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**Research Article**

# The effectiveness of cover crops on soil loss control in Gede catchment of Malang Regency, Indonesia

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**Abstract:** Cover crop is an important factor which affects soil loss. The lost of soil potential is affected by plant morphology. The aim of this study was to elaborate on the effectiveness of the type of cover crops to soil loss in the same morphology and characteristic of soil. The study was carried out by applying erosion plots. Soil loss measurements were conducted four times in each demonstration plot. Soil loss for each plot was analyzed in the laboratory. The result showed that the most erodible soil with the highest amount of soil loss was in the pre onion plot and the most effectiveness for soil loss control was carrot plot. The amounts of soil loss for carrot, cabbage, and pre-onion were 0.040991 kg/8 x $10^{-4}$ ha, 0.069901 kg/8 x $10^{-4}$ ha, and 0.077800 kg/8 x $10^{-4}$ ha, respectively. The highest runoff of 60.554 L/8 x $10^{-4}$ ha, was observed at the pre onion plot. Based on the result, the most effective cover crop for soil control was the carrot. The important parts of cover crops which influenced soil loss were the shape of shade leaves and type of roots.

***Keywords***: *catchment, effectiveness of cover crops, soil loss*

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## Introduction

Gede catchment is the upper part of Bromo Volcano. Mostly, the land-use in the Gede catchment is agricultural with horticultural crops such as coffee, cassava, carrots, cabbage, apples, and woody plants such as bamboo and cloves. Gede catchment has thick soil which formed by depositional material of Bromo Volcano. The soil loss or erosion in the Gede catchment is severe. Some soil formations that are caused by soil loss are the formation of pedestal, gully and sheet erosion. The soil loss in the area is intensive which is caused by inappropriate crop planting management.

Utilization of agricultural land with land cover affects soil conditions. Soil as a medium for growing plants has an important role in the process of plant growth (Fans and Features, 2020; Wang et al., 2020; Yan et al., 2021). Soil is the part of the earth system which has essential for addressing human needs (Glasener, 2004; Scatena and Varrin, 2010; Keesstra et al., 2016). The sustainability of soil depends on the wise of natural resources which have affected by human activities (Zeng et al., 2020).

In general, the vegetation has an impact on soil loss as it can control soil loss. Therefore, there is a relationship between vegetation cover with soil loss and soil risk assessment (Satir and Berberoglu, 2016; Jourgholami and Etehadi Abari, 2017; Ashraf et al., 2019; Onda et al., 2020; Wang et al., 2020; Yan et al., 2021). However, soil loss is not only affected by vegetation cover, but it is also affected by soil physical condition. The effectivity of vegetation on soil loss can be clearly seen if the vegetation is applied in the same soil physical condition and morphology. The parts of vegetation which affect soil loss are vegetation cover and vegetation roots.

Inappropriate cultivated vegetation can increase the soil loss, so one of the keys to minimize the soil loss is appropriate cultivation and sustainable land management (Martínez-Graña et al., 2017). Mostly, research regarding the relationship between vegetation and soil loss tends to stratify vegetation type with the different structure, i.e. woody plants, shrub, grass and kind of cover crops. The soil loss will be different in each stratified vegetation type with a different structure. For instance, mixed forest and natural vegetation will more effective for control soil loss (Ashraf et al., 2019; Song et al., 2019; Liu et al., 2020). It can be predictable because of the different structure in their every part regarding the kind of their roots and leave which influence for water absorption and runoff (Sans-Fuentes and Meixner, 2016; Li et al., 2019). Other studies regarding the influence of vegetation on soil tend to deal with the effect of cropping system and soil health. Cropping system has a more positive impact on soil health than the perennial vegetation system ( Zeiss, 2000; Keesstra et al., 2016; Yang et al., 2020). The intensity of the soil loss process such as erosion and landslide decreases organic matter content and reduces soil fertility, affecting agricultural production (Maltsev and Yermolaev, 2020; Sadeghi et al., 2020; Wang et al., 2020; Wolka et al., 2020).

