WHICH DEGRADABLE ROLLED EROSION CONTROL PRODUCT (RECP) SHOULD I USE FOR SLOPE PROTECTION?

Kurt Kelsey – Research Scientist
Tony Johnson – National Research Director
Ryan Vavra – ErosionLab Manager
American Excelsior Company
Rice Lake, WI

INTRODUCTION

Stormwater runoff is a growing problem that recently has been emphasized by the US EPA through the Phase II National Pollutant Discharge Elimination System (NPDES) permitting process. Rolled erosion control products (RECPs) are only one of the many families of best management practices designed to improve stormwater runoff quality. The goal of RECPs is to minimize soil erosion, which reduces the amount of soil particles that potentially could end up in storm water runoff.

Many people frequently ask the question of "which RECP should I use for slope protection?" because there are so many different makes and manufacturers to choose from today. Degradable RECPs are commonly comprised of wood, straw, coconut, or straw/coconut blends that are bound together to form a continuous blanket-like configuration. Products are manufactured with no netting, netting on the top of the product only, or netting on both the top and bottom of the product. There are many RECPs with different properties to consider when selecting the right product for the right job.

COMMON RECPS

<u>Wood Fiber RECPs</u>

Wood fiber RECPs for the use of erosion control and vegetation establishment evolved in the 1960s as the original breed of erosion control blanket (ECB). The fibers are stitched or glued together to form a continuous matrix. Wood fiber RECPs are produced with no netting, netting on the top side only, or netting on both the top and bottom. Wood fiber RECPs are commonly manufactured at approximately .75 lb/yd^2 (.41 kg/m^2) up to 1.65 lb/yd^2 (0.90 kg/m^2) and have a functional longevity ranging from 12 to 36 months. It is important to remember at all times that functional longevity varies from region to region because of differences in climatic conditions.

<u>Straw RECPs</u>

Straw RECPs contain straw fibers stitched to netting on the top or both top and bottom of the product. Netting is essential to maintain the integrity of straw blankets because the straight straw fibers cannot interlock together on their own. Straw RECPs are commonly manufactured at .50 lb/yd^2 (.27 kg/m^2) and have a maximum functional longevity of 12 months.

<u>Straw/Coconut Blended RECPs</u>

Straw/Coconut blended RECPs commonly contain 70% straw fibers and 30% coconut fibers by weight. The RECPs commonly contain the blended fibers stitched to UV stabilized netting on both the top and bottom of the product. The blend is commonly manufactured at .50 lb/yd^2 and is given a functional longevity up to 24 months. One thing to consider when selecting a straw/coconut blend RECP is that 70% of the product consists of straw fibers, which the erosion control industry agrees have a functional longevity up to one year (Erosion Control..., 2004). Therefore, only 30% of the straw/coconut blend matrix remains "functional" for the second 12 months of the product's life.

100% Coconut RECPs

Coconut RECPs contain coconut fibers that are commonly stitched to heavy duty UV stabilized netting on both the top and bottom of the product. Coconut RECPs are commonly manufactured at .50 lb/yd^2 (.27 kg/m^2) and have a functional longevity up to 36 months.

RECP COMPONENTS

RECP Netting

There are many different types of nettings used on RECPs. Biodegradable Jute netting is commonly used on products that will be installed in areas that are deemed environmentally sensitive. Jute netting does not contain any welded joints. Historically, the absence of welded joints has been believed to prevent wildlife entrapment. Many of the other frequently used RECP nettings are polypropylene. There are numerous grades of polypropylene used on RECPs. Rapid degradable netting, which is usually white in color and degrades within 90 days, contains a UV degrader additive that accelerates photo-degradation. The most frequently used netting on degradable RECPs is a green polypropylene netting, which contains a UV stabilizer that slows photo-degradation. Thicker polypropylene nettings are generally black in color and may contain UV stabilizers that prolong the longevity of the products. Additional materials are used to manufacture RECP nettings, but they are not seen as frequently as the Jute and polypropylene products.

RECP Thread

A majority of the RECPs manufactured today affix the fibers of the product by stitching to one or more of the netting types described above; however, it should be noted that a few manufactures provide RECPs that are glued to the netting instead of stitched. The most common type of thread material used on RECPs is composed of polypropylene. The longevity of the photo-degradable polypropylene thread material can be matched to longevity of the fibers and the netting of a particular product. Other thread materials used on RECPs include cotton, polyester, polyolefin, rayon, and various yarns (Texas Department..., 2004).

SELECTION CRITERIA

Performance

The most important factor to consider when selecting the proper RECP for a job site is the product's ability to perform. All RECPs work when installed properly in conditions the product was designed for, but not all RECPs can be utilized on steeper slopes. In addition, some RECPs perform much better than other similar products. Selecting a product that will provide superior slope erosion performance for each specific project is a must in order to stay in compliance with potentially costly NPDES Phase II litigations, which are gaining more and more enforcement support each day.

