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Effect of geo–textiles on runoff, soil loss, soil quality and vegetation in slopping lands of Western Ghats of India

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ABSTRACT

A study was conducted to compare jute geo–textiles' performance with synthetic geo–textiles on runoff, soil losses, nutrient losses, soil moisture retention, and grass growth parameters. The study was conducted in two slope groups, namely 60% and 90% and three types of geo–textiles *viz.,* 500 GSM synthetic geo–textile, 500 GSM non–woven JGT 500 GSM open weave JGT were applied, and one control plot was maintained. Root slips of weeping love grass *(Eragrostis curvula)* were directly planted after the treatment. The results of the study showed that the natural jute geo–textiles have performed with higher efficiency in controlling soil erosion. Higher runoff reduction efficiency of 41.3% and 38.4% was attained by open weave JGT in 60% and 90% slope, respectively. Similarly, maximum soil loss reduction efficiency of 86.6% and 86.8% was attained by open weave jute geo–textiles under 60% and 90% slopes, respectively. Growth and root parameters of grass (*E. curvula)* also showed that the maximum was attained by open weave jute geotextiles. Thus, the study concluded that the natural JGT could be effectively utilized for slope stabilization by establishing grass species with maximum slopes of 90%.

1. INTRODUCTION

Geosynthetics comprise a variety of products such as geotextiles, geogrids, geomembranes, and geocomposites that are largely found to be in immense use for many infrastructure development projects in India (Rickson, 1988). Apart from the conventional civil engineering applications, these geosynthetics play a vital role in environmental engineering, including pollution control, landfills and erosion control. Surface coverage, roughness, water holding capacity, wet weight, and ability of increased flow depth are the unique features of geotextiles used for erosion control (Rickson, 2006). As the locally available soil or dredged material and rocks are used as fill material in construction, Geosynthetic structures are considered to be economical in nature (Brooker and Ireland, 1965; Nagami and Yong, 2003; Deb *et al*., 2013). Alternatively, natural fibre based geotextiles is being applied in slope stabilization, erosion control, and road construction (Ogbode and Essien, 2018; Vishnudas *et al*., 2012). Jute is one of the natural fiber geotextiles being used (Vivek *et al*., 2019) as it is very effective in reducing soil erosion. It improves slope stabilization processes subsequently. Jute geo–textile (JGT) is a fabric made from jute smeared with resistant chemicals is highly used to control soil degradation in the eroding bank of Indian rivers. JGT has also been recommended as a pioneering material for controlling soil erosion, where it has been successful in establishing itself as a potential agent (Ingold, 1994).

Several researchers successfully used JGT for slope management, erosion control, stabilization of earthen embankment, river and canal bank protection, strengthening of subgrade of road pavement and railway track, consolidation of soft soil, and so forth (Ramaswamy and Aziz, 1989; Sanyal and Chakraborty, 1993; Rickson *et al*., 2003). The additional factors such as abundant availability and economical choice of manufacturers as well as end–users play an influencing role in the application of JGT for erosion control (Ghosh *et al*., 1994). For its wide application, the environment–friendly nature of JGT makes it a safe and congenial natural choice, especially in the area of erosion control (Majumder *et al*., 1980). The weave JGT (weft yarns) provides a series of mini barriers which act as a kind of check dams across the direction of overland flow (Sanyal, 2011). The 3D construction of weave JGT reduces the speed of overland flow and opening of the material retains dislodged soil particles that are set to be over excited by overland flow (Choudhury and Sanyal, 2010). Open weave JGT structure with 40% to 60% open area provides a partial cover to the soil surface and heavy strands of JGT helps to absorb the impact of the kinetic energy of the raindrops. JGT has excellent drapability and can be laid out to follow the soil contours on which it is laid (Thomson and Ingold, 1986).

JGT is very hygroscopic thanks to the intrinsic properties of jute fiber and its flexibility increases thanks to the absorption of water. The uniqueness of JGT is the capacity to absorb 4.5–6 times its dry weight water because of its high cellulosic content (Rickson, 1988). It also bio– degrades within 2 to 5 years (Oosthuizen and Kruger, 1994) adding nutrients to the soil at the micro–level. Once vegetation starts growing, the role of JGT is taken over and established vegetative cover provides canopy interception to falling raindrops and protects the soil from splash detachment of soil particles (Bhattacharyya *et al*., 2010). The fibrous root system of vegetation penetrates, reinforces the slope soil, and provides long term stability. JGT is preferred over other geotextiles for slope stabilization as they carry additional environmental complimentary support (Sanyal, 2004). Perennial grasses along with the geotextiles are more effective for stabilization of slopes and reducing soil erosion (Jankauskas *et al*., 2004).

