According to [13] the intensive cultivation causes the decreasing of organic carbon. This research has the same findings that the cultivation in crops land is much more intensive than that of the gliricidea area. The research finding resulted by [14] shows that forest soil is a source of organic matter that required for improving soil fertility and productivity, includes soil structure, cation exchange capacity (CEC), and source of Nitrogen and other nutrients and as an energy for soil microbial. In more detail, it was studied by [16] that total carbon stocks did not differ significantly between the soil types, but they differ among land use classes. Moreover, [17] mentioned that soil aggregate structure and soil organic matter are closely interrelated and commonly considered as key indicators of soil quality.

![Soil permeability, bulk density and specific bulk density](image)

Figure 2. Soil permeability, bulk density and specific bulk density

Soil permeability is the capacity of a porous material to allow fluids through it. It depends on the soil structure, texture, organic matter content and porosity. The highest average soil permeability was at grass plantation (41.32 cm/hr ) followed by teak forest, gliricidea and crops land (11.05 cm/hr). The high soil permeability at grass plantation is a result of the good root development and less soil disturbance, by contrary, at the crops land the disturbance is higher and the farmer tillage the soil. So, the human disturbance impacts on the soil to be more compact as showed by the soil bulk density of the crops land which is relatively high (2.17 g/cm³).

The soil porosity was calculated by dividing the soil Bulk density (BD) with the soil particle density times 100 percent. Bulk density were the most discerning variables differentiating forest cover from land uses dominated by grass cover [18]. The average bulk density (BV) varies from 0.70 g/cm³ (at the gliricidea) to 1.04g/ cm³ at the teak forest. Research carried out by [19] showed that generally, at all altitudes, the soil under natural forest had the lowest bulk density (g/cm3) compared to the other land use. The specific density (BJ) at all areas is almost the same, varies from 1.91 g/ cm³ (at the gliricidea area) to 2.17 g/ cm³ (at teak forest). The porosity at all areas is in average, ranges from 51.94% (at teak forest) to 63.43% (at gliricidea area). This finding supports the earlier work by [20] who reported inverse relationship between bulk density and porosity of the soil. At the teak forest, it has the highest bulk density and the lowest porosity, by contrary, the gliricidea where it has the lowest bulk density, it has the highest porosity. The soil texture was resulted by analyzing the clay, silt and sand content of the soil. In general, the soil texture of the study area can be classified as clay, silty clay and clay loam.
3.2. Erodibility index

Soil is a highly heterogeneous, diverse and dynamic system. It acts as a medium for sustenance of plant and animal productivity and supports human health and habitation [21]. Soil erosion is the main mechanism of land degradation and one of the most serious environmental problem in the world [22]. Soil erodibility is defined as the inherent capacity of the soil withstand disintegration of its particle and their transport [23]. Land use changes have a significant impact on soil properties and in some cases they are considered to be among the main threats to soil quality [24]. Furthermore, changes in land use and improper soil management have led to severe land degradation around the globe through the modification in soil physicochemical and biological processes [25].

Soil erodibility is the second important factor in erosion process after rainfall erosivity. Soil erodibility is influenced by 4 soil characteristics that are soil structure, texture, organic matter content and permeability. According to [26] probably due to the forest cover that increases the organic matter content, which consequently lowers the K-factor. That is why deforestation and conversion of natural grasslands to agricultural land constitute two of the main threats to soil and water conservation, causing erosion, and likely, desertification.

Figure 3. The distribution of soil texture throughout the study area

Figure 4. The distribution of soil erodibility of the study area
The gliricidea area has the highest erodibility because it has relatively low permeability and the soil texture is clay loam. The grass plantation relatively has the low erodibility because they have high permeability, but less porosity and soil texture are mostly clay.

Table 2. Statistical analysis of the $K$ factor throughout the study area

| No | Code      | difference | $P$     | result |
|----|-----------|------------|---------|--------|
| 1  | GM - JT   | 0.07940    | 0.1390  | NS     |
| 2  | GM - PG   | 0.00994    | 0.7530  | NS     |
| 3  | GM - RA   | 0.06910    | 0.1040  | NS     |
| 4  | GM - RB   | 0.09700    | 0.0370  | SIG    |
| 5  | GM - RT   | 0.09940    | 0.0040  | SIG    |
| 6  | JT - PG   | -0.06940   | 0.2290  | NS     |
| 7  | JT - RA   | -0.01030   | 0.8500  | NS     |
| 8  | JT - RB   | 0.01760    | 0.7430  | NS     |
| 9  | JT - RT   | 0.02000    | 0.6640  | NS     |
| 10 | PG - RA   | 0.05910    | 0.2170  | NS     |
| 11 | PG - RB   | 0.08710    | 0.0900  | NS     |
| 12 | PG - RT   | 0.08950    | 0.0370  | SIG    |
| 13 | RA - RB   | 0.02790    | 0.5410  | NS     |
| 14 | RA - RT   | 0.03030    | 0.4030  | NS     |
| 15 | RB - RT   | 0.00240    | 0.9420  | NS     |

4. Conclusion
In general the soil has a good chemical as well as physical properties which results in a relatively low erodibility. Compare to the three other land uses that are teak, gliricidea, and crops land; the grass plantation has the relatively low erodibility, so, grass plantation has a significant role in reducing the erosion rates.

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