Comparison of Soil Erosion Control by Mulch and Cultivated Grass

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Abstract. Soil erosion has deteriorated water quality and caused land degradation. As human industrialization quickens, the effects of soil erosion are getting worse. Therefore, it is essential to have an effective mitigation measure at hand to solve this problem. In this research, two types of erosion control methods were compared to determine their effectiveness in controlling soil erosion. The two methods used were mulch made from dried grass clippings and grass cultivation grown with Axonopus compressus or more commonly known as cow grass. The plots were placed under five rainfall events together with a control plot. The runoff volume, turbidity and total suspended solids (TSS) from the plot discharges were tested and compared. The effectiveness of each erosion control method under different rainfall conditions were also evaluated. Results indicated that the mulch plot produced a lower runoff volume but the grass plot did manage to improve performance over time. The turbidity of both plots were similar. The TSS produced by the grass plot was lower than the mulch plot in 4 out of the 5 testing periods. The grass plot also performed better in longer duration and high intensity rainfall events. The mulch was able to produce similar results with the grass in short duration, low or moderate intensity rainfall events. As a conclusion, the grass cultivation is a more effective erosion control method when compared to the mulch.

1. Introduction

Soil erosion is a removal of topsoil due to human, natural or animal activities in our environment. Generally, the topsoil is removed faster than natural soil forming processes that can replace it [1].

Globally, there are numerous environmental, social and economic problems caused by soil erosion. The main environmental problem associated with soil erosion is the decrease in water quality as a result of runoff. Turbidity and total suspended solids (TSS) can prevent sunlight to penetrate water. In addition, the eroded soil can change the chemical composition of water as they might contain pesticides from agricultural land, heavy metals from industrial activities and nutrients from the soil itself. Excess nutrients in the water can cause eutrophication, which can lead to an increase in Biological Oxygen Demand (BOD) [2].

In recent times, Malaysia as a developing country has experienced significant environmental changes due to higher population, urbanization and faster economic growth. This has brought upon tremendous land use changes which has made the land in Malaysia more susceptible to soil erosion [3].

A slope is prone to soil erosion, but there are challenges to conserve the slope due to lacking of knowledge, technical support and cost constraint. Engineers introduce slope protection by designing gabion, retaining wall, riprap and other engineering methods [4, 5]. It has been much research done previously on the topic of soil erosion control using a plot of land [6]. The effectiveness of soil erosion
control using mulch and grass has not been well identified. Mulch and grass cover represent the most cost effective and economic ways to control soil erosion at a slope among the common methods. The main objectives of this study were as follows:

1. To examine the quality of the surface runoff produced by measuring the physical properties of the water namely the runoff volume, turbidity and total suspended solids (TSS).
2. To evaluate the effectiveness of two methods of soil erosion control, namely mulch and cultivated grass under different rainfall conditions.

Furthermore, this research is able to contribute to water quality improvement as the effective soil erosion method at low cost with less turbidity, TSS and runoff volume at the soil erosion affected areas.

2. Materials and Methods

Different methods, designs, parameters and procedures were performed in previous studies [7, 8]. In this experiment, a small-scale plot of land will be constructed and placed on a slope to induce erosion. It was then placed outside during a natural rainfall and the runoff was collected. The runoff was checked for its turbidity, TSS and runoff volume and was measured to evaluate which erosion control method is more effective in reducing sedimentation.

Plot was designed according to other similar experiments done by other researchers [9, 10]. The plot designed into a width of 0.6m, length of 1m and a depth of 0.2m. The plot was made using thin waterproof plywood. The box was nailed together using nails and any gaps were closed using a hot glue gun. Three holes were drilled at the front of the box with a diameter of one and a half inches. PVC pipes were joined at each of the holes to direct the runoff out. The top of the PVC pipes was covered with a 0.1m long wooden cover. The collection buckets were placed below the PVC pipes.

2.1. Control plot

Bare soil was created as a control plot. This plot was filled to a depth of 6 inches. It was placed on an incline in the horizontal: vertical ratio of 3:1.

