Soil Management Impact on Soil Characteristics (Physiques) and Erosion on Hapludalfs Bogor

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Abstract: ***The experiments were performed to find out the effect of terrace types and elephant grass (Pennisetum purpureum) on erosion, aggregate stability, and permeability of Typic Hapludalfs. The experiment was done in the rainy season in Sukamulya village, Sukamakmur, Bogor, West Java with the altitude of 800 m above sea level and slope of 30%. Randomized block design was used in this experiment; consist of 5 treatments and 3 replications. Treatments were: without terrace and without grass (T_0) as a control, dike terrace without grass (T_1), dike terrace with grass (T_2), bench terrace without grass (T_3), and bench terrace with grass (T_4). The results showed that, there were highly significant difference effect of terrace types and grass (Pennisetum purpureum) on erosion, soil aggregate stability, and soil permeability. The treatment of the bench terrace with elephant grass (T_4) gave the lightest eroded soil of 6.698 t ha^{-1}. The decreasing value on aggregate soil stability and soil permeability were significantly affected by increasing erosion. These relationships were much closed, showed on the coefficients of regression determination of 96% and 97% respectively. Meanwhile the increasing of rainfall followed significantly by increasing of erosion, with a regression determination coefficient of 99%. The results of this study, showed that, there were significantly correlated between erosion with soil aggregate stability, soil permeability, and rainfall.***

Keywords: Typic Hapludalfs, soil characteristics, terrace types, grass, erosion

1. Introduction

Land is a natural resource that is very important in agriculture, resulting in the use and management should always be associated with the preservation of the environmental issues in order to achieve the target of agricultural production and the desired profits and sustainable. Land degradation or loss of land quality lately, so rife among others due to the incompatibility kinds of land use with the ability or the carrying capacity of the land.

One soil order of dry land farms in Indonesia is Alfisols, whose presence in West Java around 244,000 ha of 5.153 million ha in Indonesia (Puslitanak - Indonesian Center for Soil Research, 2000). The main problem encountered in the utilization of Alfisols origin Sukamakmur (study sites) for the management of the farm, is the high level of potential erosion. This is supported by the local climatic conditions of Sukamakmur with an average annual rainfall over the last 10 years of 2682.3 mm (Balitklimat – Indonesian Agency for Agrocilamtological Research, 2006). Farmers with all its limitations often penetrated into the sloping land as a place of their farm with all the attendant risks, causing landslides, erosion and flooding during the rainy season. According Sarief (1988), the amount of erosion and surface runoff depends on some physical properties of soil, such as infiltration capacity, aggregate stability, and permeability. If the erosion process takes place continuously, it will be increasingly depleted soil solum, physical properties, chemical, and biological soil is getting worse (Arsyad, 2000). To resolve these factors, it needs the erosion control efforts, which, among other things can be done through terracing and planting implementations.

Some research results show, dike and bench terraces with cover crops is quite effective in reducing erosion and maintain the physical characteristics of the soil. Abdurachman (1988) research results show that the use of the dike and bench terraces with cover crops on Ultisols Darmaga with a slope of 10-30 %, the average erosion decreased by 62.8 % in the first year of observation when compared without terrace. Puslitanak research results (1997), showed that the use of the Inceptisols Ciampea with dike terrace with a slope of 10-30 %, the amount of erosion of 0.20 t ha^{-1} during the growing season, and from the bench terrace on the same slope, erosion has the same great anyway.

In terms of the research, which is to determine the role of the type of terraces and planting elephant grass (Pennisetum purpureum) in reducing the rate of erosion and maintain the physical characteristics of the Typic Hapludalfs Sukamulya. The benefits derived from this study is able to contribute information on the science of soil and water conservation and soil physics, whereas for farmers can be applied in an effort to control erosion and maintain the physical characteristics of the soil, especially on aggregate stability and permeability of Typic Hapludalfs.