The Nilgiris hill ranges are located in the delicate environment of Western Ghats with an elevation ranges from 300 m to 2634 m above mean sea level (AMSL). The Nilgiris mountainous region forms an area of 5500 sq km and extends in three Indian states, namely Tamil Nadu, Kerala, and Karnataka. It is known for its rich biodiversity and source of water for major reservoirs in the plateaus. The major area of the Nilgiris is covered under natural and manmade forest (56%) followed by plantation crops (20%) like tea, coffee and the remaining 24% of the area is cultivated with vegetable crops. In recent times, forest and plantation crops are replaced by vegetables without adopting any soil and water conservation measures. Apart from this vertical road cutting, huge earth cut for developmental works and construction of buildings coupled with high intensity rainfall led to mass soil erosion in sloppy lands. In the history of the Nilgiris biosphere, landslides were very rare but now becoming frequent and occurring bi–annually or annually in one or other parts. Landslide occurrence is periodical especially during the north–east monsoon resulting huge damages to the properties and life in the region. Keeping in view of the erosion control characters of jute geo–textiles and geographical nature of Nilgiris, a study was conducted to compare the performance of jute geo–textiles with synthetic geo–textiles on erosion control. The main objective of the study is to compare the impact of natural jute geo–textiles over the synthetic geo–textile on runoff, soil and nutrient losses, and soil moisture retention.

2. MATERIALS AND METHODS

Study Area

The study was carried out at the Research Farm of ICAR–Indian Institute of Soil and Water Conservation (formerly known as Central Soil and Water Conservation Research and Training Institute), Regional Centre, Udhagamandalam, Tamil Nadu, which represents the geographical area of Nilgiris and lies in between 11°24'59" N latitudes and 76°41'11"E longitudes and located 2225 m AMSL. The climate is sub–humid subtropical with an annual rainfall of 1324.9 mm with average of 119 rainy days. As it falls within the active zone of both monsoon seasons, namely the south–west monsoon and the north–east monsoon, it rains almost every month of the year. The average temperature of the study area is relatively low with an annual average temperature of 14.6ºC. The study site has the initial soil pH of 5.2, available nitrogen of 145 kg ha^{-1}, available phosphorous of 35 kg ha^{-1}, available potassium of 220 kg ha^{-1} and organic carbon of 0.7%.

Methodology

The experimental plot was divided into two sections of slope groups, 60 and 90% with an intermediate transition area. In each slope group, four plots having the dimensions of 16 m × 4 m were created with three treatments *viz.,* 500 GSM synthetic geo–textile, 500 GSM non–woven JGT and 500 GSM open weave JGT and one control plot without applying geo–textiles for comparing the effect of geo–textiles. After imposing the treatments, root slips of weeping love grass *(E. curvula)* which is generally well adapted to local climatic conditions were directly planted in the already made hole during onset of monsoon season with the spacing of 50 cm × 50 cm and firmly filled with soil. Properties of geo–textiles used in this study are presented in Table 1. The study was replicated for three years from 2013 to 2015 and

Table: 1
Properties of jute geo–textiles evaluated for erosion control

Specifications	Jute geo–textile evaluated	
Weight (GSM) at 20% MR	500 GSM open weave JGT	500 GSM non–woven JGT
Width (cm)	≥122	150
Thickness (mm)	4.5 (±10%)	4
Wide width tensile strength (KN m^{-1}) MD × CD	≥6.5 × 6	4 × 5
Elongation at break (%) MD × CD	≤10 ×10	3.5 × 7
Open area (%)	50 – 65	Nil
Water holding capacity (%) on dry weight	450 – 500	250 – 300

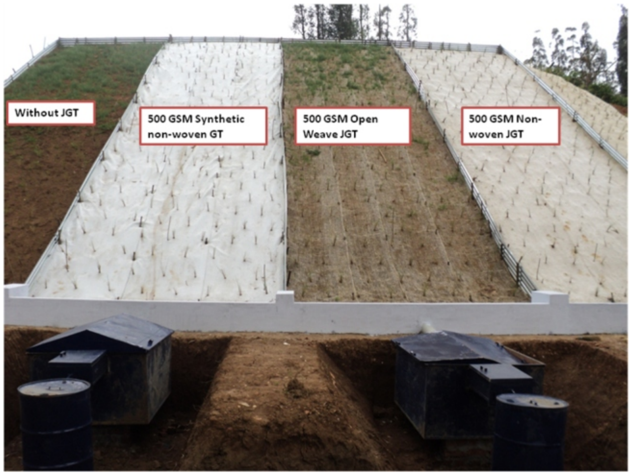

Plate 1. Experimental view of the study showing the treatments and control plot in 90% slope

hydrological parameters were monitored on time replication.

