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Combined Hydroseeding and Coconet Reinforcement for Soil Erosion Control

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1. Introduction

Soil erosion is a worldwide problem that washes away fertile farmlands, slopes of roadway cuts and embankments, produces undesirable deposits in rivers and reservoirs, and at a larger scale result to landslides (Kothyari, 1996 and Thakur, 1996) . Soil is eroded by water and wind (Toy, et.al, 2002). In tropical countries like the Philippines, precipitation is high and erosion by water is the dominant driving force based reported cases. Protection of soil surfaces especially of slopes is needed…

To protect the soil surface from erosion, it should be protected from direct contact with erosive forces. Plant cover helps protect the soil surface and provide supplemental soil stability (Morgan, 2005). Hydroseeding is an innovative method of growing vegetation and is designed for slope protection. In the Philippines, its effective application is showcased in the Subic-Clark-Tarlac Expressway (SCTEX) Project.

Another green technology being used is the application of coconut coirs or coconets. Coconets helped stabilize the slope and improved the growth of vegetation in pilot projects of the Department of Public Works and Highways (DPWH).

Newly planted vegetation on slopes could be easily washed away by heavy downpour of rain. Erosion of the slope and replanting of vegetation would be a costly consequence. Coconets, on the other hand, will show its full potential if coupled with a good growth of vegetation. Artificial vegetation is needed to facilitate the even growth of plants. Attempts of combining coconets with vegetation were done using grass (vetiver grass) and trees (Madre de Cacao and neem tree) (DPWH, 2005).

Limited and very little information about hydroseeding is available since it is newly introduced in the Philippines. Tests to assess this method were only made by private construction companies which makes the data's exclusive only for the company's use.

The use of combined hydroseeding and coconets in slope protection was investigated in this study. The study was aimed to assess the effectiveness of the combined technologies to control soil erosion in a representative slope at different series of tests.

The research involved an outdoor component of the experiment to facilitate growth of vegetation. Transportation of each representative slopes to the laboratory was by means of a forklift to minimize disturbance. To further minimize the disturbance factor, the test boxes were transported carefully. Only one type of soil, degree of slope and the intensity of rainfall were considered. However, results were captured at different times in the entire duration of the rainfall simulation.

2. Hydroseeding

Hydroseeding is one of the methods of ground re-vegetation to stabilize bare soil surface to prevent soil erosion. It calls for the use of cellulose mulch material mix with a tackifier acting as binder. The cellulose binder mulch, together with the grass seeds, fertilizer and water are mixed inside the tank of hydroseeding machine to form into consistent and homogeneous slurry and then hydraulically sprayed to the ground. When sprayed, the cellulose fiber mulch together with the fertilizer and the grass seed will act as an absorbent mat, holding enough moisture to allow proper germination of the grass seeds and the same time forming a firm blanket cover to the soil surface even before the grass seeds germinates to prevent soil erosion. The cementitious geobinder forms a permeable curst on the soil surface which control water, soil and wind erosion. The geobinder is a non toxic cementitious binder that safely holds the grass seeds uniformly in place, prevents surface erosion and water evaporation in the soil. The cellulose fiber mulch which is biodegradable and in time will revert back to organic matter, enhances vigorous establishment of the grass ground cover. The application of hydroseeding process can be considered for temporary and permanent erosion control, seeding and mulching.