2. Materials and Method

The experiment was conducted in the village of Sukamulya, District Sukamakmur, Bogor Regency, West Java, with the altitude of 800 m above sea level and about 25 % of slope. Soil Typic Hapludalfs including type C of precipitation class (Schmidt and Fergusson, 1951). The materials used were: (1) land area with a slope of 25 %, (2) erosion receptacle, (3) plastic for each plot bulkhead receptacle coating erosion, (4) cuttings of elephant grass (Pennisetum purpureum). While the tools used in the field consists of: (1) clinometer, (2) the ring sampler, (3) meter, (4) hoes, (5) spades, (6) the hammer, (7) scales, (8) plastic bags, (9) equipment in the laboratory, and (10) stationery and other support tools. Laboratory equipment used consisted of (1) analytical balance, (2) oven, (3) wet and dry sieve, and (4) stationery and other supporting tools.

Experiments using experimental methods in randomized block design (RBD). In this experiment, there were 5 treatments with 3 replications, so there were 15 experimental plots. The treatments are T_0 = no terrace and no elephant grass (control), T_1 = dike terrace without grass, T_2 = dike terrace with grass, T_3 = bench terrace without grass, and T_4 = bench terrace with (elephant) grass. The variables observed and tested statistically were: (1) magnitude of erosion (t ha^{-1}), determined using the method of Morgan's small plots, the size of each experiment plot was (10 × 2) m2, with a soil collector to intercept eroded soil was placed at the lower end part of plot., (2) Aggregate Stability Index determined by the method of dry sieving and wet sieving according to De Leenheer and De Boodt, (3) Permeability (cm hr^{-1}) is determined by Darcy's law is done by using the tool of permeability. For supporting variables, carried out observations of: the initial soil analysis of Typic Hapludalfs and rainfall during the experiment.

The statistical test performed was randomized block design (RBD) with the following linear model (Gomez and Gomez, 1995):

$$\mathbf{Y_{ij} = \mu + \alpha_i + \beta_j + \varepsilon_{ij}}$$

where:

Yij = observation on the i-th treatment in the j-th repetition
μ = average value of observations
αi = effect of the i-th treatment
βj = effect j-th replication
εij = effect of experimental error of the i-th treatment in the j-th repelication

Differences between treatments were tested by the F test at the 5% level, while for the average test values using Duncan's multiple range tests at the 5% level. To see the correlation between erosion and the variables observed (soil permeability, soil aggregate stability, and the amount of rainfall, the regression test was used (Gomez and Gomez, 1995), and the regression model was

$$\mathbf{Y = \alpha + \beta_1 X + \beta_2 X^2}$$

where:

Y = dependent variable
α = intercept of the line on the y-axis
β_1 = regression coefficient y for every one unit of x
β_2 = regression coefficient y for every one unit of x2
X = independent variables

3. Results and Discussion

Soil characteristics of Typic Hapludalfs

This soil has a bulk density value of 1.34 g cm^{-3} and containing clay of 40.97 %, total porosity of 59.62 %, classified as moderate. The pore distribution showed that pore rapid and pore slow were 7.63% and 3.21 % respectively. Available soil water content classified as being 25.35 % (moderate), so water available to plants is relatively sufficient. Relatively little slow of soil permeability (1.96 cm hr^{-1}), due to the porous soil drainage is low, so it can cause the soil to become saturated resulting in the flow of surface water to erode the soil increased (Hardjowigeno, 1993). Meanwhile the stability of soil aggregates quite a bit more stable with a dispersion index of 58.00 which caused by a high clay content of 40.97 %. The sand and dust contents of soil were 39.71 % and 19.32 % respectively. Some soil chemical properties, among others: have acidic pH, low organic C content, cation exchange capacity, moderate, high base saturation, and low total N. Available potassium was very low, very low availability of phosphorus and exchangeable bases range from low to being. Overall soil fertility in land area (field trials), including the criteria being.

