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The Effect of Different Layers Above Soil on the Amount of Soil Erosion

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Abstract

Soil erosion, caused by wind or water, poses significant environmental and economic challenges, including the degradation of agricultural land, increased crop damage, and risks to infrastructure. This study investigates the effectiveness of different surface layers—dried leaves, mulch, and rocks—in reducing soil erosion under simulated rainfall. Its purpose was to find the most effective method for preventing soil loss and maintaining land stability in everyday farmlands and neighborhoods. The experiment utilized trays filled with soil, each covered with one of the materials or left bare as a control. Water was poured over the trays from a consistent height, and the amount of soil eroded was measured by the mass of soil lost. Throughout the study, the experimenter took precautionary measures to protect the skin and eyes from harmful particles. The results demonstrated that all protective layers reduced erosion compared to controlled bare soil. Rocks proved most effective, reducing erosion to an average of 1.8 grams, compared to 26.5 grams from the bare soil. Mulch and dried leaves provided minimal protection, with average erosion rates of 2.5 grams and 3 grams, respectively. The study supports the hypothesis that physical barriers, especially rocks, can significantly mitigate soil erosion by reducing the runoff velocity and maintaining soil structure. These findings suggest that using natural materials can be a practical strategy for controlling erosion in agricultural and urban environments. Future research could explore the long-term impact of these materials and their potential in combination with different soil types and environmental conditions.

Keywords: runoff control; land degradation; rainfall impact; protective barriers; sediment loss; sustainable agriculture; environmental conservation