Hydroseeding is now a widely used process of controlling soil erosion abroad. Countries like the United States use this type of grass planting since the process is fast, efficient, and economical. It is more effective than conventional seeding and more economical than conventional sodding. In the Philippines, hydroseeding is first introduced in the Subic-Clark-Tarlac Expressway Project. Reports show that the adoption of hydroseeding is advantageous to the said project. Centrocema Pubescens (Centro) and Calopogonium Muconoides (known as Calapo) are the plants used in the project. The application of hydroseeding method yields the following observations and conclusions: (a) Hydroseeding planting process is the fastest way of preventing soil erosion; (b) the temporary seeds will germinate forty-eight (48) hours after spraying and the planting seedbed of the embankment is already 100% stabilized even before the establishment of the permanent ground cover; (c) Aside from nursing the grass seeds, the planting seedbed stabilizer called "geobinder" holds the ground cover grass seed in place and other soil planting amelioration materials; (d) Less watering is needed once the ground cover grass seed is 100% established; (e) The mulch material serves as moisture retention absorbing mat and at the same time reduces the development of the undesirable weeds; (f) In hydroseeding, 10,000 to 15,000 square meters of planting seedbed can be accomplished in a day; (g) There is no rill or gully erosion in case of heavy rain once hydroseeding is in place; (h) The Pure Living Seed (PLS) population per square meter is guaranteed to be 70-75 Living Grass Seed; (i) Hydroseeding final end product will require only very little maintenance once the permanent ground cover is purely established. (BCDA, 2006)

3. Coconets

Coconets are made from 100% coir fiber twine woven into high strength nets for extreme slope stabilization, protection of high velocity stream banks and high velocity intermittent flow channels. The natural coconut coir material perform very well in applications such as erosion control blankets for landscaping. The mesh of woven coconut coir matting acts as miniature dams that prevents the seeds or seedlings to be washed away by rain and wind and facilites the growth. The netting breaks up runoff from heavy rains and dissipates the energy of

flowing water. Once the growth of vegetation has occurred the function of the coir is over and the vegetation takes over the protection of the soil further. Coconut fiber also promotes the growth of new vegetations by absorbing water and preventing the topsoil from drying out.
In the study conducted by Bureau of Research and Standards (BRS) of DPWH, results showed that the method of using Geonets (specifically, coconets) to protect developing vegetation against water and wind erosion have proven to be essential since it provides the soil surface with partial shading, moderation of soil temperatures and moisture retention. These materials are prescribed to initially stabilize the soil but without live plants and trees, the effective erosion control would not be achieved. The benefits of applying
Bioengineering techniques such as the use of hydroseeding and coconets in accelerating vegetation helps control soil erosion and stabilize the soil. With the use coco coir products as slope protection, slope above the road will be prevented from caving in. Thus, damages triggered by soil erosion on infrastructure such as roads and bridges will be prevented if slope protection is present.

4. Methodology

To represent the slope covered with combined Hydroseeding and coconets, test boxes were constructed sloping at 65 degrees and having a surface area with dimension of 106 cm long by 63 cm wide as shown in Fig. 1. Three (3) trial boxes were constructed. The test boxes were covered with soil. These test boxes covered with soil only were all initially subjected to artificial rainfall simulator for the bare soil tests. After the bare soil tests, the test boxes were covered again with soil and covered with combined hydroseeding and coconets for another three (3) sets of samples. Vegetation was allowed to flourish for 21 days before subjected to the rainfall simulator.

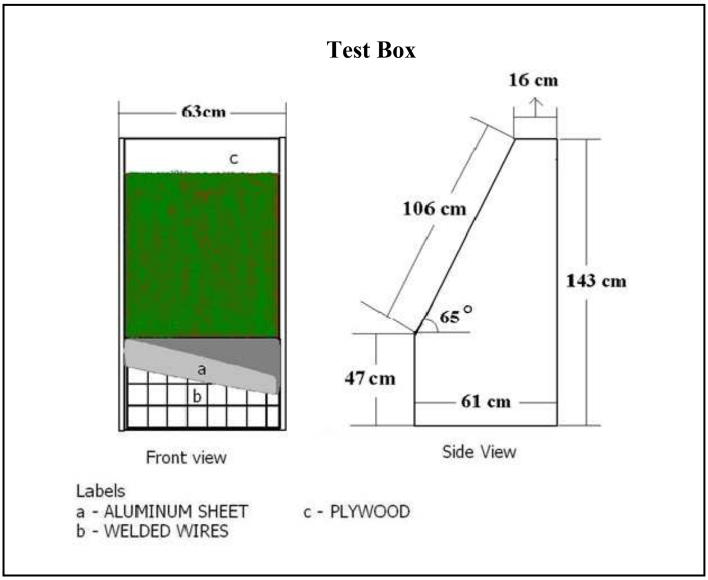

Fig. 1. Dimensions of the test box.

