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Evaluation of Net-free Erosion Control Blankets

Prepared By
Rabin Bhattarai
Yufan Zhang
Owen Yao
University of Illinois Urbana-Champaign

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16. Abstract

Erosion control blankets (ECBs) protect soil from being detached and transported by raindrops and subsequential overland runoff while assisting in vegetation growth. ECBs have several characteristics, for example, thickness, mass per unit area, tensile strength, elongation, water absorption, etc. However, the impact of these characteristics on the performance in mitigating erosion has yet to be well understood. To better understand the interactions of ECB properties with the detachment and transport of sediment, field tests were conducted at the Erosion Control Research and Training Center at the University of Illinois Urbana-Champaign. Various ECBs, including net-free ECBs and bionet ECBs, were tested on a 3H:1V hillslope under a 30-minute simulated rainfall event (2 in./hr). The soil used on the testing plot was silty clay loam. To investigate ECB effectiveness, total runoff volume, runoff start/end time, peak runoff rate, and sediment yield were monitored during each test. The results showed that water absorption played a big role in enhancing the performance of ECBs. The materials absorbed a large amount of water at the beginning and then acted as a wet film to cover the hillslope, reducing soil erosion by the overland flow when the soil was saturated. This wet film continued to reduce soil detachment, although it probably did not help with runoff reduction after saturation. Among the blankets tested, Profile F4 Netless was the most degradable and lightest one. North American Green DS75 had the most cost efficiency with $0.4 /sq. yd. There was no big difference in the installation method.

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Members of the Technical Review Panel (TRP) were the following:

- Scott Marlow, TRP Chair, Illinois Department of Transportation
- Kim Burkwald, Illinois Department of Transportation
- Michael Copp, Illinois Department of Transportation
- Steve Ferguson, Illinois Department of Transportation
- Bradley Hayes, Illinois Department of Transportation
- Erin Holmes, Illinois Department of Transportation
- Felecia Hurley, Illinois Department of Transportation
- Andrew Kuhns, Illinois Department of Transportation
- Darien Siddall, Federal Highway Administration
- Heather Shoup, Illinois Department of Transportation
- Frances Whalen, Illinois Department of Transportation

EXECUTIVE SUMMARY

Earthmoving operations during construction activities involve substantial disturbance of topsoil and vegetative cover. As a result, stormwater runoff and erosion rates can increase significantly. Improperly managed construction sites contribute significantly to high soil erosion rates. If soil erosion can be controlled by preventing soil particles from being detached and transported, then it will reduce the workload for sediment control downstream and potentially save costs. Erosion control blankets (ECBs) have been proven to be effective in reducing raindrop energy and preventing soil particles from being detached. However, ECBs are usually contingent upon plastic netting, which is designed to hold the fiber matrix in place. This plastic netting can stay on-site for years and cause entanglement issues with wildlife and mowing machines. Therefore, some net- or plastic-free ECBs have been developed. It is necessary to investigate how well these new ECBs perform in terms of sediment yield reduction, wildlife friendliness, cost, etc.

Field experiments were performed at the Erosion Control Research and Training Center at the University of Illinois Urbana-Champaign. The experiments examined the performance of ECBs to prevent soil particles from being detached and transported due to a rainfall event. The goal of this study was to compare various net- or plastic-free ECBs to traditional ECBs (plastic net), examining how well they protect the slope as well as other criteria of interest to the Illinois Department of Transportation, including cost, availability, ease of installation, degradation rate, etc. The blanket matrix (inner material) of 10 products examined in this study includes wood fiber, straw fiber, and coconut coir fiber. Some of them were net-free, while others were either single or double netting.

The products installed on a 3H:1V slope were subjected to a 30-minute, 2 in./hr simulated rainfall. Water quality samples of 250 mL were collected at 5-minute intervals downstream, once the runoff started, till the runoff ceased. These samples were analyzed for total sediment concentration. These grab samples were also used to examine the outflow rate by recording how long it took to fill each sample jar. A hydrograph and sedigraph were plotted to compute the total runoff volume and total sediment yield. Total runoff volume was collected and measured on-site.

None of the products tested exhibited major product failure. They all performed well in trapping sediment on the slope with at least 95% sediment trapping efficiency. Most products showed a high degradation rate (over six months), except for Profile F4 Netless, which is also the lightest product in this study. North American Green DS75 is the most cost-efficient, with $0.4/sq. yd. in this study. Cost should be the top priority when an ECB is selected for use, considering it has a similar performance in technical and sustainability. A higher rainfall intensity scenario is recommended to be explored in the future to evaluate whether these ECBs still perform similarly in trapping sediment on a slope in extreme rainfall conditions.

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CHAPTER 1: INTRODUCTION

The erosion of topsoil from bare lands often leads to sediment ending up in water bodies, causing numerous negative effects. Construction activities rank among the highest of activities leading to topsoil erosion, sedimentation, and subsequent water body impairments in the United States. Construction sites have sediment runoff rates typically 10 to 20 times higher than agricultural lands (EPA, 2018). Construction activities often entail earthmoving operations that involve the removal of vegetative cover and the disturbance of topsoil. As a result, stormwater runoff and erosion rates can increase significantly.

In order to mitigate soil erosion and reduce stormwater runoff at construction sites, there are several best management practices (BMPs) that have been recommended by the US Environmental Protection Agency and other environmental organizations. Sediment control practices are used to limit eroded soil or sediment from being deposited off-site and involve practices and technology that dam or filter stormwater runoff as it exits the site. In contrast, erosion control practices seek to minimize erosion and to provide some means of keeping soil in place or preventing it from being exposed to erosion-causing processes. Common erosion control practices include vegetation, erosion control blankets (ECBs), soil blinders, mulch, turf reinforcement mats, and riprap. With slopes steeper than 2H:1V, riprap may be unstable. ECBs can be especially useful for establishing permanent vegetation on slopes 2H:1V or greater. They are generally effective for slopes up to 1.5H:1V but may be used for slopes as steep as 1H:1V. ECBs play a significant role in reducing erosion on slopes steeper than 3H:1V, which usually occurs on highway or roadway construction sites (Minnesota Stormwater Manual, 2023). However, ECBs usually come with plastic nets on either one side or both sides, which causes entanglement issues with animals and mowing machines. Therefore, designers aim to find a way to avoid these issues as some net- or plastic-free ECBs have come onto the market. Most net- or plastic-free ECBs are currently untested and unproven under a standardized testing method and simulated rainfall events, especially in nonprofit institutes.

This study used a field-scale testing protocol to examine the technical performance of various ECBs. Each product was evaluated based on multiple criteria, including technical performance (runoff trapping efficiency, sediment trapping efficiency), cost and availability, ease of installation/removal, and sustainability. The outcomes indicated whether these products have merit as approved ECBs on Illinois construction sites and should be recommended to the Illinois Department of Transportation.

CHAPTER 2: OBJECTIVES

The purpose of this study was to investigate several net- or plastic-free ECBs and to compare them to traditional ECBs (plastic nets) in terms of technical performance, cost and availability, ease of installation/removal, vegetation growth potential, and degradation rate. Conclusions and recommendations on erosion control blanket application were provided at the end of this document based on the observations and qualitative results.

The specific objectives of the project were as follows:

- Review literature on the use of plastic-free, natural-fiber, and loose-woven-fiber erosion control blankets.
- Review other state departments of transportation practices for utilizing net- and plastic-free erosion control blankets as well as how they have implemented those specifications for construction projects.
- Determine and compare the technical performance (total outflow volume and sediment yield) of net- and plastic-free erosion control blankets through field-scale experiments at the University of Illinois Urbana-Champaign's Erosion Control Research and Training Center.
- Review the cost of products and observe vegetation growth potential, ease of installation, the likelihood of failure, and sustainability.
- Provide data and recommendations to assist in establishing an approved product list for ECBs.

CHAPTER 3: LITERATURE REVIEW

As a best management practice (BMP) on construction sites, erosion control blankets provide a layer of protection to reduce the potential of soil particles being detached and transported by stormwater. Based on previous research, ECBs have been proven to reduce soil loss and water pollution effectively. A typical ECB consists of continuous fibrous materials assembled in a rollable mat and netting on one or both sides. The continuous fiber mat is the main component of ECBs to alleviate the strike of raindrops on the soil surface. The netting is used to improve the stability and lengthen the life span of ECBs by holding the fibrous materials in place. The rollable mat is mainly made of environmentally friendly natural fiber materials, such as straw, coconut fiber, or wood fiber. Most ECBs use netting with plastic or synthetic materials because of their high stability, easy access, and low cost. However, plastic poses a big threat to the environment. The main drawbacks associated with plastic netting include unintentional injury or death of protected animal species, damage to on-site lawn care machinery, and the longevity and persistence of plastic-based materials after project completion (Figure 1). These drawbacks have led many transportation authorities to advocate for phasing out the use of plastic mesh nets in favor of biodegradable alternatives. As a result, more and more companies have been working on the design and examination of novel ECBs. Based on the literature review, there are five types of novel ECBs in terms of different netting materials, weaving patterns, etc.

Figure 1. Photo. Snake entanglement (California Coastal Commission, 2012).

NOVEL EROSION CONTROL BLANKET CATEGORIES

Netting with Too Small or Too Large Opening

While little research has been done on the optimal mesh size in netting to avoid snake entrapment, the Natural Resources Conservation Service (NRCS, 2013) in Indiana recommends that if netting is not movable, openings should be at least 2 inches wide. Snakes may be particularly vulnerable to entanglement in netting if they get stuck partway through but cannot back out because their scales catch on the netting. Mesh netting with an opening that is either too small for snakes to attempt to pass through or too large to impede the passage of snakes is optimal to reduce the threat of entrapment. However, even small mesh netting may still entangle naturally small snakes and other small wildlife (California Coastal Commission, 2012).