Slope Rating

Degradable RECPs are designed to be used within certain slope classes. Properties unique to each type of RECP determine the maximum slope the product is rated to. Figure 1 illustrates the maximum slope rating for common degradable RECPs (Erosion Control..., 2004). Product failure may occur when a RECP is installed on a slope steeper than it is designed for.

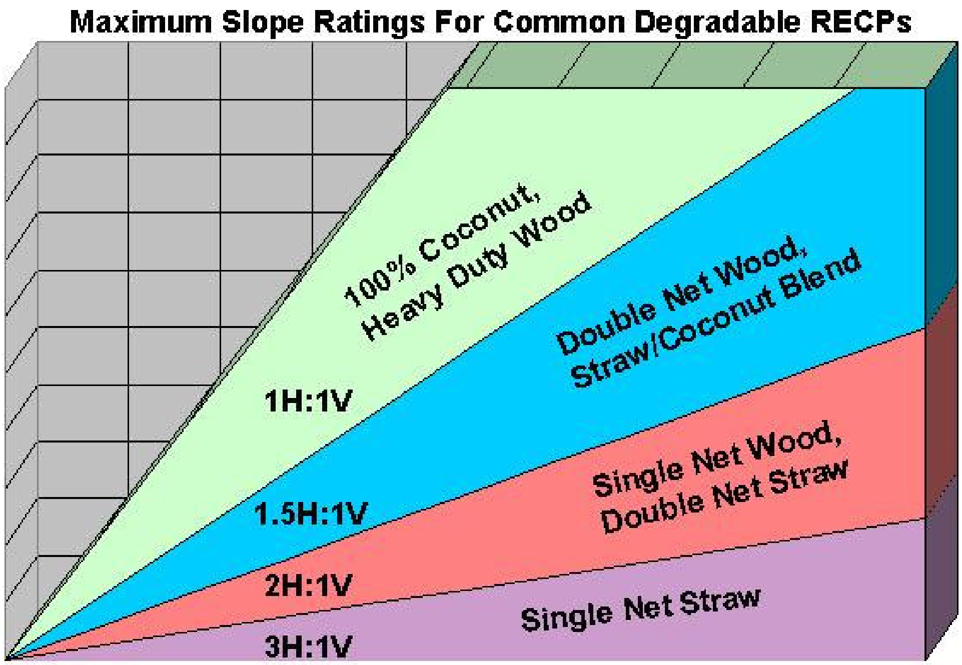

Figure 1. Maximum slope ratings for common degradable RECPs.

Cost
Another important factor to consider when selecting the proper RECP is cost. Some of the reasons why RECPs vary in cost are due to differences in raw material of the fiber, netting used, and threading. The products that were evaluated in this study are priced in general according to Figure 2.

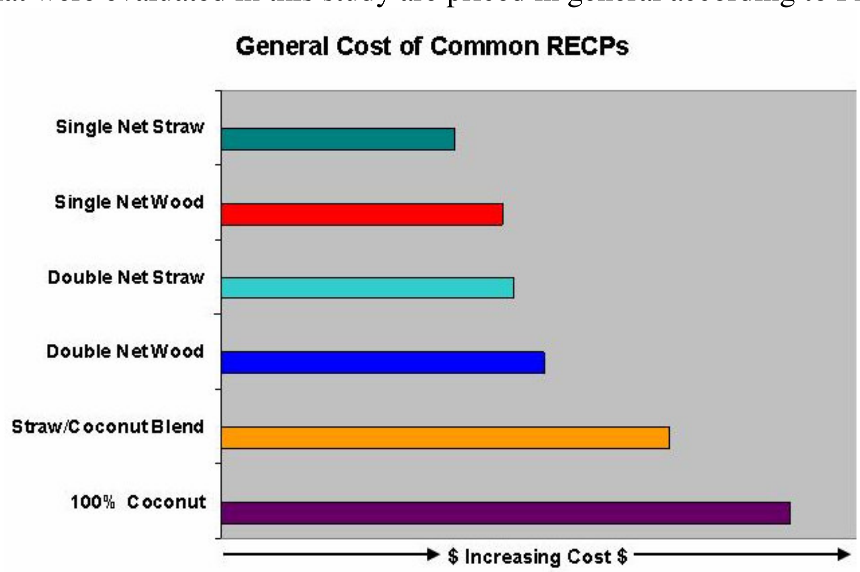

Figure 2. General cost of RECPs that are commonly used for erosion control and vegetation establishment.

