Uluslararası İleri Doğa Bilimleri ve Mühendislik Araştırmaları Dergisi
Sayı 8, S. 154-161, 3, 2024

Araştırma Makalesi

IJANSER
https://as-proceeding.com/index.php/ijanser
ISSN: 2980-0811

International Journal of Advanced Natural Sciences and Engineering Researches
Volume 8, pp. 154-161, 3, 2024

Research Article

SOIL EROSION MITIGATION USING ECO FRIENDLY MATERIALS

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(Received:17 April 2024, Accepted: 25 April 2024)

(2nd International Conference on Scientific and Innovative Studies ICSIS 2024, April 18-19, 2024)

ATIF/REFERENCE: Sheeraz, A. & Aamir, E. (2024). Soil Erosion Mitigation Using Eco Friendly Materials. *International Journal of Advanced Natural Sciences and Engineering Researches*, 8(3), 154-161.

Abstract-A serious environmental problem, soil erosion may cause deforestation, disrupt ecosystems, and remove valuable topsoil. Sustainable practices and materials are crucial for preserving sustainability and reducing erosion. An investigation conducted at NUST looked at the elements affecting erosion on a plot of land situated between the Animal Lab House and the Institute of Environmental Sciences and Engineering. The study discovered that mulching without control measures and with dry leaves had comparable outcomes. Fines of 26g and 23g were kept, respectively. However, the best retention of small particles (up to 55g) was seen in soil treated with dry sludge from NUST's Membrane Bioreactor. This research was presented at the 1st international conference on climate change and emerging trends in civil engineering (CCETC 2024) at GIKI. Similar research was performed mimicking a larger area which was the recently built: NUST school of health sciences. This research focuses on sustainable cities and communities, which is a component of SDG 11, with the goals of minimizing floods, maintaining a healthy ecological, and protecting land.

Keywords: Sustainability, Soil Erosion, Dewatered Sludge, Stabilizer, Mulching.

I. INTRODUCTION

Soil erosion is one of the world's most critical environmental issues today, threatening both agriculture and the natural environment [12]. Soil erosion has been a significant environmental issue for many years because it erodes the most fertile soil layers, endangering global food supply among other things. Even though the impacts have been known for a while, reducing soil erosion in many ecosystems still presents a number of difficulties [13].

Soil erosion is often defined by three processes: soil loosening, transport, and deposition. The topsoil, which is rich in organic matter, nutrients, and soil life, is typically moved as a result of these processes and either builds up over time elsewhere on the site or is taken off-site and accumulates in drainage channels. It usually affects exposed, messy areas severely [14]. Rainwater is one of the main factors contributing to soil erosion because it erodes soil, lifts it out of its surrounding material, and then washes it away as runoff. The process of soil erosion is also influenced by the type of land use [16].

These days, slope drains, ground covers, blankets, plastic covers, and silt fences are among the best management practices used to prevent soil erosion. If these techniques are correctly developed and applied, they work well. They are, nevertheless, frequently more costly, less environmentally friendly, and transient [15]. In order to minimize erosion and preserve soil health, this study will examine and assess a variety of sustainable approaches that make use of ecosystems and natural processes.

II. REVIEW OF LITERATURE

Soil erosion, which is a significant environmental problem can result in degraded land, it is the process of detachment, transportation, and deposition of soil particles from one location to another due to natural or human-induced factors [1]. Environmental implications include the disruption of ecosystems, sedimentation of water bodies, and degradation of water quality. Agricultural significance involves the loss of fertile topsoil, reduced agricultural productivity, and increased vulnerability to extreme weather events [6].

Traditional soil erosion control techniques, such as terracing, contour farming, and vegetative cover, have been employed to mitigate erosion. Terracing involves creating stepped levels on hilly terrain to reduce water runoff and encourage absorption [9]. Contour farming employs farming along the natural contours of the land to minimize erosion. Vegetative cover involves planting vegetation to stabilize the soil. However, these techniques have limitations, including high costs, labor intensity, and maintenance requirements [1]. Moreover, they may not be suitable for all types of terrain or may not provide long-term sustainability [10].

Sustainable materials for soil erosion control present an alternative approach. These materials focus on ecological balance and long-term viability [6]. They encompass both natural materials like straw, coconut coir, and geotextiles made from natural fibers, as well as engineered options such as bioengineering techniques and erosion control blankets [7]. These materials promote environmental sustainability, minimize ecological impact, and provide effective erosion control [8].

Mulching is a temporary or long-term erosion control method that involves covering the topsoil with crop residues, garden residues, wood chips, wood fibres, gravel, etc. Mulching is strongly advised as a long-lasting, inexpensive method of preventing soil erosion. Mulches can be made from both natural and artificial materials, including organic (compost, grass clippings, straw, bark, and leaf litter) and inorganic (stone) materials. Today's raised bed vegetable farming often uses plastic and rubber mulchers. These mulches are used for a variety of landscaping purposes, such as in playgrounds, in addition to controlling erosion and preventing weed growth.