Net-free Erosion Control Blankets

A net-free erosion control blanket is a continuous natural fiber blanket without netting. This type is less common than the others but is still used in many applications. The absence of a net means that it is not capable of handling higher runoff volumes or steeper slopes. Typically, a net-free ECB is used for temporary erosion control in areas that experience light rainfall. It would not be suitable for allowing the growth of vegetation but does not experience the same drawbacks as traditional ECBs, such as wildlife entanglement or plastic pollution. Net-free ECBs are typically made of wood fibers instead of coir or straw fiber, as wood fiber is much more durable and can last a reasonable amount of time without netting (Curlex® NetFree™, American Excelsior Company, 2023).

Erosion Control Blankets with Natural Fiber Netting

The Illinois Department of Natural Resources (IDNR, 2020) is evaluating the phased removal of plastics in all temporary erosion control products. The use of plastic ECBs, especially those with welded netting that poses risks of wildlife entanglement, raises environmental issues that contradict IDNR's conservation and sustainability objectives. While it may not be possible to find viable alternatives for all ECBs, we seek the elimination of plastic ECBs in favor of practical biodegradable alternatives (Indiana Natural Resources Conservation Service, 2013). Erosion control specifications should focus on products with natural fiber and promote the use of biodegradable materials.

The plastic netting used in temporary erosion and sediment control products is designed to be "degradable." However, degradable is not the same as biodegradable. Biodegradable means that the material decomposes into elements found in nature within a reasonably short period after customary disposal. In contrast, degradable plastics break down into plastic fragments that remain in the environment after degradation. Degradable plastic netting may be labeled photodegradable, UV-degradable, oxo-degradable, or oxo-biodegradable (however, it is not truly biodegradable) (California Coastal Commission, 2012).

Biodegradable natural-fiber ECBs are more snake-friendly than synthetic products. Natural fiber netting typically has less tensile strength than plastic netting and thus may allow entrapped animals to break free. Jute and coir fiber show promise for replacing plastic netting as an industry standard. In addition, it is more environmentally friendly if it can degrade completely after the construction project is completed. However, it is common for these netting types to be not 100% biodegradable (California Coastal Commission, 2012). In order to maintain the stability and performance of ECBs, companies usually are unwilling to decrease the tensile strength to a large extent. Thus, these kinds of so-called biodegradable ECBs still have the same issue as traditional ECBs, which include plastic netting. In other words, there is always a trade-off between protection performance and wildlife safety.

Natural fiber includes, but is not limited to, straw, jute, and wood fiber; they have relatively different erosion control effects in different situations. Horner et al. (1990) conducted plot-scale studies to explore the effectiveness of various erosion control measures on reducing downstream water pollutants, including sediment and phosphorus. In terms of sediment, several treatments achieved erosion control effectiveness above 85% as measured by settleable solids and total suspended solid reductions. Wood fiber mulch, tackifier, and seeding treatments performed the best in this regard.

Straw mulch accompanied by seeding performed almost the same as well. Only these treatments achieved turbidity reductions of over 90%. In terms of phosphorous, straw mulch exhibited variable effectiveness. They found slopes with wood fiber mulch, tackifier, and seeding treatments exhibited high phosphorus yields in the first two storms during 1988–89, but these yields decreased greatly as the grass became established. Overall, the wood fiber, tackifier, and seeding treatments were the most effective measures in this study.

Figure 2. Photo. Jute fiber netting (California Coastal Commission, 2012).

Erosion Control Blankets with Loose-Weave Netting (Moveable Joint)

Typically, plastic netting is assembled by welding the corners, allowing for a simplistic manufacturing process and reliable fiber blanket stabilization. An important factor in snake-friendly netting is to have movable (not fixed or welded) joints between the twines, allowing the twines to move independently (California Coastal Commission, 2012). This design allows each opening between the twines in the netting to be stretched as an animal passes through, reducing the potential for entrapment. Netting designs with movable joints may be called loose weave, leno weave, or gauze weave.

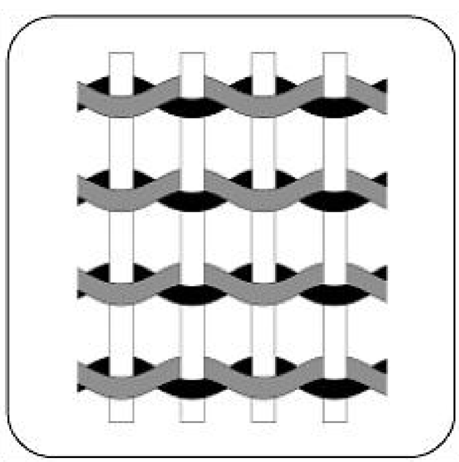


Figure 3. Photo. Leno-weave pattern (California Coastal Commission, 2012).

Wildlife-safe weaving patterns refer to netting that employs weaving patterns known to decrease the rate of entanglement and allow for entangled animals to escape. Figure 3 is a diagram of a leno-weave fabric, where the moveable joints are located at the junction of the grey net fabric and black fabric. These increase the size of the net hole when they are moved. Leno weave netting used in many biodegradable netting options retains a similar level of stability to welded netting. A suitable replacement for plastic netting must be able to employ wildlife-safe weaving patterns (Ebert et al., 2019).

Continuous Netting Made from Woven Fiber

Continuous netting made from woven fiber is unique because it does not have a fiber matrix but has only netting. These types of ECBs tend to be lighter than erosion control blankets with loose-weave netting. Applications for this type of ECB typically center around establishing vegetation or providing moderate erosion control, which means they are not equipped to handle higher runoff volumes and steeper slopes. The absence of a fiber matrix allows for sunlight penetration and room for growth, making this type suitable for establishing vegetation as a permanent erosion control practice, as shown in Figure 4 (One Clarion, 2023). The netting for this type of ECB is usually an organic material woven in larger net hole openings.

Figure 4. Photo. Coir mat with vegetation growing through (One Clarion, 2023).

PREVIOUS RESEARCH OR GUIDELINES BY OTHER INSTITUTIONS

Some institutions have already conducted research on the design and effectiveness of novel ECBs. Guidelines have been implemented by Indiana NRCS (2013) to avoid snake entrapment in the plastic netting commonly used in erosion control blankets in Indiana. The guidelines are listed as follows:

> Erosion Control Blankets used on any NRCS project in locations with potential threatened or endangered snake species will:
>
> 1. Have net openings of 2-inch minimum width or,
> 2. Be constructed of a woven (leno weave) netting that allows openings to adjust to wide widths.

3. Be of a type that will not entangle snakes as approved by the NRCS State Biologist.

Erosion control blankets such as North American Green Bionet S150BN and Western Wood fibers EXCEL SS-2 All Natural (biodegradable jute/scrim netting with leno weave type mesh) or equivalent are considered acceptable products.

The California Coastal Commission (2012) also made a summary of the application of ECBs. To minimize wildlife entanglement and plastic debris pollution, choose temporary erosion and sediment control products that either do not contain netting or that contain netting manufactured from 100% biodegradable non-plastic materials such as jute, sisal, or coir fiber. Degradable, photodegradable, UV-degradable, oxo-degradable, or oxo-biodegradable plastic netting (including polypropylene, nylon, polyethylene, and polyester) are not acceptable alternatives. Netting used in these products should have a loose-weave wildlife-safe design with movable joints between the horizontal and vertical twines, allowing the twines to move independently and thus reducing the potential for wildlife entanglement. Avoid the use of silt fences reinforced with metal or plastic mesh. "Temporary" erosion and sediment control products are commonly left in place permanently, particularly if vegetation has grown up through the netting. Prompt removal of these products when they are no longer needed is advisable if it is possible to do so without damaging the new vegetation. Ward et al. (2020a) found that snakes exhibited a substantially lower likelihood of attempting to pass through the mesh when encountering buried edges, displaying no instances of entanglement, whereas all entanglements occurred in the treatment with exposed edges. However, the complexities of uneven terrain and potential changes in ECB characteristics over time due to degradation are factors that may influence entanglement outcomes. Another means to secure ECBs is using wooden or "live" stakes. These stakes can keep ECBs in place, reduce the ability for wildlife to crawl underneath, and help aid in vegetation growth when native live stakes are used (Rivas et al., 2006).

The selection of an erosion and pollution control material and strategy should be considered with reference to the protection objectives (Horner et al., 1990). For example:

1. When immediate erosion control is needed before vegetation develops, a woven straw blanket is a good choice to provide a relatively high level of interim protection.
2. When time is available to develop a good grass stand before much runoff occurs, wood fiber and straw mulches can afford very good erosion and pollution control.
3. Do not use a chemical alone as an erosion control agent but only as a tackifier to help secure mulches.

Ward et al. (2020b) evaluated 141 erosion control practices (ECPs) from the Texas Department of Transportation's approved product list and found that many of these products—particularly those with attributes like polypropylene mesh with small, fused apertures—present significant entanglement risks. While a majority of these products had detailed attribute information, there is a pressing need for more transparent data to ensure both effective erosion control and wildlife safety.

The U.S. Fish and Wildlife Service categorized netting materials as "Not Wildlife Friendly" (such as square plastic netting made from polypropylene, nylon, polyethylene, polyester, often left longer than necessary), "Less Risk to Wildlife" (like elongated mesh netting with a mesh size greater than

2.54 cm), and “Wildlife Friendly” (natural fiber netting or no netting, 100% biodegradable materials). They also provided recommendations for secure and environmentally responsible installation and removal (U.S. Fish and Wildlife Service, 2023). Please see Figure 5 for more details.

Figure 5. Graph. Definition of harmfulness to wildlife (U.S. Fish and Wildlife Service, 2023).