Vegetation Establishment
The ability of an RECP to foster ideal growing conditions that result in an established stand of vegetation is extremely critical. Degradable RECPs provide soil erosion protection during the period of germination and plant establishment. An established stand of vegetation is a must with degradable RECPs because the vegetation alone needs to provide erosion protection after the RECP degrades. Many studies have been conducted on the ability of various degradable RECPs to enhance vegetation

growth; however, the results of these studies are inconsistent (Benik et. al., 2000; Holdridge, 1996; Texas Department..., 2004). The inconsistent results may be due to differences in the soil type, seed mixture, aspect, sunlight intensity, and precipitation that existed for each particular study. The most important information that can be obtained from vegetation studies on RECPs is that RECPs consistently produce a better stand of vegetation as compared to bare soil conditions.

Functional Longevity

Functional longevity is another factor to consider when selecting a degradable RECP for slope protection. A clear, agreeable definition of functional longevity is hard to find. Some say that functional longevity should be based on the fibers of the RECP, some say the netting of the RECP, some say the stitching material of the RECP, and some say that functional longevity should be based on all the collective components that comprise an RECP. The bottom line is that functional longevity is the period in which a degradable RECP provides successful erosion control and vegetation establishment benefits. The functional longevity of the selected RECP should meet or exceed the time period that is anticipated for vegetation to become established at the jobsite. The maximum functional longevity of common RECPs is displayed in Figure 3. Data for Figure 3 were obtained from the Erosion Control Technology Council (2004).

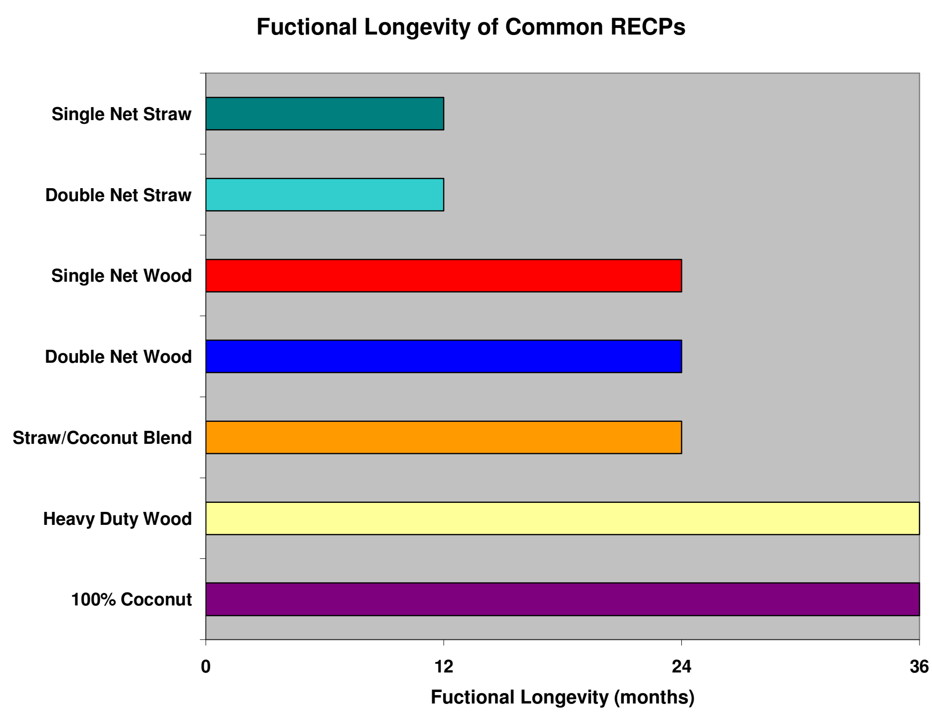

Figure 3. Functional longevity of common degradable RECPs.

OBJECTIVE

The objective of this study is to evaluate the performance capabilities of six RECPs that are commonly used for slope erosion control and vegetation establishment.

METHODS

Study Site

Field work for this study was conducted at American Excelsior Company's ErosionLab™. The Lab is an outdoor erosion control research and development facility located near Rice Lake, Wisconsin. This study used the Rainfall Erosion Facility (REF), which is the simulated rainfall portion of the Lab. Figure 4 shows the rainfall simulator during the 4 in/hr (102 mm/hr) target intensity segment of a test. REF testing follows procedures provided in ASTM D-6459, “Standard Test Method for Determination of Erosion Control Blanket (ECB) Performance in Protecting Hillslopes from Rainfall-Induced Erosion” (ASTM 2001).

Figure 4. Rainfall simulator in action during the 4 in/hr (102 mm/hr) target intensity segment of a test series.

