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A Study on Soil Erosion Control with Geosynthetic Cementitious Composite Mats for Sustainable Agricultural Practices

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Abstract— Soil erosion is a significant environmental challenge that threatens the sustainability of agricultural practices worldwide. This study investigates the efficacy of geosynthetic cementitious composite mats (GCCMs) in controlling soil erosion and promoting sustainable agricultural practices. Soil erosion is a widespread problem that leads to the loss of fertile topsoil, reduced agricultural productivity, and environmental degradation. Traditional erosion control methods, such as vegetation establishment and the use of physical barriers, have had limited success in certain regions. GCCMs have emerged as a promising solution, offering a combination of structural and hydraulic properties that can effectively mitigate soil erosion. The study aims to evaluate the performance of GCCMs in controlling soil erosion and their potential impact on sustainable agricultural practices. Specifically, the researchers seek to assess the ability of GCCMs to reduce soil loss, enhance water infiltration, and promote the establishment of vegetation in areas prone to erosion. The study is expected to provide valuable insights into the effectiveness of GCCMs in controlling soil erosion and their potential benefits for sustainable agricultural practices.

Index Terms— Geosynthetic cementitious composite mats, Soil conservation, Soil erosion, Sustainable agriculture, Water infiltration.

1 INTRODUCTION

Soil erosion poses a significant threat to sustainable agricultural practices, leading to the depletion of fertile topsoil and the degradation of land productivity. Conventional erosion control methods often involve the use of synthetic materials or labor-intensive practices, which can be costly and environmentally unfriendly. In recent years, the development of geosynthetic cementitious composite mats (GCCMs) has emerged as a promising solution for soil erosion control, offering a sustainable and cost-effective approach [1].

GCCMs are innovative materials that combine the strength and durability of geosynthetic materials with the binding properties of cementitious materials. These mats are designed to provide effective erosion control by protecting the soil surface from the erosive forces of water and wind. They can be applied to various agricultural settings, including slopes, channels, and embankments, offering a versatile solution for erosion mitigation. The study aims to investigate the performance and efficacy of GCCMs in controlling soil erosion, with a particular focus on their application in sustainable agricultural practices [1],[2].

2 SOIL EROSION CONTROL TECHNICS

Soil erosion control involves strategies and practices aimed at preventing the removal of topsoil by natural forces like water, wind, or human activities. Effective erosion control helps preserve soil health, reduce sedimentation in water bodies, and maintain land stability. Key soil erosion control methods include.

2.1 Vegetative Cover

Vetiver grass (Chrysopogon zizanioides) significantly reduced soil erosion and runoff in steep slopes, with up to 97% soil loss reduction and 21% less runoff in sandy silt. It was more effective in sandy soils, and combining vetiver with jute geotextile provided the best erosion control as shown in Fig. 1". Soil texture played a key role in erosion outcomes[4]. In the Anjiagou watershed, vegetation cover significantly reduced soil erosion, with shrub forests being most effective for short-term rain and natural grasslands for long-duration rains. Vegetation reduced erosion by 73%, double the runoff reduction, with precipitation intensity being a key factor [3].

Fig. 1 Vegetative Cover with jute mat[4]

Cover crops, particularly a mix of Legume and Gramineae grass (MG), as shown ih Fig. 2", Fig. 3", significantly reduced runoff, leaching, soil, and nutrient losses in orchards by 33–60%. MG was most effective, reducing water, soil, nitrogen, and phosphorus losses, making it a viable strategy for soil and water conservation [5].

Fig. 2 Legume [5].

Fig. 3 Gramineae grass [5].

2.2 Terracing and Contour Plowing

Slope shape affects soil erosion rates, with convex slopes experiencing the highest erosion and concave slopes the lowest.We can observe in the Fig. 4", Erosion and deposition fluctuate along slope length, showing periodic patterns. The study highlights the importance of considering slope shape, gradient, and length in erosion prediction and soil conservation planning [6].

Fig. 4 Terracing and Contour Plowing

2.3 Mulching

Applying organic or synthetic materials to cover soil, as shown in Fig. 5", retaining moisture, and protecting it from erosion. Mulching, both organic and synthetic, is crucial in dryland agriculture for conserving water, enhancing soil nutrients, and reducing evaporation, erosion, and weed growth. It effectively preserves soil moisture and improves nutrient availability, supporting sustainability in arid regions [3][7]. conventional and novel soil erosion control methods. Traditional techniques include contour planting, mulching agricultural waste, and check dams, while newer strategies involve biopolymers, geotextiles, chemical treatments, and improved agronomic practices. The study highlights the importance of these methods in mitigating erosion and maintaining environmental sustainability [16].

