Effect of the conservation plants on runoff, soil erosion, and root characteristics in the volcanic areas

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Abstract, Research on reducing surface runoff and erosion by using vegetation method has been widely carried out. But the using of grasses plants to control erosion and landslide was not yet widely done, especially the effect of plant root parameters on reducing surface runoff and erosion. A research was carried out on volcanic soil in Experimental Station, Agriculture Faculty, Andalus University. This study was carried out from April 2018 to November 2018. It uses a 15 m x 2 m plots that was limited by brick concrete on 3 sides and the other side was used for measuring runoff and soil erosion. This experiment consisted of 4 treatments with 3 replications. The experimental units were arranged to according to a completely randomized design (CRD). Data were analyzed the variance using F test at 5 % level of significance and then continued using the Least Significance difference (LSD 0.05 if  F calculated > F table. The treatments were ; A = Vetiver + Simple terrace, B = Vetiver + Napier grass, C = vetiver + King grass, D = King grass + Napier grass. Observations were carried out on surface runoff, soil erosion, soil physical properties , soil shear strength, and root characteristics . Root characteristics observations using the Mwango et al (2014) method. Their parameters were root diameter, root density, root length density, root area ratio, and relative soil particles detachment rate. The field experimental results showed that combination of Napier and King grass (D) are better than another treatment to decrease surface flow and soil erosions. Between King grass + Napier grass (D), vetiver + Napier grass (B) and vetiver + King grass (C) treatments were not significantly different, exepctly with Vetiver grass + simple terrace. This statement also contribute by soil strength, and root properties at 0-30 cm depth.

Key Word : conservation plants, runoff, erosion, soil strength, root characteristics

1. Introduction

Soil erosion has become a serious problem in most parts of the world and it has decreased agricultural productivity, forest land and environmental and ecological degradation and triggered landslide natural disasters [1]. Indonesia locate in the region of wet tropical. Soil erosion hazard is very dominant in reducing the function of land as a medium for agricultural production. So that, land productivity will drops dramatically and in turn becomes critical land [2]. The techniques of effective conservation in controlling surface runoff and erosion have not many been done, mainly use of conservation plant. The using of vegetative conservation technique through forest preservation and reforestation will take decades or more, while planting grasses up to covering the ground, only need relatively short time. Efforts to deal with erosion and landslides using vegetation or plant technology have been carried out by researchers [3,4]. According to [5] mitigation of erosion and landslides by utilizing grasses plants is very effective and has a low cost and has more potential to be accepted by the community.
The slope stabilization can be done using civil engineering and vegetative techniques. The use of vegetative techniques requires the selection of plant species to be an important key in the success of landslide prevention caused by the compaction of soil layers [6]. [3] states that the role of vetiver and bahia grasses in minimizing slope erosion informs that a minimum grass canopy cover of 60% gives decrease an average erosion rate of more than 96%. Furthermore, the research results of [7] inform that using a row of grass as a holding plant can reduce erosion by 80%.

King grass is also one of the conservation plants that has the function of preventing erosion. in the first season of the year has been done planting king grass on each main plot, to reduce erosion by 80%. Vetiver grass works by holding the run-off and erosion material. Vetiver leaves and stems will slow down the runoff and sediment carried by the runoff. The root of the vetiver plant will bind the soil under the plant to a depth of 3 meters, these roots will prevent erosion and landslides [8]. [9] stated that the cultivation of aisle with king grass (Pennisetum tydoides) as a hedgerow can be recommended to improve critical land, because king grass besides functioning as green manure can also reduce runoff and erosion. [9] stated that king grass and elephant grass plants have a better influence on decreasing surface flow and erosion compared to tithonia and vetiver grass. This can be seen from the root characteristics, it turns out that root density, root length density, and area ratio of the roots of king grass and Napier grass have higher values while the rate of release of soil particles is relatively low. The study aimed to examine the effect of the combination of grass plants with a simple terrace which most can reduce surface flow and erosion.