Rainfall Testing Series

Each bare and blanketed plot was subjected to sequential events of approximately 2 in/hr (51 mm/hr), 4 in/hr (102 mm/hr), and 6 in/hr (152 mm/hr). Each of the three test segments lasted 20 minutes. The test series were replicated three times for each surface cover tested. Six rain gauges were randomly placed throughout the plots during each test segment to measure the amount of rainfall applied.

Plot Configurations

The erosion test plots used in this study were 40.0 ft (12.2 m) long by 8.0 ft (2.4 m) wide at a 3H:1V gradient. The steepness of 3H:1V was used so the single net straw RECPs could be included in the study. The single net straw RECPs could not have been evaluated if steeper slopes were used because the product is not recommended for use on slopes steeper than 3H:1V. The test plots are separated from one another by a 16 ft (4.9 m) wide buffer of vegetated soil. Each plot contains either a 100 gallon (379 L) or 223 gallon (844 L) collection tank buried at the bottom of the plot. V-shaped metal flashing at the toe of each plot directs all materials leaving the plot into the collection tanks.

Soil Type

All testing was conducted on test plots containing an imported topsoil material that has a particle size distribution of 49.2% sand, 33.2% silt, and 17.6% clay. The test material is classified as a Loam soil according to the USDA textural triangle.

Erosion Plot Preparation

Each plot tested over the course of the study was prepared the same way. Plots were tilled up and down slope with a walk-behind roto-tiller. The plots were hand-raked to a uniform surface after tillage. Following raking, a 70 lb (32 kg) turf roller was used to lightly compact the material. If RECPs were to be tested, they were then installed on the plots according to manufacturer guidelines. The plots were not manipulated between storm increments. All plots were reconditioned following the last 20 minute storm increment.

RECPs Tested
Six RECPs and bare soil conditions were tested over the course of the study. A series of bare soil tests where no surface cover was added to the plots was used as the control in the study. The RECPs tested included single net wood fiber, double net wood fiber, single net straw, double net straw, straw/coconut blended, and 100% coconut. Table 1 provides properties of the RECPs evaluated in this study.

Table 1. Properties of the six RECPs evaluated.

Product	Composition	Mass Per Unit Area [lb/ft^2 (kg/m^2)]	Netting	Stitching Width [in (cm)]	*Functional Longevity (months)
Single Net Wood	100% Excelsior	.73 (.40)	Green Polypropylene	4.0 (10.2)	≤ 24
Double Net Wood	100% Excelsior	.73 (.40)	Green Polypropylene	4.0 (10.2)	≤ 24
Single Net Straw	100% Straw	.50 (.27)	Green Polypropylene	1.5 (3.8)	≤ 12
Double Net Straw	100% Straw	.50 (.27)	Green Polypropylene	1.5 (3.8)	≤ 12
Straw/Coconut Blend	70% Straw 30% Coconut	.50 (.27)	Black Polypropylene	1.5 (3.8)	≤ 24
Coconut	100% Coconut	.50 (.27)	Heavy Duty Black Polypropylene	1.5 (3.8)	≤ 36

* Values according to the Erosion Control Technology Council (ECTC), 2004.

Data Collection
Once runoff commenced, grab samples were collected every three minutes. Water was decanted from the collection tanks and measured following each 20 minute simulated rainfall event. The soil slurry collected at the toe of each plot was transferred from the collection tanks into pre-weighed pails. The pails were then weighed to determine soil loss on a wet basis. A homogeneous sample of the soil slurry was taken to determine soil moisture content so the equivalent dry basis soil loss could be determined. Samples were analyzed according to ASTM D-4643, "Standard Test Method for Determination of Water (Moisture) Content of Soil by the Microwave Oven Method" (ASTM, 2000). The six rain gauges were also recorded after each 20 minute increment to determine the average depth of rainfall applied to the test plot.

Data Analyses

Soil Loss
The data analyses for determining the RECPs' ability to reduce soil loss were conducted by Ayres Associates (2003, 2003, 2003, 2002, 2002, 2000, 2000). In addition, Ayres Associates provided independent third party QA/QC verification for all testing conducted during this study. The soil loss analyses followed the framework of the Revised Universal Soil Loss Equation (RUSLE) as provided by Renard et. al. (1997). Cumulative soil loss was graphed vs. cumulative rainfall erosivity (R factor) to determine the RECPs' ability to reduce soil. A complete explanation of how the data were analyzed is provided by Kelsey and Johnson (2003).

Runoff
All runoff that exited the test plots was collected and measured. Least Square linear regression was applied to the data sets and cumulative runoff was plotted vs. cumulative rainfall for each test series. The resulting regression lines provide a tool for estimating runoff volumes from plots covered with the six RECPs and bare soil conditions tested. Figure 5 provides all the cumulative runoff vs. cumulative

rainfall data. Figure 6 illustrates an example regression line fitted to the runoff data for the testing performed on single net straw RECPs.