The amount of soil splashed out by runoff from the containers were collected and weighed. The data collected were used to compare erosion in mere bare soil to that with combined hydroseeding and coconet as slope protection.

4.1 Soil core test box

The soil core test box consists of water tight (leak free) container which holds the soil core specimen. The core is made up of wood that is capable to hold soil at a desired angle of the specimens. It includes gutter which is a runoff ramp for the routing of the soil and water that are washed out from the container to the bucket without spilling out. The dimensions are shown earlier in Fig. 1. The actual soil core test box is shown in Fig. 2.

Fig. 2. Test boxes shown with compacted soil.

4.1.1 Collection bucket

The collection bucket is used for the catchments and measurement of the eroded soil. This should have sufficient volume to collect the soil and water that is spilled out. Recycled 1-gallon mineral water containers were used to temporarily store the collected soil and water.

4.1.2 Filter

A filter for the separation of the sediment from soil and water solution is used. Recycled cloth used such as sack for flour, locally known as “katsa” was utilized.

4.2 Hydroseeding technical specifications

The hydroseeding mix has the following component:

4.2.1 Grass seeds

Approved seed varieties are those that are tested to withstand harsh weather conditions, characteristically aggressive, perennial, tropical, produce both runners and rhizomes, deep rooted, will rapidly colonize bare ground and form a dense mat of vegetation ground cover.

When established, it forms as an umbrella to dissipate rain drops impact and is environmental friendly and low - maintenance.

Permanent ground cover grass seed	- Centrosema (Pubescens)
Temporary grass nursing seed	- White Millet
Seed Purity	- 85%
Germination	- 80 to 90% average
Adaptability	- Tropical

4.2.2 Geobinder
Airtol geobinder is a low cost cementitious binder used in the study. When mixed with water and mulch, this geobinder sets in a predictable way to form an erosion resistant crust. Packed in 22.8 kilo bag, it is produced from high quality gypsum and is (fully) imported from the USA.

4.2.3 Cellulose fibre mulch
The cellulose fiber mulch is manufactured and processed from recycled paper. Made in USA, it is packed in 50 lbs. bag.

Moisture Content	- 15%
Organic Matter	- 99.5%
pH Level	- 5.5 to 6.0%
Water Holding Capacity	- 100 grams DW/will hold 1,000 grams of water.

4.2.4 Cocopeat
This is a by-product of coco fiber consisting of short coco fiber and dust available locally. Packed in 15 kilo bag, this acts as a soil conditioner.

4.2.5 Fertilizer
To enhance the growth of plants, chemical grade fertilizer, in accordance to Bureau of Soil Recommendation, is added in to ameliorate common soil nutrient deficiencies. It is an organic fertilizer locally produced in palletized form that is both environmental friendly and non-toxic.

4.3 The soil for the test box
To maintain good vegetation, the soil must meet certain requirements as a growth medium. It should meet the following conditions:

a. enough fine-grained (silt and clay) material to maintain adequate moisture content usually 15-20%. This is based from Unified Soils Classification System (ASTM Designation D-2487);
b. sufficient depth of soil to provide an adequate root zone;
c. favorable pH range for plant growth which is usually 5.5-6.0 ;
d. soil must be compacted like natural conditions soil slope; and
e. sufficient pore space to permit root penetration and it will be done by not compacting the last 4-6 inch of soil.

The soil used was sieved to separate large stone and other unnecessary things not needed.
For every layer of 10 inch, the soil in the test box is compacted with use of ply board, a piece of wide flange or bricks. Compaction is done by placing the ply board on top of each layer to

flatten the soil and will be compacted by dropping the wide flange five times with the height of 8 inch. If wide flange is unsuitable for compaction for small area, bricks may be used.

