Scientific Research Publishing

Journal of Water Resource and Protection, 2025, 17(4), 265-290
https://www.scirp.org/journal/jwarp
ISSN Online: 1945-3108
ISSN Print: 1945-3094

Evaluating the Impact of Compost Blanket Thickness and Source Material on Vegetation Establishment Runoff Management and Erosion Control of Roadside Slopes

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How to cite this paper: Motahari Tabari, S.A., Al-Haider, M.R., Cutright, T.J. and Mahabadi, N. (2025) Evaluating the Impact of Compost Blanket Thickness and Source Material on Vegetation Establishment Runoff Management and Erosion Control of Roadside Slopes. *Journal of Water Resource and Protection*, **17**, 265-290.
https://doi.org/10.4236/jwarp.2025.174013

Received: March 19, 2025
Accepted: April 24, 2025
Published: April 27, 2025

Abstract

Highway construction projects increase the risk of soil erosion on disturbed roadside slopes. Quick reestablishment of vegetation is critical to prevent erosion and manage stormwater runoff, which can carry pollutants into nearby water bodies. This study evaluated the effectiveness of compost blankets on roadside slopes ranging from the steepest (2H:1V) to the mildest (6H:1V) through laboratory rainfall simulations and a field experiment. The objective was to determine the optimal compost blanket thickness and source material for minimizing runoff, controlling Total Suspended Solids (TSS), and promoting vegetation establishment. The results indicated that 5.08 cm of biosolids compost were most effective on the steepest 2:1 slope. Biosolids at 3.81 cm were effective on 3:1, 4:1, and 6:1 slopes while 2.54 cm of yard waste compost was sufficient to significantly reduce runoff and soil erosion on 6:1 slopes. Field experiments conducted over three months recorded 20 rainfall events, with a total rainfall depth of 20.93 cm. The most severe storm, a two-year return period event with 4.72 cm of rainfall over six hours, generated 30.28 L of runoff in each untreated control cell. In contrast, no runoff was collected from any of the treated plots throughout all events, demonstrating the high absorption and infiltration capacity of the compost blankets even under severe conditions. Furthermore, biosolid treatments achieved vegetation coverage of over 90%, outperforming yard waste and untreated plots. These results demonstrate that compost blankets are highly effective in managing soil erosion. The use of compost blankets promotes sustainable waste management by recycling compost materials from yard waste and wastewater treatment plants, offering a green and eco-friendly solution.

Keywords

Compost, Stormwater Management, Sustainable Engineering

1. Introduction

The Ohio Department of Transportation (ODOT) operates, manages, and maintains 78,858 lane kilometers of state, federal, and interstate routes, making it the 5th largest Interstate highway network in the country [1]. Roadside erosion is a serious geoenvironmental problem, impacting water quality, habitat integrity, and the resilience of critical infrastructure [2]. One of the primary contributing factors to this problem is stormwater runoff from roads, which can carry a range of pollutants, including sediment, nutrients, heavy metals, and hydrocarbons, ultimately affecting nearby water bodies. The soil lost from construction sites during storms is 10 to 20 times more than that of agricultural lands and 1000 to 2000 times more than that of forest lands [3]. A study in 1995 estimated total annual costs of damage from and the prevention of soil erosion was over $40 billion in the United States (U.S.) alone [4]. In 2020, the cost associated with soil erosion in the U.S. still exceeded $40 billion [5]. Erosion from stormwater runoff is not only a U.S. problem. An analysis of two sites in Normandy, France between 1995 - 2017 reported economic losses from stormwater erosion to be between $663 million and $772 million (611 - 711 million Euros) [6]. The increased frequency of short, intense rainstorms has led to increased stormwater runoff [7]. Considering the high costs and global impact of soil erosion, effective erosion and runoff control at road construction sites are essential.

Common best management practices (BMPs) at construction sites have included filter socks, filter berms, silt fences, bioswales, straw bales and vegetative filter strips [8]. Although effective at reducing erosion and metal concentrations in stormwater runoff, some BMP methods can have cost prohibitive installation and maintenance costs [9]. The U.S. Environmental Protection Agency (EPA) and multiple Departments of Transportation (DOTs) have recommended compost blankets as a promising solution to mitigate roadside erosion.

Compost blankets, composed of layers of organic material, serve as a practical tool in mitigating erosion, reducing runoff, enhancing soil infiltration, and facilitating the growth of vegetation [10]. Compost material can be comprised of organic matter from wood chips, straw, yard clippings, food wastes, etc. Bakr *et al.* [11] conducted one of the first studies with a mulch blanket in Louisianna that proved effectiveness of compost to reduce stormwater runoff. A two-year study that spanned 33 rain events in Howard County Maryland found that a yard waste compost blanket significantly decreased stormwater runoff and erosion [12]. In Ohio, acceptable compost materials include Ohio EPA-rated Class IV compost and Exceptional Quality Solids (EQS) biosolids compost [1]. Class IV compost, primarily made from yard waste and agricultural plant materials, and EQS biosolids compost, derived from wastewater treatment processes, both contribute to sustainable waste management by diverting waste from landfills and incineration. These compost types enhance soil fertility, support stormwater management through improved infiltration and water retention, and promote resilient ecosystems by facilitating diverse vegetation growth [10] [13]-[15]. Biosolids meeting Class A standards for pathogen reduction provide a continuous and nutrient-rich supply, making them valuable for roadside environmental management.

Researchers have explored how variations in organic matter content, particle size, and compost thickness influence their effectiveness in erosion control and vegetation establishment [16] [17]. Enhanced vegetation coverage will decrease erosion by stabilizing the soil with roots, dissipating the energy exerted by intense rainfall and increasing water infiltration [18]. Although, the specific vegetation will depend on the climate, a blend of early and late season native species is recommended for optimal year round vegetation establishment [19]. To date, compost blankets have not been utilized in Ohio for roadside erosion control and vegetation establishment on highway slopes. This study aims to address the gap of potential use of compost blankets in Ohio and optimal source material by evaluating the effectiveness of two ODOT-approved compost materials and two seed mixes (Roadside seed mix and 3B Slope mix) across various slopes. The laboratory study focused on determining the optimal compost thickness. It was hypothesized that (i) both compost blanket materials would be effective and (ii) higher compost blanket thickness would be more effective at reducing runoff volumes while the field tests assessed these selected combinations under natural rainfall conditions to validate their real-world performance.

2. Materials and Methods

2.1. Compost, Seed Mixes and Soil Sources

Class IV yard waste was sourced from Kurtz Bros. Inc (Peninsula OH, USA), a reputable composting facility. The yard waste had a pH of 7, 61.92% moisture content, 17.19% total organic carbon, 34.38% organic matter and Carbon:Nitrogen of 36.7:1. Analytical analysis determined yard waste to also contain 11 mg/Kg copper, 496 mg/Kg manganese, and 38 mg/Kg zinc. Compost EQS Biosolids were procured from the City of Alliance Wastewater Treatment Plant, an EPA-approved facility. These biosolid-based compost materials adhere to Class A standards for pathogen reduction and suitability for sustainable roadside environmental management, making them a compelling choice for our research. Biosolids had pH of 8.4 and contained 17,800 mg/Kg total phosphorus, 32,600 total nitrogen, 1508 mg/Kg cadmium, 234 mg/Kg copper, 24 mg/Kg lead, 6.41 mg/Kg molybdenum, 22.9 mg/Kg nickel, and 1200 mg/Kg potassium. To ensure the relevance and compliance of experiments with Ohio Item 659 for Roadside and slope 3B mixtures [1], seeds were purchased from Oliger Seed Company (Akron, OH, USA). The roadside mix contains a 30:30:40 ratio of Kentucky bluegrass, Perennial ryegrass, and Kentucky 31 fescue. The 3B Slope mix contains 56% hard fescue, 34% creeping red fescue, and 10% annual ryegrass.

Disturbed soil was collected from an ODOT active project, identified as: "SUM-77/277/US224-Various; PID 106002" (41˚0'58.71"N latitude and 81˚29'44.01"W longitude). The soil's physical and mechanical properties were determined using ASTM standard methods following the required protocols. ASTM D6913 [20] was used to determine the particle size distribution. ASTM D4318 [21], ASTM D2216 [22] and ASTM D3080 [23] to determine the Atterberg limits, moisture content and direct shear, respectively. The liquid limit and plastic limit used a Casagrande percussion cup (Humbolt H-4230N) and tools (Humboldt H-4253), respectively. Direct shear tests were conducted under dry and partially saturated conditions at a rate of 0.1 cm/min under normal stresses of 5, 10 and 15 psi using a Direct Shear System (Geotac Digishear SI). Partially saturated test conditions were used to represent the typical water content during watering of vegetation at the surface layer.

2.2. Lab Sample Preparation

Each 52.07 cm by 28.89 cm pan was constructed with a total depth of 6.35 cm to allow for the proper layering of compost and soil. The first layer ranged from 1.27 to 3.81 cm of baseline soil. Above this, compost blankets were added, varying from 2.54 to 5.08 cm based on the specific treatment condition. Maintaining uniform layer thickness was a critical aspect of sample preparation. To ensure consistency, precise measurements of layer height were taken at three distinct points within each pan. For all samples, the top half in. of compost materials was mixed with seeds, which were weighed to meet the seeding rate specification of ODOT item 659. Specifically, 4 g of seeds were added to roadside mix to achieve a rate of 2.23 Kg/92.9 m^2, and 1.85 g were added to 3D slope mix to reach a rate of 1.05 Kg/92.9 m^2 [1].