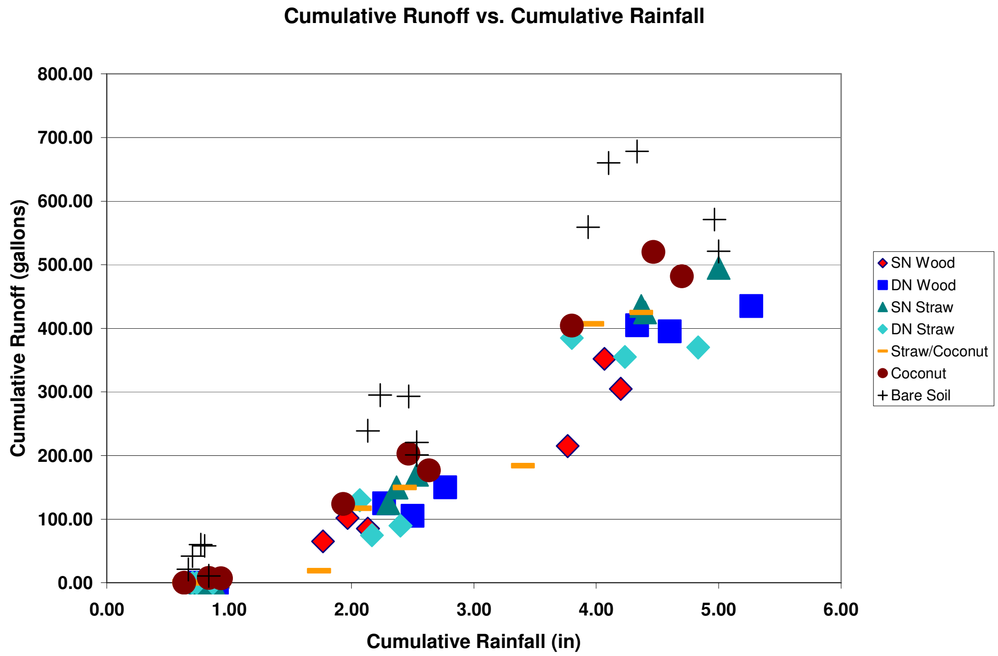

Figure 5. Cumulative Runoff vs. Cumulative Rainfall for the six RECPs and bare soil conditions tested.

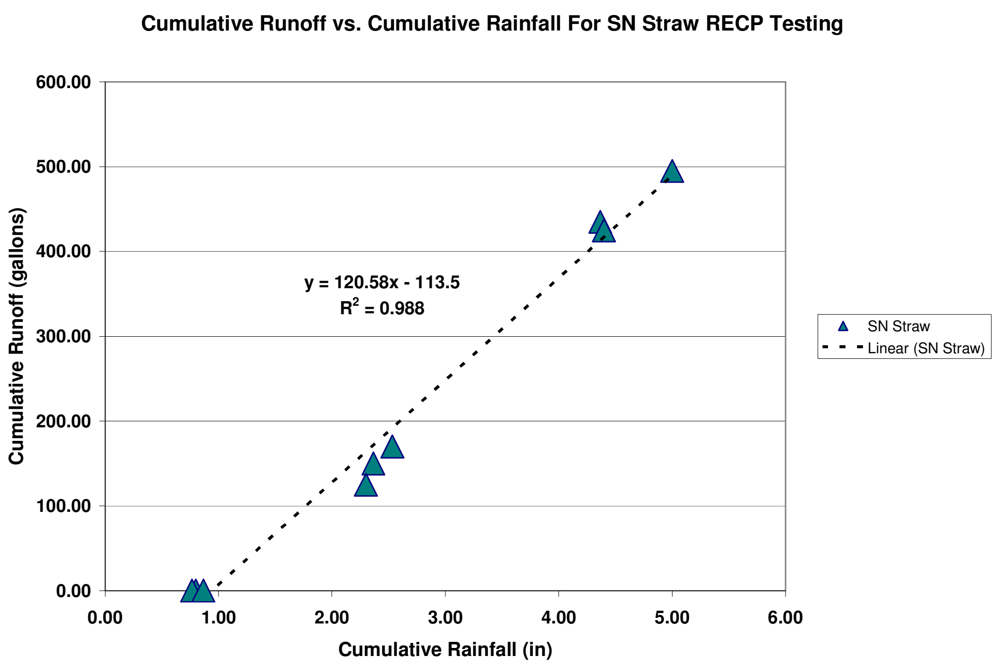

Figure 6. Cumulative Runoff vs. Cumulative Rainfall for the single net straw RECP tested. A regression line is fitted to the data set.

