Corn (Zea mays L.) Stalk Geotextile Net for Soil Erosion Mitigation

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***Abstract*—The study was conducted to introduce new natural fiber to be used in the production of geotextile net for mitigation of soil erosion. However, fiber extraction from the stalks is one of the major challenges faced during the process. Thus, an investigation on the extraction procedures of corn (Zea mays L.) stalk was first undertaken. Physical characterization of the developed corn stalk geotextile net resulted to average mass per unit area of 806.25g/m^2 and 241% water absorbing capacity. The effect of corn stalk geotextile net in mitigating soil erosion was evaluated in a laboratory experiment for 30^o and 60^o inclinations with three treatments: bare soil (A_1), corn stalk geotextile net (A_2) and combined cornstalk geotextile net and vegetation cover (A_3). Results revealed that treatment A_2 and A_3 significantly decreased sediment yield and an increase in terms of soil loss reduction efficiency.**

***Index Terms*—corn stalk, natural geotextile, sediment yield, soil erosion**

I. Introduction

Soil erosion is widely recognized as a major environmental problem which threatens the most important and non-renewable reserve of human, the farmland. This problem is mainly initiated by the erosive forces like farm tillage, wind and water resulting to removal of top soil [1]. Eroding of soil is dominantly triggered by intense rainfall and high velocity runoff to cultivated and steep areas. This condition causes great destruction not only to soil characteristics but also to its properties and fertility affecting numerous numbers of individuals [2].

In the Philippines, about 45% of the country's arable land suffers from moderate to severe soil erosion [2]. Reference [3] cited that an estimate of 623 MT of soil is lost annually from 28 million hectares of cultivated land in the country. Without immediate and appropriate protection, there will be severe soil loss that may lead to difficulty in establishing vegetation and possibly increase in sediment input to nearby rivers [4].

Hydroseeding, on the other hand, is a technique used to establish vegetation cover that can provide long-term protection against soil erosion [5]. However, growth of vegetation is difficult during early stage since seeds or seedlings might be washed away by the erosive forces of rainfall and runoff [5]. During this situation, hydroseeding combined with bioengineering techniques is one of the best options to protect the seeds from harsh environment.

Geotextile has gained popularity in mitigating various types of soil erosion in different parts of the world [6]. Like vegetation, it can reduce direct impact of raindrops; reduce runoff generation and soil detachment [7]. But, despite these advancements, geotextile from naturally occurring fiber products has not received any significant consideration as researches were mostly focused on the production and utilization of synthetic geotextiles like polyolefin and polyester [8]. Natural geotextile is also known to have a short life span, degrades easily [9], and has properties that limit its full utilization.

In an age of growing environmental awareness, biodegradation of natural geotextile as a result of microorganism's activity is of great advantage. This advantage leads to exploitation of different natural fiber resources which can be used as geotextile for a specific soil erosion problem. Natural geotextile's advantages are biodegradability, ability to protect soil from splash erosion, capacity to absorb water, and aid for reduction to water loss through evaporation [9]. These are the indications that natural geotextiles have an edge over synthetic geotextile for slope stability application. In this premise, investigation of other potential natural fiber resources such as fiber from corn stalks can be done to reduce agro-wastes left on the field which can significantly reduce soil erosion when properly converted to geotextile net [10].

A. *Statement of the Problem*

Corn ranks second next to rice as the most important grain crop in the country [11]. The volume of production of corn in the country for the year of 2014 has an output level of 7.75 million MT which is 5.1% above the 2013 output and is expected to rise up to 2.56 million hectares in 2015 [12].

The province of Pangasinan has a total land area of 536,818 hectares, which represents almost 50% of the total area of the entire Region 1 and constitutes to about 1.8% of the total land area of the country. Report from

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[12] showed that Pangasinan has a total corn production of 289,607 MT for the cropping year 2012-2013 with an average yield of 5.63 tons/ha within the harvest area of 51,430 ha.