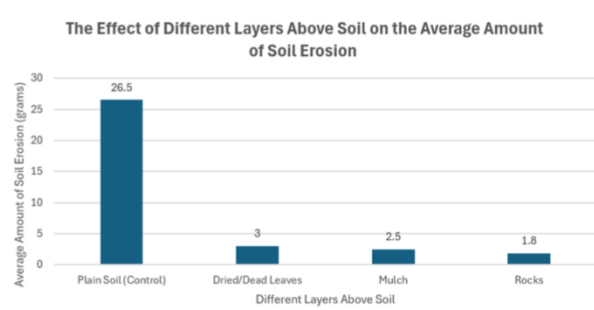
1. Introduction

Erosion is a geological process that removes or transports parts of Earth's surfaces. This can be rocks, soil, or sand that are able to be moved from one location to another by erosion. This usually occurs when water or wind takes particles from these objects and removes them, which then causes the particles to begin deteriorating or migrating into a different location.[2] However, soil erosion doesn't only result in the shifting of land but can create natural disasters that pose hazards to citizens living in an area affected by them.[5] It's possible for natural disasters such as landslides and sinkholes to occur from water soaking through the top layer of soil and rock, eventually washing away the dirt, which critically weakens the soil below. This can create a hollow area, which is able to collapse at any given moment, possibly putting nearby constructions at risk of danger.[6] Over the summer of 2024, many Virginians have seen large amounts of rainfall. The heavy rains have resulted in soil on sidewalks and hills being washed off. The excess erosion doesn't just pose a problem for marine life, but also one for people globally. The UN FAO (United Nations Food and Agriculture Organization) claims that approximately 80% of the food that people consume comes from agricultural sites.[5] However, due to increasing amounts of soil erosion, there is a lack of fertile land left for farming crops. The economic consequences of this are significant. It impacts farmers' livelihoods and increases costs for food production and disaster management. Just annually (2023), the United States is forced to face a loss of about $22 billion in crop damage.[5] Layers above the soil, such as organic matter or physical barriers, play a crucial role in protecting the ground from erosion caused by natural forces. The levels of the independent variables in this experiment are dry leaves, rocks, and mulch. Leaves are one of the three essential organs of a plant. They're mainly responsible for being able to photosynthesize sunlight into food for a plant.[8] However, dead leaves are simply leaves that have fallen off tree branches and can now be used as a source of organic matter.[9] When organic layers like fallen leaves cover the soil, they act as a shield, reducing the impact of rainfall and wind. This layer helps retain moisture, improving soil stability and structure.[3] Similarly, when mulch is applied, it insulates the soil, which reduces the soil's direct exposure to external elements. Mulch is simply a protective layer of a material that is spread over the surface of the soil.[10] Mulch is commonly composed of organic materials and comes in several forms. It's most often made of tree bark, wood chips, pine straw, moss, grass clippings, or leaves.[10] Organic mulches, in particular, break down over time, enriching the soil, while also preventing it from being easily displaced by water or wind. These protective layers above the soil not only reduce the immediate impact of erosion but also contribute to long-term soil health and ecosystem balance.[8] On the other hand, layers like rocks, which don't contribute directly to nutrient cycling, offer consistent, long-lasting protection. Rocks are naturally occurring mineral material composed of one or more minerals. They're typically known as one of the basic units of Earth and form in several ways. They help protect soil-filled areas that are prone to harsh weather conditions or heavy water flow. By reducing runoff velocity, rocks prevent the formation of gullies and ruts, which can lead to more severe erosion problems if left unchecked. Together, these layers, whether organic or inorganic, work in harmony to maintain soil stability, reduce the risk of erosion, and promote a healthier, more sustainable environment for plant life and ecosystems.[1] The purpose of this experiment is to find which layer above the soil will provide the greatest decrease in soil loss. This is so that we as ordinary people can find an effective way to reduce basic erosion in our own communities in order to help keep our land safe. The independent variables in this experiment will consist of layers found above the soil. They're daily items like dead leaves, mulch, and rocks. These will cover a tray of soil where we will attempt to figure out which one decreases erosion the most by measuring the amount of soil erosion in grams. The control for this experiment will be plain soil with no layers above it to help replicate everyday soil erosion from rain. The constants in this experiment are the type of soil, the container the soil is in, the amount of water, the angle of the container, and the distance of the water sprinkler to the soil. The hypothesis in this experiment states that if the layer above the soil used is rocks, then the amount of erosion will decrease. In many cases of erosion, layers of rocks are able to hold in soil and prevent runoff and erosion from rain.[1] These coarse-grained rocks reduce the speed of water runoff, so instead of letting it move the soil into another location, it soaks the water up instead.[7]

2. Methods

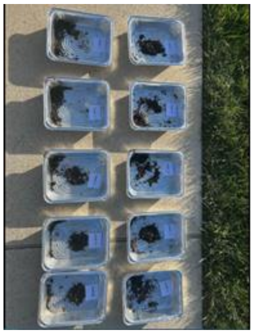
To begin the experiment, the experimenter first prepared 40 aluminum trays, each in which the different effects of different materials on soil erosion would be tested. Every 10 trays were assigned to the four levels of the independent variables: plain soil, dried leaves, mulch, and rocks. Each 20.32 by 20.32 centimeter tray with a gap of approximately 7.62 by 5.5 in the center of the edge was tilted, sitting on the edge of the 22.86 by 33.02 cm tray. It was angled at 7.2 cm high and contained 185 grams of soil, which was laid at the 2.5 cm mark. Beneath the tilted trays was the 22.86 by 33.02 cm tray used to catch and observe soil runoff. Once each of the trays needed for the experiment was set up, the experimenter scattered the different materials over the different bodies of soil. Each material possessed a different volume so the levels of independent variables determined the amount of surface area which was covered by them. However, they were all layered until the 4 cm mark on the 20.32 by 20.32 tray. A small-sized watering pail containing 7 fluid ounces of cold tap water was held 58 cm above every tray and then poured out over the soil to recreate rain. After each body of soil was flooded evenly with water, the 22.86 by 33.02 cm tray, containing the runoff, was mostly dried by pouring the muddy water through fresh cheesecloth and then left outside for two days. However, all soil masses needed to be completely dry, for if the soil held any water weight, it would result in inaccurate data. Following this, the experimenter placed each group of soil into the oven for 1 hour and 30 minutes at 150 degrees. Once the soil runoff had dried, it was measured in grams in order to understand which independent variable had the greatest impact on reducing the amount of runoff. The constants in this experiment consisted of the soil type, the 20.32 by 20.32 cm tray in which the soil was originally placed, the 22.86 by 33.02 cm tray the soil runoff fell into, the height at which the trays were tilted, and the distance the water pail was held from the trays. Before conducting the experiment, the experimenter wore protective goggles, gloves, and an apron. Goggles were worn to ensure no particles or dirt entered or irritated the eyes. An apron and gloves were worn to protect the skin from harmful particles and to avoid contact with the materials. The experimenter maintained a clean workspace to prevent distractions and create a safe environment. All materials used during the experiment were removed after the trials were completed. This procedure was repeated for all levels of the independent variables, including the control, the plain soil, the dried leaves, the mulch, and the rocks.