Sediment Concentrations

The average sediment concentration for each 20 minute test segment was calculated by dividing the equivalent dry mass of soil collected by the total volume of water collected. Least Square linear regression was applied to the data sets and sediment concentration was plotted vs. cumulative rainfall erosivity. The resulting equation of the regression line provides a tool to determine sediment concentrations as described by Kelsey et. al. (2004).

RESULTS

Figure 7 illustrates the results of the RECPs' ability to reduce soil erosion as compared to the bare soil control plots.

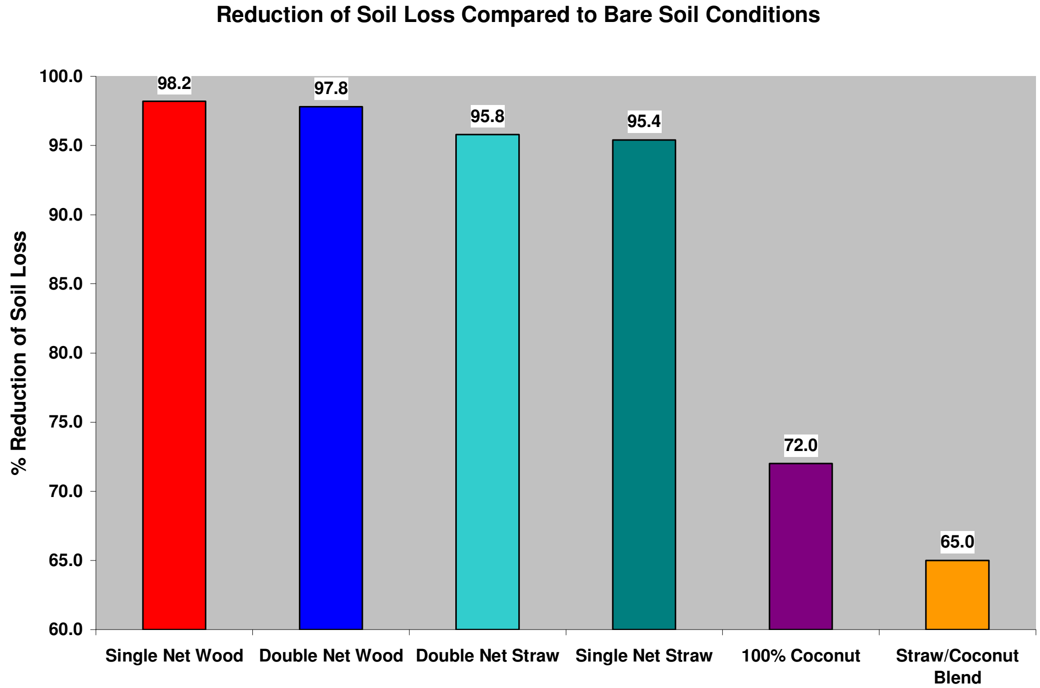

Figure 7. Percent reduction of soil loss as compared to bare soil control plots.

Figures 8 through 10 show the condition of plots with different surface covers following the entire test series. The RECPs were carefully removed from the plots in Figures 8 and 9 before the photos were taken.

Figure 8. Plot after wood fiber blanket was removed following the completion of the test series.

Figure 9. Plot after straw/coconut blanket was removed following the completion of the test series.

Figure 10. Bare soil control plot following the completion of the test series.

Expected runoff from plots covered with the RECPs and bare soil conditions tested are presented in Figure 11. The expected runoff volumes were calculated using the equations of the regression lines for each RECP and bare soil conditions. Figure 11 is based on a test series of exactly 2 in/hr (51 mm/hr) + 4 in/hr (102 mm/hr) + 6 in/hr (152 mm/hr) each lasting for 20 minutes.