Since there is a massive production of this crop, there is also a high biomass production. The common practice of farmers is to leave the residues in the field and some are burnt which causes pollution. Corn residues are also left by the farmers on the ground immediately after harvesting to act as mulch material in conserving soil moisture for the next cropping season. The problem, however, is that corn stalks, without any prior physical alteration, may damage small machineries during land preparation. Also dried corn stalks when used as mulch can be easily blown by wind and be washed away through runoff. Lastly, huge quantities of corn stalks left in the field to decompose may lead to emergence of diseases among crops.

B. Objectives

The general objective of the study was to develop corn stalk geotextile net for erosion mitigation. Specifically, the study aimed to:

1. Determine the physical properties of the developed corn stalk geotextile net; and,
2. Evaluate the effect of developed corn stalk geotextile net and vegetation cover in sediment yield, and Soil Loss Reduction Efficiency (SLRE).

C. Scopes and Limitation of the Study

The study focused on the production of geotextile net derived from corn stalk. The effect of using corn stalk geotextile net as ground cover was evaluated under the following conditions: two different soil slopes (30° and 60°), 60-minute rainfall durations (data taken at 10-minute interval) and rainfall intensity of 75mm/hr. Sandy loam type of soil was used. The testing of physical properties of developed corn stalk geotextile net included mass per unit area and water absorption. The hydroseeding mixture was limited only at single mixing ratio wherein Centrosema Pubescens and White Millet were the seeds used. The performance evaluation of the man-operated twining machine used was not included in the study.

II. MATERIALS AND METHODS

A. Corn Stalk Geotextile Net

Fig. 1 shows the extracted fiber from corn stalk used in the production of geotextile rope.

Figure 1. Stalk fiber

Production of single and double spline ropes was through the use of locally used rope making device. Cornstalk geotextile net weaving process follows the traditional open-weave pattern. This was done by interlacing the single-splined fiber ropes at right angle with each other. Mesh size opening used was 25 mm x 25 mm. The end part of each interlocking rope was tied with a brown yarn to avoid disengagement of each rope (Fig. 2).

Figure 2. Net weaving

B. Vegetation Cover Prepration

The experiment employed hydroseeding to establish vegetation cover. Hydroseeding mixture ingredients were carefully weighed and then were mixed together in a container (Fig. 3).

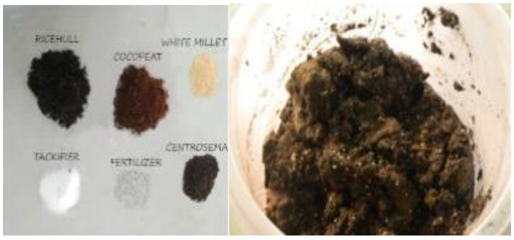

Figure 3. Hydroseeding ingredients

Figure 4. Slurry application

Fig. 4 illustrates the manual application of hydroseeding mixtures to experimental plots. The slurry was manually applied at the top of soil surface. Due to uneven application of the mixture, follow-up applications to cover weak spots were done as needed. Vegetation was allowed to establish for 21 days before subjecting to final simulation.

The installation of corn stalk geotextile net after hydroseeding application was done by anchoring the top and bottom edge of the net by small wire pegs to avoid slippage. After the geotextile net has been installed, test boxes were put outside the Hydraulic Laboratory, enabling the newly planted grass to get enough light and natural rainfall necessary for its growth (Fig. 5).

Figure 5. Vegetation establishment

C. *Experimental Set-up*

A laboratory test was conducted to evaluate the physical characteristics and impact of corn stalk geotextile net in mitigating soil erosion. Rainfall simulator apparatus was owned and operated at Hydraulic Laboratory of the Project Management Office (PMO)-Flood Control and Sabo Engineering Center (FCSEC) of the Department of Public Works and Highways (DPWH), Pasig City, Philippines. The rainfall simulator was set to give a rainfall intensity of 75mm/hr.