PRODUCT LIST AUTHORIZED APPROVED BY INSTITUTIONS

The products, such as SC150BN, Curlex® NetFree, AEC Premier Straw/Coconut FibreNet, Curlex® III fibernet, Excel CS-3, Excel CC-4, SC3000BD, and C4000BD, are made predominantly from biodegradable materials like straw, coconut fiber, and Aspen wood excelsior. They vary in longevity (ranging from 18 to 36 months) and are suitable for different slope grades. The SC150BN, with its blend of straw and coconut fiber, is effective for slopes between 2:1 and 1:1 and has a lifespan of 18 months. Similarly, Curlex® NetFree is suitable for temporary applications on slopes of 3:1 or less, emphasizing its use in less steep areas. The AEC Premier Straw/Coconut FibreNet and Curlex® III fibernet both offer longer durability of 36 months, with the former being effective for slopes of 1.5:1 or less and the latter for steeper slopes greater than 1:1.

Excel CS-3 and Excel CC-4, both produced by Western Excelsior Corporation, have differing life spans of 24 and 36 months, respectively, and are suitable for slopes of 3:1 or less, showcasing their utility in moderately inclined areas. SC3000BD and C4000BD, made by Enviroscape ECM, offer 24 and 36 months of erosion control, respectively, suitable for slopes of 2:1 or less. This variety in performance characteristics allows for a wide range of applications, catering to different environmental and topographical needs in erosion control. Table 1 provides more information on various new erosion control blankets and their characteristics.

Table 1. Approved Erosion Control Blanket List and Their Respective Qualities

Product Name	Product Description	Erosion Control Performance	Transportation Authority Approval	Additional Notes
SC150BN	Biodegradable jute netting, 70% straw 30% coconut fiber blanket, leno weave netting	Longevity of 18 months, slopes 2:1-1:1	Category 4N-straw/coir (MnDOT, 2018)	Produced by North American Green (n.d.)
Curlex® NetFree	No netting, Aspen curled wood excelsior blanket, biodegradable thread Wildlife-safe threading	Temporary application, slopes of and less than 3:1	Category 0 (MnDOT, 2018)	Produced by American Excelsior Company
AEC Premier Straw/Coconut FibreNet	Biodegrable jute netting, 70% straw 30% coconut fiber blanket	Longevity of 36 months, slopes of and less than 1.5:1	Category 4N-straw/coir (MnDOT, 2018)	Produced by American Excelsior Company, leno weave netting
Curlex® III fibernet	Biodegradable jute netting, Aspen curled wood excelsior blanket	Longevity of 36 months, slopes greater than 1:1	Category 4N-Wood (MnDOT, 2018), Class II Type C (Intermediate), (NYSDOT, 2023)	Produced by American Excelsior Company
Excel CS-3	Biodegradable jute netting, 70% straw 30% coconut fiber blanket	Longevity of 24 months, slopes of and less than 3:1	Category 4N-straw/coir (MnDOT, 2018), Class II Type C (Intermediate) (NYSDOT, 2023)	Produced by Western Excelsior Corporation (n.d.)
Excel CC-4	Biodegradable jute netting, 100% coconut fiber blanket	Longevity of 36 months, slopes of and less than 1:1	Class II Type D (Intermediate) (NYSDOT, 2023)	Produced by Western Excelsior Corporation (n.d.)
SC3000BD	Biodegradable jute netting, 70% straw 30% coconut fiber blanket	Longevity of 24 months, slopes of and less than 2:1	Category 4N-straw/coir (MnDOT, 2018)	Produced by Enviroscape ECM (n.d.-b)
C4000BD	Biodegradable jute netting, 100% coconut fiber blanket	Longevity of 36 months, slopes of and less than 1:1	Class II Type C (Intermediate), (NYSDOT, 2023)	Produced by Enviroscape ECM (n.d.-a)
C4000BD	Biodegradable jute netting, 100% coconut fiber blanket	Longevity of 36 months, slopes of and less than 1:1	Class II Type C (Intermediate), (NYSDOT, 2023)	Produced by Enviroscape ECM (n.d.-a)

CHAPTER 4: METHODOLOGY

TESTING PROTOCOL

Testing Apparatus

To investigate the technical performance of ECBs, the testing protocol for this study is based on American Society for Testing and Materials (ASTM) standard D6459-19 (2019). Experiments were conducted at the Erosion Control Research and Training Center located at the south farm of the University of Illinois Urbana-Champaign. All testing apparatus, including the rainfall simulator, test plot, and water supply, were set up on or near a berm (3H:1V slope), as illustrated in Figure 6. The water supply came from the nearby workshop all the way to the water tank (1,000 gal) at the toe area of the testing berm. There are four testing plots on the berm, each with an 8 ft width and a 32 ft length. A pump was used to deliver the water from the water tank to the testing plot, around which 10 rainfall sprinklers were installed. The detailed rainfall simulator layout is illustrated in Figure 7. Four nozzles on each rainfall sprinkler sprayed water on the testing plot to generate artificial rainfall (Figure 8). An impervious tarp (Figure 9) covered the converging pan to avoid direct rainfall on the pan, which caused unexpected sooner runoff. Twenty rain gauges (Figure 10) were mounted on the testing plot in two rows with the same spacing to measure the rainfall intensity and uniformity for each single test (Figure 9).

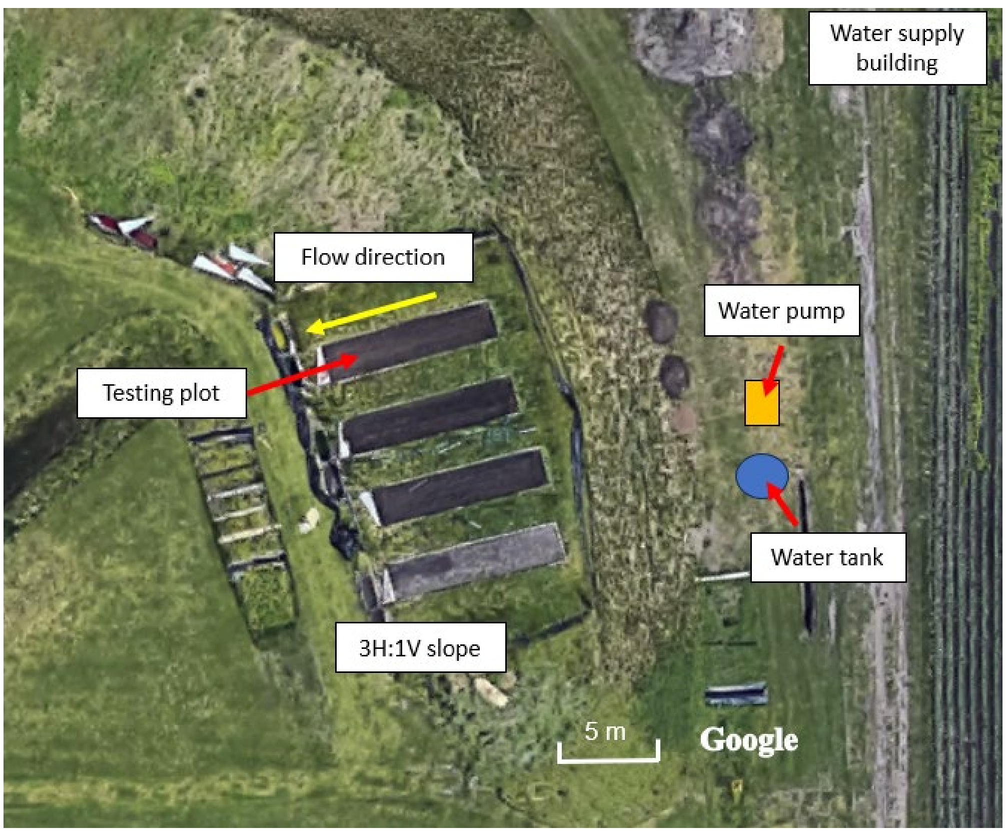


Figure 6. Photo. Experimental set-up at the Erosion Control Research and Training Center.

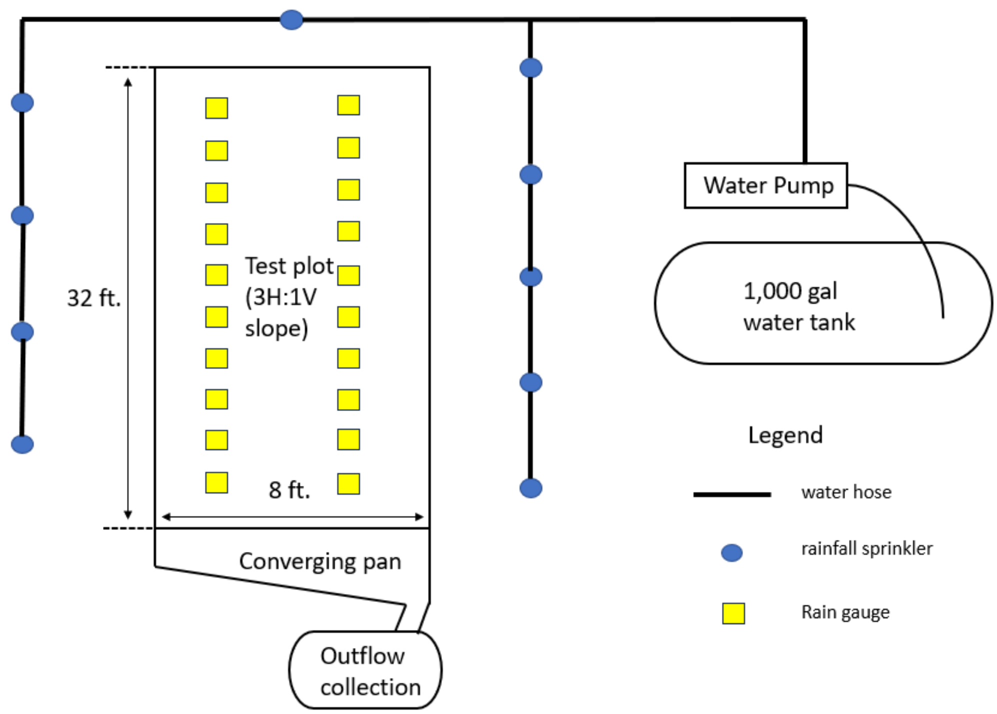


Figure 7. Graph. Plan view of testing apparatus.