Hammer (1978) in Hardjowigeno and Widiatmaka (2001), set the value of soil erodibility (K) based on the following formula:

$$K = \frac{2{,}731\, M^{1{,}14}(10^{-4})(12 - a) + 3{,}25(b-2) + 2{,}5(c-3)}{100}$$

Where **K** is the soil erodibility value, **M** is the value of the grain size (texture class), a is the percentage of organic matter, **b** is the value of the soil structure, and **c** is the value of the permeability of the soil. Based on the calculation, the value of soil erodibility **(K)** is 0.43. According to the classification of soil erodibility value after Dangler and El - Swaify (1976) in Suwardjo et al. (1984), this land belongs to a rather high soil erodibility class which indicates quite sensitive to erosion.

Terrace

Dike terrace and bench terraces implemented in this study, are well known by the farmers in Indonesia on agricultural land and forestry area. These mechanical works, done to minimize the risk of run-off and erosion. Bench or stairs terrace, made by cutting the slopes and leveling the ground in the field so that if there is a ladder-shaped row. In principle, the bench terrace has the advantages: effectively controls soil and water runoff and erosion, traps sediment in the drainage ditches built along the terrace, reduces slope length, every 2-3 meters of slope length are leveled to the terraces, the velocity of water running down the slope is greatly reduced, improves soil fertility over the long run, facilitate the cultivation and maintenance of gardens and simplify harvesting.

Dike terrace is a row of mounds drains, equipped by draining in the back dike. This method is also known by the term-canal ridges. The dike terrace consists of mounds, drainage, and planting area. The function of dike terrace and bench terrace almost the same, namely to curb runoff and improve water absorption into the soil. The drains are made to drain run-off from planting area water drains. To improve effectiveness dike terrace in tackling erosion and surface runoff, mounds reinforced with plants. Types of plants that can be used are valuable crops (cash crops), for example, plant cinnamon, cayenne pepper, or others.

Elephant Grass (Pennisetum purpureum)

Elephant grass (Pennisetum purpureum) is a type of grass that is used as a cover crop and an amplifier terrace in soil and water conservation methods, as well as effective in reducing erosion, runoff, and improving soil physical properties. This plant is from Africa, then spread almost in the tropics around the world with rainfall greater than 1000 mm. This type of grass tolerant of wet areas, acidic, sandy soils with low fertility rates, and grow at pH 4,5 - 5,5. Elephant grass is a type of fodder forage crops are widely used in Indonesia because of high production. The production of fresh grass can reach 184 t ha^{-1} year^{-1}. According Subagyono et al. (2003), its perennial can grow as high as 1.8 to 4.5 meters, if allowed to grow freely can be as high as 7 m. The roots can reach 4.5 m and rhizome can grow up to 1 m. Stems covered with a leaf shield rather jointed, long grass leaf ranged between 16-90 cm with a width of 8-35 mm.

Elephant grass can protect the soil surface from direct blows rain water, so it does not spoil the soil aggregates. Effect of vegetation on run-off and erosion is mainly determined by its ability to cover the soil surface. Mechanism in reducing the rate and amount of surface flow is as follows: (1) rain drop collision inhibited / reduced, (2) delay the onset of surface flow and delay the onset of water loss, (3) restraining instantly scours run-off, thereby reducing run-off, and (4) inhibits the soil compaction (Sinukaban, 1989). According Haridjaja (1990) greatly determines the elephant grass infiltration capacity. The crop canopy closure system protects the soil surface from raindrop punches, thereby reducing soil compaction.

Rainfall

During the study: February, March, and April; precipitation that falls in the area were 455.09 mm, 512.53 mm, and 371.62 mm month^{-1} respectively; and the rainy days of 19 , 25, and 20. So the average daily rainfall amounted to 16.25 mm day^{-1}, 16.53 mm day^{-1}, and 12.39 mm day^{-1} and the average rainfall during the experiment was 446.41 mm month^{-1}. Bols (1978) in Hardjowigeno and Widiatmaka (2001) set the value of monthly rainfall erosivity (RM) based on the following formula:

$$\mathbf{RM = 6{,}119(Rain)_m^{1{,}21} . (Days)_m^{-0{,}47} . (Max.P)_m^{0{,}53}}$$

Where RM is the value of rainfall erosivity, (Rain) m is the monthly rainfall (cm), (Days) m is the number of rainy days per month, and (Max.P) m is the maximum daily rainfall (cm). The value of rainfall erosivity (RM) in February, March, and April respectively (527.45), (360.25) and (332.83). Rainfall during the experiment, indicating that the crop water requirement was satisfied. Required amount of rainfall of more than 1000 mm year^{-1} during the elephant grass grow optimally, therefore, the experiment was not carried out during watering.