The effect of corn stalk geotextile net was evaluated in terms of sediment yield, sediment concentration and soil loss reduction efficiency. Various soil erosion covers as listed below were used as treatments: A1 - bare soil (control); A2 - 25 mm x 25 mm mesh size corn stalk geotextile net and A3 - 25 mm x 25 mm mesh size corn stalk geotextile net combined with hydroseeding (Fig. 6).

a) A_1 b) A_2 c) A_3

Figure 6. Experimental plots

D. *Evaluation of Corn Stalk Geotextile Net*

1) *Physical characterization*

The physical properties were limited to: mass/unit area and Water Absorption (WA). Technical specification of corn stalk geotextile net included number of twines crosswise and lengthwise, single and double spline rope diameters.

Mass/unit area is an important property that can directly measure fabric cost. It was determined by weighing samples in an accurate digital weighing scale.

Water absorption was computed through (1) as cited in [13]. Net weight refers to the weight of geotextile after the protruding fibers in the rope have been removed and the final weight refers to the weight of the net after soaking.

$$WA = \frac{WA_f - WA_i \times 100}{WA_f} \quad (1)$$

where WA is water absorption (%), WA_i is net weight (g) and WA_f is final weight (g)

2) *Sediment yield*

This determines the mass of the sediment over its plot area with respect to time. This is the mass of the oven-dried sediment collected over the area of the soil test box and duration of simulation. It was estimated by using (2) cited in [14], [10].

$$SY = \frac{Sm}{tAb} \quad (2)$$

where SY is sediment yield (g/m^2.hr), Sm is mass of oven-dried sediment collected (g), Ab is area of soil test box (m^2) and t is duration of rain simulation (hr).

3) *Soil loss reduction efficiency*

This determines how well a certain geotextile controls soil erosion. Computation was in accordance to (3), as given in [15], [16], [17]:

$$SLRE = \frac{SYb - SYg \times 100}{SYb} \quad (3)$$

where SLRE is soil loss reduction efficiency (%), SYb is bare sediment yield (g m^2-hr) and SYg is geotextile net sediment yield (g m^2-hr).

III. RESULTS AND DISCUSSIONS

A. *Description of Corn Stalk Geotextile Net*

Fig. 7 shows the developed corn stalk geotextile net and the physical specifications of the corn stalk geotextile net are presented in Table I.

Figure 7. Corn stalk geotextile net

TABLE I. PHYSICAL SPECIFICATION OF CORNSTALK GEOTEXTILE NET

PHYSICAL PROPERTY	AMOUNT
Mass per unit area, g/m^2	806.25
Water Absorption, %	241
Single spline rope diameter	5.22
Double spline rope diameter	10.89
No. of twine-crosswise	28
No. of twine-lengthwise	14

The average mass per unit area is 806.25g/m^2. Mass per unit area of corn stalk geotextile net falls under heavy weight-type natural geotextile as classified in [18]. This specific physical property implies that corn stalk geotextile net is a suitable material for soil erosion mitigation.

The change in weight before and after soaking was obtained using a digital weighing scale. Results showed that the average water absorption of geotextile sample is 241% of its initial weight. Water absorbing ability of geotextile greatly influences the amount of runoff generated.

Natural geotextile has been demonstrated as a suitable material for use in various erosion control experiment because of its water absorbing capacity by reducing the volume of runoff. Reference [12] showed that natural fiber geotextile for erosion control has a lower runoff velocity which is due to high water absorbency. Also, its natural water absorbing capacity helps conserve soil moisture and anchor soil firmly (drapability) [10].

B. Impact of Corn Stalk Geotextile Net on Soil Erosion Mitigation

From Table II and III, sediment yield seemed to increase with the decrease in the amount of surface cover at any given period of the rainfall simulation. For example, at 30° inclination (Table II), the sediment yield recorded for 60-minute rainfall simulation with 10-minutes interval were 100.00, 134.37, 170.83, 215.62, 217.50 and 232.29g/m^2-hr.