Vegetation establishment progress was monitored by capturing daily photographs using front and top view photographs with GoPro (Hero 11) cameras at a fixed distance. For the side view photographs, each GoPro was mounted with a detachable stainless-steel platform, positioned 25.4 cm from the front of a pan and at 20˚ angle with respect to vertical axis through the camera. Top view photographs for all the pans were taken from a fixed 35.56 cm elevation from the bottom of the pans. A specialized MATLAB code was developed to identify vegetation by detecting the green color in digital images, leveraging the HSV (Hue, Saturation, Value) color space. The code was calibrated to detect green hues by setting specific HSV ranges: hue (h) between 0.15 and 0.47, saturation (s) from 0.01 to 0.99, and value (v) from 0.08 to 0.9. This range was selected to capture a wide variety of green shades and lighting conditions. Before conducting lab rainfall simulations, top-view photographs of each sample area were captured. Vegetation coverage was then quantified through digital image analysis by comparing the original photographs with their MATLAB-processed counterparts (see **Figure S1**).

2.3. Rainfall Simulations

The 5-pan simulator purchased from Conversation Demonstrations in 2023 was used to replicate natural environments, matching Ohio's roadside conditions with slope ratios of 6:1, 4:1, 3:1, and 2:1. The simulator was calibrated to correlate pressure values (measured in psi) to rainfall intensities. At 9 psi, complete surface coverage was achieved on 4:1 and milder slopes. However steeper slopes like 2:1 exhibited up to a 20% reduction in coverage at the top of the pans. Due to this inconsistency, the 2:1 slope was analyzed separately, with comparisons made only among the other slopes. Pressures below 6 psi resulted in water pooling centrally, failing to cover the surface evenly. Event 1 involved a 1-hour rainfall at 9 psi, followed by a 13-hour dry period, replicating a rainfall intensity of 11.48 ± 0.76 cm per hour. This 9-psi pressure setting was used for less intense rainfall events, where it achieved complete surface coverage on slopes of 4:1 and gentler. Event 2 simulated a more intense 30-minute rainfall at 26.5 psi, representing a severe storm event with a rainfall intensity of 15.7 ± 0.84 cm per hour. This higher intensity was selected to simulate short, intense rainfall events after a 12-hour dry period, reflecting extreme weather conditions.

Seeds were allowed to germinate and grow for 35 days prior to initiating a rainfall simulation. Each experiment was conducted using five pans, with the least vegetated (control) pans placed in the center and the most vegetated pans on the outside. During each simulation, runoff samples were collected using 3.2 L jars. Total runoff volumes were recorded, with detailed analyses of sediment concentration and nutrient content conducted on the first and last jars. The time taken to fill each container was also recorded. The total runoff volume for each event was calculated by counting the number of filled containers and measuring the amount collected in the last container during the simulation (as shown in **Figure S2**).

A minimum sample volume of 250 mL was required for accurate measurement of TSS. Samples were sealed and stored in a refrigerator and analyzed within 24 hours. TSS was determined by the method described in EPA 2540 D [13].

2.4. Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) Analysis

Initial statistical analysis using ANOVA Tukey's method identified significant differences between treatments. The TOPSIS method, widely used in multidisciplinary research [24] was applied to determine the optimal treatment using multiple parameters Vegetation Coverage (%), Runoff Volume (L), and Total Suspended Solids (TSS) (mg). These criteria were selected as they directly reflect the main objectives of the study to establish vegetation, minimize stormwater runoff and reduce erosion. Each criterion was assigned equal weight to reflect its equal importance in the evaluation framework. Nutrient concentrations (e.g., nitrate and soluble reactive phosphorus) were exclude from the TOPSIS analysis because they were shown to be directly dependent on runoff volume (i.e., mass loss scaled with water quantity) and therefore did not offer an independent decision making. Including nutrients would have skewed the ranking without adding insight.

To ensure comparability across variables with different units and scales, all criteria were normalized to a common 0 to 1 scale. Beneficial criteria, such as vegetation, were normalized such that higher values corresponded to better outcomes while cost criteria such as runoff volume and TSS were normalized such that lower values were preferred. This approach standardized the sensitivity of each parameter and enabled for a balanced evaluation of alternatives within the TOPSIS framework. Normalization of beneficial criteria (vegetation coverage) used was Equation (1):

$$X\_normalized = \frac{X - Min(X)}{Max(X) - Min(X)} \tag{1}$$

Cost criteria of runoff volume, TSS, SRP, and Nitrate, used the normalization in Equation (2):

$$X\_normalized = \frac{Max(X) - X}{Max(X) - Min(X)} \tag{2}$$

The Euclidean distance from ideal and negative-ideal solutions was calculated using Equation (3):

$$Total\ Distance = \sqrt{\left(V - V^*\right)^2 + \left(R - R^*\right)^2 + \left(T - T^*\right)^2} \tag{3}$$

where V is normalized vegetation coverage, R is normalized runoff volume, T is the normalized TSS and V^*, R^* and T^* are best normalized value for each variable. Treatments were then assigned scores (0 - 10) based on performance, with higher scores indicating better outcomes. Treatments scoring above 8 were identified as optimal.

2.5. Field Test

Following the laboratory simulations, field experiments were conducted at The University of Akron main campus, Akron, Ohio (**Figure 1**) as permits for tests at active interstate sites were not possible during the project time-period. Six field cells, each measuring 0.91 m by 1.68 m, were established on slope averaging 3:1. To replicate real-world conditions, a mulch blower (model BB302) was rented to simulate the broadcasting scale of actual projects. It involved an initial pass applying only the compost material, leaving it half an in. thinner than the desired final thickness. A subsequent pass then adds the remaining 1.27 cm, blended with the seed mixture to aid in seed preservation. The compost blankets with seedlings were applied using the BB302 mulch blower on April 23, 2024. The cells, from left to right were: Bare soil control (serving as baseline for comparison); Vegetated Control with Roadside mix (current practice at ODOT); Treatment with2.54 cm. Biosolids and Roadside mix; Treatment with 3.81 cm. Biosolids and Roadside mix;

Treatment with 5.08 cm. Biosolids and Roadside mix; and Treatment with 3.81 cm. Yard waste and Roadside mix. A RainWise Rainew rainfall gauge (KestrelMet 1012) was installed to accurately capture rainfall intensity. Runoff from each qualifying event was collected in containers to measure runoff volumes. Post-collection, samples were analyzed in the lab for runoff volume and TSS. Runoff samples were also analyzed for soluble reactive phosphorus, nitrate, and potassium using a handheld colorimeter (HACH DR900) and the specific DR900 program following the manufacturer's guidelines.

Rain events are commonly defined by specifying the required length of rainless intervals that precede and follow a rain event. While official weather services such as the National Oceanic and Atmospheric Administration (NOAA) and the National Weather Service (NWS) offer general guidelines, they do not specify exact definitions for minimum precipitation duration or dry periods. For this research, we adopted the definition provided by Henja and Cutright [25], which defines an event as a minimum of 0.025 cm of rain over a 5-minute interval, continuing until no rain is recorded for twelve consecutive hours. Based on this definition from 5/1/2024 to 7/31/2024, 20 rainfall events were recorded at the site.

Figure 1. Layout for field cells.

3. Results and Discussion

3.1. Disturbed Soil Characterization

Particle size distribution determined that the disturbed soil was comprised of soil particles that were 0.071 ± 0.001% D10, 0.341 ± 0.006% D30, 2.093 ± 0.014% D60.

The uniformity coefficient (Cu) and curvature coefficient were determined to be 29.51 ± 1.48% and 0.78 ± 0.04, respectively. The Atterberg limit test yielded a liquid limit of 26 and plastic limit of 8. These results classified the soil as a poorly graded sand with clay and gravel.

The mechanical properties of the disturbed soil were determined using direct shear test performed under quick, under drained conditions. Dry soil had a 33˚ friction angle and an initial cohesion of 8.71 psi. As the moisture content increased, soil cohesion decreased (3.94 psi) and the friction angel increased (37˚).

3.2. Vegetation Establishment During Laboratory Experiments

The initial germination process for seeds sown in biosolids was slower during the first week compared to those sown in Class IV yard waste. However, by day 35, biosolids outperformed yard waste in 20 out of 24 sample sets under the same conditions ($p < 0.05$). Tukey's groupings (**Figure 2**) show that treatments with biosolids achieved the highest vegetation coverage, outperforming other treatments, placing them in Group A ($p < 0.05$). Yard waste with roadside vegetation mix demonstrated moderate vegetation coverage but was still better than controls ($p < 0.05$, Group B). Biosolids with Roadside mix showed better vegetation coverage than yard waste ($p < 0.05$). Yard waste with the 3B slope seed mix showed lower vegetation coverage than biosolids ($p < 0.05$) but was still better than control treatments ($p > 0.05$). The smaller sample size for the 3B slope treatments may explain why yard waste, despite showing better average values, did not achieve statistical significance compared to the vegetated controls.

Compost blankets also offer long-term benefits by providing essential nutrients for vegetation growth. This is particularly important for disturbed soils alongside roads, where natural regrowth after construction is often slow or inadequate [26]. Oregon DOT [27] reported that compost blankets not only accelerated germination and growth rates but also enhanced the resilience of vegetation against environmental stressors. They noted that while biosolids resulted in superior vegetation coverage, increased application thickness did not always lead to proportional improvements in growth. However, Poland [28] and Evanylo *et al.* [29] found that thicker compost blankets provided nutrients over a longer period, sustaining vegetation health and coverage more effectively over time. Evanylo *et al.* [29] also reported that 5.08 cm of compost blankets maintained optimal total potassium levels, significantly better than 2.54 cm blankets or control samples, thereby promoting longer plant growth. ANOVA Tukey's analysis of the current laboratory results indicated that biosolids were significantly more effective than yard waste and control samples ($p < 0.05$) in promoting vegetation coverage for both Roadside and 3B Slope mixes. The efficacy of biosolids is advantageous for soil protection and plant growth enhancement along highways. California DOT [30] studies also demonstrated that biosolids exhibited significantly higher initial establishment percentages than other treatments.