2. Material and Method

2.1. Material
This research was carried out on volcanic land with a great group Dystropept at the Experimental Garden of the Faculty of Agriculture, Andalas University, Padang, Indonesia. The soil contains 14.75% sand, 16.67% silt, and 67.58% clay. The average level of organic matter is 5.80% classified as medium. The mean bulk density is 990 kg m\(^{-3}\). Conservation plant materials used in this study were vetiver grass (Vetiveria zizanioides), king grass (Pennisetum tydoides), and Napier grass (Pennisetum purpereum). This experiment was carried out using plots with 4 treatments as shown in Table 1.

| Code | Treatments                                              |
|------|---------------------------------------------------------|
| A    | Terracing + vetiver grass (Vetiveria zizanioides)       |
| B    | Vetiver grass (Vetiveria zizanioides) + Napier grass (Pennisetum purpereum) |
| C    | Vetiver grass(Vetiveria zizanioides) + King grass (Pennisetum tydoides) |
| D    | King Grass (Pennisetum tydoides) + Napier grass (Pennisetum purpereum) |

The design of the study was arranged according to a completely randomized design, with 3 replications. Statistical analysis using the F test and Least significance design test (LSD 0.05). Plans for placement of experimental units in the field are shown in Appendix 1.

2.2. Preparation of research plots and grass planting
The soil is cleaned of existing weeds and processed until loose. The plot is made with a size of 15 m x 2 m (30 m\(^2\)). Especially for treatment A plots, simple terraces are made with a distance of 5 meters. The treatment plot was placed lengthwise in the direction of the slope with a slope of 10%, then at the lower end of the plot was given a reservoir channel in the form of gutters made of PVC with a diameter of 7.5 cm with a size of 15 m x 2 m. Amid the gutters two holes were made. The first hole is connected to the channel to the
storage drum for observation of surface flow and eroded soils and other holes are left alone to escape (Fig 1). So the calculation of the amount of runoff water and eroded land is multiplied by 2.

![Figure 1. Research Plot](image)

Planting grass was done according to the treatment (Table 1) which consists of a combination of vetiver grass + simple terrace, vetiver + Napier grass, vetiver + king grass and and Napier grass + king grass. The distance of grass plants was 30 cm x 100 cm.

2.3. Observation of the soil physical properties
Observations were made on the physical properties of the soil by taking composite soil samples and undisturbed samples. Composite sample used to determine soil texture and carbon organic content by Walkley and Black method. Undisturbed samples used to determine bulk density by gravimetric method, soil water holding capacity by using pressure plate and cell extractcy apparatus, and soil permeability by De Bodt method. Measurements of soil shear strength were carried out by using Pilcone tools.

2.4. Measurements the amount of surface runoff and soil eroded every event of rain
The measurement of the amount of surface runoff is carried out every rainy event by storing all the water flowing from the plot and into the reservoir. The amount of water collected is the amount of runoff water multiplied by 2, because there are two holes out of the water. The way to measure eroded soil is to add up all the collected soil in the reservoir, both settling and the soil suspended in the water. The calculation of eroded soil weight is carried out by separating the soil with water, weighing the soil weight (x gram), then taking soil samples (y gram), then drying the soil samples, weighing the dry soil weight (z grams). So dry soil weight is calculated by equation 1:

\[
K = \frac{x}{y} z
\]

Then the water that has been separated from the soil is put into a bucket, then the volume is measured (a liter). Take as much water (b liters), let it settle until it is clear, and drain the water, then dry the soil (c gram). The weight of dry suspended load in water is calculated using equation 2:

\[
\frac{a}{b} \times c = d
\]

So the amount of eroded land is \( K + d \) (g/plot)

2.5. Observation of plant characteristics and plant roots
Plant observations are carried out every 2 weeks for the cover of the plant canopy. Root sampling was carried out using a sample ring measuring 15 cm in diameter and 30 cm high. The ring is inserted into the soil as deep as 30 cm in the clump of plants, then below it is cut and lifted up so that all the roots are carried to a depth of 30 cm. Then, measuring root density, number of root lengths, the ratio of root area is carried out every 10 cm. Observation of plant root characteristics was determined using parameters according to the method of Rubben et al. (2007), Mwango et al (2014), [11] namely:

1. Root diameter (mm) (D) is measured using the NSK Japan micrometer.
2. Root density (RD) (kg m\(^{-3}\)) = root dry weight (kg) per soil volume (m\(^3\)) = MD/V
3. Root length density (RLD) (km m\(^{-3}\)) = root length per volume of soil penetrated by roots
4. Root area ratio (RAR) = (RLD x Single root area of upright cross section (RCSA) (m\(^2\)), and
5. The relative soil particles detachment rate (RSD) (Mwango et al. 2014)

\[
RSD = e^{-1.45 \text{RD} (1 < \text{RD} < 5 \text{mm})} e^{-0.47 \text{RD} (\text{RD}>5\text{mm})}
\]  (3)

Furthermore, it is equipped with photographs of plant roots in collaboration with soil particles.