TABLE II. SEDIMENT YIELD MEANS AT 30 °SLOPE

RAINFALL DURATION	SURFACE COVER		
	Bare soil	Geotextile net	Combined geotextile net and vegetation
10	100.00^a	62.500^{ab}	0.00^b
20	134.37^a	65.62^{ab}	0.00^b
30	170.83^a	62.50^{ab}	0.00^b
40	215.62^a	64.06^b	0.00^b
50	217.50^a	72.50^b	0.00^b
60	232.29^a	69.79^b	0.00^b

In a row under each rainfall duration, means followed by a common letter are not significantly different at 5% level by DMRT.

TABLE III. SEDIMENT YIELD MEANS AT 60 °SLOPE

RAINFALL DURATION	SURFACE COVER		
	Bare soil	With geotextile net	Combined geotextile net and vegetation
10	1212.50^a	487.500^{ab}	0.00^a
20	1418.75^a	390.62^{ab}	0.00^b
30	1437.50^a	368.75^{ab}	0.00^b
40	1431.25$_a$	364.06^{ab}	0.00^b
50	1467.50^a	348.75^b	0.00^b
60	1448.95^a	307.29^b	0.00^b

In a row under each rainfall duration, means followed by a common letter are not significantly different at 5% level by DMRT.

TABLE IV. SLRE (%) MEANS AT 30 °SLOPE

RAINFALL DURATION	SURFACE COVER	
	With geotextile net	Combined Geotextile net and vegetation
10	29.36^b	100^a
20	38.04^b	100^a
30	54.45^b	100^a
40	58.62^b	100^a
50	62.07^b	100^a
60	66.98^b	100^a

In a row under each rainfall duration, means followed by a common letter are not significantly different at 5% level by DMRT.

TABLE V. SLRE (%) MEANS AT 60 °SLOPE

RAINFALL DURATION	SURFACE COVER	
	With geotextile net	Combined Geotextile net and vegetation
10	57.68^b	100^a
20	72.67^b	100^a
30	71.79^b	100^a
40	73.34^b	100^a
50	75.34^b	100^a
60	78.18^b	100^a

In a row under each rainfall duration, means followed by a common letter are not significantly different at 5% level by DMRT.

Experimental units with combined corn stalk geotextile net and vegetation cover have 100% reduction efficiency for both 30° and 60° slope (Table IV and Table V). Result revealed that the type of surface cover had significant effect on soil loss reduction efficiency. These values can be attributed to the ability of the surface covers to reduce the kinetic energy of flowing water thereby reducing its ability to transport soil particles.

IV. CONCLUSION

Based from the results, the following conclusions were derived:

Alteration of the physical structure of corn stalks should be done first before it can be converted into geotextile product for soil erosion mitigation. The processes in corn stalk geotextile net production involve retting, fiber extracting, rope making and net weaving.

Corn stalk geotextile net may be characterized in terms of such physical properties as mass per unit area and water absorbing capacity. Mass per unit area of the net (806.25g/m^2) was affected by the mass of single and double spline ropes used in the production. Water absorbing capacity is about 241% of its initial weight.

The corn stalk geotextile nets that were developed were effective in mitigating soil erosion at 30° and 60° slope inclination under a laboratory condition. Soil loss reduction efficiency ranged from 29-66.99% for 30° slope and 72.67-78.19% for 60° slope.

V. RECOMMENDATION

Results revealed that the developed corn stalk geotextile net has the potential to be used for soil erosion control. Sediment yield and soil loss efficiency were significantly reduced when compared with plots without soil covering. Other recommendations derived from the results of the experiments include:

Developing and designing of decorticating and rope-making machines specifically for corn stalks to decrease the labor requirement, cost of producing geotextile net and fiber extraction duration.

Validating the results of the laboratory experiment through field testing.

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