Fig. 5 Mulching

2.4 Retaining Walls and Riprap

Structures built to hold back soil on steep slopes or shorelines,as shown in Fig. 6” to preventing erosion caused by water and gravity. This study highlights the crucial role of vegetation in slope stabilization, emphasizing that plant roots enhance soil cohesion and reduce erosion, while above-ground vegetation improves infiltration and reduces raindrop impact. Different vegetation types, such as grasses and shrubs, affect slope stability differently; a combination of these can optimize soil reinforcement and erosion control[8].

Fig. 6 Retaining Walls and Riprap

2.5 Geosynthetic Cementitious composite mats (GCCMs)

The Geosynthetic Cementitious Composite Mats (GCCMs) effectively reinforce soil slopes by reducing displacement and delaying pore-water pressure increase during rainfall, showcasing their potential for improving slope stability [9]. A reinforced Geosynthetic Cementitious Composite Mat (GCCM) with enhanced stability and impact resistance by incorporating yarn-in-lay technology and a blowing agent. The optimized double raschel GCCM exhibited improved flexural strength and durability after just 10 days of curing[2][11].

2.6 Silt Fences and Sediment Traps

Temporary measures used in construction areas to filter runoff and reduce sediment flow into nearby water bodies like as shown in Fig. 7” Sediment traps, designed to reduce sediment loss in agricultural areas, showed in Fig. 8, variable effectiveness (10% to 98% reduction) with an average of 59% sediment trapping efficiency. A storage ratio of at least 120 m^3/ha is recommended to achieve a sediment trapping efficiency of 55% or better [12]. soil erosion control measures, highlighting the impact of splash, sheet, rill, and gully erosion. It emphasizes the importance of protecting soil in arid and semi-arid areas and advocates for organic mulching to improve soil structure and promote biological activity, thereby enhancing erosion control [13]

Fig. 7 Geotextile sediment fences targeted to catch sediment from cultivated land on slopes.

Fig. 8 Example of within-ditch flood storage for sediment capture

Nebraska conditions assessed the effectiveness of 50 ft vegetated buffers in sediment capture, averaging 92.6%. Large-scale testing of sediment barriers like silt fences, mulch berms, and wattle checks on highway construction sites identified deficiencies and proposed modifications, improving structural performance and sediment capture[14].Three sediment basin designs aimed at reducing sedimentation, focusing on Total Suspended Solids (TSS). Using baffles and vegetation in the basin, the TSS concentration in water decreased from 598.0 mg/L to 33.3 mg/L after flowing through the basin[15].

2.7 Soil Erosion Prediction Technologies with GCCMs

This study evaluates soil erosion in the Talas area using the RUSLE model and climate projections from CMIP6 GCM. Results show that 56.29% of the area has low erosion susceptibility, 33.56% is at moderate risk, and 7.36% faces high erosion risk. Climate projections indicate increased precipitation by 21.4%, 24.2%, and 26.4% in 2030, 2050, and 2070, respectively, leading to corresponding increases in soil loss. The findings highlight the need for targeted soil conservation strategies in response to changing precipitation patterns [17]. to evaluate the erosion resistance of geosynthetic cementitious composite mats (GCCMs) under different environmental conditions. The authors investigated the performance of GCCMs in mitigating soil erosion caused by rainfall, overland flow, and hydraulic shear stress. The study involved subjecting GCCM specimens to simulated rainfall events, overland flow conditions, and hydraulic shear stress tests in a laboratory setting. The authors examined the influence of various factors, such as curing time, temperature, and freeze-thaw cycles, on the erosion resistance of SCC. The results demonstrated that GCCMs exhibited excellent erosion resistance under different environmental conditions, significantly reducing soil loss and sediment transport compared to bare soil conditions. The authors also found that longer curing times and higher [17].

3 CONCLUSIONS

It is concluded from the study that Geosynthetic Cementitious Composite Mats (GCCMs) are very successful in minimizing soil loss, enhancing water infiltration, and preventing soil erosion. In regions where erosion is a concern, GCCMs have shown a great potential to speed up the growth of vegetation and encourage more sustainable farming methods. When it comes to soil erosion, GCCMs are the best option because they have better structural and hydraulic qualities than previous approaches. According to these results, the broad use of GCCMs may have a major positive impact on agricultural output, environmental sustainability, and long-term soil conservation.

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