2.2. Mulch plot

The plot was filled with soil to a depth of 6 inches. Mulch was made using dried grass clippings and dried grass. It was laid onto the soil and spread evenly throughout the soil. The thickness of the mulch used was 1 – 1.5 cm.

2.3. Grass cultivation plot

The plot was filled with soil to a depth of 6 inches. Patches of cow grass (*Axonopus compressus*) was planted along the soil. The plot was watered with 1 litre of water every day for a month to ensure that it grows properly. The grass coverage had more than 90% observable coverage on the soil before beginning to record the data.

2.4. Soil analysis

A soil analysis test was conducted to determine the type of soil. The test conducted is a Standard Operating Procedure (SOP), which was based on ASTM D422-63 standard Test Method for Particle-Size Analysis of Soils through sieving [11].

2.5. Rainfall data

The rainfall data was collected by the weather station located in the Curtin Malaysia campus. The rainfall intensity was categorized as low, moderate or high using the mean rainfall intensity over the specific time period. It was assumed that a low intensity rainfall event has a mean intensity of lower than 10 mm/hr, a moderate intensity rainfall event as having a mean intensity of between 10 mm/hr and 20 mm/hr and a high intensity rainfall is as having a mean intensity of more than 20 mm/hr. For the duration of rainfall, a short rainfall duration was assumed as occurring for less than one hour while a long duration
was quantified as occurring for more than 1 hour. The rainfall data for different test periods is shown in Table 1.

**Table 1. Rainfall data for different test periods.**

| Period       | Duration of rain exposure (min) | Average rainfall intensity (mm/hr) | Description                                                                 |
|--------------|---------------------------------|-----------------------------------|----------------------------------------------------------------------------|
| 1 (02/09/2018)| 35                              | 32.15                             | The rain started intensely before dropping to a lower intensity and then rising back up to a higher intensity. It was a short duration and high intensity. |
| 2 (05/09/2018)| 60                              | 9.09                              | During this rainfall event, the intensity was quite low throughout the rainfall period although it was for a longer duration. It was a long duration and low intensity. |
| 3 (06/09/2018)| 80                              | 15.71                             | The rain started intensely for only 15 minutes before reducing to a very low intensity. It was a long duration and moderate. |
| 4 (19/09/2018)| 105                             | 26.26                             | The rainfall stopped briefly after 55 minutes before resuming again. It was a long duration and high intensity. |
| 5 (01/10/2018)| 55                              | 13.17                             | The rainfall indicated a high intensity when it started before dropping in intensity. It later increased back up after 30 minutes before subsiding. It was a short duration and medium intensity. |

3. **Results and Discussion**

3.1. **Soil analysis**

Soil used for this experiment was put through a sieve analysis test and the data was recorded in Table 2. The soil comprised of 4% of silt, 52% of sand and 44% of gravel.

**Table 2. Particle size distribution.**

| Silt (%) | Sand (%) | Gravel (%) |
|----------|----------|------------|
|          | Fine     | Medium    | Course  | Fine | Medium | Course |
| 4        | 12       | 12        | 28      | 29   | 15      | 20     |

3.2. **Runoff volume**

The control plot consistently produced more runoff when compared to the other two plots. This is expected as the control plot has no erosion control method and is solely to provide comparison for the other two plots. Comparison of runoff volume between mulch and grass is shown in Figure 1.

Both plots produced the least amount of runoff volume during the first test period which was the period with the shortest rainfall duration. The rainfall intensity during this testing period started out high, but later subsided. The mulch plot only produced 80 mL of surface runoff while the grass produced 184 mL. The mulch was probably able to produce such a low runoff due to the decreased amount of rainfall as it was the shortest duration. This was mainly due to the function of the mulch whereby it prevented the surface water from accumulating and forming micro rills. The grass plot was able to produce a low
amount as well due to the short rainfall duration, the water had been absorbed into the soil instead of accumulating on the surface. It produced more runoff than the mulch as it could not obstruct the flow of the surface runoff [12].