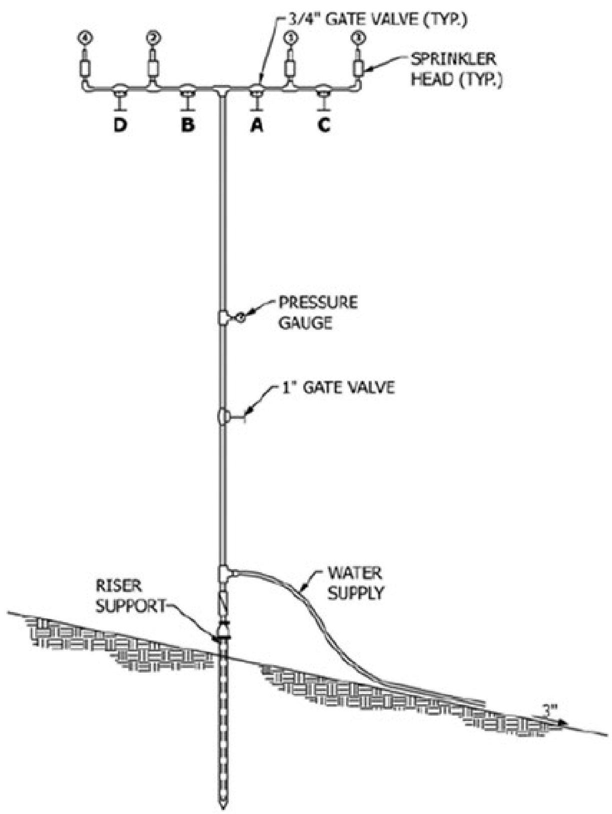
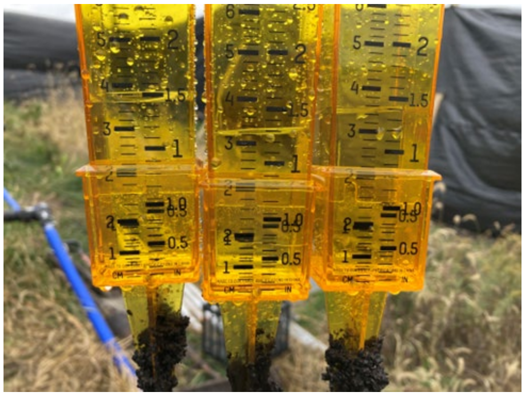


Figure 8. Graph. Rainfall sprinkler (ASTM D6459, 2019).

Figure 9. Photo. Test plot with rain gauges and tarp on the pan avoiding direct rainfall.

A. Rain gauge mounted on the slope



B. Rain gauge reading

Figure 10. Photos. Rain gauges.

Designed Storm Events

Based on ASTM D6459-19 (2019), a rainfall event with an intensity of 2 in./hr was simulated by adjusting the nozzle opening. The rainfall uniformity was examined in this study according to the Christiansen uniformity coefficient (C_u), which was calculated in the following formula in Figure 11:

$$C_u = 100\left[1.00 - \sum|d| \div n\bar{X}\right]$$

Figure 11. Equation. Christiansen uniformity coefficient.

Where:

- C_u = Christiansen uniformity coefficient
- $d = X_i - \bar{x}$
- n = number of observations (20 in this case)
- $\bar{x}$ = average depth caught
- X_i = depth caught in each rain gauge

According to the literature review (Luk et al., 1993; Merkley, 2001), a rainfall simulator is acceptable when the C_u value is over 70% for large-scale testing. The rainfall simulator was calibrated every year before resuming the test.

Sample Collection

At the end of the testing plot, a tilted converging pan was installed to converge all the outflow to a runoff collection device, where grab samples were also examined for flow rate measurement and total sediment concentration analysis (Figures 7 and 12). When the flow rate was too high and a 250 mL sample jar was filled quickly, a mini bucket with a capacity of 2 L (Figure 13) was used to measure the flow rate by recording the time duration. Several buckets with a capacity of 13 L (Figure 14) were used to measure the total runoff volume.

Figure 12. Photo. Sample collecting.

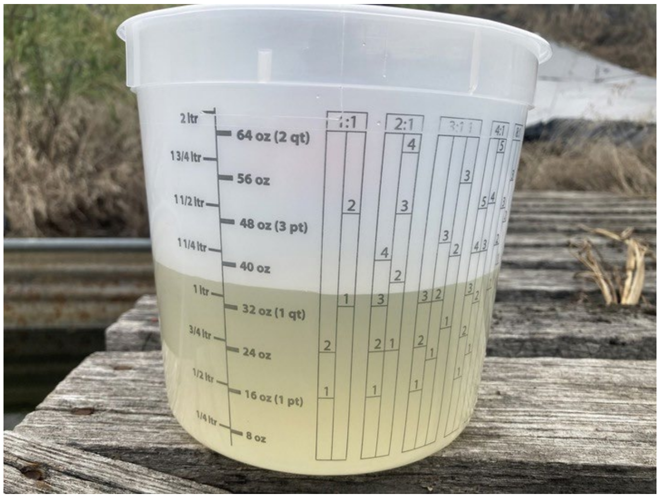


Figure 13. Photo. Mini bucket (2-liter capacity).

Figure 14. Photo. Runoff reading (13-liter capacity).

Laboratory Analysis

Total sediment concentration analysis is based on ASTM D3977 (2013). As samples were acquired during the experiment, they were organized based on time duration from initial to final. The samples were taken to the lab, where they were weighed (W1) (Figure 15). Jars were then placed in an oven at 98°C for 48 to 72 hours to evaporate the water. Once the water evaporated, the bottles containing soil residue were weighed again (W2) (Figure 16). The bottles were washed and weighed (W3). The weight of the soil residue was obtained by subtracting W3 from W2 (W4 = W2 − W3).

Figure 15. Photo. Water/sediment sample weighing (W1).

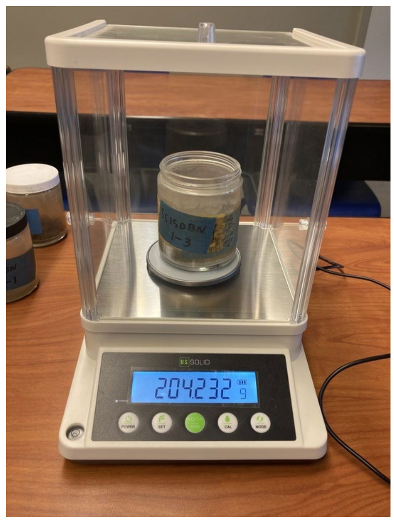


Figure 16. Photo. Dried sediment sample weighing (W2).

Evaluation Criteria

Technical performance represents how well the product protects soil from being detached and transported. For the purposes of this report, technical performance specifically refers to runoff trapping efficiency (RRE) and sediment trapping efficiency (SRE), which were calculated as shown in Figure 17 and 18.

$$RRE = \frac{V_{bare} - V_i}{V_{bare}}$$

Figure 17. Equation. Runoff trapping efficiency.

$$SRE = \frac{M_{bare} - M_i}{M_{bare}}$$

Figure 18. Equation. Sediment trapping efficiency.

Here, V_{bare} - the total runoff volume under the bare soil plot (L)

V_i - the total runoff volume under a certain ECB (L)

M_{bare} - the total sediment yield under the bare soil plot (kg)

M_i - the total sediment yield under a certain ECB (kg)

It should be noted that the sum of SRE and soil loss ratio (SLR), commonly used in calculating C-factor in soil erosion prediction models, is equal to 100%.

PRODUCT INTRODUCTION AND INSTALLATION

Ten products (Table 2), including four traditional ECBs (plastic net) and six net- or plastic-free ECBs, were tested. Besides the product testing, tests with bare soil subjected to the simulated rainfall were also examined as a baseline to compute the efficiency.

Traditional Erosion Control Blankets (Plastic Netting)

Products categorized as traditional ECBs typically contain plastic nets on either one side or both sides of the material matrix.

American Excelsior Curlex® I

The American Excelsior Curlex® I blanket consists of wood fiber material and a polypropylene net on the top side, as illustrated in Figure 19. When the wood fiber gets wet, it expands and interlocks to form a strong fiber matrix, which allows the blanket to have close contact with the slope surface (Curlex® I and II Blankets Brochure, 2023).

Figure 19. Photo. American Excelsior Curlex® I close-up.

American Excelsior Curlex® II

The American Excelsior Curlex® II blanket is almost the same as the Curlex® I blanket, but it has polypropylene nets on both sides. Figure 20 shows Curlex® II placed on the plot before the rainfall.

Figure 20. Photo. American Excelsior Curlex® II placed on the slope.

North American Green DS75

North American Green DS75 is made of a 100% straw fiber matrix with a polypropylene net on the top, as illustrated in Figure 21.

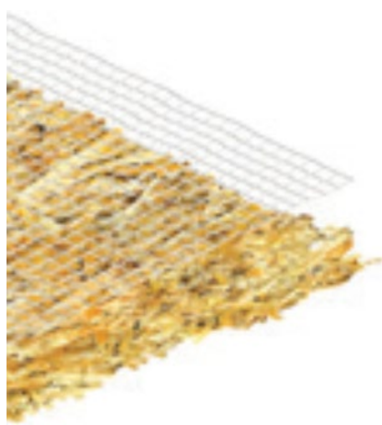


Figure 21. Photo. North American Green DS75 components.

North American Green SC150

North American Green SC150 consists of a fiber matrix made of 70% straw and 30% coconut coir and heavy weight polypropylene nets on the top side, and light weight polypropylene nets on the bottom side, as illustrated in Figure 22.