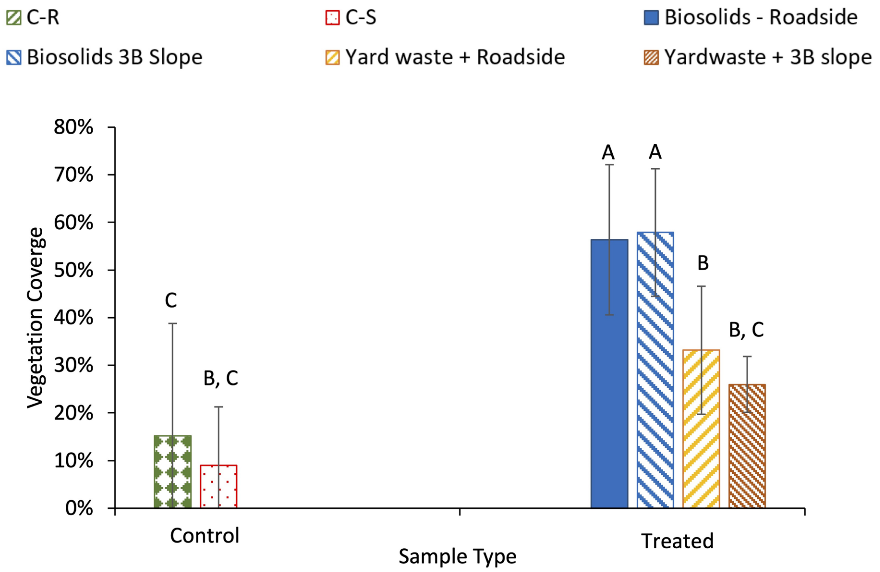
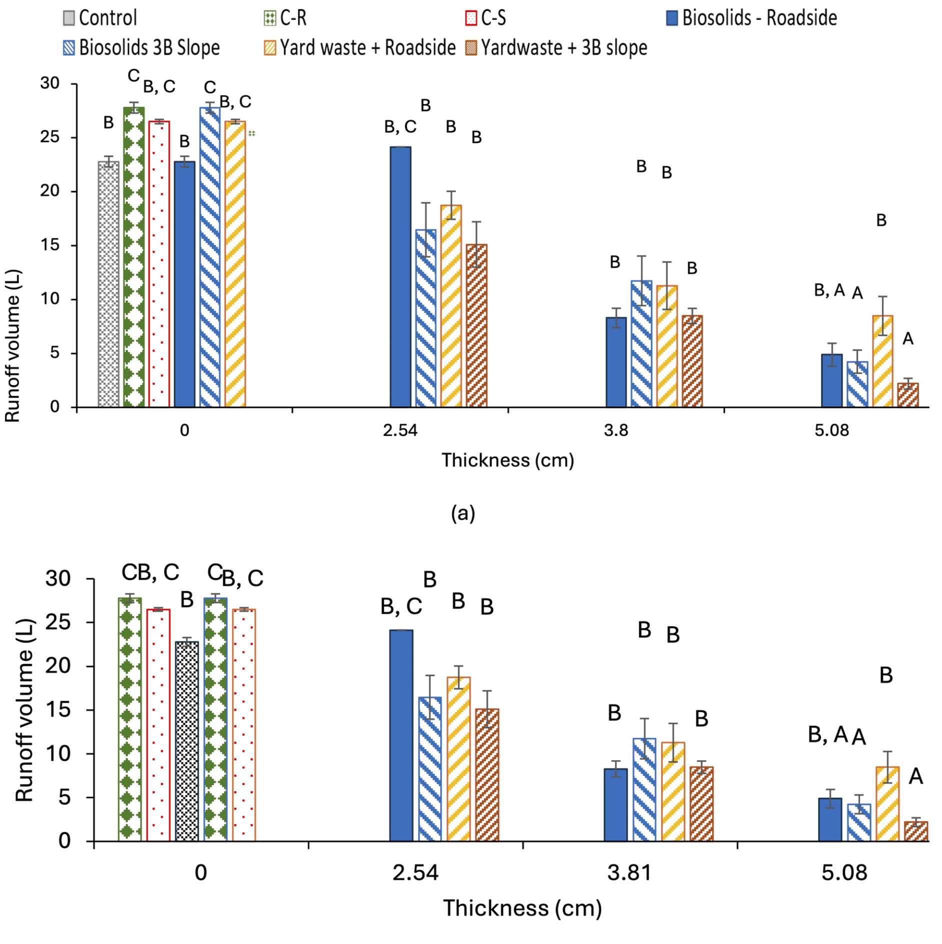


Figure 2. Vegetation establishment across all samples during the laboratory study. C-R is the control of bare soil with Roadside seed mix and C-S is bare soil sown with 3B-Slope mix.

3.3. Run-Off Volume During Laboratory Rainfall Simulations

The results indicated that factors such as slope steepness, compost material, and blanket thickness significantly influenced runoff control. It is important to note that the top one-fifth of the 2:1 slope was not exposed to water flow, leading to uneven water coverage and preventing direct comparisons across different slopes. As expected, control treatments exhibited the highest runoff volumes in both events (Figure 3). Biosolid and Yard waste treatments at 5.08 cm thickness with 3B Slope mix consistently produced the lowest runoff volumes, outperforming thinner treatments and control samples ($p < 0.05$). Furthermore, increasing the thickness of compost treatments resulted in more effective runoff control. However, 2.54 cm biosolid treatments did not provide substantial reductions in runoff volume. This is consistent with studies by Owen *et al.* [16], where 2.54 cm biosolid blankets were also found ineffective in reducing runoff and sediment loss on steep slopes. In contrast, 5.08 cm biosolid blankets significantly reduced runoff volume across both rainfall events ($p < 0.05$). In Event 1 (Figure 3(a)), treatments with 5.08 cm of yard waste (Y-S-2) and biosolids (B-S-2) were more effective in reducing runoff volumes compared to other treatments and the control group ($p < 0.05$). A similar trend was observed in Event 2 (Figure 3(b)), although the reduction was less pronounced than in Event 1.

On the milder slopes of 3:1, 4:1 and 6:1, a reduction in runoff volume was observed across all treatments, with 3.81 cm treatments outperforming 1-in. and control treatments (Figure 4). Although increasing the thickness from 3.81 to 5.08 cm resulted in statistically similar runoff volumes ($p > 0.05$), all treatments performed better at reducing runoff than control samples ($p < 0.05$). Compost blankets applied in 2.54 cm thickness were less effective in reducing runoff when vegetation coverage was inadequate. For instance, a 2.54 cm biosolid treatment with only 24% vegetation coverage (**Figure S3(a)**) resulted in runoff volumes as high as 18.93 L while treatments with better vegetation coverage under the same thickness reduced runoff to less than 3.78 L (**Figure S3(b)** and **Figure S3(c)**). At a 5.08 cm. thickness, all biosolid treatments, regardless of vegetation coverage, consistently exhibited low runoff volumes (<0.45 L). This underscores the importance of both blanket thickness and vegetation in reducing runoff variability.



(a)

(b)

Figure 3. Generated runoff volume on 2:1 slope for (a) Event 1 with 1 hour duration of 11.48 cm/hr intensity and (b) Event 2 for rainfall of 30 minutes with 15.7 cm/hr intensity. Bars with with different letters are significantly different from each other.

The structural differences between biosolids and yard waste also contributed to their respective performances in runoff control. Biosolids, consisting of looser and more separated particles, required a thicker application to form a continuous blanket that effectively controlled runoff. Yard waste, on the other hand, featured more interlocking particles, that created a cohesive mat even for thinner applications.