In the second test period, the rainfall period was longer but was a low intensity rain throughout the rainfall period. Nevertheless, both plots produced more runoff with the mulch producing 196 mL and the grass producing 540 mL. This is a stark difference when compared to test period 1 where the difference between the two was only 104 mL. In this case, it is more than double the amount. The longer duration could have caused the water to accumulate on the grass plot thereby producing more surface runoff. The low intensity rainfall did not seem to have much effect on the mulch plot as there was minimal difference between the test period 1 and test period 2. The low intensity rain caused the rain drops to be absorbed by the mulch material.

In the third test period, the rainfall was even longer and started out with a high intensity. But this high intensity only lasted for 10-15 minutes before reducing to a low intensity rain. It was a moderate intensity rainfall event. However, it must be noted that test period 3 took place only a few hours after test period 2. Hence, this is a chance to investigate the erosion control performance of the two methods after successive rainfall events. Both the test plots produced significantly higher amounts of runoff with the mulch producing 687 mL and the grass plot double that with 1287 mL. This could be attributed to the soil sealing which occurs in the grass plot reducing the infiltration rate of the soil [6]. Water accumulated on the soil surface resulting in more runoff produced. This soil sealing had a lesser effect on the mulch as the raindrops were absorbed by the mulch material as well as the soil.

In the fourth test period, the rainfall was the longest among the testing periods. The mulch produced more or less the same amount of runoff when compared to period 3. This could indicate that although the rainfall was longer and with a high intensity, the mulch plot was unaffected by extended periods of rainfall. The grass plot on the other hand, showed a significant reduction by producing 645 mL of runoff which was lower than the volume produced by mulch plot. The roots from the grass had grown more and increased infiltration rates in the soil thereby decreasing the occurrence of soil sealing [13].

In the last testing period, the rainfall was a short rainfall event with a medium intensity. Both plots produced similar results with the runoff volume produced being 155 mL and 165 mL for the mulch and grass plots respectively. The grass plot had once again showed significant improvement in the reduction in runoff produced.
The percentage reduction obtained shows that the mulch had more or less the same performance throughout the testing period as its percentage reduction ranged between 83% – 95.04%. The grass plot showed more variance as its percentage reduction ranged from 53.17% - 94.72%. When compared to results obtained from previous work done [10], the engineered fiber matrix (EFM) with seed showed the highest percentage reduction of runoff volume at 68.0%. These results from the previous work are based on average runoff volume. Nevertheless, the difference between the results obtained from this experiment and the results from the previous research are too large. Hence, both of the erosion control methods used in this experiment is more effective in controlling runoff.

The mulch consistently produced a lower runoff volume when compared with the grass plot except in the last two testing periods where the runoff volume produced was very similar. The grass required sufficient time to grow which caused the roots not deep enough into the soil, therefore, the porosity of the soil was low and the water accumulated on the surface of the soil. The grass plot was a better erosion control method in terms of runoff volume over time. The mulch on the other hand, did not show any significant improvements in its performance in reducing runoff over time.

3.3. Turbidity

The control plot showed a higher turbidity (ranged from 8,550 to 23,760 NTU) when compared to the mulch plot and grass plot. Comparison of turbidity for mulch plot and grass plot is shown in Figure 2.

![Figure 2. Turbidity of mulch and grass.](image)

In period 1, the mulch plot had a turbidity of 368 NTU and the grass plot a turbidity of 464 NTU. Both control measures produced similar results with the mulch performing slightly better. This could be due to period 1, having a very short rainfall duration. In a short rainfall duration, the mulch could absorb the raindrops before it hit the soil surface and dislodge the soil particles thus, resulting in a lower turbidity [6].

In period 2, the mulch plot had turbidity of only 98 NTU and the grass plot a turbidity of 668 NTU. This could be due to the surface cover provided by the mulch. As the rainfall had a low intensity, there was not enough kinetic energy in the rain drop particles to dislodge the soil. The grass cover had not grown fully to cover the soil causing the raindrops to directly impact the soil and dislodge the particles.