Studies regarding the influence of vegetation with the same stratification, such as cover crops are still rare. Coffee plant is one of the cover crops, which is widely planted to prevent soil loss (Ataroff and Monasterio, 1997; Meylan et al., 2013; Giacomini et al., 2020). Coffee plant affects soil loss because it can shade the soil during the rain. Coffee plant is the one efficient plantation for soil conservation (Latini et al., 2020). Therefore, coffee plant as the one effective cover crops for soil loss (Ataroff and Monasterio, 1997; Meylan et al., 2013; Giacomini et al., 2020). Even though coffee plant is planted, soil loss still can occur because the soil loss is also influenced by the soil condition and planting system (Ramos-Scharrón and Figueroa-Sánchez, 2017). Soil which is intensively cultivated will have greater of soil loss than soil with minimum cultivation (Bonfanti et al., 1997; Evrard et al., 2010; Peter et al., 2014; Tang et al., 2019; Meliho et al., 2019; Wolka et al., 2020; Golosov et al., 2021). The intensive of soil loss is affected by the agriculture management system, including the type of vegetation planted in the study area. This study aimed to explore the effectiveness of cover crops on soil loss control in Gede catchment of Malang Regency.

## Materials and Methods

### *Site description*

The experiment was conducted a the Gede catchment which is located in the upper part of Bromo Mountain (Figure 1). The study area covers 17 km$^2$. The subsurface material is dominated by deposition of Bromo Volcano material. Landslides and erosion that are morphological processes are very intensive happened in the study area. At several points, slopes which were cut for roads caused the geomorphological processes such as the increase of landslides erosion. The occurrence of these geomorphological processes increases the amount of soil loss. Mostly, the land of this study area is cultivated for agricultural crops with agroforestry system. The main crops are cabbage, pre onion, and carrot.

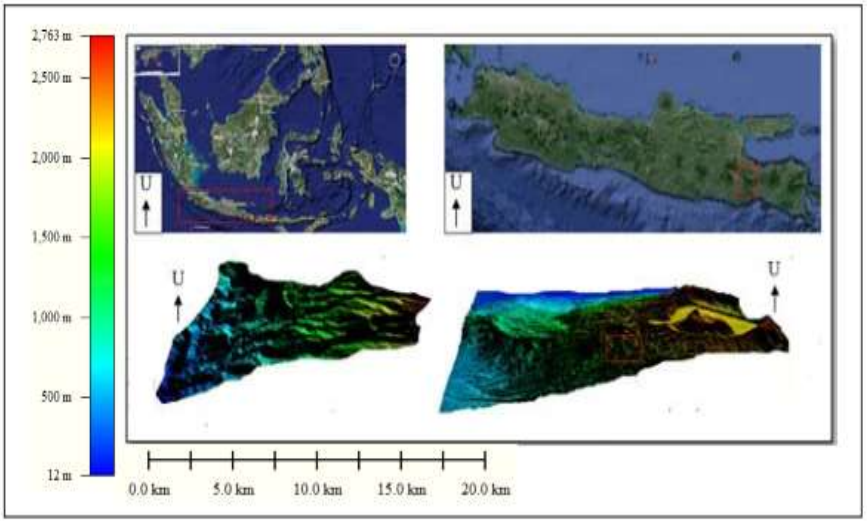


Figure 1. Study area.

***Preparation of plots***

Selection of the plot area was based on morphological consideration and type of cultivated crops in the area. The selected morphology was in the upper slope because it is the first place where the flows in the catchment system and soil in the upper slope is not developed from depositional materials.