Soil Aggregate Stability

Statistical test results showed that the shape of terraces planted with or without elephant, grass has a very real effect on the stability of soil aggregates (Table 1).

Table 1. Influence of Shape and Elephant Grass Terrace on Soil Aggregate Stability

Treatment	Aggregate Stability (Dispersion index)	Permeability (cm hr-^{1})	Erosion (t ha^{-1})
T_0 = without terrace and without grass	60,67 a	1,67 a	9,590 d
T_1 = dike terrace without grass	63,33 b	1,73 b	8,718 c
T_2 = dike terrace with grass	65,00 b	1,82 c	8,563 c
T_3 = bench terrace without grass	68,67 c	2,06 d	7,035 b
T_4 = bench terrace with (elephant) grass	72,33 d	2,17 e	6,698 a

Note: the numbers followed by the same letter are not significantly different according to Duncan's test at the 5% level.

The use of various forms of terraces planted with or without elephant grass have aggregate stability different significantly. Bench terraces are planted with grass and without it, having the stability of aggregates is significantly larger than the dike terrace planted with or without elephant grass.

Bench terraces are planted with elephant grass have an average top soil aggregate stability index that is equal to 72.33. Soil aggregate stability index is significantly different from other treatments. Seen that the stability of soil aggregates in all treatments ranged from rather stable-to-stable. This is presumably due to the reduction in slope as well as the planting of elephant grass as a ground cover plants and terrace amplifier which causes soil aggregates to be strong because the roots hold the power plant so large erosion on the lower bench terraces are planted with grass. In addition, cover crops allows for the non-occurrence of blow the drops of rain that directly destroy the surface of soil particles in the soil, because it is hampered by the plant canopy. This is in accordance with the opinion Arsyad (1989), that the level of crop canopy closure will affect the inhibition of the drops of rain destroys soil aggregates in the erosion process. Surface flow of the erosion process takes organic material so that the soil organic content decrease. Organic material was very influential on the formation of stable soil aggregates. High soil organic matter, resulting in increased metabolism of soil microorganisms in soil stabilizers produces substances that act directly in the formation of stable soil aggregates. This is in accordance with the opinion Soepardi (1983), that the run-off that took place continuously adversely affects the land, as it accelerates the oxidation of organic matter, destroy boulders and aggregates that have been formed, and the occurrence of soil compaction.

Treatment bench terrace without grass significantly different compared it to bench terraces planted with grass, whereas the treatment dike terrace without grass were not different significantly with treatment dike terrace planted with grass. In fact not different between the two treatments against major erosion allegedly due to lack of good grass growth. Plants will grow better if the field is more flat because the power plant roots hold the soil will be more powerful. Lax per plant bulrush lead levels canopy closure and hold the power plant roots to be low. This causes water droplets of rain that passes more directly to the soil surface, thus causing the release and destruction of soil aggregates to be eroded. Arsyad (1989) states that through the roots of plants and plant remains that have been decaying will assist the formation and stabilization of soil aggregates.

Soil Permeability

Statistical test results showed that the shape of terraces planted with or without elephant grass has a very real effect on soil permeability. Effect of treatment and elephant grass terraces form the permeability of the soil are presented in Table 1.

The use of various forms of terraces planted with or without elephant grass has a greater permeability significantly compared with no terraces and land without grass. Bench terraces are planted with or without elephant grass has a greater permeability significantly compared with dike terrace planted with or without elephant grass.