3. Results

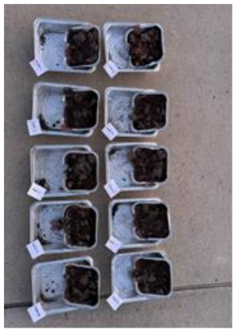


Graph 1: Average Amount of Soil Loss for Every Layer Above Soil

The graph above represents the averages of data from each level of independent variables. It's shown that the effect of the different layers above soil reduces the amount of soil erosion overall. To measure the amount of erosion for each layer, the eroded soil was weighed on a scale in grams.



Plain Soil (Control)



Dried/Dead Leaves

Mulch

Rock

Picture Set 1: Eroded Soil from Each Tested Trial Set

In the photos displayed above, you're able to observe the average amounts of soil erosion being 26.5 g, 3 g, 2.5 g, and 1.8 g. The results of the experiment demonstrated a significant difference in the amount of soil eroded when comparing the different types of layering to bare soil (control). The difference in erosion is apparent from the data exhibited in the charts and graphs, showing a minimum 23-gram reduction in erosion with a layer compared to leaving the soil exposed. For the plain soil (control), the average amount of soil eroded was 26.5 grams. In comparison, the average soil erosion for the other types of layering was much lower. This is seen in the average results: 3.0 grams for leaves, 2.5 grams for mulch, and 1.8 grams for rocks. The median erosion values further support these findings. For bare soil, the median erosion was 34.0 grams compared to the median for leaves, which was 3.0 grams. Mulch had a median erosion of just 1.5 grams, and rocks had a median of 1 gram. The mode of the data set (the most frequently occurring value) for bare soil was 46 grams, while the mode for leaves was 2 and 4 grams. For mulch, the mode was 1 gram, and for rocks, the mode was 1 gram as well.

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Statistical Analysis	Amount of Soil Eroded (Grams)			
	Plain Soil (Control)	Dried/Dead Leaves	Mulch	Rocks
Mean	26.5 g	3 g	2.5 g	1.8 g
Median	34 g	3 g	1.5 g	1 g
Mode	46 g	2 g & 4 g	1 g	1 g

The results demonstrate that the application of a protective layer, such as leaves, mulch, or rocks, significantly reduces the amount of soil erosion compared to leaving the soil plain and bare. The layers of mulch and rocks were particularly effective, with erosion levels significantly lower than both bare soil and dried leaves. Overall, it seems that the layers with larger masses proved to be better at decreasing the amount of soil erosion.