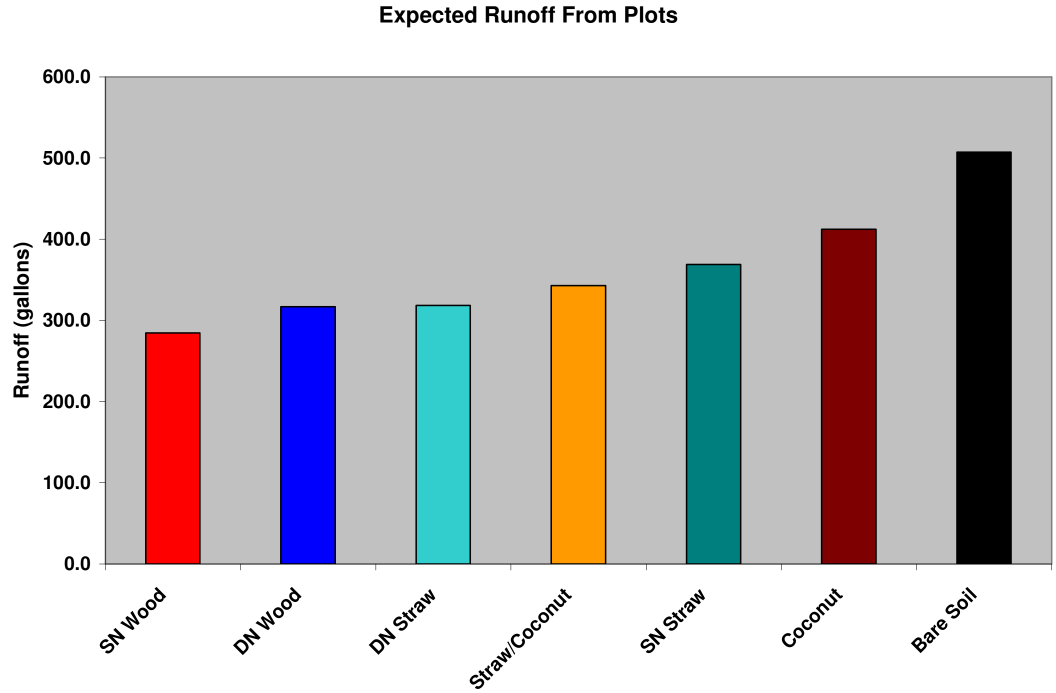

Figure 11. Expected runoff from plots covered with the RECPs or bare soil conditions tested.

The percent reduction of sediment concentration as compared to the bare soil control plots is displayed in Figure 12 for the six RECPs tested.

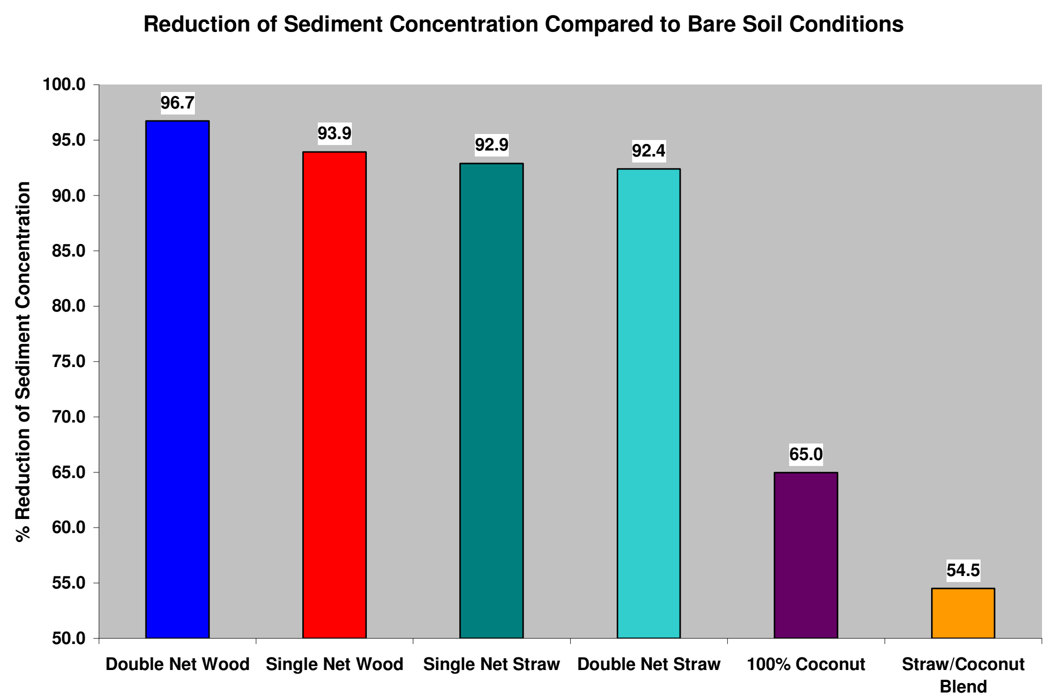

Figure 12. Percent reduction of sediment concentration as compared to bare soil control plots.

Figures 13 and 14 illustrate an example of the runoff that was measured during the testing of a double net wood RECP and a straw/coconut RECP respectively.

Figure 13. Runoff during the 6 in/hr (152 mm/hr) segment of a double net wood RECP test.

Figure 14. Runoff during the 6 in/hr (152 mm/hr) segment of a straw/coconut blend RECP test.

DISCUSSION

Figures 7 through 12 show that RECPs obviously reduce soil loss, runoff, and sediment concentrations as compared to unprotected bare slopes; however, some of the RECPs performed better than others.