In all treatments had significantly different soil permeability to each other. Treatment bench terraces planted with elephant grass has the highest permeability than other treatments. The average yield is equal to the highest permeability of 2.17 cm hr^{-1}. Seen that the permeability of the soil in all treatments ranged from rather slow to moderate. This is presumably due to the reduction in slope as well as the planting of elephant grass as a ground cover plants and terrace amplifier, so that a large erosion becomes low on bench terraces planted with elephant grass (Table 1). This causes the infiltration time becomes longer, so there is no soil compaction due to higher run-off. Compaction of soil aggregates and urged the soil particles become more cumulate, so that the total volume of pore space is reduced and increased bulk density. Some macro pore space (macro porosity) and closed micropores soil particles, so that aeration and water movement is reduced. This causes the permeability to be slow. Soil aggregate stability has a good enough to maintain the porosity of the soil so that the soil will not be easily damaged, and the permeability of the soil can be maintained because the soil pores are not covered by soil particles are separated from the aggregates. This is in accordance Soepardi opinion (1983), that the run-off that took place continuously adversely affect the land, as it accelerates the oxidation of organic matter, destroying aggregates that had been formed, and the occurrence of soil compaction. The rate of soil permeability is reduced, resulting in the less rainwater can be absorbed by the soil so that surface run-off increases.

Erosion

Statistical test results showed that the shape of terraces planted with or without elephant, grass has a very real effect on the magnitude of erosion (Table 1).

The use of various forms of terraces planted with grass and no erosion value significantly smaller than the land without a terrace and without grass. Bench terraces are planted with grass and no erosion value significantly smaller than the dike terrace planted with or without elephant grass. Bench terraces are planted with elephant grass has an average value of the lowest erosion is 6.698 t ha^{-1}. The erosion values significantly different from other treatments. The low erosion on bench terraces planted with grass, allegedly due to a reduction in slope and the planting of elephant grass as a cover crop and amplifier terrace on the field though, mounds, and planting area which causes soil aggregates to be strong. This combination causes the infiltration time last longer so that the amount of flow of the carrier surface erosion is reduced, whereas the opposite occurred in the treatment with no porch and no grass. This is in accordance with the opinion Arsyad (1989) and Sarief (1988), that the land is sloping fields without cover crops allow the drops of rain destroy large amounts of soil particles, sliding down and sedimentation occurs below the ground plane.

Treatment bench terrace without grass significantly different with treatments bench terraces planted with grass, whereas the treatment dike terrace with or without grass not differ significantly. Not, in fact the difference between the two treatments against major erosion allegedly due to lack of good grass growth. Plants will grow better if the field is more flat because the power plant roots hold the soil will be more powerful. Lack of good grass growth caused the level of canopy closure and hold the power plant roots to be low, even though almost the same as the fields that are not planted elephant grass. This causes water droplets of rain that passes more directly to the soil surface, thus causing the release of soil particles to be eroded. In general, the results of the average treatment forms terraces and grass erosion showed a substantial decrease erosion by improving the soil and water conservation measures.

Erosion relationship with Aggregate Stability and Soil Permeability

The relationship between erosion with soil aggregate stability and permeability indicated by the regression equation presented in Figure 1 and 2.