The experiments were conducted in three runoff and soil loss plots with the plot size of 8 m long, 1 m wide, 0.3 m deep, with a slope of $24^0$ and the elevation of 900 m above sea level. This study was conducted in five steps, i.e. 1) identification of the main cultivated cover crops, 2) preparation of soil loss plot, 3) monitoring and measurement of soil loss and runoff, 4) collection of soil samples for soil physical identification, and 5) analysis of sediment load, soil physical condition, vegetation type and volume of runoff. Before constructing soil loss plots, texture, permeability, and bulk density of the soil were measured to know the soil physical condition in each plot. A storage tank was installed at the outlet of each plot to accommodate the soil loss. The land-use in the Gede catchment is agriculture with mixed garden. It consists of woody plants, coffee, coconut, cabbage, carrot, cassava, pre onions, mangoes, and apples. Most of the land use cover crops with cabbage, coffee, pre-onion, and carrots. The existing dominant cover crops are the one way for vegetative conservation.

The soil in the study area is a thick soil dominated by deposition of Bromo Mountain materials. Another cover crop that is cultivated in the Gede catchment is coffee, but it is not the dominant crop in the Gede catchment, The selected plots represented three types of cover crops, i.e. carrot, cabbage, and pre-onion (Figure 2). Measurement of soil loss value was done by collecting the sediment and volume of runoff water that were accommodated in the storage tank of each plot. Samples were taken 5 times in each plot; so the number of runoff and sediment load analysis samples were 20, which were used to identify the effectiveness of the cover crops. The characteristics of cover crops in the plot were also elaborated as differences in leaves and roots of each main cover crops affect the capability of infiltration and runoff, affecting soil loss. In addition, there were 10 samples for the measurement of soil texture, permeability, bulk density, and structure. The purposive sampling method was used in this study. One kilogram of soil sample collected from each plot was put into a plastic bag. The soil samples for the permeability and bulk density analysis were collected using ring samples with the diameter ring size 5 cm.

*Calculation of soil loss and runoff value*

The calculation of the soil loss value was done by calculating the weight of sediment in the sample bottles. The sample contained in the suspension was filtered by using filter paper. The remaining sediment on the filter paper is the oven-dried until the moisture in the soil run out. After the sediment has been oven-dried and weight, soil loss total was calculated using equation (2). Whereas, the runoff value was calculated using equation (3).

$$\text{Sediment weight} = \frac{\text{soil mass (g)}}{\text{water volume in the bottle}} \text{ …….. eq (1)}$$

$$\text{Total soil loss} \frac{\text{sediment weight (kg)x run off volume}}{1000} \text{…eq (2)}$$

$$\text{Runoff volume} = \text{h (dm)x } r^2\text{(dm)x 3,14 ……..eq (3)}$$

Source: Wardhana (2017)

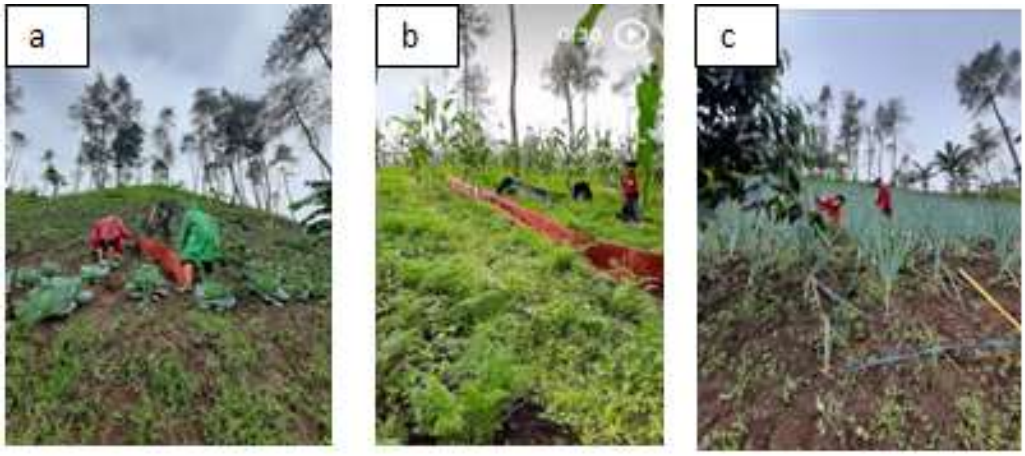


Figure 2. Plots and cover crops a) cabbage X: 701014 Y: 9120671; b) carrot X: 701303 Y: 9120832 ; c) pre-onion X: 701548 Y: 9120936.