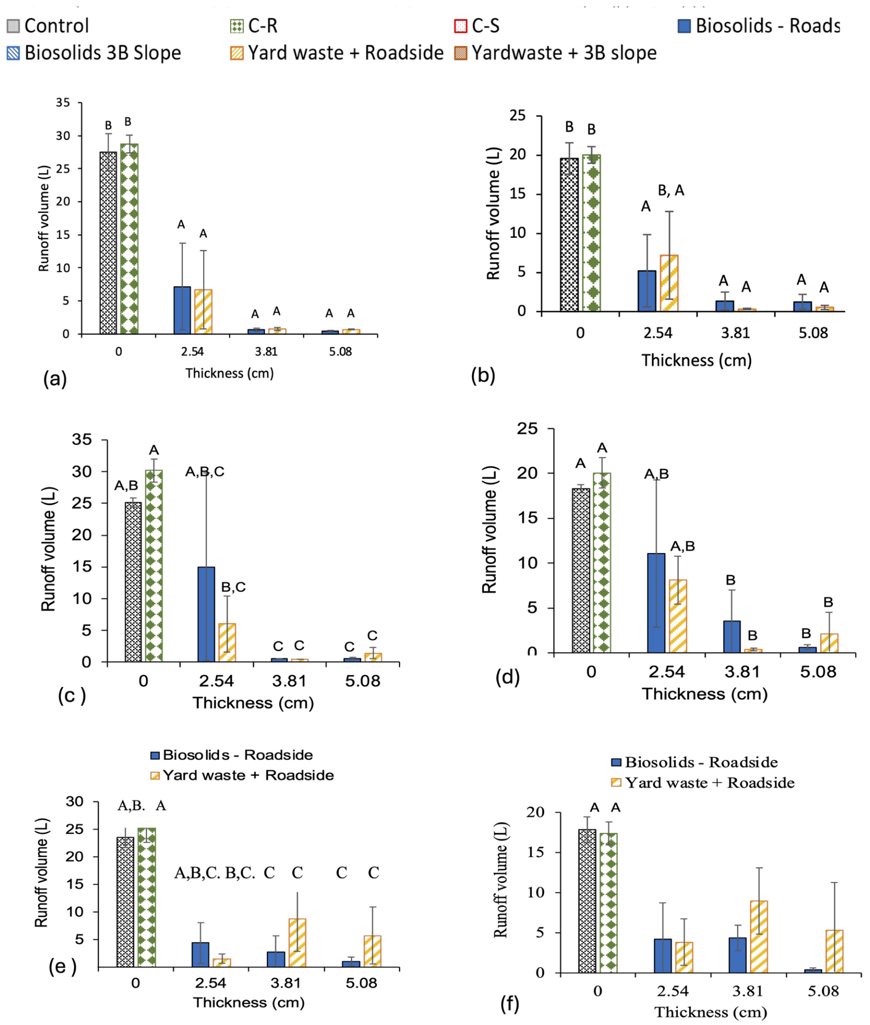
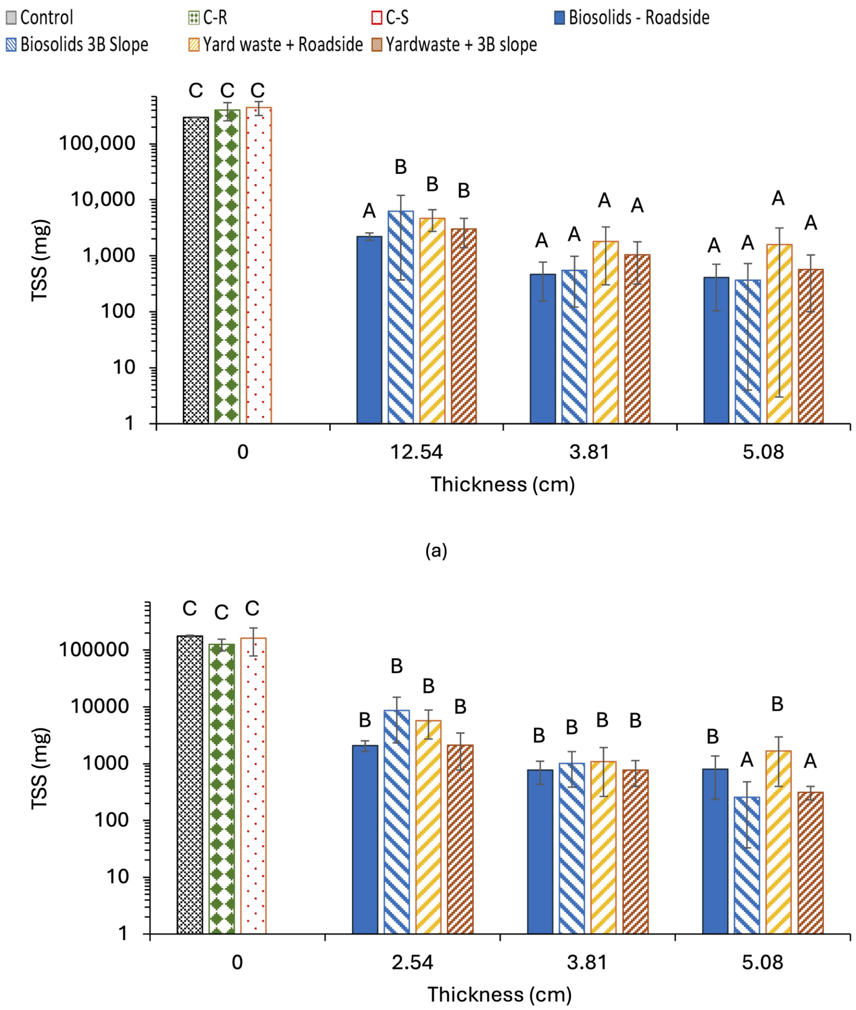


Figure 4. Generated runoff volume on milder slopes: 3.1 for (a) Event 1 with 1 hour duration of 11.48 cm/hr intensity, (b) Event 2 for rainfall of 30 minutes with 15.7 cm/hr intensity, 4.1 for (c) Event 1 with 1 hour duration of 11.48 cm/hr intensity, (d) Event 2 for rainfall of 30 minutes with 15.7 cm/hr intensity, 6.1 for (e) Event 1 with 1 hour duration of 11.48 cm/hr intensity and (f) Event 2 for rainfall of 30 minutes with 15.7 cm/hr intensity. C is control of bare soil, C-R is the control of bare soil sown with Roadside seedmix and C-S is bare soil sown with 3B-Slope mix. Bars with different letters are significantly different from each other.

3.4. Total Suspended Solids in Runoff Samples During Rainfall Simulations

Compost blankets play a significant role in reducing soil erosion by managing TSS in runoff. The application of 2.54 to 5.08 cm of biosolids and yard waste composts reduced TSS mass by 90 to 99% compared to vegetated and non-vegetated control samples. These findings are consistent with results from the Massachusetts DOT study [31], which reported erosion reductions of 95% to 97% when using compost blankets compared to unprotected areas. More than 80% of heavy metal and nutrient losses during soil erosion is associated with the sorption to the particulate matter. Therefore, reducing TSS losses is critical as most of the heavy metal and nutrients will be sorbed to the TSS [32]. Although both the EQS biosolids and Class IV yard waste contained high levels of nutrients overall, both compost blankets released less soluble phosphorus than the controls. Full details of the nitrate and soluble reactive phosphorus losses during the laboratory simulations can be found in Al Haider [33] and Motahari Tabari [34].

Throughout the experiments, biosolids generally outperformed yard waste in reducing TSS concentrations. The color and clarity of the collected runoff samples visually demonstrate the significant differences in TSS content among the treatments (**Figure S4**). Samples from bare soil (control), class IV yard waste, and EQS biosolids had substantial visual differences in suspended solids.



(a)

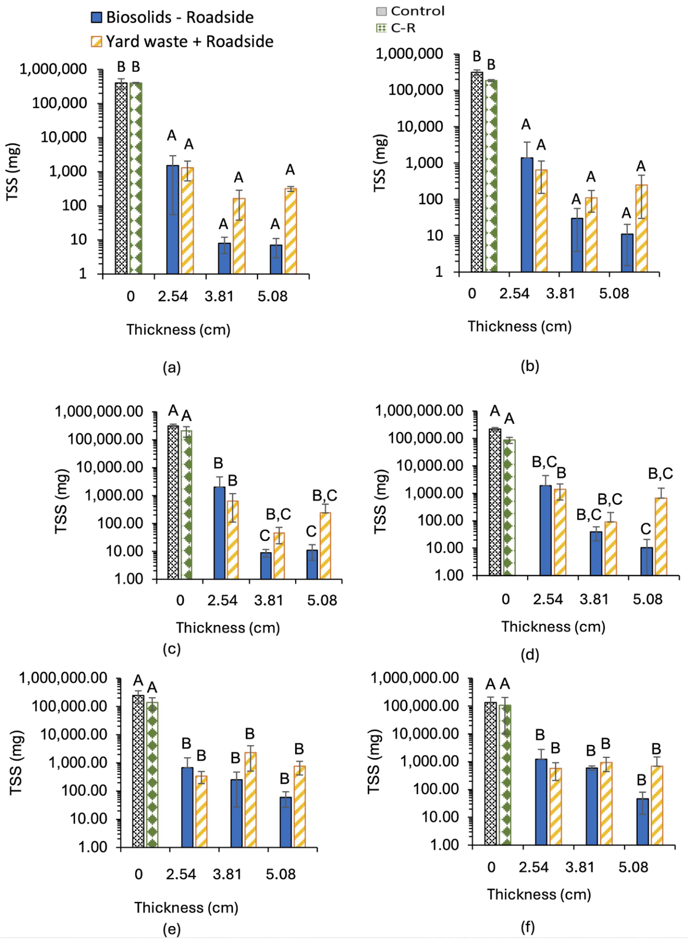
(b)

Figure 5. Total suspended solids (TSS) on slope 2.1 for (a) Event 1 with 1 hour duration of 11.48 cm/hr intensity and (b) Event 2 for rainfall of 30 minutes with 15.7 cm/hr intensity. C is control of bare soil, C-R is the control of bare soil sown with Roadside seedmix and C-S is bare soil sown with 3B-Slope mix. Bars with different letters are significantly different from each other.

Figure 5(a) and **Figure 5(b)** present the TSS mass for the 2:1 slope during Event 1 and Event 2, respectively. Given the drastic reduction in TSS concentration when compost blankets were applied, a logarithmic scale was used on the Y-axis to enable clearer comparisons. For example, in Event 1, TSS mass for control samples exceeded 297,000 mg, whereas the average TSS mass was reduced to 2,200 mg with 2.54 cm biosolid applications and 406 mg with 5.08 cm biosolid applications, representing a reduction of >99.9%.