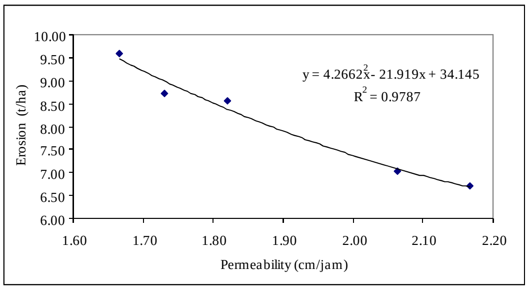

Figure 1: Soil Aggregate Stability - Erosion Relationship

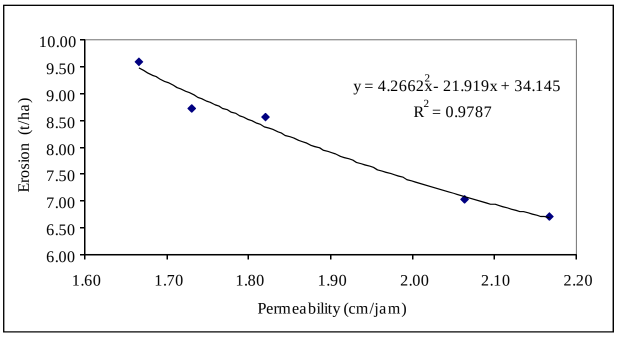

Figure 2: Soil Permeability - Erosion Relationship

Aggregate stability and soil permeability significantly larger effect on erosion in all treatments. The coefficient of determination of regression respectively 96 % and 97 %. The coefficient of determination shows that the aggregate stability and permeability of the soil has a significant correlation with large erosion. The decrease in aggregate stability and soil permeability influence on the increase of erosion.

The decrease in soil aggregate stability led to an increase in erosion. This is presumably due to the influence of blow rain drops of water in the process of erosion that results in damage to the soil aggregates. Easy absence of soil aggregates dispersed and suspended in the water determines the sensitivity of the soil to erosion. This is in accordance opinions Baver et al. (1978), that soil aggregates are easily dispersed by water and a small infiltration as well as the size of a grain of fine soil, susceptibility to erosion or have high erodibility.

The decrease in the permeability of the soil causes increased erosion. This is presumably due to the compaction of soil erosion in the process, because the macro and micro pores covered soil particles. These circumstances lead to greater erosion; it will decrease the permeability of the soil. This is in accordance with the opinion Arsyad (1989), that in the process of erosion, run-off carries soil particles, especially clay fraction and macro pores that cover most of the soil compaction or micro pores become dominant.

Rainfall - Erosion Relationship

The relationship between rainfall and erosion indicated by the regression equation presented in Figure 3

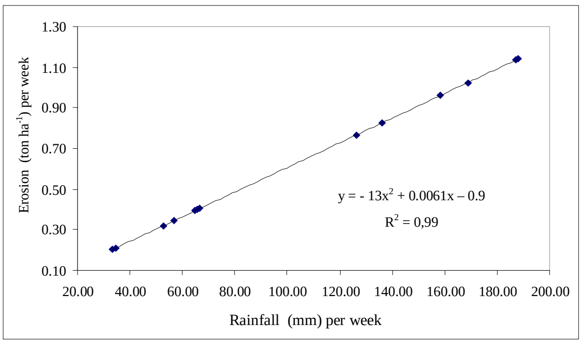

Figure 3: Rainfall - Erosion Relationship

Changes in rainfall significantly affect erosion on all treatments. Regression coefficient of determination of 99%, showed that rainfall has a significant correlation with erosion. Increasing the amount of precipitation influence on the increase of erosion. Increasing the amount of rainfall causes increased erosion. This is presumably due to the influence of rainfall erosion through rain blows on the surface of grains of soil and surface flow so that the soil becomes saturated quickly and rapidly destroyed by soil particles often hit the drops of rain that falls to the ground and carried by run-off into place lower. This is in accordance with the opinion of Abdurachman et al. (1995), that rainfall has a significant correlation with erosion, either daily or monthly based on the data.

4. Conclusions

Based on observations and discussions that have been described, it can be concluded as follows:

- Forms of terrace and grass have the real effect on the magnitude of soil erosion, soil aggregate stability, and soil permeability in Typic Hapludalfs.
- The bench terrace planted with large grass has a lower erosion than dike terrace and without terrace on Typic Hapludalfs.
- There was a significant correlation between erosion with soil aggregate stability, permeability, and precipitation with a coefficient of determination of regression respectively 96%, 97%, and 99%. This suggests that the decrease in aggregate stability and permeability of soil erosion resulted in a large increase, and an increase in precipitation can result in a large increase in erosion.
- Need to do further research with additional treatment that is with a combination of vegetative conservation techniques, mechanical, and chemical, as well as observations made include physical, chemical, and biological properties of soil.
- The cultivation of agricultural land, especially on sloping land is recommended to always pay attention to soil and water conservation efforts so that agricultural land can be utilized for the long term.

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