4.4 Hydroseeding mixing process

First, mix the cellulose fiber mulch and cocopeat together, followed with grass seeds, fertilizer amelioration materials and a geobinder tackifier in a pail full of water. Continue loading ingredients and mixing process until mixture forms a consistent, uniform and homogeneous slurry mixture ready to be applied. Fig. 3 shows the hydroseeding components and mixture.

(a) (b) (c)

Fig. 3. The hydroseeding components and mixture. (a)Hydroseeding Mix Components(b) Mixing the components(c) Hydroseeding Mixture

4.5 Hydroseeding application

The slurry was applied manually on the soil surface as shown in Fig. 4. Application started from the top of the slope down to the toe. Exposed area at the top and toe of the slope were completely covered by applying the mixture 15 inches beyond the top and toe of the slope. Spots that might not be covered with the hydroseeding mixture were simply hydroseeded again. Hydroseeded areas were regularly watered daily during the dry days for the first four (4) weeks of application.

Fig. 4. Hydroseeding by manual application

4.6 Installation of coconet

With the hydroseeding completed, the coconet is installed over the entire hydroseeded area as shown in Fig. 5. To ensure total coverage of the slope, nets are laid adjacent to each other and were anchored securely on the slope with bamboo pins or any other appropriate material(s) depending on the nature of the slopes.

Fig. 5. Hydroseeded test boxes covered with coconet. The green net is used for protection from birds and other factors.

4.7 Rainfall simulation

In this study, a laboratory test was performed using the Artificial Rainfall Simulation Apparatus at the Hydraulic Laboratory of the Flood Control and Sabo Engineering Center (FCSEC) of DPWH to assess the effectiveness of Hydroseeding with Coconet in erosion control and water run-off. The rainfall simulator is capable of creating uniform drops and desired intensities. This is used to apply uniform rain over the entire area of the specimen. In this study the researchers will use the worst rainfall rate which is 120 mm/hr. The rainfall simulator used is shown in Fig. 6.

The FCSEC artificial rainfall simulator is a device with adjustable /changeable nozzle for rainfall intensity variation. The said simulator has a dimension of 10m x 5m x 10m that produces drops simulating rainfall intensity of up to 235mm/hr. Raindrop sizes are representative of typical heavy rains/storms in the country. The spatial distribution of rain is essentially uniform, and the control of application rates is within the accuracy requirement of most experimental protocols.

For the rainfall simulation on the study's test specimen, the rainfall applied was at 120mm/hour for every 10 minutes. The sediment and water runoff from the test box were collected.

Fig. 6. Artificial Rainfall Simulation Apparatus at the Hydraulic Laboratory of the Flood Control and Sabo Engineering Center (FCSEC) of the Department of Public Works and Highways (DPWH).

5. Results and discussion

Table 1 and Figs. 7 and 8 present the sediment concentration accumulated on bare soil and on soil covered with combined hydroseeding and coconet.

Sediment Concentration (g/L)							
TRIAL	Time (mins)	0	10	20	30	40	50
TRIAL 1 BOX A	Bare Soil	0.000	5.823	20.146	18.553	12.319	9.585
	Hydroseeding with Coconet	0.000	10.740	2.690	2.670	1.060	1.340
TRIAL 2 BOX B	Bare Soil	0.000	63.501	39.723	35.130	26.274	21.320
	Hydroseeding with Coconet	0.000	4.990	2.900	4.340	3.330	2.730
TRIAL 3 BOX C	Bare Soil	0.000	75.443	68.321	40.743	42.553	33.551
	Hydroseeding with Coconet	0.000	18.970	4.520	2.780	1.500	0.610

Table 1. Sediment Concentration of Bare Soil and Soil Covered with Combined Hydroseeding and Coconet Reinforcement.