The single net wood fiber RECP yielded the highest percent reduction of soil loss at 98.2%. The double net wood fiber RECP yielded the second highest reduction of soil loss followed by double net straw, single net straw, coconut, and straw/coconut blend RECPs. The single net wood RECP was witnessed to anchor into the subgrade when wetted. The absence of the bottom net improved the product's intimate contact with the soil surface. Water following the curled wood fibers to the soil surface to be infiltrated was also witnessed during testing. The Velcro-like connection between the wood fibers and the soil greatly reduced any overland flow that was generated at the higher intensity test segments. On the contrary, the additional net on the straw RECPs improved the overall performance of the products. The straw fibers were able to migrate down slope on tests containing the single net straw product. The straight straw fibers were not able to interlock to one another and anchor to the subgrade. It is believed that this property of the straw fibers will limit the straw RECP's ability to reduce soil erosion on slopes steeper and/or longer than those tested in this study. The coconut fibers seem to form a mat-like object when exposed to rainfall. The coconut fibers were able to reduce rain splash, but the limited intimate contact with the soil surface resulted in more soil loss compared to both wood fiber and straw fiber products. The poor subgrade contact between the coconut product and the soil surface seemed to be caused by the more rigid netting that was attached to both the top and bottom of the product. Test personnel noted that the coconut RECPs were very light weight when they were removed following the test series. The light weight of the RECPs after testing suggests that the coconut matrix retained minimal quantities of soil, which is evident by the soil loss data. The highest amount of runoff over the top of an RECP was witnessed with the straw/coconut blend product. The netting on both sides of the product coupled with the fibers lack of ability to cling to the subgrade resulted in the straw/coconut RECP having the highest soil loss of all the RECPs evaluated.

The single net wood RECP would generate the least amount of runoff according to Figure 11. The low volume of runoff from plots protected with a single net wood RECP supports that the product encourages infiltration due to the curled fibers' ability to train water to the soil surface and the Velcro-like intimate contact between the product and soil surface, which minimizes any overland flow that may occur. Similar amounts of runoff would be expected from areas protected with double net wood or double net straw RECPs. The straw/coconut RECPs interestingly would generate less runoff than both the single net straw and coconut RECPs even though soil loss measurements were highest with the straw/coconut RECP. This suggests that the composition of runoff coming from the straw/coconut plots contained more soil than water. The sediment concentration of the runoff from straw/coconut plots was the highest of all RECPs tested as seen in Figure 12. Single net straw RECPs would generate the third highest amount of runoff. Infiltration was low with the single net straw product because the fibers were being moved with the runoff, thus the fibers were unable to impede the down slope movement of the runoff to encourage infiltration. The highest volume of runoff would be expected from the coconut RECP. As previously mentioned, the rigid structure of the RECP is believed to limit intimate contact with the soil surface, which allows runoff to move down the slope more easily.

The double net wood RECP yielded the highest percent reduction of sediment concentration at 96.7%. The single net wood fiber RECP yielded the second highest reduction of soil loss followed by single net straw, double net straw, coconut, and straw/coconut. As described above, the curled property of the wood fibers trained the water to the surface of the plot and the Velcro-like connection between the product and the subgrade reduced overland flow. The wood fiber RECPs yielded low amounts of soil loss so the runoff contained very little sediment. In addition, the wood fibers filtered the water as it passed through the matrix. Both straw products yielded almost identical reduction of sediment concentration values. The straw fibers did not filter sediment-laden runoff to the extent witnessed with the wood fiber RECPs, but both straw products did reduce sediment concentrations much better than the 100% coconut and straw/coconut blend RECPs and bare soil conditions. Both the 100% coconut and straw/coconut blend RECPs did not appear to have much filtering affect on the runoff, but both products were a drastic improvement as compared to bare soil conditions.

SUMMARY

Selecting the proper RECP for each project is becoming more and more important. Litigations surrounding slope erosion control and stormwater runoff continue to become more stringent each day. Headaches and costly fines can be avoided by selecting an RECP that you know will work.

There are many criteria to consider when selecting a degradable RECP for slope protection. The most important criterion when deciding which degradable RECP you should use for slope protection is finding the product that performs the best for the conditions of the jobsite. This study found that the unique properties of different types of fibers within the RECPs greatly influenced the products' ability to reduce soil loss, runoff, and sediment concentrations. The slope rating, cost, functional longevity, and ability to vegetate also need to be considered when selecting the proper RECP for slope protection. Land planners and developers can use the information provided within as a guide when selecting degradable RECPs to help keep soil on disturbed hillslopes and out of our Nation's waters.

Future studies should include additional replications on the loam soil tested for this study and the methodology should also be applied to data sets across various soil types. Also, all the RECPs should be evaluated at the slope steepness they are rated to. Lastly, the RECPs should be tested at longer slope lengths to determine if the down slope migration of straight straw fibers is amplified with slope length.

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