3. Result and Discussion

3.1. Observation of soil physical properties

The results of the statistical test F for the soil physical properties such as; bulk density, total pore space, aggregate stability, soil permeability have not shown any significant effect due to the treatment of conservation plants. Then the effect of conservation plants treatment on the content of organic Carbon ends to be a real difference. Then, the results of variance analysis F and LSD P .05 testing from the effect of conservation plant on organic carbon content can be seen in Table 3.1

| Treatments                  | C- Organic (%) | C- Organic (%) |
|-----------------------------|----------------|----------------|
| A (Vetiver + Simple Terrace) | 2.28 B         | 3.40 B         |
| B(Vetiver + Napier Grass)   | 3.30 A         | 4.06 A         |
| C(Vetiver + King Grass)     | 3.23 A         | 3.89 AB        |
| D (Napier + King grass)     | 2.97 AB        | 4.12 A         |
| LSD (P. 05)                 | 0.88           | 0.58           |

Table 3.1 shows that treatment A (terrace and vetiver) gives the lowest value in donating Carbon organic compared to treatment B (vetiver + napier grass) and C (vetiver with King grass) or D (napier grass and king grass). This can be seen from the slow growth of vetiver plants compared to other plants.

3.2. Soil shear strength

Based on the results of analysis of variance, it can be seen that the conservation treatment shows a significant effect on soil shear strength using a Pilcone type tool which can be seen in Appendix 2. Furthermore, the results of the smallest advanced test (LSD P .05) can be seen in Table 3.2.

| Treatments                  | Soil shear Strength (KPa) | Soil shear Strength (KPa) |
|-----------------------------|---------------------------|---------------------------|
| A(Vetiver + Simple Terrace) | 6.890 A                   | 6.530 B                   |
| B(Vetiver + Napier Grass)   | 6.270 B                   | 7.230 A                   |
| C(Vetiver + King Grass)     | 7.090 A                   | 7.170 A                   |
| D (Napier + King grass)     | 7.160 A                   | 7.500 A                   |
| LSD (P. 05)                 | 0.270                     | 0.270                     |

Table 3.2 showed that soil shear strength in the upper layer only had significant effect on treatment B (Vetiver + Napier Grass), whereas in treatments A, C, and D that it had no significant effect in 20 cm depth. Table 3.2 showed that the effects of plants have different effects on soil shear strength according to the order of treatment D (Napier grass + king grass)> C (vetiver grass + King grass)> B (Vetiver + Napier grass)> A (Vetiver + simple terrace) both in the upper layer and in the lower layer. This means that the effect of

4
treatment of Napier Grass + King Grass is better than other treatments. According to [12] soil shear strength depends on soil texture, soil moisture content, bulk density and hydraulic conductivity; against four types of sirihan plants (Aduncun piper), glagah (Saccharum spontaneum), coffee (Coffea canephora), bamboo (Bambusa arundinacea), only one type of glagah grass (Saccharum spontaneum) has a weak positive potential found between the density of root length and soil shear strength. The plant tends to occur on different textured soils, so the shear strength index is found to be optimal in clay textures plus 0.5 times silt clarified the role of fine roots other than other types.

3.3. Surface Runoff

The results of the F test of the influence of conservation plants on surface runoff and erosion show significant effects. Then the least difference difference test results (LSD 0.5%) for surface runoff and erosion can be seen in Table 3.3.

| Treatments                        | Runoff (L Plot⁻¹) | Erosion (kg Plot⁻¹) |
|-----------------------------------|-------------------|---------------------|
| A(Vetiver + Simple Terrace)       | 21.35 A           | 0.85 A              |
| B(Vetiver + Napier Grass)         | 19.28 AB          | 0.62 B              |
| C(Vetiver + King Grass)           | 18.92 BC          | 0.56 B              |
| D(Napier Grass + King Grass)      | 16.94 C           | 0.54 B              |
| LSD (P. 05)                       | 2.13              | 0.16                |