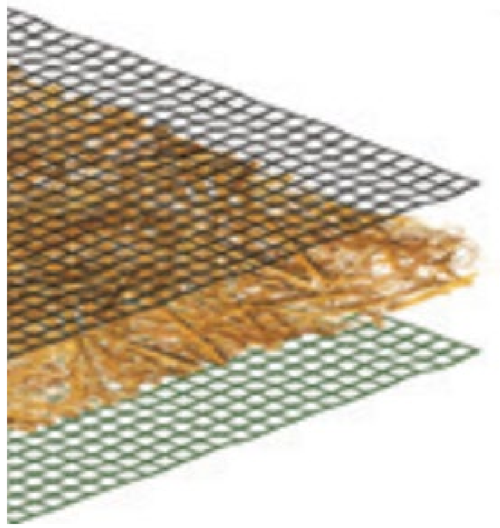


Figure 22. Photo. North American Green SC150 components.

Net- and Plastic-Free Erosion Control Blankets

Products are categorized as net- or plastic-free ECBs because they have either no net or a fiber net to hold the material matrix in place.

American Excelsior Curlex® Netfree™

The American Excelsior Curlex® Netfree™ blanket is made of 100% wood fiber without a net holding the fiber matrix, as illustrated in Figure 23.

Figure 23. Photo. American Excelsior Curlex® Netfree™ close-up (Curlex® NetFree™ Product Description, 2023).

American Excelsior Curlex® I FibreNet

The American Excelsior Curlex® I FibreNet consists of a 100% wood fiber matrix and jute net on the top side, as shown in Figure 24.

Figure 24. Photo. American Excelsior Curlex® I FibreNet close-up.

American Excelsior Curlex® II FibreNet

The American Excelsior Curlex® II FibreNet blanket is almost the same as the Curlex® I FibreNet blanket, but it has jute nets on both sides. Figure 25 shows Curlex® II FibreNet blanket placed on the slope before the test.

Figure 25. Photo. American Excelsior Curlex® II FibreNet placed on a slope.

North American Green SC150BN

North American Green SC150BN consists of a fiber matrix made of 70% straw and 30% coconut coir and jute nets on both sides, as shown in Figure 26.

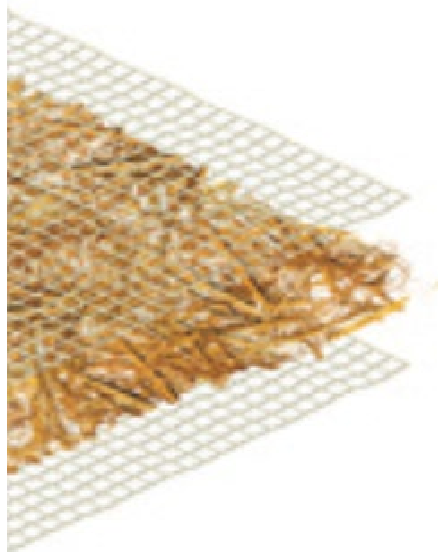


Figure 26. Photo. North American Green SC150BN components.

North American Green C125BN

North American Green C125BN consists of a 100% coconut coir fiber matrix and jute net on both sides, as illustrated in Figure 27.

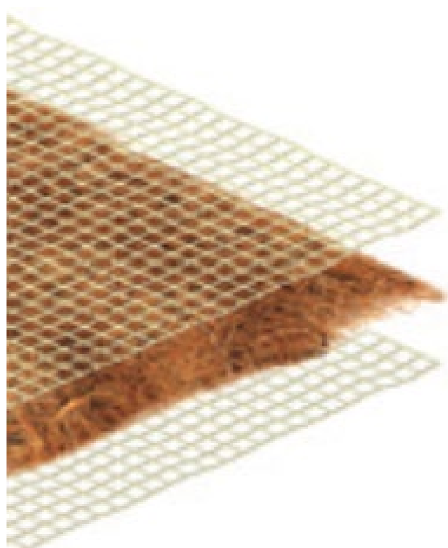


Figure 27. Photo. North American Green C125BN components.

Profile F4 Netless

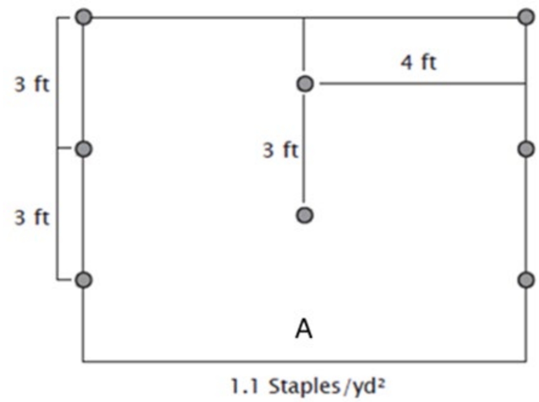
The Profile F4 Netless blanket is made of thermally refined wood and degradable man-made fibers that are intertwined into a matrix. Figure 28 shows Profile F4 Netless blanket placed on the testing plot with rain gauges on.

Figure 28. Photo. Profile F4 Netless placed on the slope.

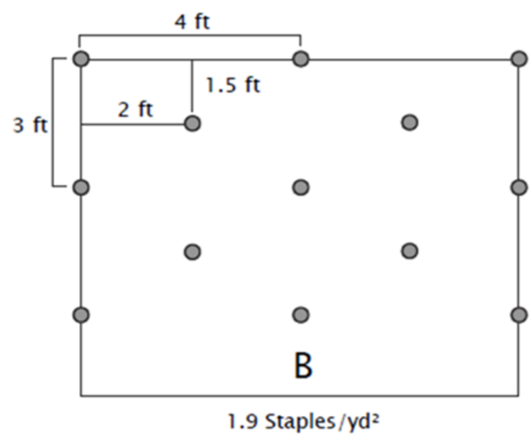
Installation

The installation method is as follows:

- Dig a trench on the top of the testing plot and place one end of the product into the trench.
- Staple the blanket in the trench and backfill.
- Unroll the blanket along the slope.
- Staple the blanket in the pattern of either A or B, depending on the potential of losing matrix materials (Figure 29). Table 2 shows which staple pattern has been applied to a certain ECB.
- Use extra staples on the bottom of the blanket.



A. Pattern A



B. Pattern B

Figure 29. Graph. Staple pattern.

CHAPTER 5: RESULTS AND DISCUSSION

PRODUCT EVALUATION

Ten products were evaluated in terms of technical performance (sediment trapping efficiency), cost, ease of installation/removal, vegetation growth potential, and degradation rate.

Technical Performance

Each product was tested twice, and the test results are provided in Table 2. Figure 30 presents the average sediment trapping efficiency for each tested ECB according to two tests. All ECBs performed very well in trapping sediment with more than 94% trapping efficiency, which indicates the top priority should go with cost, availability, ease of installation/removal, or sustainability rather than the technical performance when selecting an ECB. Figure 31 shows the rank in terms of the average runoff trapping efficiency of various products.

Table 2. Test Recording Data

Product	Test ID	Staple pattern	Wv (%)	WS (mph)	I (in/hr)	Cu (%)	Total runoff (V)	Sediment yield (g)
Bare Soil	1-1		30.70	8	2.00		284.74	3696.74
Bare Soil	1-2		31.80	5	2.26	75	136.23	2787.11
NAG-DS75	2-1	B	31.00	6	2.00		194.76	198.93
NAG-DS75	2-2	B	32.20	7	2.00		133.40	105.96
NAG-SC150	3-1	A	29.40	5	2.00		154.17	171.94
NAG-SC150	3-2	A	33.00	9	2.00		175.39	133.07
AE-Curlex® I	4-1	B	29.10	5	2.06	73	0	0
AE-Curlex® I	4-2	B	29.00	9	1.69	72	0	0
AE-Curlex® II	5-1	A	31.40	8	2.23	64	137.22	227.31
AE-Curlex® II	5-2	A	31	5	2.27	74	78.05	131.39
AE-Curlex® Netfree	6-1	B	30.70	6	2.00		61.77	55.23
AE-Curlex® Netfree	6-2	B	32.50	6	2.00		73.97	41.29
AE-Curlex® I Fibernet	7-1	B	33.50	7	2.00		44.19	22.91
AE-Curlex® I Fibernet	7-2	B	30.20	6	2.18	61	29.49	53.09
AE-Curlex® II Fibernet	8-1	A	32.00	9	2.00		46.23	17.23
AE-Curlex® II Fibernet	8-2	A	30.20	7	2.00		44.05	22.73
NAG-SC150BN	9-1	A	30.50	5	2.00		0.80	6.55
NAG-SC150BN	9-2	A	29.50	4	2.23	69	10.75	118.78
NAG-C125BN	10-1	A	30.00	6	1.63	63	0	0
NAG-C125BN	10-2	A	28.50	4	2.18	77	1.88	0.77
Profile-F4 Netless	11-1	B	30.10	1	2.25	74	8.38	4.78
Profile-F4 Netless	11-2	B	30.90	5	2.10	73	2.01	1.34