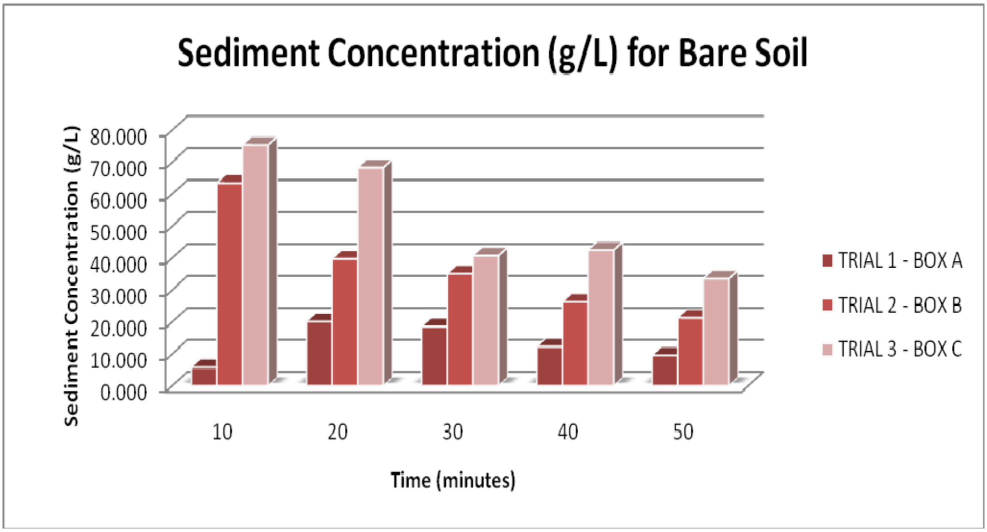

Fig. 7. Sediment Concentration (g/L) for Bare Soil

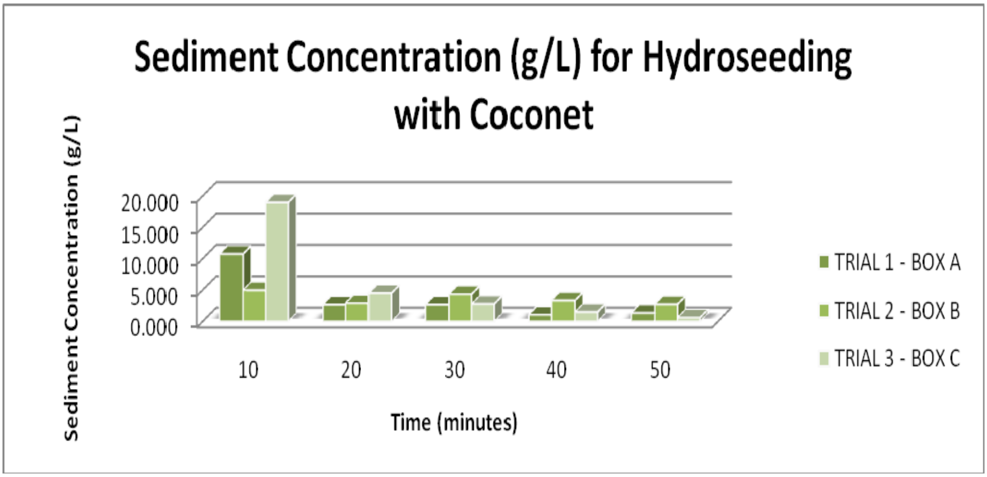

Fig. 8. Sediment Concentration (g/L) for Hydroseeding with Coconet Reinforcemen

It is shown that in each three trial boxes that were first used for bare soil specimen and the vegetated specimen, the first ten (10) minutes deposit higher sediment concentration. But, comparing the values obtained between bare soils and soil with hydroseeding and coconet reinforcement, it shows that as expected there is lower sediment concentration in the latter while higher sediment concentration in the former.

Table 2 and Figs. 9 and 10 present the sediment yield on bare soil and on soil covered with combined hydroseeding and coconet.