During period 3 which occurred a few hours after test period 2, the mulch produced 639 NTU and the grass plot 503 NTU. This grass plot showed very similar readings when compared to test period 2 with slightly decreased. However, a drastic rise in turbidity for the mulch plot. After successive rainfall events, the mulch was still full of water absorbed from the previous rainfall event. So when it rained
again a few hours after, there was more water produced as runoff instead of being absorbed by mulch. If there was time in between the rainfall events, the water absorbed by the mulch would have evaporated and it would have been able to absorb more water by the time the next rainfall event occurred.

In the fourth test period, the rainfall had the longest duration a high intensity. The mulch plot showed the highest turbidity at 858 NTU while the grass plot was 274 NTU. This could be due to the grass growing longer and thicker thereby providing more surface cover for the soil dissipating the high kinetic energy in the raindrops. The mulch plot on the other hand, was drastically affected by the high intensity and longer duration rainfall. By having these conditions, the raindrops had more kinetic energy to dislodge the soil particles, and by continuing at this high intensity for an extended period of time, the mulch cover was unable to fully dissipate the kinetic energy of the raindrops [14].

In the last test period, the mulch cover had a better performance by producing 190 NTU and the grass cover a turbidity of 271 NTU. The last test period had a short rainfall duration with a medium intensity. The grass cover produced a similar amount of turbidity as test period 4. The mulch on the other hand produced a lower amount, indicating that the mulch plot performed better when the rainfall duration is short.

The mulch plot had a reduction in turbidity with the range of 97.31% - 99.1%. The grass plot once again had a bigger variance as its range varied from 92.19% - 99.59%. These results are comparable to the previous study [10], whereby engineered fiber matrix (EFM) with seed indicated a percentage reduction of 98.7%. The research results are the average turbidity, hence it cannot be concluded that either of the methods used in this experiment are better as the percentage reduction from the previous research are still in the range obtained in this experiment.

The mulch showed the highest reduction most of the time when compared to the grass cultivation plot. Although the results are almost similar, the mulch showed a slightly higher reduction. This could be attributed to the mulch covering the surface of the top soil whereby reducing the kinetic energy of the raindrop particles which impact the surface thereby reducing the amount of soil being dislodged. They might even prevent the raindrops from even reaching the surface altogether. The surface cover on the grass cultivation plot was less due to the gaps. The gaps between grass cover caused the raindrops to fully reach the surface and dislodge the soil particles. However, the grass plot had a better performance compared to the mulch plot when it was a high intensity and prolonged rainfall event. The mulch lost the ability to dissipate the kinetic energy of the raindrops after a sustained rainfall.

The turbidity produced from both control measures was not up to the water quality standards in Malaysia as all the turbidity values are above 50 NTU. The water produced did not meet the Class III Standards as listed in the Malaysian national guidelines [15]. Hence, using these methods alone might not be enough to achieve the desired erosion control performance at construction sites.

3.4. Total suspended solids (TSS)

The control plot showed a higher TSS (ranged from 6.5 to 82 g/l). Comparison of TSS for mulch plot and grass plot is shown in Figure 3.

During the first test period. The grass plot produced 0.34 g/l as compared to the mulch which produced 0.7 g/l. During period two, the mulch plot had a better performance as it recorded 0.26 g/l as compared to the grass plot which recorded 0.42 g/l. For the following test periods, the mulch recorded 0.58 g/l, 0.64 g/l and 0.22 g/l for test periods 3, 4 and 5 respectively. The grass plot recorded 0.3 g/l, 0.16 g/l and 0.18 g/l for test periods 3, 4 and 5 respectively.