During Event 1, control samples had the highest TSS concentrations (marked "C"). Treatments with 2.54 cm of biosolids sown with Roadside or 3B Slope mixes and yard waste sown with Roadside mix showed significantly lower TSS concentrations than the controls (marked "B"; $p < 0.05$). However, yard waste combined with 3B Slope mix yielded less effective vegetation establishment. This is likely due to the different physical properties of yard waste compared to biosolids. Yard waste typically had larger particle sizes, which may not bind well with finer soils or maintain moisture as effectively, especially in thinner layers such as the 2.54 cm treatments. Without sufficient vegetation establishment, the 2.54 cm yard waste treatment could not provide adequate protection against soil erosion. In contrast, thicker layers (e.g., 5.08 cm) offered more effective TSS reduction by forming a more continuous protective barrier, even with lower vegetation coverage. Treatments with 3.81 and 5.08 cm of biosolids and yard waste showed the lowest TSS concentrations (marked "A"), indicating these treatments were more effective than 2.54 cm treatments ($p < 0.05$) regardless of vegetation coverage. Event 2 depicted a similar pattern where control samples had the highest TSS concentrations ("C"), 2.54 and 3.81 cm treatments ("B") lower TSS concentrations than the controls ($p < 0.05$) but not significantly different from each other ($p > 0.05$). The 5.08 cm biosolid treatments with the 3B Slope mix ("A") were the most effective ($p < 0.05$). TSS concentrations slightly decreased from Event 1 to Event 2, as initially, the compost absorbed water, slowing down the flow and preventing the movement of compost particles. However, during more severe events, the prolonged rainfall increased the saturation of the compost, causing higher flow rates, which in some cases, especially with the 2.54 cm treatments, led to the movement of particles down the slope. This movement exposed small patches of soil in certain areas, contributing to higher TSS concentrations. This aligned with Forgione *et al.*'s [12] observation that during larger storms, storage within vegetated compost blankets filled up early in the event, leading to some effluent flow. While the vegetated compost blankets effectively smoothed runoff peaks, they saw diminishing differences between treatments as storage capacity filled, indicating that conveyance became dominant later in the storm. Similarly, in our study, the thinner compost layers became less effective as the saturation point was reached, leading to increased particle movement. Although the TSS concentrations slightly increased from Event 1 to Event 2, the compost blanket treatments remained significantly more effective than the controls ($p < 0.05$).

All compost treatments on milder slopes (**Figure 6**) were significantly more effective in reducing TSS compared to control samples ($p < 0.05$), yet there were no significant differences among the treatments themselves (p>0.05). This suggests that reducing TSS mass is less challenging on milder slopes, with all treatments yielding effective results. Faucette *et al.* [35] also observed that compost blanket effectiveness depended on both slope gradient and rainfall intensity. As with the 2:1 slope, a larger variation in TSS was observed in the 2.54 cm biosolid treatment, likely due to lower vegetation coverage in one replicate, which caused higher TSS mass. This aligns with the runoff volume results, which also showed higher standard deviations for treatments with 2.54 cm thickness. When 3.81 or 5.08 cm of compost blankets were applied, biosolids were generally more effective than yard waste in reducing TSS concentrations. This can be attributed to the superior ability of biosolids to cover and protect soil particles, thereby minimizing erosion and TSS loss.



(a) (b) (c) (d) (e) (f)

Figure 6. Total suspended solids (TSS) generated during rainfall on milder slopes: 3.1 for (a) Event 1 with 1 hour duration of 11.48 cm/hr intensity, (b) Event 2 for rainfall of 30 minutes with 15.7 cm/hr intensity, 4.1 for (c) Event 1 with 1 hour duration of 11.48 cm/hr intensity, (d) Event 2 for rainfall of 30 minutes with 15.7 cm/hr intensity, 6.1 for (e) Event 1 with 1 hour duration of 11.48 cm/hr intensity and (f) Event 2 for rainfall of 30 minutes with 15.7 cm/hr intensity. C is control of bare soil, C-R is the control of bare soil sown with Roadside seedmix and C-S is bare soil sown with 3B-Slope mix. Bars with different letters are significantly different from each other.

Reinsch *et al.* [36] found that compost blankets reduce the kinetic energy of rainfall impact, promote water adsorption, and prevent sediment detachment. These mechanisms which was later was observed by Oviedo *et al.* [37] by application of green waste composting systems, may explain why even a 2.54 cm compost blanket significantly reduced TSS, as the physical properties of the blanket shield soil particles from being detached and transported by runoff. In contrast, on the milder slopes thinner compost blankets are sufficient to reduce TSS on milder slopes. These results are consistent with an earlier study that applied 3.81 cm of compost blankets on a 3:1 slope and observed that particle size distribution had a greater influence on TSS reduction than the type of compost used [38]. Larger particles help dissipate the energy of raindrop impacts, while smaller particles absorb rainfall and prevent runoff.

3.5. Overall Laboratory Evaluations Based on TOPSIS Analysis

In this research, treatments scoring above 8 are considered optimal. Scores are classified as follows: 9-10 as "A", 8-9 as "B", 7-8 as "C", and below 7 as "F". It is crucial to distinguish these classification letters from the groupings in Tukey's analysis. As **Table 1** indicates, only the 5.08 cm biosolid treatments mixed with the 3B Slope mix on the 2:1 slope achieved a score above 8. Other treatments exhibited much lower scores. Despite performing significantly better than other treatments in runoff and TSS reduction as analyzed using Tukey's method, 5.08 cm of yard waste scored poorly in the TOPSIS ranking due to its inadequate vegetation establishment. If a user does not prioritize vegetation on a 2:1 slope, they can refer to individual Tukey's analysis based on their own priorities, and 5.08 cm of yard waste could still be considered a good option. This flexibility in treatment selection highlights the importance of considering specific project goals and local resource availability when choosing the optimal treatment. The results from the TOPSIS analysis also showed that the scores of the best treatment plans decreased with increasing slope steepness (**Table 2**). Additionally, the thickness of acceptable treatments increased with steeper slopes, suggesting a general trend toward thicker compost blankets for more challenging terrain.

The recommended thickness for compost blankets varies based on factors such as slope gradient, vegetation, and rainfall intensity, according to recent studies and specifications. Poland [28] observed decreased runoff as the blanket thickness increased from 2.54 to 7.62 cm. Prior to Poland's study, Faucette *et al.* [35] recommended a uniform 5.08 cm thickness for all slopes when considering 10.16 cm of rainfall. California Department of Transportation [30] increased the maximum recommended thickness with increasing slope steepness, suggesting a more flexible approach to compost blanket thickness based on slope conditions. AASHTO [39] provided thickness recommendations without considering the slope, which may lead to suboptimal performance in erosion control. EPA [10] guidelines similarly offered a range of 2.54 to 7.62 cm for various slope conditions, without specifying different recommendations for slope gradients. No previous study considered a comprehensive method like TOPSIS to make their suggestions for optimal compost blanket design, considering all variables mathematically.

Table 1. Overall treatments ranking considering overall vegetation coverage, runoff volume and TSS from events 1 and 2 on slope 2:1. Suggested 5.08 cm of biosolids sown with 3B Slope mix as the only acceptable treatment. Abbreviations: B—biosolids, Y—yard waste, S—3B Slope seed mix, R—Roadside seed mix.

Event 1				Event 2			
Treatment	Euclidean distance	Score	Class	Treatment	Euclidean distance	Score	Class
B-S-5.08	**0.07**	**9.3**	**A**	**B-S-2**	**0.09**	**9.3**	**A**
B-R-3.81	0.23	7.7	C	B-R-2	0.34	7.2	C
B-R-5.08	0.26	7.4	C	B-S-1.5	0.58	5.2	F
B-S-3.81	0.36	6.4	F	B-R-1.5	0.60	5.0	F
Y-S-5.08	0.49	5.1	F	Y-S-2	0.63	4.8	F
Y-S-3.81	0.50	5.1	F	Y-S-1.5	0.66	4.5	F
Y-R-5.08	0.50	5.0	F	Y-R-1.5	0.75	3.9	F
Y-R-3.81	0.52	4.8	F	B-S-1	0.75	3.9	F
B-S-2.54	0.56	4.4	F	Y-R-2	0.75	3.8	F
Y-S-2.54	0.68	3.3	F	Y-S-1	0.80	3.4	F

Table 2. Overall treatments ranking considering overall vegetation coverage, runoff volume and TSS from events 1 and 2 on slopes 3:1, 4:1, and 6:1. Abbreviations: B—biosolids, Y—yard waste, S—3B Slope seed mix, R—Roadside seed mix.

		Event 1			Event 2		
Slope	Treatment	Euclidean distance	Score	Class	Euclidean distance	Score	Class
3:1	B-R-5.08	0.00	10.0	A+	0.04	9.7	A
	B-R-3.81	**0.19**	**8.7**	**B**	**0.19**	**8.7**	**B**
	Y-R-3.81	**0.24**	**8.3**	**B**	**0.24**	**8.4**	**B**
	B-R-2.54	0.23	8.3	B	0.24	8.4	B
	Y-R-2.54	0.26	8.2	B	0.33	7.8	C
	Y-R-5.08	0.33	7.7	C	0.36	7.6	C
	Control-R	1.40	0.1	F	1.27	1.3	F
	Control	1.41	0.0	F	1.46	0.0	F
4:1	B-R-5.08	0.00	10.0	A+	0.01	9.9	A+
	Y-R-2.54	0.18	8.6	B	0.22	8.4	B
	Y-R-3.81	0.22	8.3	B	0.26	8.1	B
	Y-R-5.08	0.25	8.1	B	0.30	7.9	C
	B-R-3.81	0.26	8.0	B-	0.36	7.4	C
	B-R-2.54	0.43	6.6	F	0.49	6.5	F
	C-R	1.04	1.9	F	0.97	3.0	F
	C-0	1.28	0.0	F	1.39	0.0	F

Continued

6:1	B-R-5.08	0.00	10.0	A+	0.00	10.0	A+
	B-R-2.54	0.17	8.5	B	0.23	8.0	B-
	Y-R-5.08	0.17	8.4	B	0.26	7.8	C
	Y-R-2.54	0.19	8.2	B	0.26	7.8	C
	Y-R-3.81	0.27	7.6	F	0.39	6.7	F
	B-R-3.81	0.34	7.0	F	0.45	6.2	F
	C-R	1.00	0.9	F	1.07	0.9	F
	C-0	1.11	0.0	F	1.17	0.0	F

3.6. Observations from Field Experiment

The field test was initiated on April 23, 2024. A longer cold period during the last week of April and the first week of May 2024 kept the temperature below 60˚F for long periods, especially at night. The colder weather might have delayed the germination process. However, after six weeks, there were no concerns regarding vegetation coverage on the biosolid-treated samples. Similar to the greenhouse experiments, vegetated control cells and those treated with Class IV yard waste exhibited poor vegetation. Another important observation was that cell number 3, treated with 2.54 cm of biosolids, showed exposed areas after almost three weeks (**Figure S5**). This vulnerability could be due to the water absorption characteristics of biosolids, which can lead to erosion and expose the underlying soil. Applications of biosolids 3.81 and 5.08 cm effectively covered the soil completely (**Figure S5(b)**), whereas 3.81 cm of yard waste showed much less vegetation. This observation matched the vegetation coverage trends from samples grown in the greenhouse regardless of the initial soil organic matter. The strongly established vegetation needed to be trimmed on day 53 (6/13/2024) for the first time to keep the height of the vegetation under 10.16 cm According to ODOT item 659 [1]. While the non-vegetated control was not intentionally seeded, some vegetation was present primarily weeds and some grass that may have resulted from birds transferring seeds from adjacent cells (**Figure 7(a)** and **Figure 7(b)**). While vegetation species in the 5.08 cm treated cell were more consistent with the Roadside mix, more bald spots were observed in the 5.08 cm biosolid-treated cell. No significant difference in vegetation was reported ($p > 0.05$) with changes in thickness during the greenhouse experiments.