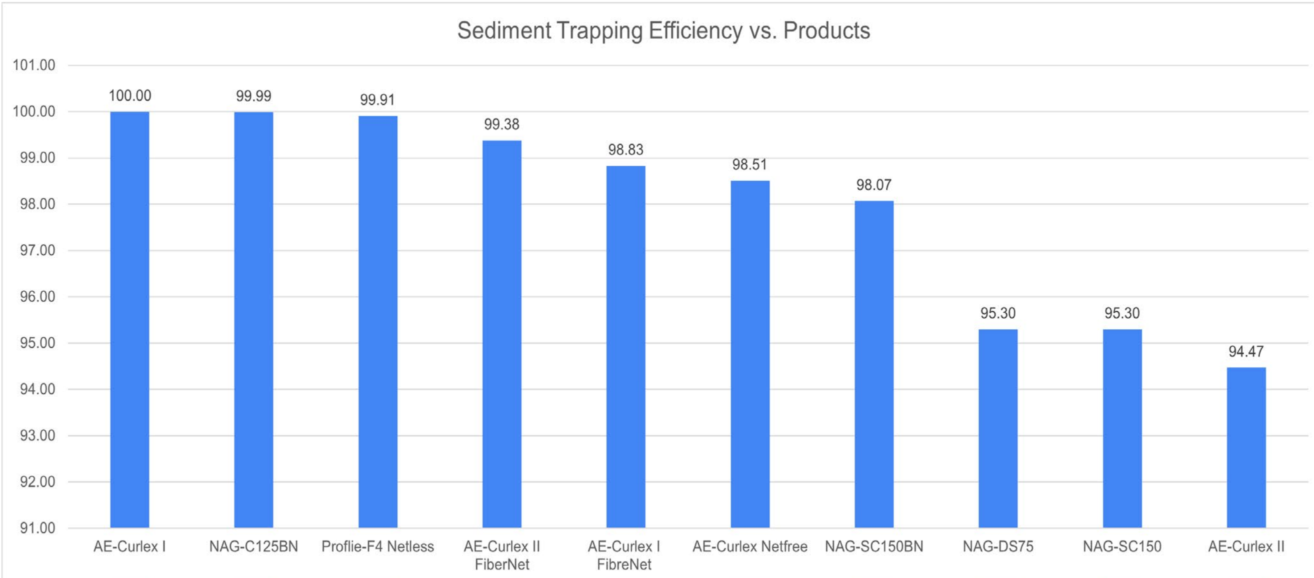


Figure 30. Graph. Sediment trapping efficiency of various products.

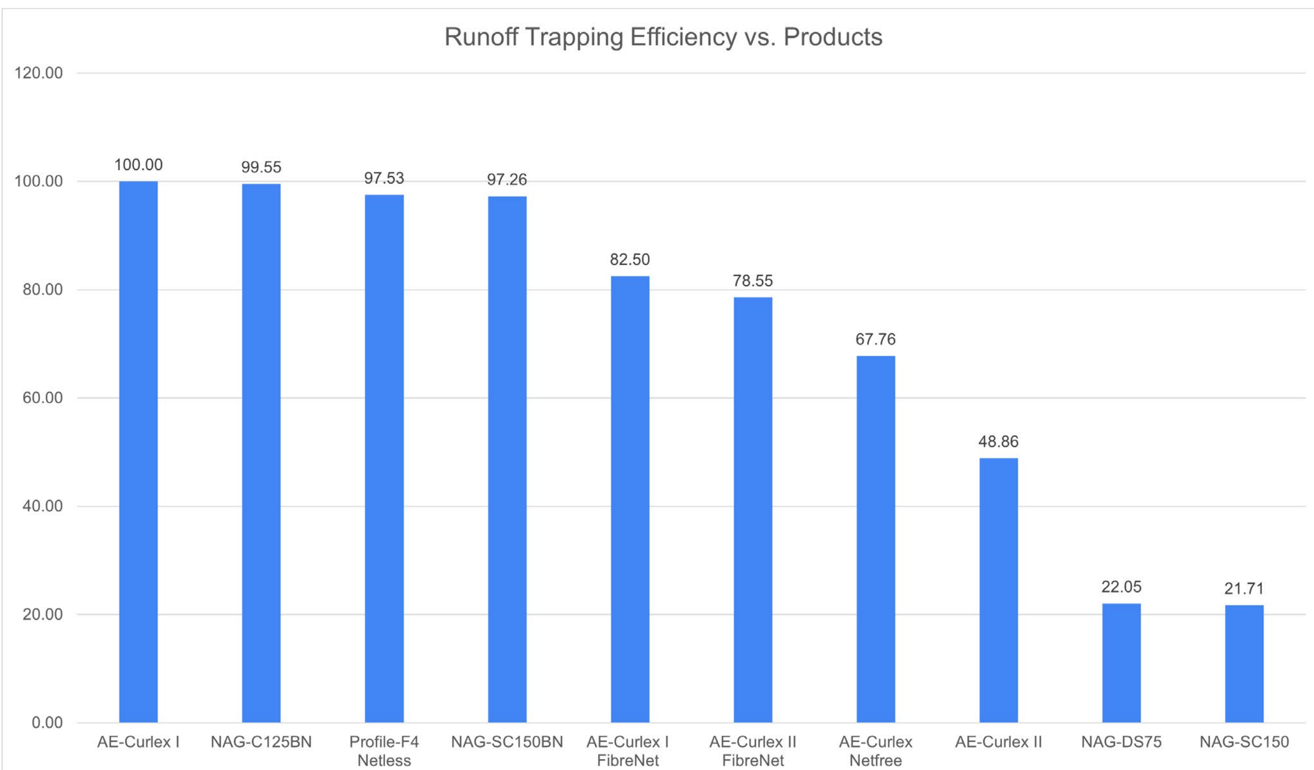
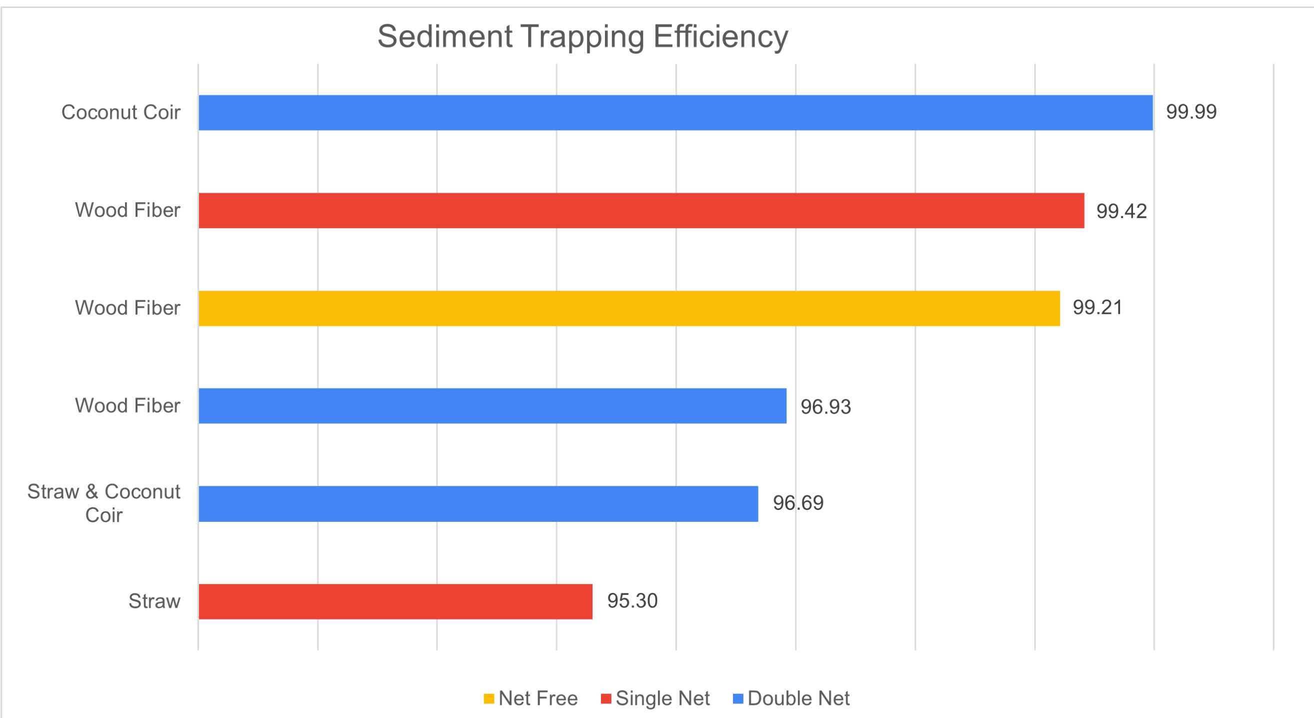


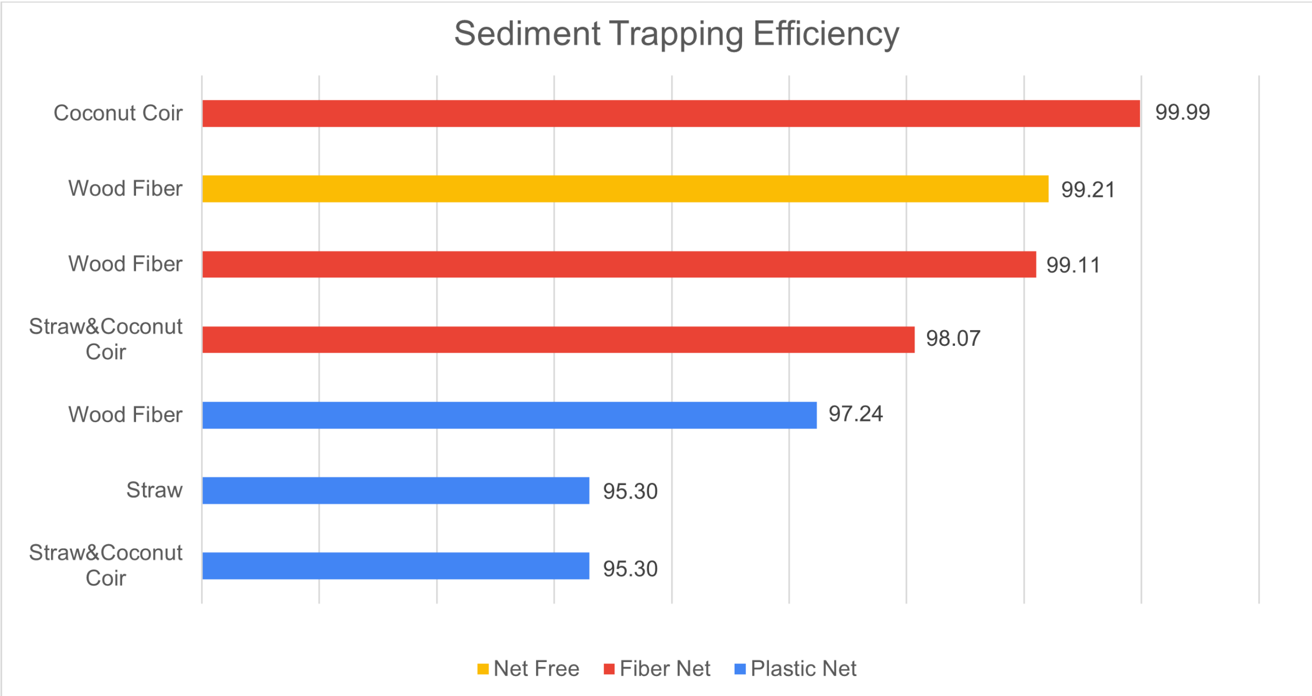
Figure 31. Graph. Runoff trapping efficiency of various products.