Sediment Yield (g/m²h)							
TRIAL	Time (mins)	0	10	20	30	40	50
TRIAL 1 BOX A	Bare Soil	0.000	73.873	272.503	225.529	126.809	78.247
	Hydroseeding with Coconet	0.000	155.330	34.380	18.010	5.650	5.930
TRIAL 2 BOX B	Bare Soil	0.000	1533.594	877.431	646.308	356.162	257.866
	Hydroseeding with Coconet	0.000	49.300	24.870	16.610	9.180	6.020
TRIAL 3 BOX C	Bare Soil	0.000	850.000	1169.062	581.067	472.833	227.832
	Hydroseeding with Coconet	0.000	226.670	83.370	35.430	13.560	5.210

Table 2. Sediment Yield (g/m²h) of Bare Soil and Hydroseeding with Coconet Reinforcement

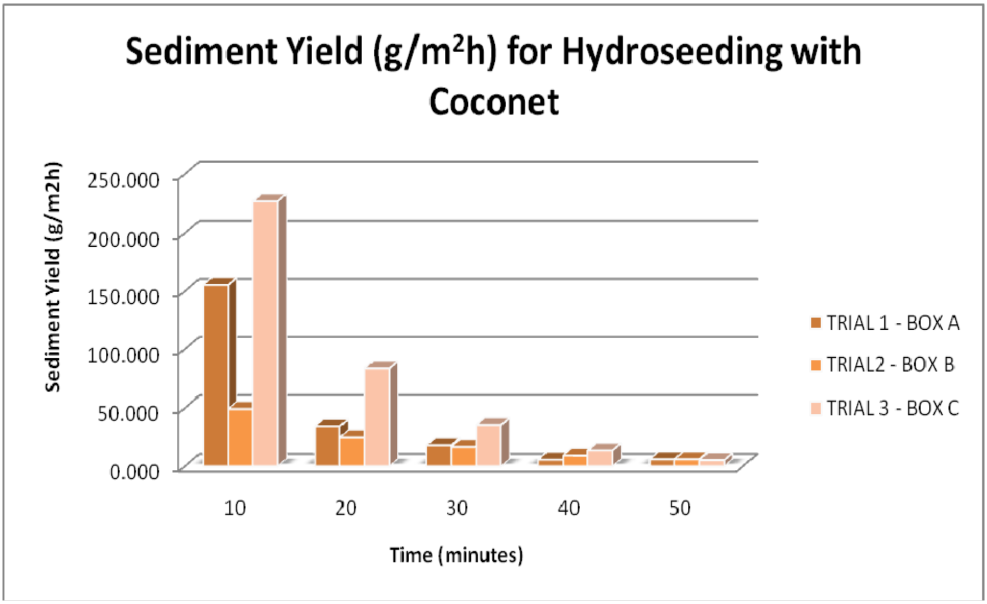

Fig. 9. Sediment Sediment Yield (g/m²h) for Bare Soil

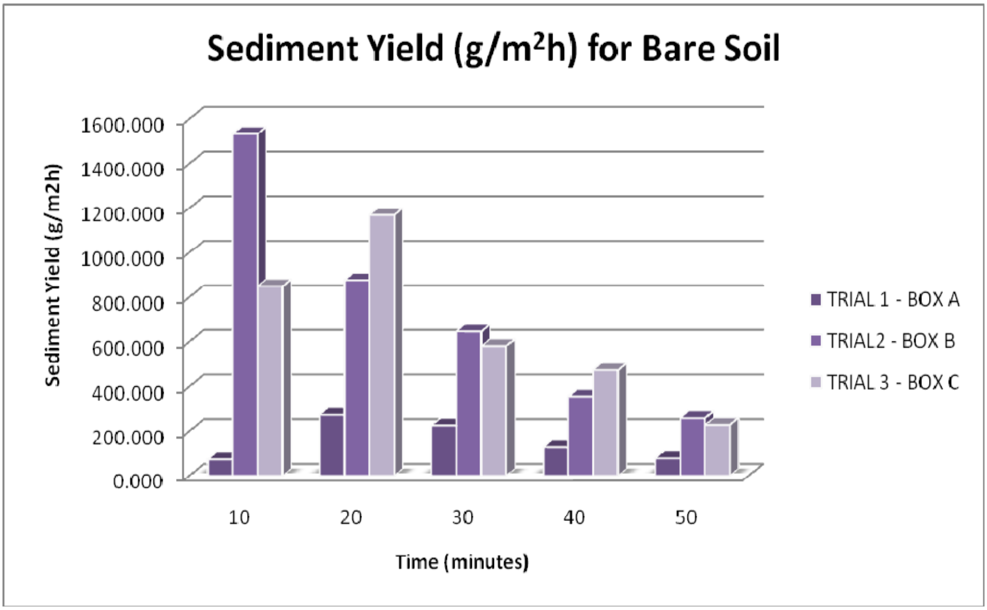

Fig. 10. Sediment Sediment Yield (g/m²h) for Hydroseeding with Coconet Reinforcement

As specified, the sediment yield determines the mass of the sediment over its plot area with respect to the time. The results of three trials from Table 2 show that the Hydroseeding with Coconet reinforcement obtained lesser sediment yields than the bare soil, which is already expected since soil without protection from rain splash would deposit greater amount of soil sediments.

The proceeding discussion presents the mean sediment concentration and sediment yield for the bare soil and for soil with combined hydroseeding and coconet.