Between May 5, 2024, and July 31, 2024, a total of twenty rainfall events were recorded (**Table 3**). The most severe event occurred on May 29, with 4.72 cm of rainfall over six hours. This event included a storm with an intensity of 2.82 cm per hour from 8 AM to 9 AM, corresponding to a two-year return period storm in Northeast Ohio [40]. The storm generated 30.1 L and 25.29 L of runoff in the non-vegetated and vegetated control cells, respectively, while no runoff was generated in treated samples. This highlighted the high absorption and infiltration capacity of compost blankets, even under severe conditions. These findings align with previous research where compost-treated areas have shown increased water retention and reduced surface runoff [41]. A total of 79.12 L and 78.35 L of runoff were collected from the non-vegetated and vegetated control cells, respectively (**Table 3**). The amount of runoff led to substantial releases of TSS. In contrast, the absence of runoff in treated cells helped retain these suspended solids and prevented nutrient transfer via runoff. Although the field test used individual cells, the results were in-line with previously discussed laboratory data.

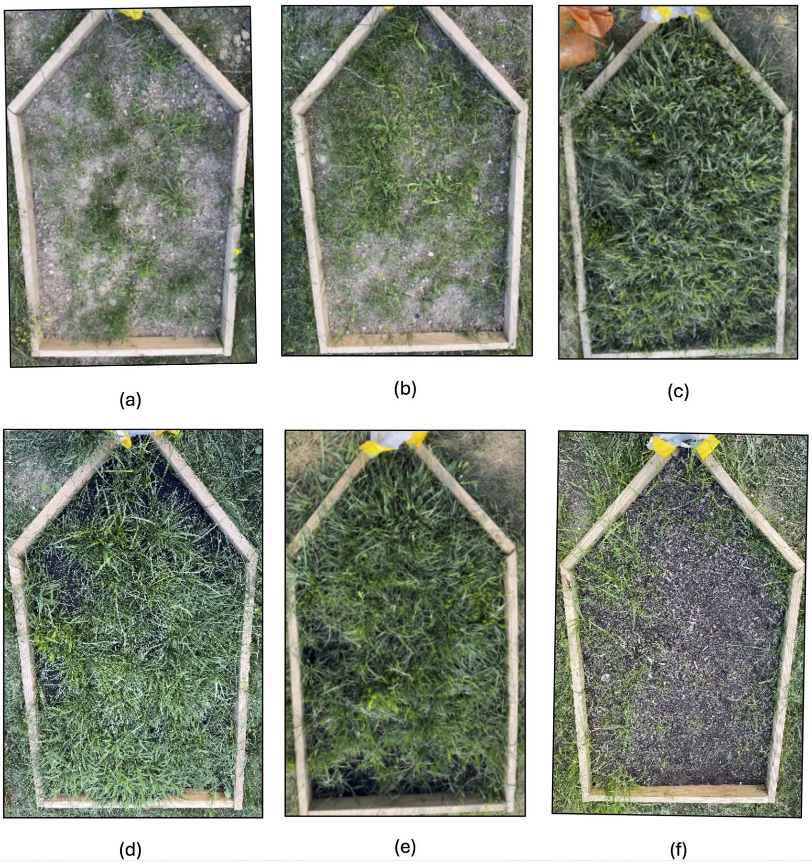

(a) (b) (c)
(d) (e) (f)

Figure 7. Vegetation in different cells after trimming on day 53: (a) non-vegetated control; (b) vegetated control; (c) 2.54 cm biosolids; (d) 3.81 cm biosolids; (e) 5.08 cm biosolids; (f) 3.81 cm yard waste compost blankets.

After four rain events the TSS released from the vegetated control cell (cell 2) was less than the non-vegetated control indicating that vegetation establishment contributed to reducing soil erosion. During events 6 and 8 multiple samples were taken within the same event. The decreasing TSS concentration over time indicated TSS level will drop as rainfall continues, which aligns with the laboratory results. Other researchers have also found that the initial flush of contaminants occurs at the start of a rain event [16] [42], particularly after long antecedent dry periods [25]. A recent study conducted in Columbus Ohio reported higher TSS and nutrient runoff concentrations during initial spring rains (May and June) compared to precipitation events during July through December [43].

Soluble reactive phosphorus (SRP) was present in almost all the runoff from control cells (**Table 4**). Potassium was also consistently detected in most of the samples while nitrate (NO_3) depicted the most variability. This variability and low NO_3 concentrations were attributed to uptake from grass cover [44]. While the field test was short in duration, other researchers supported the long-term benefits of compost blankets. Logsdon *et al.* [41] study from 2008-2014 reported persistent increased water retention, reduced run-off and nutrient losses.

Several researchers have discussed the potential leaching of heavy metals from compost blankets [12] [45] [46]. The extent of heavy metal release will depend on the source of the compost material and if the compost blankets had vegetation. Although the presence of heavy metals was not tracked in either the laboratory or field tests, the interaction of plant roots and soil microorganisms have been found to help retain heavy metals. For instance, Lin *et al.* [47] found that *Polygonum capitatum* and mosses decreased the migration of cadmium and copper form a mine tailings site by more than 40 and 55% respectively. The use of vegetated compost blanket and reduction of TSS would decrease mobilization of metals.

Table 3. Rainfall events and runoff generated from control cells during field experiment. '-' denotes no runoff.

Event	Start Date	Antecedent dry period (Days)	Event (hr: min)	Rain depth (cm)	Runoff Cell 1 (L)	Runoff Cell 2 (L)	TSS Cell 1 (mg)	TSS Cell 2 (mg)
1	5/5/2024	-	7:30	1.22	1.51	7.57	30,138	140,787
2	5/9/2024	3.9	10:27	2.89	-	3.41	-	7,345
3	5/11/2024	1.9	11:19	0.86	-	0.91	-	2,369
4	5/17/2024	5.5	13:03	0.53	1.09	1.44	26,028	14,454
5	5/22/2024	4.5	12:43	0.61	-	0.15	-	1,122
6	5/25/2024	2.7	1:18	0.08	-	-	-	-
7	5/26/2024	1.0	19:40	0.81	2.65	2.65	54,929	19,641
8	5/29/2024	1.8	6:19	4.72	27.23	24.79	188,074	90,332
9	6/5/2024	7.2	6:49	0.30	-	-	-	-
10	6/17/2024	11.5	0:11	0.56	3.78	6.06	53,329	28,345
11	6/23/2024	6.0	9:11	0.38	-	-	-	-
12	6/26/2024	2.5	5:55	1.68	1.06	0.79	17,262	2,717
13	7/3/2024	6.9	0:33	1.07	8.52	8.52	91,236	20,680
14	7/4/2024	1.0	6:09	3.28	17.41	17.03	98,088	47,360
15	7/10/2024	5.2	5:39	0.76	6.44	6.44	32,897	9,292
16	7/17/2024	7.2	1:45	0.30	-	-	-	-
17	7/23/2024	6.1	0:18	0.25	-	-	-	-
18	7/24/2024	1.0	1:45	0.79	6.62	6.62	25,358	7,790
19	7/29/2024	4.9	0:12	0.30	-	-	-	-
20	7/30/2024	0.5	11:32	0.1	-	-		-

Table 4. Rainfall events and soluble reactive phosphorus (SRP), nitrate (NO_3) and potassium (K) released from control cells during field experiment. ‘bdl’ denotes below detection limit.

Event	Rain depth (cm)	Cell 1			Cell 2		
		SRP (mg)	NO_3 (mg)	K (mg)	SRP (mg)	NO_3 (mg)	K (mg)
1	1.22	0.73	1.30	3.7	0.55	3.0	4.3
2	2.89	bdl	bdl	bdl	0.52	0.4	1.9
3	0.86	bdl	bdl	bdl	0.48	bdl	bdl
4	0.53	0.37	0.80	4.9	0.35	bdl	3.8
5	0.61	bdl	bdl	bdl	0.41	0.8	6.3
6	0.08	0.44	2.2	4.3	0.46	0.4	3.5
7	0.81	0.49	1.0	2.9	0.49	bdl	2.7
8	4.72	0.85	0.2	3.5	0.74	bdl	3.6
9	0.30	0.85	bdl	bdl	0.69	bdl	bdl
10	0.56	0.59	bdl	bdl	0.54	bdl	bdl
11	0.38	0.57	bdl	2.5	0.51	bdl	1.7
12	1.68	1.14	bdl	6.1	2.01	bdl	6.3
13	1.07	1.47	0.4	4.5	2.28	bdl	6.8
14	3.28	1.79	3.2	4.4	2.02	0.2	3.9
15	0.76	1.59	0.6	3.7	1.28	bdl	2.1
16	0.30	1.02	bdl	1.9	0.91	bdl	1.0
17	0.25	3.56	bdl	3.6	3.44	bdl	4.6
18	0.79	4.32	bdl	2.7	4.22	bdl	2.5
19	0.30	bdl	bdl	bdl	bdl	bdl	bdl
20	0.5	bdl	bdl	bdl	bdl	bdl	bdl

4. Conclusion

This study highlights the crucial role compost blankets play in controlling soil erosion and managing runoff on post-construction roadside slopes. Through both laboratory simulations and field experiments, vegetated compost blankets were effective at reducing TSS and run-off volumes. For a 2:1 slope, 5.08 cm biosolids sown with 3B Slope mix was the most effective. Roadside seed mix with 3.81 cm biosolids was more effective than controls and Class IV yard waste blanket for both 3:1 and 4:1 slopes. For 6:1 slope, either a 2.54 cm yard waste or 3.81 cm biosolids sown with Roadside seed mix would be recommended. These findings contribute valuable practical guidelines for the use of compost blankets in erosion control, promoting environmental sustainability and supporting informed decision-making in stormwater management practices. However, a comprehensive cost comparison with traditional erosion control methods that incorporates the site-specific costs would be needed before full implementation.