Measurement of Runoff, Soil and Nutrient Losses and Soil Moisture Retention

Runoff and soil loss were directly measured using multi–slot divisors with 11 no of slots developed by R.V. Geib in the USA for measuring runoff and soil loss from small experimental plots that were locally fabricated and installed at the outlet of each experimental plot (Harrold and Krimgold, 1943). Runoff and soil loss were measured directly during every rainfall event and added total runoff and soil loss for annual events. For each rainfall event, soil loss was estimated by taking 1000 ml of homogenized sample from the runoff tanks of each treatment and dried at 105°C in hot air oven and subsequent weighing of the dry soil samples. Then total soil loss for each rainfall event was calculated by multiplying dry soil weight and total runoff volume generated in the event divided by 1000 ml. Soil loss (t ha^{-1}) for each treatment was calculated by by adding all the soil loss of each rainfall event and it is converted to t ha^{-1}. Nutrients losses, namely nitrogen (Subbiah and Asija, 1956), phosphorus (Bray and Kurtz, 1945) and potassium (Jackson, 1973) and organic carbon (Walkley and Black, 1934) were estimated from the runoff samples as per standard laboratory procedures.

Soil moisture content was monitored using the gravimetric method at monthly intervals considering the rainy days in three soil depths (0–15 cm, 15–30 cm and 30–45 cm) to quantify the effect of different types of JGT on the soil moisture retention capacity of soil. Annual runoff, soil and nutrient losses and soil moisture retention were worked out for three years period from 2013 to 2015.

Efficiency of Geotextiles in Runoff and Soil Loss Reduction

The runoff reduction effectiveness (RRE %) and Soil loss reduction effectiveness (SLRE %) of different geo–textiles were evaluated using the formula of Sutherland (1998).

$$RRE\ (\%) = \frac{R\ Control - Ri}{R\ Control} \times 100$$

$$SLRE\ (\%) = \frac{SL\ Control - SLi}{SL\ Control} \times 100$$

Where, *RRE (%)* and *SLRE (%)* are runoff and soil loss reduction efficiency of treatment *i*, and *R* and *SL* are runoff and soil loss, respectively. A higher and positive value indicates the high effectiveness of geo–textiles in the reduction of runoff and soil loss over control.

Growth Parameters of Grass

The growth parameters of weeping love grass *(E. curvula)* namely height, foliage lateral spread and volume of the root were observed at monthly interval and consolidated on yearly basis for three years. The height of grass was measured vertically up to the main stem from the ground level. The foliage lateral spread was measured in 2 directions perpendicular to each other the diameter and average value was calculated as follows:

$$FLS = (Y_1 + Y_2) \div 2$$

Where, *FLS* is average foliage lateral spread

Y_1, Y_2 = Foliage lateral spread in 2 directions perpendicular to each other passing through the main stem as vertical central axis.

The grass was uprooted by digging and the rooting depth was measured vertically down from the ground level. The lateral spread of the roots was measured at 3 directions from the main stem (central) of the grasses and the radii and average value was calculated as follows.

$$RLS = (X_1 + X_2 + X_3) \div 3$$

Where, *RLS* = average root lateral spread

X_1, X_2, X_3 = root lateral spread in 3 directions from the main stem (central).

Volume of the root was measured by water displacement method. Root mass density was calculated by dividing the volume by the root dry weight and expressed in gram cc^{-1} of soil volume.

Soil Conservation Properties of Grass

Grasses are shallow rooted and it is assumed that fibrous roots bind the soil in a cylindrical shape (Pang *et al.,* 2011). It is because a more lateral spread of the roots provides umbrella for the soil beneath up to the maximum rooting depth. Hence, formula of volume of cylinder is used for calculating the volume of soil bound by the roots as follows:

Formula adopted for the volume of soil bound by roots $= \pi (RLS)^2 (RD)$.

Where, *RLS* = root lateral spread (radial form from the main stand of grass); and *RD* = rooting depth of grass.

The ground surface area protected by grass foliage against direct raindrop effect is calculated using the formula to calculate the area of circle ($A = 2\pi d/4$) as follows:

Protected ground surface area = $2\pi (FLS)/4$

Where, *FLS* is foliage lateral spread (taking as diameter passing through the main stand of the grass) and *d* is the diameter.