For advanced erosion control in steep areas, erosion mats made of materials like chopped straw, wood fibres, or coconut fibres sandwiched between layers of jute or UV-degradable plastic netting are used. These mats can be adjusted to a variety of circumstances, such as slope, water flow, longevity, and desired vegetation [4].

Soil erosion is immediately reduced by two orders of magnitude when straw mulch is used. Additionally, mulches made from chopped and broken branches are quite effective, but they take longer to stop soil erosion. Catch crops and weeds are excellent erosion controllers [3].

There is a gap between study and use of soil erosion control measures. Although the engineering subcategory of soil erosion control techniques was the most diverse, agricultural and biological techniques have garnered the most interest in recent soil erosion control techniques research. Research on soil erosion control approaches may be incorrect and have a limited impact on erosion control in the real world if practice and theory are not integrated. The development of soil erosion management techniques was sparked by countries with significant soil erosion, and these nations also understood the value of adapting soil conservation tactics to the local environment and population. However, coordinated efforts are required to create a strong worldwide platform for knowledge sharing that enables the nations to prepare for, adapt to, and reduce the harm caused by soil erosion. Last but not least, the majority of current soil erosion management methods have been resource-intensive, which limits their use in the future. To solve this problem, the development of eco-friendly soil erosion control approaches can continue efficient in soil erosion management [5].

III. METHODOLOGY

Study Area:

Figure 1: NUST school of health sciences

The site selected was the NUST school of health sciences (NSHS) with latitude and longitude 33.64827 72.99494 respectively. A thorough analysis of the field was done to replicate the characteristics of the current land topography before downscaling to the laboratory experimental setting. The area was chosen carefully based on its topography and the environmental and human health hazards that could be caused in the event of extreme soil erosion since the lab house is located at a slope and any erosion occurring would directly affect the NSHS parking lot which can consist of up to 200 cars.

Laboratory scale experimental set up: The study area field conditions were replicated using 4 plastic boxes of equal dimensions (2.0m × 1.0m × 0.15m), and they were then placed at a slope of 20 degrees. The soil samples collected were filled in 3 layers, after compaction at each layer to mimic field conditions and porosity. Artificial rain was then simulated according to Islamabad's average rainfall intensity during the winter months, and it was provided for 30 minutes every day over a period of 60 days.

Figure 2. In process of filling 4 similar trays with soil

Erosion control experiments: The experiment was done in such a way that could deduce results between sustainable and conventional soil erosion techniques, therefore, the variables were mulch, dewatered sludge, a soil stabilizer, and the control. For mulching, dry leaves were used. Sludge was collected from the membrane bio reactor plant and manual dewatering was performed; the sludge was then left to dry. The soil stabilizer used was 10% magnesium chloride solution. Soil samples from each box were taken for sieve analysis to determine the number of fines present and compare that with those before the experiment was carried out. Each sample consisted of soil from the topmost layer, middle, and bottom layer. A moisture content test was also performed in the lab.

IV. RESULTS AND DISCUSSION

Experiments and tests performed to analyze erosion control

In this experimental setup, a plastic tray was loaded with well-graded soil, and a systematic compaction process was applied to ensure uniform density across the soil layers. To simulate precipitation, an artificial rainfall event was induced on each tray using a manually operated device. Subsequently, soil samples weighing 500 grams were meticulously extracted from three distinct locations within each tray. These samples underwent sieve analysis to discern the percentage of fines, providing insights into the soil's susceptibility to erosion. Additionally, the moisture content of each sample was calculated, enabling a comprehensive understanding of the interplay between erosion control measures, precipitation simulation, fines retention, and moisture levels in the examined soil.

Results with no erosion control measures:

Results without erosion control measures revealed that 42g of fines were retained according to sieve analysis. This implies that in the absence of any control measures, there is a reduced retention of the finer particles. Additionally, the moisture content of the samples fell within the range of 7%-8%.

Figure 3. Sieve analysis

Results with mulches:

Figure 4. Mulching with dry leaves

The tray was covered with dry leaves also known as “mulching”. It was observed from the results of sieve analysis that the mass of fines retained was 50g. This is a clear improvement over no control measures being taken as there is more retention of the % finer, an improvement of 19% from using no control measures. Moisture Content of the samples was also found to be in-between 12%-13%.

Results with dry Sludge:

Figure 5. Dewatered sludge covering

The result with the application of dry sludge indicated a fines retention of 79g as per sieve analysis. This suggests that the implementation of this control measure leads to an increased retention of finer particles, representing an 88% improvement compared to the scenario without any control measures. This indicates that this is the superlative sustainable method to prevent soil erosion as there was minimum soil deposition. Additionally, the moisture content varied from 13-14%.

Results with soil stabilizer:

Sieve analysis demonstrated that 72g of particles were retained when stabilizer (10% magnesium chloride) was used. This suggests that finer particles were retained more successfully than when mulching (44% better) or no control methods were used (71 % better), but it was not nearly as effective as when dry sludge was utilized. In addition, the sample's moisture contents varied from 7% to 8%.