Acknowledgements

This paper is prepared in cooperation with the Ohio Department of Transportation (ODOT) and the U.S. Department of Transportation, Federal Highway Administration (FHWA). The contents do not necessarily reflect the official views or policies of the ODOT or FHWA.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

[1] Ohio Department of Transportation (2024) Item 659—Seeding and Mulching. https://www.dot.state.oh.us/Divisions/ConstructionMgt/OnlineDocs/Specifications/2023CMS/2023_CMS_Final_to_Printer.pdf

[2] de Oliveira, A.K.B., Battemarco, B.P., Barbaro, G., Gomes, M.V.R., Cabral, F.M., de Oliveira Pereira Bezerra, R., *et al.* (2022) Evaluating the Role of Urban Drainage Flaws in Triggering Cascading Effects on Critical Infrastructure, Affecting Urban Resilience. *Infrastructures*, **7**, Article 153. https://doi.org/10.3390/infrastructures7110153

[3] Islam, M.M., McLaughlin, R.A., Austin, R., Kranz, C.N. and Heitman, J.L. (2024) Compost Incorporation and Wildflowers Introduction for Stormwater Infiltration and Erosion-Control Vegetation Cover Establishment in Post-Construction Landscapes. *Journal of Environmental Management*, **369**, Article ID: 122324. https://doi.org/10.1016/j.jenvman.2024.122324

[4] Pimentel, D., Harvey, C., Resosudarmo, P., Sinclair, K., Kurz, D., McNair, M., *et al.* (1995) Environmental and Economic Costs of Soil Erosion and Conservation Benefits. *Science*, **267**, 1117-1123. https://doi.org/10.1126/science.267.5201.1117

[5] Streeter, M.T. and Schilling, K.E. (2019) Assessing and Mitigating the Effects of Agricultural Soil Erosion on Roadside Ditches. *Journal of Soils and Sediments*, **20**, 524-534. https://doi.org/10.1007/s11368-019-02379-3

[6] Patault, E., Ledun, J., Landemaine, V., Soulignac, A., Richet, J., Fournier, M., *et al.* (2021) Analysis of Off-Site Economic Costs Induced by Runoff and Soil Erosion: Example of Two Areas in the Northwestern European Loess Belt for the Last Two Decades (Normandy, France). *Land Use Policy*, **108**, Article ID: 105541. https://doi.org/10.1016/j.landusepol.2021.105541

[7] Hu, P., Ma, Y., Xue, H. and Zhang, F. (2017) Application of Low Impact Development Technology in Rainwater Drainage System Reconstruction Project. *Cluster Computing*, **22**, 533-543. https://doi.org/10.1007/s10586-017-1284-7

[8] Moore, T.L., Rodak, C.M., Ahmed, F. and Vogel, J.R. (2018) Urban Stormwater Characterization, Control and Treatment. *Water Environment Research*, **90**, 1821-1871. https://doi.org/10.2175/106143018x15289915807452

[9] El-Husseini, H., Chowyuk, A.N., Gustafson, R.R., Gough, H.L. and Bura, R. (2023) Roadside Vegetated Filter Strips to Simultaneously Lower Stormwater Pollution Loadings and Improve Economics of Biorefinery Feedstocks. *Journal of Environmental Management*, **347**, Article ID: 119168. https://doi.org/10.1016/j.jenvman.2023.119168

[10] U.S. Environmental Protection Agency (2023) Stormwater Best Management Practice Compost Blankets. https://www3.epa.gov/npdes/pubs/compostblankets.pdf

[11] Bakr, N., Weindorf, D.C., Zhu, Y., Arceneaux, A.E. and Selim, H.M. (2012) Evalua-

tion of Compost/Mulch as Highway Embankment Erosion Control in Louisiana at the Plot-Scale. *Journal of Hydrology*, **468**, 257-267. https://doi.org/10.1016/j.jhydrol.2012.08.040

[12] Forgione, E.R., Felton, G.K., Aydilek, A.H. and Davis, A.P. (2024) Hydrologic Performance of Vegetated Compost Blankets for Highway Stormwater Management. *Journal of Sustainable Water in the Built Environment*, **10**, Article No. 223. https://doi.org/10.1061/jswbay.sweng-537

[13] U.S. Environmental Protection Agency (2015) Compost Blankets. https://www.epa.gov/sites/production/files/2015-11/documents/compostblankets.pdf

[14] Bhattarai, R., Kalita, P.K., Yatsu, S., Howard, H.R. and Svendsen, N.G. (2011) Evaluation of Compost Blankets for Erosion Control Form Disturbed Lands. *Journal Environmental Management*, **92**, 803-812. https://doi.org/10.1016/j.jenvman.2010.10.028

[15] Kutos, S., Stricker, E., Cooper, A., Ryals, R., Creque, J., Machmuller, M., *et al.* (2023) Compost Amendment to Enhance Carbon Sequestration in Rangelands. *Journal of Soil and Water Conservation*, **78**, 163-177. https://doi.org/10.2489/jswc.2023.00072

[16] Owen, D., Davis, A.P. and Aydilek, A. (2020) Maryland Department of Transportation State Highway Administration (MDOT SHA) Report—Understanding the Effects of Slope Ratio, Straw Mulching, and Compost Addition to Topsoil to Establish Permanent Vegetation and Reduce Nutrient Run-Off. https://www.roads.maryland.gov/OPR_Research/MD-20-SHA-UM-5-13_Compost-StudyPhaseII_Report.pdf

[17] Naserian, E.S., Cheraghi, M., Lorestani, B., Sobhanardakani, S. and Sadr, M.K. (2021) Qualitative Investigation of Sewage Sludge Composting: Effect of Aerobic/Anaerobic Pretreatments. *Arabian Journal of Geosciences*, **14**, Article No. 836. https://doi.org/10.1007/s12517-021-07232-x

[18] Seutloali, K.E. and Reinhard Beckedahl, H. (2015) A Review of Road-Related Soil Erosion: An Assessment of Causes, Evaluation Techniques and Available Control Measures. *Earth Sciences Research Journal*, **19**, 73-80. https://doi.org/10.15446/esrj.v19n1.43841

[19] Askew, S.D., Goatley, J.M. and Gonçalves, C. (2023) Promoting Native Roadside Plant Communities and Ensuring Successful Vegetation Establishment Practices (No. FHWA/VTRC 23-R14). Virginia Transportation Research Council (VTRC).

[20] ASTM International (2023) Standard Test Methods for Particle-Size Distribution (Gradation) of Soils Using Sieve Analysis (ASTM D6913/D6913M-23). ASTM International.

[21] ASTM International (2017) Standard Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soils (ASTM D4318-17). ASTM International.

[22] ASTM International (2019) Standard Test Methods for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass (ASTM D2216-19). ASTM International.

[23] ASTM International (2023) Standard Test Method for Direct Shear Test of Soils under Consolidated Drained Conditions (ASTM D3080/D3080M-23). ASTM International.

[24] Pandey, V., Komal, and Dincer, H. (2023) A Review on TOPSIS Method and Its Extensions for Different Applications with Recent Development. *Soft Computing*, **27**, 18011-18039. https://doi.org/10.1007/s00500-023-09011-0

[25] Hejna, M. and Cutright, T.J. (2021) Stream Restoration Reduces Elevated Phosphorus

Levels in an Urban Watershed. *Limnologica*, **91**, Article ID: 125921. https://doi.org/10.1016/j.limno.2021.125921

[26] Kranz, C.N., McLaughlin, R.A. and Heitman, J.L. (2022) Characterizing Compost Rate Effects on Stormwater Runoff and Vegetation Establishment. *Water*, **14**, Article 696. https://doi.org/10.3390/w14050696

[27] Oregon Department of Transportation (2023) Erosion Control Manual. https://www.oregon.gov/odot/GeoEnvironmental/Docs_Environmental/Erosion_Control_Manual.pdf

[28] Poland, C.J. (2018) Reviewing Compost Use in Construction and Modeling the Hydrologic Response of Vegetated Compost Blankets. Master's Thesis, University of Wisconsin-Madison.