Table 3 and Fig. 11 show the comparison of the mean sediment concentration of Bare Soil and hydroseeding and cocconet Reinforcement. As shown in the table, bare soil accumulates greater mass of soil sediment than of the hydroseeding and coconet Reinforcement.

Mean Sediment Concentration (g/L)							
Time (mins)	0	10	20	30	40	50	Average
Bare Soil	0	48.26	42.73	31.48	27.05	21.49	171.01
Hydroseeding with Coconet	0	11.57	3.37	3.27	1.97	1.56	3.694

Table 3. Mean Sediment Concentration of Bare Soil and Combination of Hydroseeding with Coconet Reinforcement

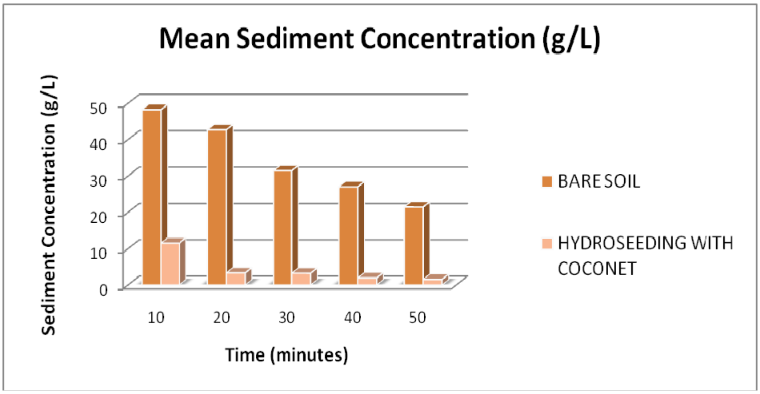

Fig. 11. Mean Sediment Concentrations of Bare Soil and Combination of Hydroseeding with Coconet Reinforcement

Mean Sediment Yield (g/m²h)							
Time (mins)	0	10	20	30	40	50	Total
Bare Soil	0	2457.47	2319	1452.91	955.81	563.95	7749.14
Hydroseeding with Coconet	0	143.77	47.54	23.35	9.47	5.72	229.85

Table 4. Mean Sediment Yield of Bare Soil and Combination of Hydroseeding with Coconet Reinforcement

The value projected in the Table 4 and Fig. 12 show that the mass of the bare soil with respect to the plot area and time is definitely greater than of the Hydroseeding with Coconet reinforcement.

