The influence of grass plantation harvesting to soil in relation to sustainable forest management

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Abstract. Wanagama’s success in rehabilitating forests with the community is a mutually beneficial relationship between the community and Wanagama. Farmers are allowed to take grass to meet their animal feed needs. Harvesting grass will have an impact on changing the physical and chemical properties of the soil. This research aimed to analyse the soil properties at the grass plantation and at the area of post grass harvesting. Also, aimed to relate the impact of the grass harvesting with sustainable forest management. Soil samples were taken from the field randomly both at the three areas of grass plantation and post harvesting. It is located at the upper, middle, and lower area of a slope with 3 replications. The soil samples then were brought to the laboratory to analyse. The result showed that all of the soil have the texture of clay with the clay content varies from 48.33 to 76.3%. The bulk density and particle density are also various that are 1.09 - 1.55 and 1.8 - 1.99 respectively. Soil porosity ranges from 13.89 to 43.52 % which is considered as moderate. The soil permeability is mostly considered as slow and the soil organic matter content of 3.26 - 7.66 %. In general, grass harvesting does not change the soil properties so, it remains the sustainability of the soil.

1. Introduction
The Wanagama Educational Forest was considered successful in the process of rehabilitating critical land. The land, which was originally in the form of earthy stones, with very thin soil depth, has been successfully rehabilitated in the form of forest land cover and growing soil depth. Over time, the average soil depth has reached about 20 cm. During its development, Wanagama Forest does not only function as an example of successful rehabilitation. However, more than that, Wanagama must also be able to provide an example of the success of forest development with the community. One of the functions that must be fulfilled is the productivity of biomass, one of which is a grass that is harvested by the community for animal feed. As feedback, farmers must return the fertility of the forest in the form of livestock manure as manure. This form of cooperation is clearly very beneficial for farmers because they use land without rent, the reward is to help maintain forest security. However, the sustainability of forest productivity is questionable. Especially with the relatively thin soil depth resulting from land rehabilitation, it is very sensitive to erosion, so it is urgent to maintain properly and even improve. Soil characteristics, both chemical and physical reflect its fertility and will influence the development process of the soil. It relates to soil function as plant growth media also to other processes 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, gliricidia, 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 percent of land sustains 60% world’s population that exploited the natural resources (soil, water, and vegetation) and that disturbing ecological balance. Therefore, efficient utilization of water resources and conservation of soil is important for sustainable agricultural production [4]. The purpose of this study is: to analyse the soil properties at the grass plantation and at the area of post grass harvesting. Also, aimed to relate the impact of the grass harvesting with sustainable forest management.

2. Material and methods

2.1. Location
This research was done in Wanagama I Education Forest located in Gunung Kidul Regency. Soil samples were taken from the field both at the grass plantation and post harvested areas.

2.2. Material
The materials used in this study are:
1. Soil samples were taken from 3 plots of grass located at three areas that are upper, middle, and lower of a slope.
2. Land covered with grass with 2 types of treatment, that are with grass and post harvested in Wanagama I Education Forest.

The equipment used in this study consists of soil ring sample, tally sheet, plastic, ruler, analytical scales, oven, clinometer, roll meter, hagameter, tape meter, and camera.

2.3. Methods
The data was collected in Wanagama at three areas of grass plantation. Soil samples were taken from the field randomly both at the three areas of grass plantation and post harvested. It is located at the upper, middle, and lower area of a slope with 3 replications, so totally there were 18 soil samples. The soil samples consist of disturbed and undisturbed. The undisturbed soil was taken by using soil ring sample[5]. Disturbed soil samples are used for texture determination, Particle Density, and Organic Matter analysis. Undisturbed soil is required to determine bulk density (BV).

Then, the soil samples were brought to the laboratory for analysis of texture, structure, BD, PD, porosity, organic matter. Soil texture was analyzed by piping method, soil structure was observed with a microscope, BV was obtained gravimetrically, PD was measured using piknometer, while organic matter was measured using the Walkley and Black method.

2.4. Data analysis
After the data from the field were collected and the result of laboratory analysis was published, then data analysis was carried out.
3. Results and Discussion

3.1. Soil characteristics

The table below consists the result of soil analysis from the laboratory. Table 1 shows that all of the soil have the texture of clay with the clay content varies from 48.33 to 76.3%. The bulk density and particle density are also various, that are 1.09 – 1.55 g/cm$^3$ and 1.8 – 1.99 g/cm$^3$ respectively. Soil porosity ranges from 13.89 to 43.52 % which is considered as moderate. Soil permeability is mostly considered as slow and the soil organic matter content of 3.26 – 7.66 %. In general, the soil structure is sub angular blocky.