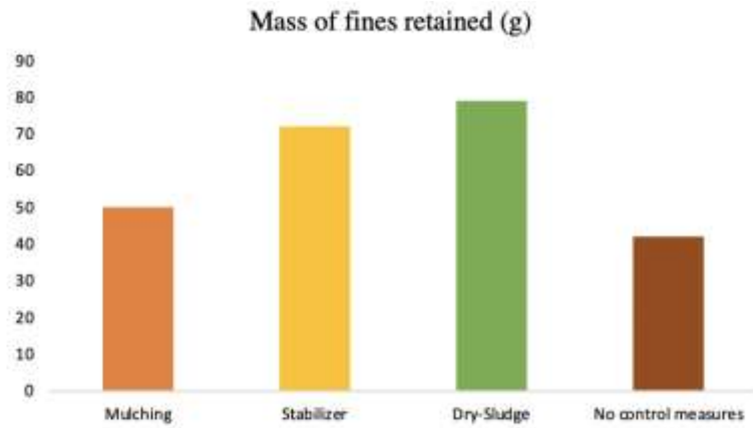

Figure 6. Mass of fines retained

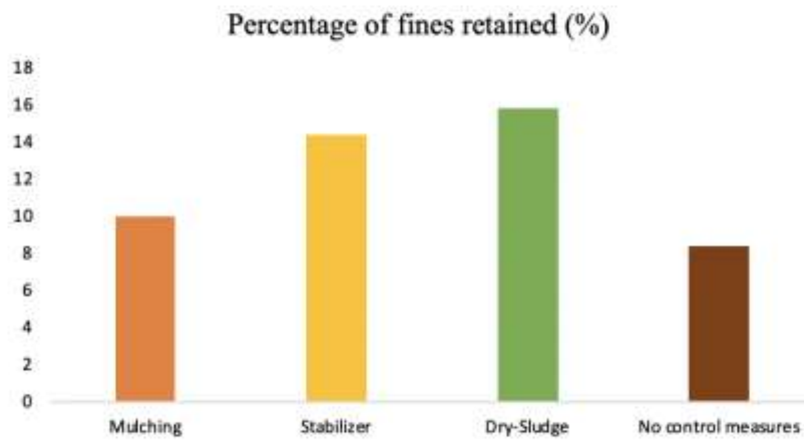

Figure 7. Percentage of fines retained

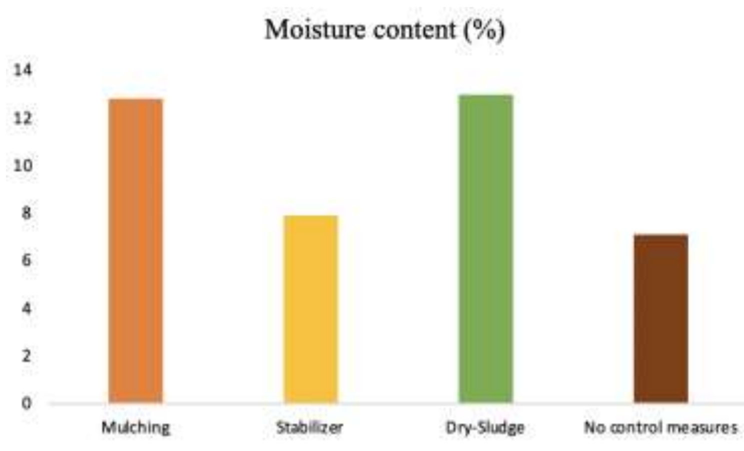

Figure 8. Moisture content

The results of the experiment reveal distinct variations in the percentage of fines retained among different soil erosion control measures. Mulching, employed as a control measure, demonstrated a fines retention rate of 10%, indicating its efficacy in minimizing soil erosion. Stabilizer, another method utilized in the study, exhibited a slightly higher fines retention of 14.4%, suggesting its effectiveness in preventing fines from being washed away. Notably, dry sludge emerged as the most successful control measure, with an impressive fines retention rate of 15.8%, underscoring its potential as a robust solution for soil erosion prevention. In contrast, the absence of any control measures resulted in a fines retention rate of 8.4%, emphasizing the importance of implementing effective erosion control strategies to mitigate the loss of fines in soil. These findings underscore the significance of selecting appropriate erosion control measures based on their demonstrated fines retention capabilities.

V. CONCLUSION

The study found that mulching with dry leaves and mulching without control results in almost the same percentage of fine particles, which is 10% and 8.4% respectively. However, soil treated with dry sludge from NUST's Membrane Bioreactor retains fine particles the best -up to 15.8%. Addressing soil erosion through sustainable approaches is crucial for agriculture and the environment. A comprehensive strategy incorporating afforestation, mulching, cover crops, dewatered sludge, and other sustainable activities can reduce negative consequences, enhance soil health and biodiversity, protect arable land, ensure food production, and enhance ecosystem resilience. Prioritizing soil erosion prevention is essential in addressing climate change and global environmental concerns, fostering a balance between human activities and the preservation of planet's resources.

VI. ACKNOWLEDGMENTS

Thanks to the MBR and Geotech lab (NICE, NUST) faculty for resources, and colleagues for enriching discussions. Thanks to everyone who made this research possible. Family and friends provided essential support.

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