Figure 32-A and 33-A indicate coconut coir and wood fiber performed very well in trapping the sediment on-site and reducing the runoff. However, straw fiber has adverse effects on performance. Based on the researchers' observations, wood fiber and coconut coir were good at absorbing water and afterward acted like a wet film, sticking on the slope tightly to prevent the soil particles from being detached and transported. However, straw fiber did not absorb water and could not have good ground contact once the soil profile got saturated. This caused a thin water layer between the slope surface and the ECB, which does not help with runoff reduction and sediment trapping. This observation is also reflected in Figures 31, where products with straw as components only trap about 20% runoff, while others can achieve at least more than 48%. In addition, Figure 32-A demonstrates that the net type (double-net, single-net, net-free) has no significant effect on the performance.

Figure 32-B and Figure 33-B show a jute net helped to improve performance compared to a plastic net in terms of straw and coconut coir mix fiber, but not for the wood fiber because wood fiber contributes a lot in trapping sediment by absorbing water.

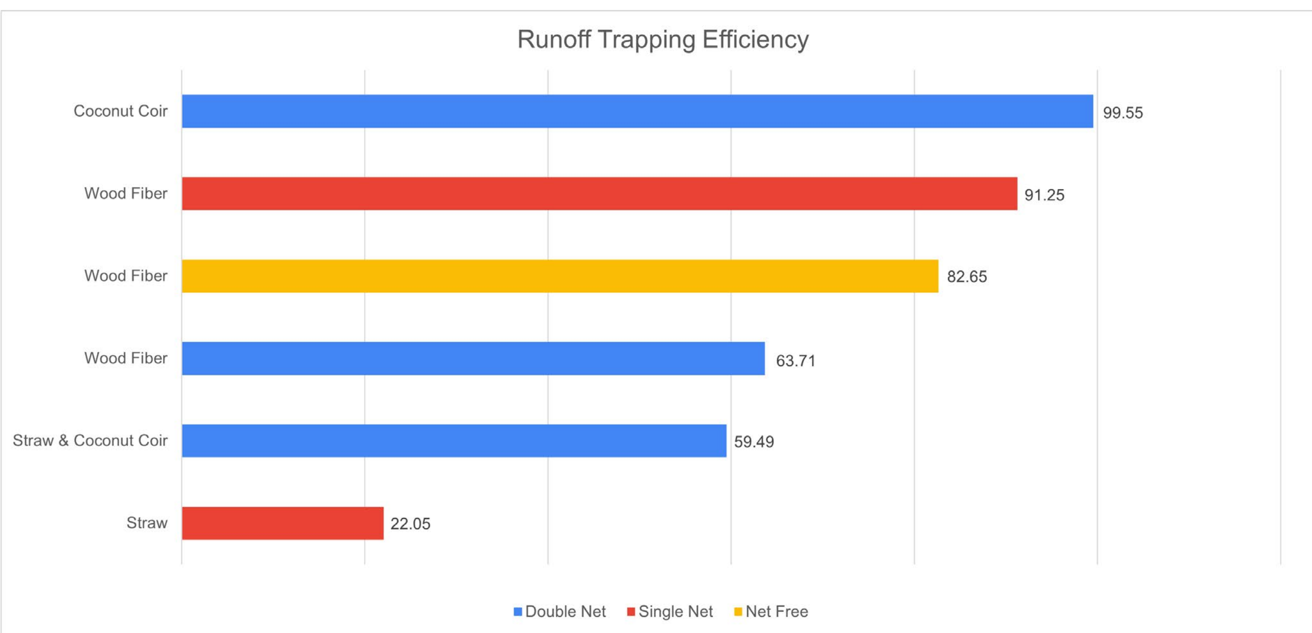


A. Categorized by net count

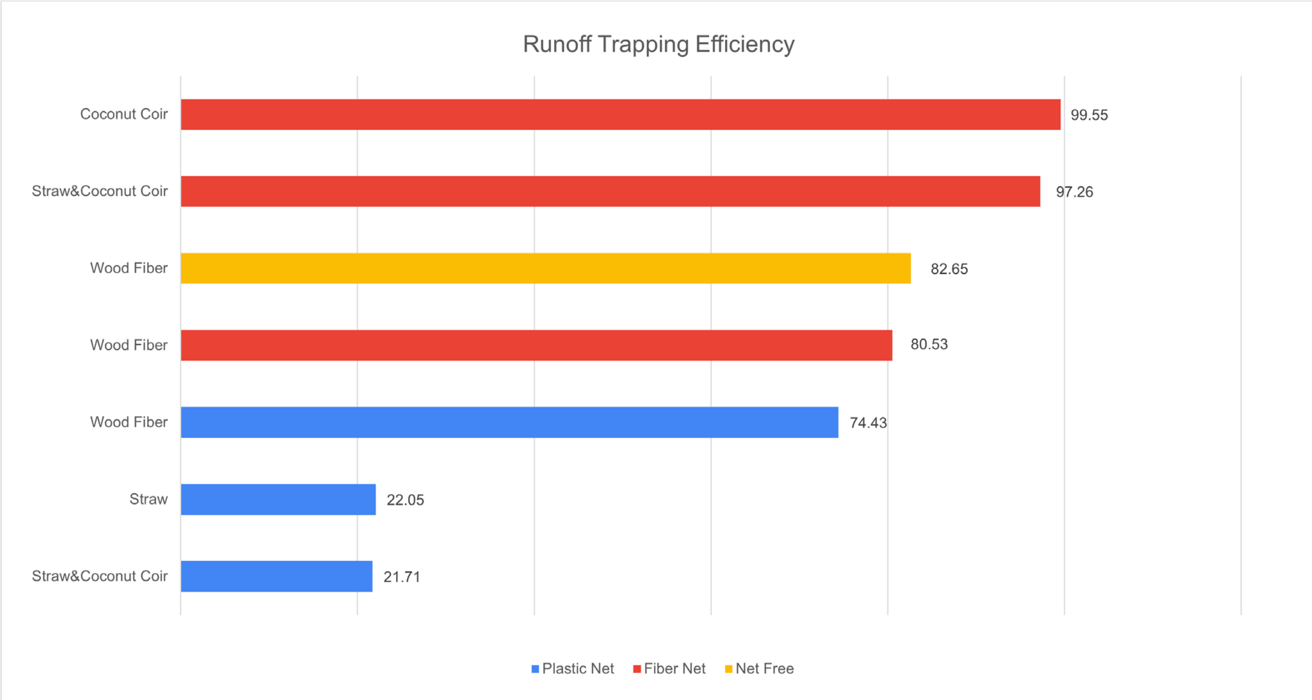


B. Categorized by net material

Figure 32. Graph. Sediment trapping efficiency versus matrix material.



A. Categorized by net count



B. Categorized by net material

Figure 33. Graph. Runoff trapping efficiency versus matrix material.

Figure 34 shows that there is no significant difference in rainfall uniformity between different wind speed ranges, here 1–3 mph was defined as low wind speed, 4–6 mph was defined as medium speed, and 7–9 mph was defined as high speed. This finding indicates that wind screens are not necessary as long as researchers do not run a test when the wind speed is higher than 10 mph.

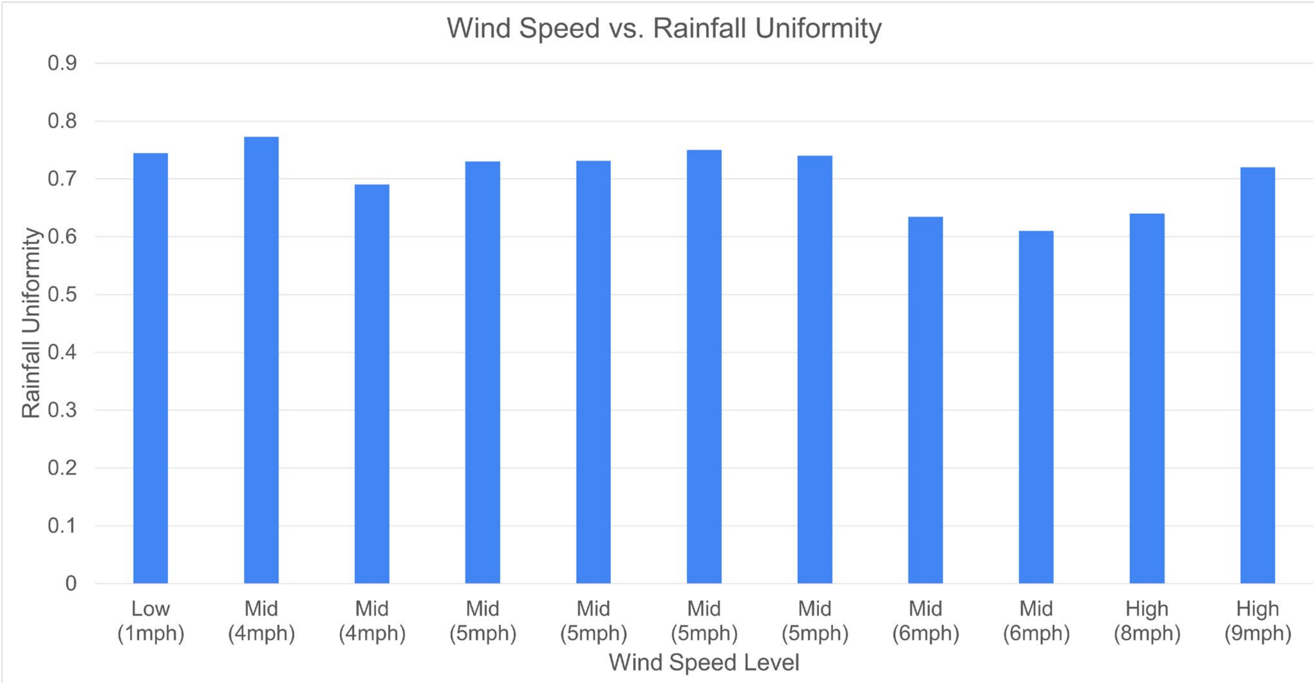


Figure 34. Graph. Effect of wind speed on rainfall uniformity.