## Results and Discussion

Several soil physical parameters have been measured and analyzed to see the effect of soil properties. Soil parameters measured were texture, permeability, volume weight, and structure. Sand, silt and clay contents of each plot were in different proportions. In general, soils with high silt content and low organic matter are the easiest to erode (Cassol et al., 2018; Wischmeier and Mannering, 1969). The soil texture of each plot with the type of plant tested, which had high silt content, was the plot with onion (48.10%) and the plot with cabbage (64.71%), while the lowest silt content was the plot with carrots (31.34%). Meanwhile, sand-dominated soils have low erodibility (Dariah et al., 2002). Based on laboratory data, it shows that there is a relationship between the proportions of sand, silt and permeability values. Plots with carrots that have the smallest proportion of silt compared to plots with pre-onion, and plots with cabbage plants. For the proportion of sand content, the plots with carrots had the largest proportion and had the greatest permeability value, so that laboratory results showed carrots as the most effective crop compared to shallots and cabbage. Table 1 shows the results of the soil physics analysis.

Table 1. Soil physics analysis.

| No | Soil Characteristic | Cover Crops | | |
|---|---|---|---|---|
| | | **Pre Onion** | **Cabbage** | **Carrot** |
| 1 | Sand fraction | 46.15% | 19.83% | 56.34% |
| 2 | Silt fraction | 48.10% | 64.71% | 31.34% |
| 3 | Clay fraction | 5.74% | 15.46% | 12.07% |
| 4 | Texture | Silty loam | Silty loam | Silty loam |
| 5 | Permeability | 34.893 cm/hour | 28.076 cm/hour | 40.063 cm/hour |
| 6 | Bulk Density | 0.772 g/cm$^3$ | 0.823 g/cm$^3$ | 0.871 g/cm$^3$ |
| 7 | Structure | Granular | Granular | Granular |

The difference in the results of soil physics analysis between the 3 plots affects the difference in soil erodibility (Gholami et al., 2016; Hou et al., 2020). Based on the sediment load analysis results from measurements in the field, carrot plants are the most effective plants in reducing soil loss. Although the slope degrees in each plot were similar, there were differences in the amount of soil loss, indicating the effect of type cover crops on soil loss. Based on the laboratory analysis, the most conserving cover crops are carrot, cabbage, and prep-onion. The data showed that the sediment loads in the plot were 0.040991 kg/8 x $10^{-4}$ ha, 0.069901 kg/8 x $10^{-4}$ ha, and 0.077800 kg/8 x $10^{-4}$ ha for carrot, cabbage, and pre-onion, respectively. The highest runoff of 60.554 L/8 x $10^{-4}$ ha was observed for pre-onion (Figure 3). This means that the leaves and root morphology affect soil loss.

Root morphology, i.e. types of root including taproots and fibrous roots, vertical and lateral and leaves morphology, are the main factor which influences the soil loss control. Almost all plant requires roots to provide anchorage and to take up water and nutrients. Plant roots are usually branched but vary greatly in their morphology. Results of laboratory analysis showed that the most effective cover crops in the study area are carrot, cabbage, and pre-onion. Each cover crops has its own leaves and root morphology. Carrot (*Daucus carora* L.) is the annual crop with shrub shape, and it will grow upright with a height between 30-100 cm depending on the type of variety. The carrot type in the study area is imperator type with the characteristic such as the type of the tuber is pointed. It has different from the chantey type with the characteristic such as the type of tuber is blunt and short ( Wang et al., 2015; Que et al., 2019).