Figure 3.1. Effect of conservation plants on runoff and erosion

Table 3.3 and Fig 3.1 showed that surface runoff parameters have different values between each treatments. Treatment D gives the lowest surface flow (16.94 L plot⁻¹), but it is not different from treatment C and the largest surface runoff is treatment A (21.35 L plot⁻¹). Furthermore, the parameters of soil erosion showed that the same effect between B, C, and D treatments, except treatment A has a different effect. So, the smallest erosion parameter is also found in treatment D, which is 0.54 kg plot⁻¹. Next in Table 3.3 and Fig 3.1 also shows the order of the lower of amount of surface runoff and erosion parameters are as follows ie: A (Vetiver + simple terrace)> B (Vetiver + Napier Grass)> C (Vetiver + King Grass)> D (Napier Grass + King Grass) treatments. This is related to the growth of Napier grass and king grass growing faster so that, these plants canopy cover more of the soil surface. This will have an effect on the power of raindrops which can be reduced by the canopy of plants, while the simple terrace in this case is not yet good enough, because the vetiver is not enough to cover the soil surface when compared to other plants.
3.4. Plant canopy cover

Analysis of crop canopy covers from plant conservation treatments can be seen in Table 3.4.

| Treatments                  | Canopy Cover (%) | Criteria     |
|-----------------------------|------------------|--------------|
| A (Vetiver + Simple Terrace)| 64.0             | good         |
| B (Vetiver + Napier Grass)  | 71.0             | good         |
| C (Vetiver + King Grass)    | 73.5             | good         |
| D (Napier + King grass)     | 80.5             | Very good    |

Table 3.4. Effect of conservation plants on plant canopy cover

Figure 3.2. Canopy covers of each treatments

Table 3.4. And Figure 3.2. showing that treatment D (Napier + King grass) have canopy cover is greater than treatment C (Vetiver + King Grass) > B (Vetiver + Napier Grass) > A (Vetiver + Simple Terrace).

3.5. Characteristics of plant root properties

Observation of plant root characteristics includes variables such as root density (RD), root length (RLD), root area ratio (RAR), relative soil particle detachment rate (RSD). The results of the variance analysis F and LSD 0.05 test, and then continued from observing the characteristics of plant roots carried out at a depth of 0-10 cm, 10-20 cm, and 20-30 cm can be showed in Table 3.5. It can be seen that some observations have a significant effect such as the root density and root length density at 0-10 cm, and 20-30 cm depth. The increase of depth, development of root of plant is getting low, because this plant is a fiber-rooted plant.

Table 3.5 Characteristics of roots due to treatment of conservation plants

| Treatments                  | RD (Kg m$^{-3}$) | RLD ( km m$^{-3}$) | RAR (%) | RSD  |
|-----------------------------|------------------|-------------------|---------|------|
| Root Depth (cm)             |                  |                   |         |      |
| A (Vetiver + Simple Terrace)| 2.420 A          | 3.840 A           | 9.620 A | 0.093 A |
| B (Vetiver + Napier Grass)  | 1.77 AB          | 3.56 AB           | 6.37 AB | 0.092 A |
| C (Vetiver + King Grass)    | 1.86 AB          | 3.16 BC           | 5.96 B  | 0.089 A |
| D (Napier + King grass)     | 2.040 B          | 3.030 C           | 6.430 AB| 0.051 A |
| LSD (P. 05)                 | 0.38             | 0.51              | 3.36    | 0.059  |
| Root Depth (cm)             |                  |                   |         |      |
| A (Vetiver + Simple Terrace)| 0.56 A           | 1.05 A            | 0.018 A | 0.536 A |
| B (Vetiver + Napier Grass)  | 0.56 A           | 1.02 A            | 0.018 A | 0.556 A |
| C (Vetiver + King Grass)    | 0.52 A           | 0.89 AB           | 0.015   | 0.484 A |
| D (Napier + King grass)     | 0.42 A           | 0.61 B            | 0.011 B | 0.472 A |
| LSD (P. 05)                 | 0.31             | 0.39              | 0.067   | 0.167  |
Table 3.5 showed that the effect of conservation plants on root characteristics is evident in root density, root length density, and root area ratio at a depth of 0-10 cm, except on relative soil particle detachment rate. Then at a depth of 10-20 cm only that has a significant effect on the ratio of root area and root length density, but, it was not effect on root density and relative soil particle detachment rate. Furthermore, at a depth of 20-30 cm, the conservation plants have a significant effect on root density, root length density, ratio of root area, and relative soil particle detachment rate. The density of root length and root area ratio are largest on the treatment of Napier grass + King grass (D). Whereas the effect of conservation plants on the relative soil particle detachment was found in treatment A (Terrace + Vetiver) then followed by treatment B (Vetiver + Napier grass) > treatments C and D. So that it means that treatment A (terrace + vetiver) is a treatment that has surface flow and erosion is greater than the other treatments. Thus, the treatment of conservation plants with treatment D (Napier Grass + King Grass) is better than treatment B (Vetiver + Napier Grass), C (Vetiver + King Grass) and treatment A (Vetiver + simple Terrace). The order of influence follows the following sequence: treatment D is better than > treatment C > treatment B > treatment A.