According to [6] 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 [7] 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 [8]. Furthermore, the soil organic matter is driven by the soil texture [9].

| Code | Sand (%) | Silt (%) | Clay (%) | Bulk Density (g/cm$^3$) | Particle Density (g/cm$^3$) | Porosity (%) | Permeability (cm/hr) | OM (%) |
|------|----------|----------|----------|------------------------|----------------------------|--------------|----------------------|--------|
| RA1  | 3.86     | 23.89    | 72.25    | 1.2                    | 1.96                      | 38.78        | 0.36                 | 4.31   |
| RA2  | 3.53     | 20.17    | 76.3     | 1.18                   | 1.94                      | 39.18        | 0.32                 | 4.34   |
| RA3  | 7.05     | 23.26    | 72.25    | 1.5                    | 1.91                      | 21.47        | 0.29                 | 3.26   |
| RT1  | 3.05     | 25.14    | 71.81    | 1.25                   | 1.91                      | 34.55        | 0.37                 | 4.35   |
| RT2  | 3.08     | 22.86    | 74.06    | 1.09                   | 1.93                      | 43.52        | 0.28                 | 5.43   |
| RT3  | 3.29     | 28.68    | 68.03    | 1.38                   | 1.92                      | 28.13        | 0.46                 | 6.44   |
| RB1  | 4.9      | 44.79    | 50.31    | 1.15                   | 1.84                      | 37.5         | 0.67                 | 7.66   |
| RB2  | 5.79     | 40.17    | 54.03    | 1.55                   | 1.8                       | 13.89        | 0.72                 | 6.56   |
| RB3  | 5.92     | 45.74    | 48.33    | 1.34                   | 1.95                      | 31.28        | 0.66                 | 7.61   |
| PA1  | 8.9      | 20.52    | 70.58    | 1.45                   | 1.96                      | 26.02        | 0.45                 | 4.85   |
| PA2  | 7.69     | 31.49    | 68.3     | 1.54                   | 1.99                      | 22.61        | 0.23                 | 4.3    |
| PA3  | 6.2      | 22.13    | 71.67    | 1.26                   | 1.9                       | 33.68        | 0.34                 | 12     |
| PT1  | 6.68     | 25.25    | 68.06    | 1.19                   | 1.97                      | 39.59        | 0.31                 | 4.28   |
| PT2  | 9.28     | 34.5     | 56.22    | 1.29                   | 1.96                      | 34.18        | 0.27                 | 4.29   |
| PT3  | 7.35     | 35.1     | 57.55    | 1.1                    | 1.88                      | 41.49        | 0.33                 | 5.36   |
| PB1  | 4.36     | 33.82    | 61.82    | 1.46                   | 1.93                      | 24.35        | 0.41                 | 6.45   |
| PB2  | 4.9      | 27.18    | 57.92    | 1.18                   | 1.94                      | 39.18        | 0.38                 | 7.49   |
| PB3  | 5.88     | 22.55    | 71.57    | 1.36                   | 1.91                      | 28.8         | 0.44                 | 5.39   |

R = grass area, P = post harvested area, A = upper, T = middle, B = lower of a slope.

The description of soil texture of the study area can be seen in Figure 1 as follows. 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.
Figure 1. The soil texture (sand, silt, clay content) of the study area.

The bulk density, particle density, and porosity of the soil are presented in Figure 2. In Figure 2, it can be seen that the bulk density and particle density as well as soil porosity of all areas are almost similar. On average the BD and PD of the grass plantation area were 1.29 and 1.91 g/cm$^3$ respectively. Whereas that of post harvesting area were 1.31 and 1.94 g/cm$^3$ on average respectively.

Figure 2. Soil bulk density, particle density and porosity
The soil porosity was calculated by dividing the soil Bulk density (BD) with the soil particle density times 100 percent. The average bulk density (BD) varies from 1.09 g/cm$^3$ to 1.55 g/cm$^3$. The particle density (PD) at all areas varies from 1.8 g/cm$^3$ to 1.99 g/cm$^3$. The porosity at grass plantation areas on average is 32.03%, almost the same as the average porosity of the post harvested areas that is 32.21%. At the grass plantation, it has the highest bulk density and the lowest porosity, by contrary, at the post harvested area it has the lowest bulk density, it has the highest porosity. This finding supports the earlier work by [13] who reported inverse relationship between bulk density and porosity of the soil.

Figure 3. Soil permeability and soil organic matter content

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 soil permeability was at grass plantation (0.72 cm/hr) and the lowest was at the post harvesting area (0.23 cm/hr). The high soil permeability at grass plantation is a result of the good root development and less soil disturbance. The human disturbance impacts on the soil to be more compact as shown by the average soil bulk density at the grass plantation is lower than that of post harvested area (1.31 g/cm$^3$).

According to [6] 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 [7] 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 [8]. In addition, the soil organic matter is driven by the soil texture [9].

The average soil organic content of the grass plantation area was 3.26% and that of the post harvesting areas was 7.66%. According to [10] the intensive cultivation causes the decreasing of organic carbon. This research has the opposite findings that the grass harvesting resulted in the higher soil organic content as a result of the old grass can be decomposed and improved the organic content of the soil. The research finding resulted by [11] shows that forest soil is a source of organic matter that is 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 [12] that total carbon stocks did not differ significantly between the soil types, but they differ among land use classes.