[29] Evanylo, G.K., Porta, S.N., Li, J., Shan, D., Goatley, J.M. and Maguire, R. (2015) Compost Practices for Improving Soil Properties and Turfgrass Establishment and Quality on a Disturbed Urban Soil. *Compost Science & Utilization*, **24**, 136-145. https://doi.org/10.1080/1065657x.2015.1096866

[30] California Department of Transportation (2019) Erosion Control Toolbox: Compost. https://dot.ca.gov/programs/design/lap-erosion-control-design/tool-1-lap-erosion-control-toolbox/tool-1k-11-compost

[31] Ahern, J., Ramage, C., Piantedosi, M. and Bayer, A. (2020) Compost Blankets for Erosion Control and Vegetation Establishment (MassDOT Project No. 20-012). University of Massachusetts

[32] Trenouth, W.R., Gharabaghi, B. and Farghaly, H. (2018) Enhanced Roadside Drainage System for Environmentally Sensitive Areas. *Science of the Total Environment*, **610**, 613-622. https://doi.org/10.1016/j.scitotenv.2017.08.081

[33] Al Haider, M.R. (2024) Evaluating the Effectiveness of Compost Blankets for Vegetation Establishment and Stormwater Management on 6:1 and 4:1 Roadside Slopes. Master's Thesis, The University of Akron.

[34] Motahari Tabari, S.A. (2024) Assessment and Optimization of Compost Blankets for Erosion and Stormwater Management on Steep Roadside Slopes in Ohio. Master's Thesis, The University of Akron.

[35] Faucette, L.B., Scholl, B., Beighley, R.E. and Governo, J. (2009) Large-Scale Performance and Design for Construction Activity Erosion Control Best Management Practices. *Journal of Environmental Quality*, **38**, 1248-1254. https://doi.org/10.2134/jeq2008.0415

[36] Reinsch, C.T., Admiraal, D.M., Dvorak, B.I., Cecrle, C.A., Franti, T.G. and Stansbury, J.S. (2007) Yard Waste Compost as a Stormwater Protection Treatment for Construction Sites. *Water Environment Research*, **79**, 868-876. https://doi.org/10.2175/106143007x220545

[37] Oviedo-Ocaña, E.R., Abendroth, C., Domínguez, I.C., Sánchez, A. and Dornack, C. (2023) Life Cycle Assessment of Biowaste and Green Waste Composting Systems: A Review of Applications and Implementation Challenges. *Waste Management*, **171**, 350-364. https://doi.org/10.1016/j.wasman.2023.09.004

[38] Faucette, L.B., Governo, J., Jordan, C.F., Lockaby, B.G., Carino, H.F. and Governo, R. (2007) Erosion Control and Storm Water Quality from Straw with PAM, Mulch, and Compost Blankets of Varying Particle Sizes. *Journal of Soil and Water Conservation*, **62**, 404-413.

[39] AASHTO (2019) R 52-10—Compost for Erosion/Sediment Control (Compost Blankets). Standard Specifications for Transportation Materials and Methods of Sampling

and Testing. American Association of State Highway and Transportation Officials.

[40] National Oceanic and Atmospheric Administration (NOAA) (2024). https://www.weather.gov/current

[41] Logsdon, S.D., Sauer, P.A. and Shipitalo, M.J. (2017) Compost Improves Urban Soil and Water Quality. *Journal of Water Resource and Protection*, **9**, 345-357. https://doi.org/10.4236/jwarp.2017.94023

[42] Shokri, M., Kibler, K.M., Hagglund, C., Corrado, A., Wang, D., Beazley, M., *et al.* (2021) Hydraulic and Nutrient Removal Performance of Vegetated Filter Strips with Engineered Infiltration Media for Treatment of Roadway Runoff. *Journal of Environmental Management*, **300**, Article ID: 113747. https://doi.org/10.1016/j.jenvman.2021.113747

[43] Smith, J.S., Winston, R.J., Tirpak, R.A., Wituszynski, D.M., Boening, K.M. and Martin, J.F. (2020) The Seasonality of Nutrients and Sediment in Residential Stormwater Runoff: Implications for Nutrient-Sensitive Waters. *Journal of Environmental Management*, **276**, Article ID: 111248. https://doi.org/10.1016/j.jenvman.2020.111248

[44] Curtis, M.J., Rider, D.E., Fristensky, A. and Claassen, V.P. (2009) Cumulative Sediment, Nitrogen and Phosphorus Losses from Bare and Compost-Amended Fill Slopes. *Compost Science & Utilization*, **17**, 25-30. https://doi.org/10.1080/1065657x.2009.10702396

[45] Zennaro, M., Cristofori, F., Formigoni, D., Frignani, F. and Pavoni, B. (2005) Heavy Metal Contamination in Compost. A Possible Solution. *Annali di Chimica*, **95**, 247-256. https://doi.org/10.1002/adic.200590027

[46] Chen, J., Fan, P., Zhang, F., Tai, L., Fang, N., Niu, Y., *et al.* (2025) Heavy Metal(loid)s Migration Mechanisms during Soil Erosion: A Systematic Quantitative Review. *International Soil and Water Conservation Research*, **13**, 410-421. https://doi.org/10.1016/j.iswcr.2025.02.002

[47] Lin, K., Jian, J., Zhang, Y., Liu, Y., Li, S., Zhao, Y., *et al.* (2024) Study on Plant-Blanket to Reduce Heavy Metal Migration Caused by Precipitation and to Improve the Soil Environment of Pyritic Tailings. *Science of the Total Environment*, **939**, Article ID: 173376. https://doi.org/10.1016/j.scitotenv.2024.173376

Supplement

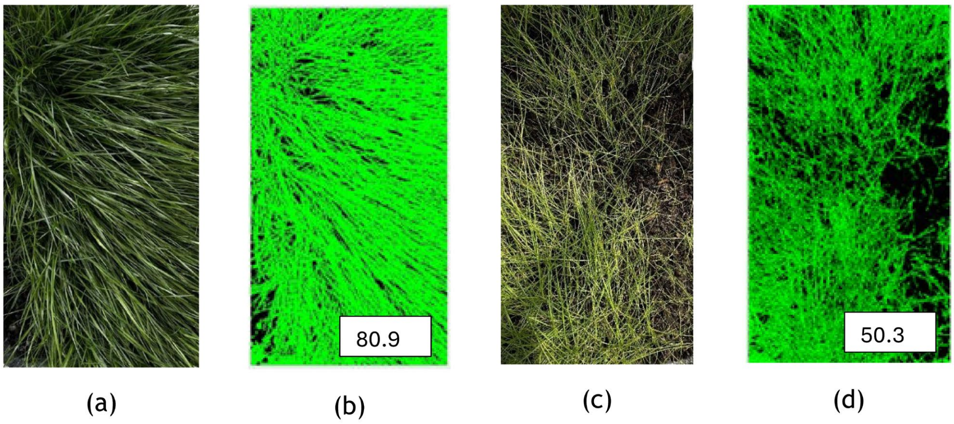


Figure S1. The effectiveness of digital image analysis for different conditions and ranges. (a) Top view of sample "1", (b) Digital processed image of sample "1" showing 80.9% coverage, (c) Top view of sample "2", and (d) Digital processed image of sample "2" showing 50.3% coverage.

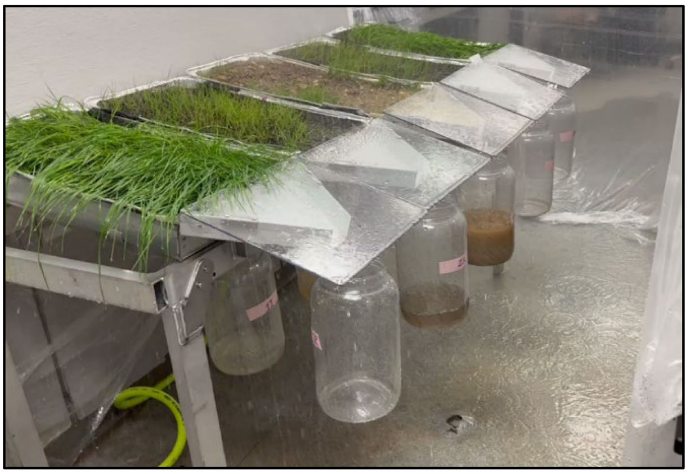


Figure S2. Attached jars to collect samples from runoff and infiltration.

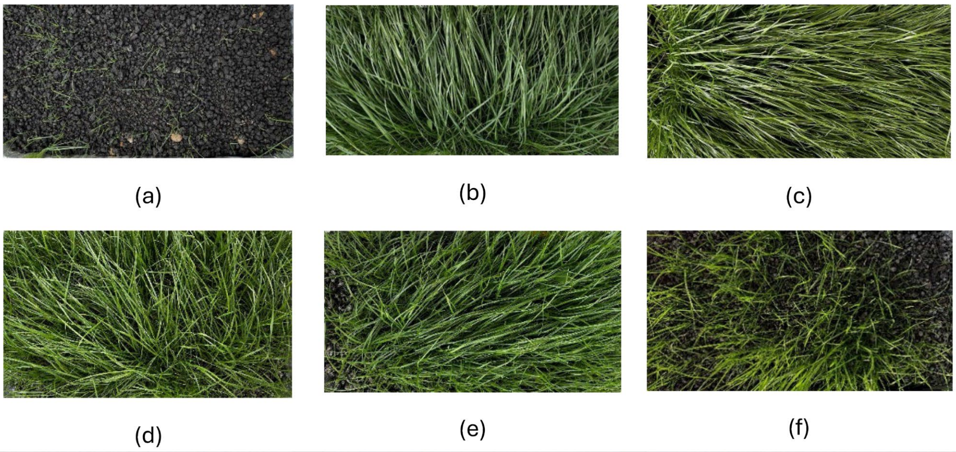


Figure S3. Top view photographs of samples with biosolids + Roadside mix in 2.54 cm thickness (a)-(c) 5.08 cm thickness; (d)-(f) for 3:1 slope.

Figure S4. Collected runoff samples from bare soil (control cases), class IV, and EQS biosolids (left to right).

Figure S5. (a) Cell covered with 2.54 cm of biosolid showing exposed soil points after 3 weeks; (b) Cell treated with 3.81 cm of biosolids, completely covering the surface