The shape of the tuber will affect the capability to absorb the water. The chantey carrot type with pointer tuber and long will absorb more water into the soil; thus, it leads to less runoff and can control the soil loss. Carrot is considered the more conservative plant compared to pre-onion and cabbage plants because of the shapes of its tubers, roots and shade leaves. Carrot has a taproot and fibrous roots. The fibres roots attach to the taproots, which has enlarged (tuber). The grown-up fibre roots can absorb water and can reduce the amount of runoff (Johansen et al., 2015). According to Johansen et al. (2015), the fibre roots is developed with lateral shape in the upper 20 cm soil layer. These fibre roots are further branched with short roots; sometimes in the fibrous roots grow up more than 50% with the lateral root system. These conditions are the ways of the carrot roots to absorb the water. Johansen et al. (2015) reported that the potatoes plants make the soil more compact than carrots. In compact soil, it will inhibit root growth, so that it will not grow optimally and in turn will affect the ability to absorb water.

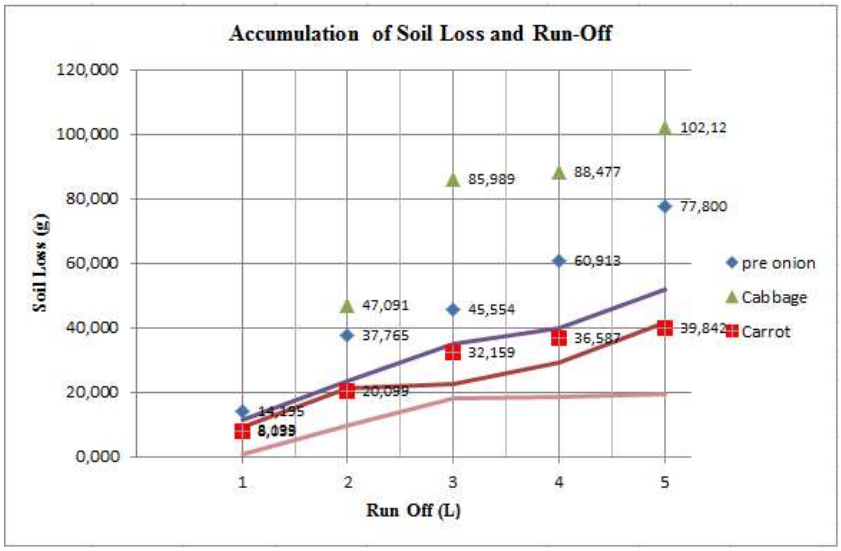


Figure 3: The accumulation of soil loss and runoff.

Figure 4. The leaves and roots morphology.

In potatoes plant the roots just reach down about 140 cm and the carrots more than 200 cm. It means that the carrot is more conservative than potatoes regarding the capability of water absorption. Growth of fibrous roots that grow laterally on carrots will grow when the soil is loose, but this root growth can help water absorption (Pietola and Salo, 2000; Pietola and Smucker, 1998). The leaves of the carrot plant are compound leaves with a slightly long, stiff and thick surface smooth. It can be shade leaves when rains come; thus, it will increase the water absorption. Pre-onion is the least conservative crop compared to cabbage and carrots. Pre-onion (*Allium fistulosum* L.). Pre-onion is including the type of seasonal leaf vegetable crops. Pre onion has fibrous roots which grow and develop in all direction around the ground level. It has not taproots and has a shallow root system (Khokhar, 2019). The roots are quite shallow between 8-20 cm, which grow and develop in the loose soil and fertile (Figure 4). In contrast to the field vegetable crops, the scientific evidence relating to pre onion root development and water response is very limited (Pérez Ortolá and Knox, 2015).

In comparison with carrots and cabbage, pre onion doest not have the shade leaves that can be used when it rains; thus the water directly hits the ground surface and causes the geomorphological processes such as soil loss. The root morphology and leaves have important roles for soil loss control. They are related to the ability of the root to absorb water. The taproots, fibre roots, vertical and horizontal root morphology are related to the ability of the plants to absorb water and control soil loss.

## Conclusion

The most effective crops in controlling soil loss in the Gede catchment was carrots, while the least effective crop was pre onion. This is related to the morphology of the leaves and roots of the crops. Carrot plants which have fibrous roots in their taproots can increase water absorption. The leaves types of carrots can cover the soil from the rains, whereas pre-onion does not have shade leaves and fibrous roots.

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