3.2. Comparison of soil characterist of the grass plantation and post-harvest area

It is assumed that the grass harvesting will influence the soil characteristics which then can reduce the soil fertility and might be connected with the soil erodibility and soil erosion rates. Soil erosion is the main mechanism of land degradation and one of the most serious environmental problem in the world [14]. Soil erodibility is the second important factor in erosion process after rainfall erosivity.
Figure 4. Soil characteristics at the grass plantation compared to the post harvesting area

It can be analysed that the grass harvesting in general does not change the soil characteristics as shown in Figure 4. The soil texture remains the same, whereas there were little changes in other soil characteristics such as soil bulk density, particle density, porosity, permeability, and organic matter content.

4. Conclusion
In general, the soil of the study area has good chemical as well as physical properties. Secondly, the grass harvesting does not change the soil characteristics, the soil texture remains the same, and a little change due to the grass harvesting was shown at the soil bulk density, particle density, porosity, permeability, and organic matter content.

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References
[1] Kusumandari, A., Kusumawardani, F., Subroto S.A., and Wianti, K.F. (2018). Soil Chemical and Physical Characteristics as a Base for Achieving Sustainable Forest Land Use in RPH Watugudel, KPH Ngawi, Jawa Timur. UGM Digital Press Life Sciences: Vol. 1. Proceeding of the 2nd International Conference on Tropical Agriculture. (pp. 1-6).
[2] Gharde, K.D. and Mahale, D.M. 2012. Modelling of Erosivity Index from Rainfall Data of South Konkan Region. Bioved. 23 (1): 13-18.
[3] Aroengbinang, B.W. and Kaswanto. 2015. Driving Force Analysis of Land use and Cover Change in Cimandiri and Cibumi Watersheds. Procedia Environmental Sciences. 24: 184-188.
[4] Pramoedibyo, R.I.S., Ranoeprawiro, Soebronto. 2004. Dari Bukit-Bukit Gundul sampai ke Wanagama I. Yayasan Sarana Wana Jaya. Yogyakarta.
[5] Purwowidodo. 2005. Mengenal Tanah. Laboratorium Pengaruh Hutan Jurusan Manajemen Hutan Fakultas Kehutanan IPB. Bogor.
[6] Remivahiarivo, N., Brossard, M., Grinand, C., Andriamananjara, A., Razafimbelo, T., Rasolohery, A., Razafimahatratra, H. Seyler, F., Ranaivoson, N., Rabenarivo, m., Albrecht, a., Razafindrabo, F., Razakamanarivo, H. 2017. Mapping Soil Organic Carbon on a National Scale: Towards an Improved and Updated Map of Madagascar. Geoderma Regional Vol. 9: 29 – 38.
[7] Aziz, S.A. and Karim, S.M. 2016. The Effect of Some Soil Physical and Chemical Properties on Aggregate Stability in Different Location in Sulaimana and Halabja Governorate. Open Journal of Soil Science Vol. 16: 81-88.
[8] Chaney, K and Swift, R.S. 1984. The Influence of Organic Matter on Aggregate Stability in
Some British Soils. *European Journal of Soil Science*. Vol. 35: 223-230.

[9] Poggio, L. and Gimona, A. 2017. 3 D Mapping of Soil Texture in Scotland. *Geoderma Regional*. Vol. 9: 5 – 16.

[10] Mukhlis, Nasution, Z. and Mulyanto, B. 2014. Effect of Land Use on the Physico-Chemical Properties of Andisols in Mt. Sinabung, Northern Sumatera, Indonesia. *Malaysian Journal of Soil Science*. Vol. 18: 51-60.

[11] Didjajani, B.W. 2012. Nutrient Loss Caused by Erosion (A Case Study in Teak Forest). *Agrovigor Journal*. Vol. 5. No. 1: 58-65.

[12] Natalia, D., Arisoesilaningsih, E., Hairiah, K. 2017. Are High Carbon Stocks in Agroforests and Forest Associated with High Plant Species Diversity? *Agrivita Journal of Agricultural Science*. Vol. 39 (1): 74-82.http://doi.org/10.17503/agrivita.v39i1.676.

[13] Arevalo-Gardini, E., Canto, M., Alegre, J., Loli, O., Juica, A., Baligar, W. 2015. Changes in Soil Physical and Chemical Properties in Long Term Improved Natural and Traditional Agroforestry Management System of Cacao Genotypes in Peruvian Amazon. *PLoS One* 10 (7) e 0132147 doi: 10: 1371/journal pone 0132147.

[14] Baumgertel, A., Lukic, S., Simic, S.B., and Miljkovic, P. 2018. Effect of Ameliorative Afforestation on the Erodibility Factor and Soil Loss in the Grdelica Gorge. *Original Scientific Paper*. 28: 37-46. Doi: 10.7251/GSF1828037B.

[15] Pouyat, R.V., Dyesilonis, I., Rusel – Anelti, J., Noerchal, N.K. 2007. Soil Chemical and Physical Properties that Differentiate Urban Land Use and Cover Types. *Soil Science Society America* Vol. 71. No. 3: 1010-1019.