3. RESULTS AND DISCUSSION

Runoff andSoil Loss

Runoff and soil loss data showed less during the first year and increased during second year then subsequently decreased during third year. The less runoff and soil loss during the first year (2013) is due to high infiltration rate as the soil was filled to make required slope for the experiment. The fact of decreasing trend during third year was (2015) due to stabilized soil, canopy and root establishment of grass (Fullen and Booth, 2006). Minimum runoff of 59.4 mm was produced under 500 GSM open weave JGT followed by 66.9 mm in 500 GSM non−woven JGT against 83.9 mm of runoff in control plot during the year 2013 in 60% sloppy land (Table 2). However, during the second year of the study, out of a total rainfall of 1392.2 mm, minimum runoff of 125.6 mm was produced by 500 GSM open weave JGT followed by 149.8 mm by 500 GSM non−woven JGT and 178.6 mm by 500 GSM synthetic geo−textiles against maximum runoff of 215.1 mm from the control plot. Similarly, minimum runoff of 72.4 mm was produced by 500 GSM open weave JGT followed by 500 GSM non−woven JGT (86 mm) and 500 GSM synthetic geo−textiles (105.8 mm) against maximum runoff of 154.1 mm in control plot during the year 2015. Application of geo−textiles on bare soils is generally reduce the runoff volume (Sutherland, 1998) and the same was confirmed in the present study.

The runoff data recorded in 90% sloppy land shows that minimum runoff of 69.5 mm was produced under 500 GSM open weave JGT followed by 78.9 mm in 500 GSM non−woven JGT against 98.5 mm of runoff in control plot during the year 2013. However, during the second year of the study, out of a total rainfall of 1392.2 mm, minimum runoff of 185.1 mm was produced by 500 GSM open weave JGT followed by 197.8 mm by 500 GSM non−woven JGT and 221.2 mm by 500 GSM synthetic geo−textiles against maximum runoff of 253.6 mm from the control plot. Similarly, minimum runoff of 77.1 mm was produced by 500 GSM open weave JGT followed by 500 GSM non−woven JGT (92.6 mm) and 500 GSM synthetic geo−textiles (124 mm) against maximum runoff of 186.3 mm in control plot during the year 2015 (Table 3).

Runoff data recorded in three years period and mean data shows that overland flow is less in the plot covered by 500 GSM open weave JGT compared to the plots covered by non−woven JGT and synthetic geo−textiles. It was also noticed that the open weave JGT reduced the runoff from 3.0 to 6.5% in 60% slope and 3.5 to 7.7% in 90% slope (Fig's

Table: 2
Rainfall and runoff under different geo−textiles for hill slope stabilization at 60% sloppy land

Year	Rainfall (mm)	Runoff (mm)				Percentage of runoff			
		500 GSM synthetic non−woven geo−textiles	500 GSM non−woven JGT	500 GSM open weave JGT	Control	500 GSM synthetic non−woven geo−textiles	500 GSM non−woven JGT	500 GSM open weave JGT	Control
2013	843.6	78.2	66.9	59.4	83.9	9.3	7.9	7.0	10.0
2014	1392.2	178.6	149.8	125.6	215.1	12.8	10.8	9.0	15.5
2015	1409.8	105.8	86.0	72.4	154.1	7.5	6.1	5.1	10.9
Mean	1215.2	120.9	100.9	85.8	151.0	9.9	8.3	7.1	12.1
CD (0.05%)		31.61				1.71			

Table: 3
Rainfall and runoff under different geo−textiles for hill slope stabilization at 90% sloppy land

Year	Rainfall (mm)	Runoff (mm)				Percentage of runoff			
		500 GSM synthetic non−woven geo−textiles	500 GSM non−woven JGT	500 GSM open weave JGT	Control	500 GSM synthetic non−woven geo−textiles	500 GSM non−woven JGT	500 GSM open weave JGT	Control
2013	843.6	90.2	78.9	69.5	98.5	10.7	9.4	8.2	11.7
2014	1392.2	221.2	197.8	185.1	253.6	15.9	14.0	13.3	18.3
2015	1409.8	124.0	92.6	77.1	186.3	8.8	6.6	5.5	13.2
Mean	1215.2	145.1	123.1	110.6	179.5	11.8	10.0	9.0	14.4
CD (0.05%)		36.46				2.04			