The conservation plants not yet showed significantly effect on root characteristics, because only has effect on the density of root length, ratio of root area in the layer 10-20 cm. root length density, root area ratio and relative of soil particles detachment rate were found at depths of 20-30 cm. Whereas the influence of conservation plants on the relative of soil particles detachment shows the opposite effect of root density, root of length density, and root area ratio. This situation is in line with the influence of conservation plants on the amount of surface flow and erosion.

Effect of conservation plants treatment against root density and root length density at a depth of 0 - 30 cm has the same effect on treatment A (terrace + Vetiver), B (Vetiver + Napier Grass), and C (Vetiver + King Grass), but has a different effect on treatment D (Napier Grass + King Grass). So the role of root properties in reducing the amount of surface runoff and erosion. This is in accordance with the opinion of Shi et al. (2012) that erosion is related to plant root characteristics (root density (RD), root length density (RLD), root area ratio (RAR) and root surface area density (RSAD).

4. Discussion

Treatment C (Vetiver + King grass) and D (Napier Grass + King Grass) has a smaller surface flow and erosion compared to treatment A (terrace + Vetiver grass) and B (Vetiver + Napier Grass), then followed by soil shear strength showing the same trend value with the parameters of surface flow and erosion. The parameters of root characteristics are shown by root density, root length density, root area ratio, which shows the significant effect of the conservation plants. The study used grass plants that have root diameter which generally consists of <3 mm in diameter. Thus the effect of roots> 3 mm in diameter cannot be shown in this study. So to get the value of the rate of detachment of soil particles relative using the formula [4] only use root diameter <3 mm. Many studies have studied the effect of roots on topsoil resistance on surface flow and erosion generally using root density, root length density as root parameters to predict a reduction in the effect of water erosion [7]. According to [14] that RLD is a good parameter for expressing the area of contact between soil and root, but it is stated that the root effect is not appropriating to predict if only using...
the number of roots <1 mm. [13] stated that plant roots can reduce surface runoff and soil erosion by binding to soil particles in forming a good soil structure and resulting in steady soil aggregate stability. This will result in an increase in infiltration, and soil permeability, the content of soil organic matter and increase soil shear strength thereby reducing soil erodibility.

5. Conclusions

The effect of conservation plants on runoff, erosion, soil shear strength follows the order i.e. treatment D (Napier grass + King grass)> C (Vetiver + King grass)> B (Vetiver + Napier Grass)> A (Vetiver + Terrace). The effect of the treatment of conservation plants on root density, root length density, and root area ratio at a depth of 0 - 30 cm has almost the same effect for treatment D (Napier + King grass) > treatment A (terrace + vetiver), C (vetiver + King Grass), and B (vetiver + Napier Grass), but has an effect slightly different on relative soil particle detachment, because, the effect will be opposite with the other root properties. The role of conservation plants on root properties showed that treatment D (Napier Grass + King Grass) is better than treatment B (vetiver + Napier grass), C (vetiver + King grass) and A (vetiver + simple terrace). While, between the treatment A, B, and C are almost the same the effect on root density, root length density, and root area ratio.

Thus, the order of influence of the treatment of conservation plants on runoff, erosion, root characteristics follows the following sequence: treatment D (Napier Grass + King grass) is better than> treatment C (Vetiver + King grass) > treatment B (vetiver + Napier grass)> treatment A (terrace + vetiver).

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Appendix 1. Layout of experiments