4. Discussion

The purpose of this experiment was to determine which layer above the soil would best reduce the amount of soil erosion. This experiment was conducted to help understand which material was able to best stop the contact between rainwater and soil in order to find a solution for erosion and runoff in farmlands. Research has shown that the presence of protective layers, such as organic matter or physical barriers, helps prevent soil erosion by absorbing the impact of rainfall, reducing runoff, and stabilizing the soil structure. Rocks effectively reduce runoff velocity and help maintain soil integrity by creating a barrier that prevents soil from being displaced by water.[1] This is further supported by Southwest Boulder & Stone[7], which emphasized that rocks, particularly coarse-grained ones, help absorb water, preventing soil erosion by slowing down the movement of water across the surface. Based on the findings, rocks demonstrated the most effective reduction in erosion, with only 1.8 grams of soil lost, compared to 26.5 grams for bare soil. Their weight and stability kept the soil beneath them in place, while their surface weakened the force of moving elements, protecting the sediment from direct impact. The rocks served as a protective barrier that shielded the soil from the impact of wind, water, and other erosive forces. They slowed the flow of water, reducing its energy and ability to carry soil and sediments away. As expected, as the mass of the material above the soil increased, the effect on the amount of erosion decreased. The hypothesis in this experiment stated that if the layer above the soil consists of rocks, then the amount of soil erosion will decrease. The results of this experiment show clear support for the hypothesis that protective layers above soil can significantly reduce erosion. The data demonstrates that all layers—dried leaves, mulch, and rocks—decreased soil erosion when compared to the plain, exposed soil. Among the tested materials, rocks were the most effective in reducing soil erosion, followed by mulch and dried leaves. The findings are consistent with previous research highlighting the importance of protective layers in mitigating erosion caused by rainfall. If this experiment were to be repeated again, the experimenter would attempt to apply a more even layer of the independent variables for every trial. The materials used each had different masses and inconsistent shapes. This resulted in the trials not having the same application of material for every single tray. Though this was an identified error in the experiment, the way the layers were applied didn't prove to be much of a problem since the results were similar to the ones expected. The findings from this experiment were consistent with the research that the coarse-grained rocks used could reduce the speed of water runoff. Instead of letting heavy rains and other external forces transport the soil into another location, it soaks the water up instead due to how weak the flow becomes.[7] This proved rocks are a source of long-lasting protection for the soil and a great way to reduce erosion. We're able to use rocks to protect our farmland and water bodies from large amounts of sediment buildup and erosion. For further study, these results can be explained using the principles of fluid dynamics. These principles develop the understanding that reducing the overall velocity of water decreases its erosive force.[2] In the experiment, the rocks slowed down the flow of water from the watering can, dispersing its energy and preventing the soil particles from being carried away. Additionally, the weight and stability of the rocks worked as an anchor for the soil beneath them. This aligns with the concept of soil cohesion, which resists displacement of the particles.[4] The other layers used in the experiment, such as dried leaves or mulch, had larger amounts of erosion, possibly due to gaps or a weaker coverage of the soil, demonstrating less effective energy dissipation. An improvement to this experiment could be to incorporate multiple soil types. Including soils such as sand, clay, or silt could expand the applicability of the findings to the vast number of environmental conditions. Future studies could explore a wider range of materials, including the combinations of different layers, like rocks with vegetation, to determine if hybrid approaches to the issue could enhance erosion prevention. Additionally, conducting the experiment under varying weather conditions, such as high wind speeds, could allow for a more comprehensive understanding of how each layer performs in real-world scenarios.

5. Conclusion

The significant reduction in erosion with all protective layers suggests that their application can play an important role in preventing soil degradation, particularly in areas prone to heavy rainfall. Soil erosion is not only a concern for agricultural production but also for infrastructure and the environment. Erosion can lead to dangerous outcomes, including landslides and sinkholes, which put both people and properties at risk. The results of this study indicate that simple, cost-effective materials such as rocks, mulch, or leaves can help mitigate these risks and promote a more sustainable environment. In conclusion, this study supports the hypothesis that protective layers above soil can significantly reduce erosion. The results suggest that rocks are the most effective material for preventing soil erosion, followed by mulch and dried leaves. These findings highlight the potential for using natural materials to combat soil erosion in both agricultural and urban settings. Further studies could explore the long-term effects of these materials on soil health and the ecosystem, as well as the potential for combining these materials for even more effective erosion control strategies.

Abbreviations

UN FAO: United Nations Food and Agriculture Organization

Cm: centimeters

G: grams

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Conflicts of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Ethics Statement

Ethics approval was not required for this research.

Data Availability Statement

All data are included in the paper as well as supplementary files.

AI Use Statement

The authors did not use generative AI or AI-assisted technologies in the writing or preparation of this manuscript.

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