The grass plot indicated a better performance in 4 out of the 5 test periods. The reduced performance of the mulch could be due to the mulch biodegrading over time as it is an organic material. This could have contributed to tiny organic matter to be eroded together with the soil causing the TSS value to be higher. However, the rate of mulch decomposition is unclear. Nevertheless, when the mulch decomposes it could create a more conducive environment for the microorganisms in the soil underneath by stabilizing the temperature and moisture [16]. This advantage is nullified, however, the increase in TSS in the surface runoff causing increased pollution to water bodies.
The higher amount of TSS detected in the grass plot during period 2 could be attributed to the soil not settling fully. Also, the roots of the grass had not grown fully at that time hence after the rainfall event, the soil on the surface was easily washed away. In addition, the rainfall conditions did not affect the TSS values obtained [8]. During period 4 when there was a high intensity and long duration rainfall event, the TSS value obtained by the grass plot was the lowest for all the test periods. The mulch plot produced a high amount of TSS during test period 4 but this amount is similar with the TSS amount produced during test period 3. Hence, the rainfall conditions did not affect the amount of TSS produced.

The percentage reduction of the mulch plot ranged from 96% - 99.2% while the grass plot ranged from 93.54% - 99.8%. During test period 4, when the rainfall event was the longest and had a high intensity. The grass plot showed the lowest TSS among all periods tested during period 4. When compared to previous work [10], the best performing control method which was the engineered fiber matrix (EFM) with seed achieved a 99.8% reduction. The engineered fiber matrix (EFM) with seed performs better than the two erosion control methods employed here in terms of TSS reduction.

The grass plot and mulch plot was able to occasionally achieve TSS values of below 300 mg/l which is the Class IV standard listed in the Malaysian national guidelines [18]. However, the grass cultivation plot is considered a more viable option as the biodegradation of the mulch over time was not fully quantified.

3.5. Cover factor

The cover factor is calculated by using the ratio of sediment yield from a surface with a specific control measure to a surface with no control measures. The cover factor is one of the most commonly used parameters to test the effectiveness of soil erosion control measures. The cover factor is scaled from 0 to 1 where zero means a 100% reduction of erosion and one meaning a 0% reduction in erosion or in other words it is the same as the bare soil. The average cover factor for mulch plot and grass plot is shown in Table 3.

| Plot          | Average Cover Factor |
|---------------|----------------------|
| Mulch         | 0.024                |
| Grass Cultivation | 0.022              |

The cover factor is one of the parameters used in the Universal Soil Loss Equation (USLE). It is used to represent the control method used when compared to a bare unprotected soil. Among the many
parameters in use for the USLE equation, the cover factor is the most easily influenced. It is the factor most considered by policy makers and farmers [17].

The grass cultivation showed the better cover factor as compared to the mulch. The grass was better to be used as a cover than the mulch. However, these results are not entirely accurate as the TSS from different test periods with varying rainfall conditions were averaged out. Mulch with a 100% cover which is used as an erosion control at construction sites have a C factor value of 0.02 based on the Malaysia Department of Irrigation and Drainage (DID) [18]. The grass with more than 90% cover in this experiment indicated the C factor value of 0.02. Hence, the cover factor is this experiment is similar to the guideline listed in DID.

4. Conclusion
The mulch plot was able to consistently produce a lower runoff volume when compared to the grass plot. The turbidity produced by both sets of erosion control measures are very similar although the mulch produced a slightly lower value. The mulch acted as a better surface cover, which is effective in reducing the kinetic energy of the raindrops. However, the mulch was biodegrading over time that causing small organic particles to be eroded as well. In terms of runoff volume and turbidity, the grass plot was able to perform better in high intensity and longer duration rainfall events when compared to the mulch plot. During low and moderate intensity rainfall events, the mulch plot produced slightly better results when compared with the grass plot. It proved that the rainfall conditions had no effect on the TSS produced. Although there were certain instances when the results were very similar, after taking into account the increase in performance of the grass over time as well as its ability to perform better in harsher conditions, it is concluded that the grass cultivation is the better option to be used as an erosion control method. However, mulch can still be used as a temporary erosion control method on construction sites while it would be better to apply grass as a more permanent erosion control method.

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