Cost Analysis

In this study, the American Excelsior Curlex® II FibreNet has the least cost efficiency with $1.3/sq. yd., which is more than three times that of North American Green DS75 (Figure 35).

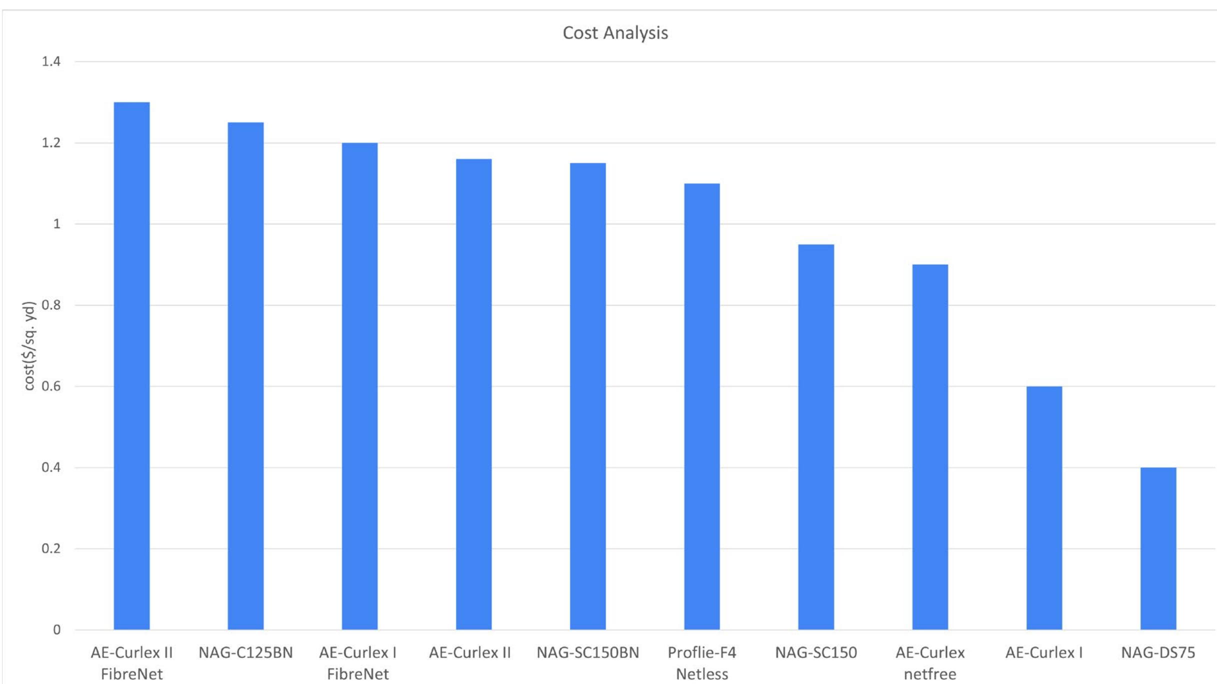


Figure 35. Graph. Cost of various products.

Ease of Installation/Removal

Because the installation approach is the same for each product except for the staple pattern, the product weight is the only parameter affecting the ease of installation and removal (Figure 36).

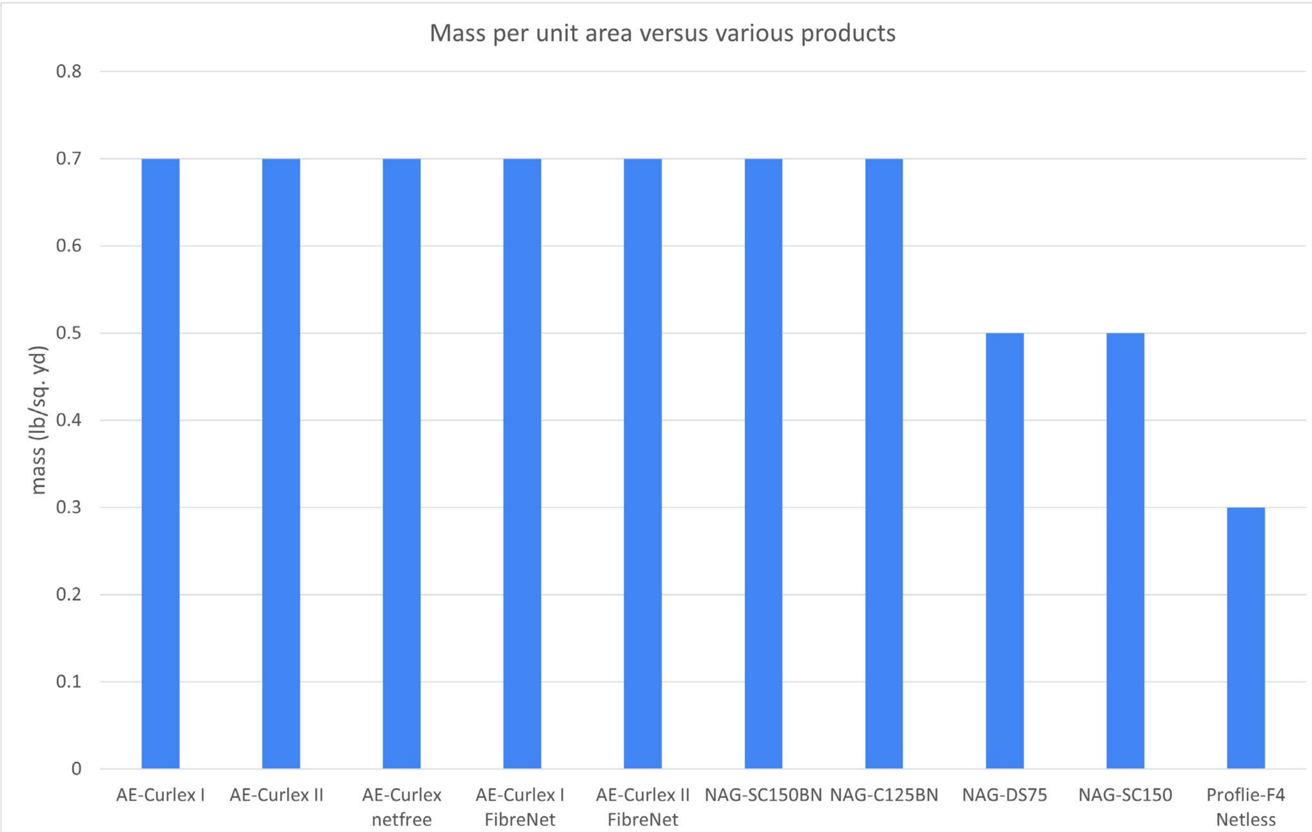


Figure 36. Graph. Mass per unit area of various products.

In this study, the lightest product was Profile F4 Netless, which is more than two times lighter than most ECBs studied.

Degradation Observation

The F4 Netless blanket is easy to rip into small pieces, even before use, which has less potential for mowing machines to be entangled (Figure 37). Because there is no net in this case, animals are not supposed to be trapped in it.

A. Material left on-site right after the test

B. Ripped material after two months

Figure 37. Photo. F4 Netless material degradation after two months.

The jute net still existed on-site after six months, which brings a risk of animal and mowing machine entanglement (Figure 38). For the blanket with netting, the blanket matrix (wood fiber in the case of Curlex) degraded gradually. However, the plastic netting was clearly visible even after six months (Figure 39 and 40).

A. Right after the test

B. After two months

C. After almost six months

Figure 38. Photo. Jute net degradation.

Figure 39. Photo. Wood fiber degradation.

Figure 40. Photo. Plastic net left on-site permanently.

CHAPTER 6: CONCLUSION AND RECOMMENDATIONS

Based on the observations and data analysis, the following conclusions or recommendations are provided:

1. As the matrix material, wood fiber and coconut coir outperformed straw fiber by absorbing more water during the storm event, delaying the saturation of the soil profile.

2. Whatever matrix material was used, all ECBs performed well in sediment trapping with more than 95% efficiency compared to the bare soil.

3. Technical performance should not be the top priority when a designer selects a blanket, considering there were no obvious differences in sediment trapping efficiency between different products.

4. North American Green DS75 is the most cost-efficient product, with $0.4/sq. yd. in this study. Most ECBs have a cost of more than $0.9/sq. yd.

5. The Profile F4 Netless blanket is the lightest product in this study, with 0.3 lb/sq. yd. Most ECBs have a mass per unit area of 0.7 lb/sq. yd.

6. The Profile F4 Netless blanket performed the best in terms of the highest degradation rate.

7. The jute net did not degrade well, even over six months, which could cause entanglement issues.

8. Cost should be the top priority, considering similar performance in technical and sustainability. A product with a high degradation rate could be utilized.

9. A higher rainfall intensity scenario is recommended to be explored in the future to evaluate whether these ECBs still perform similarly in trapping sediment on a slope.

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