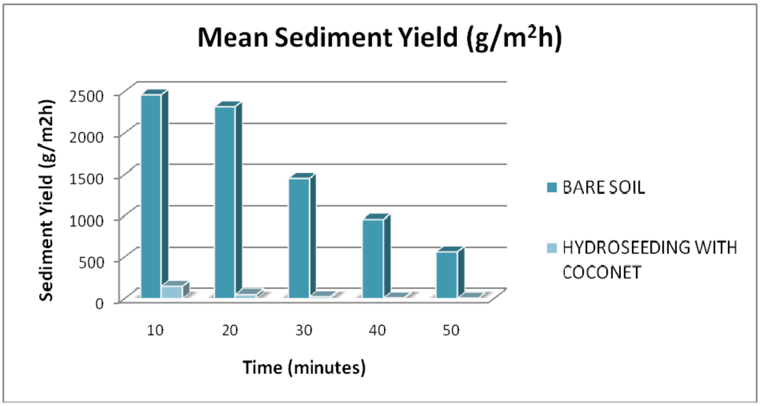

Fig. 12. Mean Sediment Yield of Bare Soil and Combination of Hydroseeding with Coconet Reinforcement

The following discussions summarize the total sediment concentration and total sediment yield.
Table 5 compares the sediment concentration and sediment yield of bare soil and hydroseeding with coconet reinforcement. From the numerical value indicated above, it was found out that the Hydroseeding with Coconet reinforcement lessen the mass of the soil eroded.

Total Sediment Concentration (g/L) and Sediment Yield (g/m^2h)		
Experiment	Sediment Concentration (g/L)	Sediment Yield (g/m^2h)
Bare Soil	21.49 ± 28.26	563.95 ± 2457.47
Hydroseeding with Coconet	1.56 ± 11.57	5.72 ± 143.77

Table 5. Total Sediment Concentration (g/L) and Sediment Yield (g/m^2h)

Table 6 presents the effectiveness of the applied hydroseeding with coconet reinforcement to control against soil erosion. From the results, it was found out that combined hydroseeding with coconet reinforcement is an effective soil erosion control instrument.

Effectiveness Of Hydroseeding with Coconet Reinforcement versus Bare Soil Against Soil Erosion (%)						
Time (mins)	0	10	20	30	40	50
Hydroseeding with Coconet versus Bare Soil	0	94.15	97.95	98.4	99.01	98.99

Table 6. Effectiveness of Hydroseeding with Coconet Reinforcement versus Bare Soil Against Soil Erosion (%)

6. Conclusion

Results of actual laboratory experiments that were conducted with the use of the DPWH Artificial Rainfall Simulation Apparatus showed that the specimen of soil covered with combination of hydroseeding and coconet passed the surface run-off tests. The said specimens did not show any sign of failure in the measurement of run-off in the surface of the slope. Erosion problem was not encountered in the specimen of combined hydroseeding with coconet. The primary effect is that water is absorbed by the hydroseeding materials as well as by the coconet that were put in place to hold the soil and control soil erosion.

7. Recommendations

The experiment conducted was limited only for a fixed slope of 65 degrees. The hydroseeding mix had a single set of mixture components. Rainfall simulation rate was at a constant 120mm/hr. Future studies on combined hydroseeding with coconet may consider variable slopes and different length to width and depth dimensions. Other plant varieties locally available in a particular area may be considered. Other rainfall intensities may be tested. Consideration of wind and other environmental factors could be included to simulate stormy weather.

8. Acknowledgement

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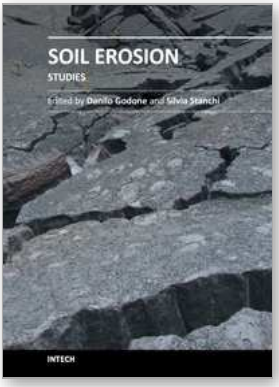

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Soil erosion affects a large part of the Earth surface, and accelerated soil erosion is recognized as one of the main soil threats, compromising soil productive and protective functions. The land management in areas affected by soil erosion is a relevant issue for landscape and ecosystems preservation. In this book we collected a series of papers on erosion, not focusing on agronomic implications, but on a variety of other relevant aspects of the erosion phenomena. The book is divided into three sections: i) various implications of land management in arid and semiarid ecosystems, ii) erosion modeling and experimental studies; iii) other applications (e.g. geoscience, engineering). The book covers a wide range of erosion-related themes from a variety of points of view (assessment, modeling, mitigation, best practices etc.).

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