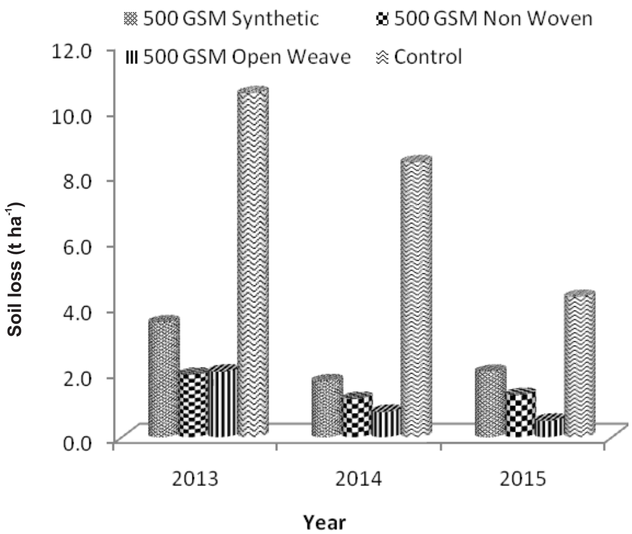

Fig. 1. Effect of different geo–textiles on annual soil loss under 60% slopping land

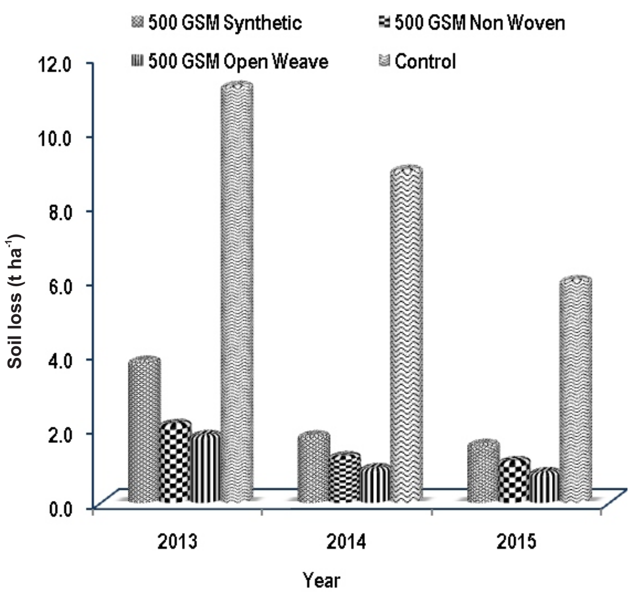

Fig. 2. Effect of different geo–textiles on annual soil loss under 90% slopping land

1 and 2). The application of geo–textiles on soil is effective in reducing runoff by altering the shear stress partitioning of overland flow on hill slopes (Thomson, 2001).

Both the Jute and synthetic geo–textiles produced lower annual soil loss rates than the control. In 60% slope, soil loss was reduced by open weave JGT from 3.8 to 8.5 t $ha^{-1}yr^{-1}$ compared to control plot. Minimum mean soil loss of 1.1 t $ha^{-1}yr^{-1}$ was recorded in the plot covered by 500 GSM open weave JGT followed by 500 GSM non–woven JGT (1.4 t $ha^{-1}yr^{-1}$) and 500 GSM synthetic geo–textiles (2.4 t $ha^{-1}yr^{-1}$) against maximum soil loss of 7.7 t $ha^{-1}yr^{-1}$ in control plot. Similar fact of decreased soil loss by geo–textiles with perennial grass was already reported by Jankauskas *et al.* (2008).

Similarly, in 90% slope, mean minimum soil loss of 1.2 t $ha^{-1}yr^{-1}$ was recorded in the plot covered by 500 GSM open weave JGT followed by 500 GSM non–woven JGT (1.5 t $ha^{-1}yr^{-1}$) and 500 GSM synthetic geo–textiles (2.4 t $ha^{-1}yr^{-1}$) against maximum soil loss of 8.7 t $ha^{-1}yr^{-1}$ in control plot. Least soil loss in jute geotextiles covered plots proved the importance of natural fiber based geo–textiles in soil conservation. Jana *et al.* (2016) also reported that the soil loss reduction due to application of 500 GSM JGT was the tune of 99.4%. The effectiveness of the Jute geotextiles in reducing the soil erosion is attributed to their great drapability which refers to its attachment to the soil especially when wet (Alvarez–mozos *et al.,* 2013).

Runoff and Soil Loss Reduction Efficiency of Geo–Textiles

The runoff and soil loss reduction efficiency of all the geo–textiles were low in initial years due to less vegetation establishment and more runoff. The mean RRE showed the efficiency of open weave JGT which was higher followed by non–woven JGT when compared to synthetic geo–textiles, the same was the trend in SLRE. Maximum RRE of 41.3% and 38.4% was attained by open weave JGT in 60% and 90% slope, respectively. Similarly, maximum SLRE of 86.6% and 86.8% was observed under 60% and 90% slope,

Table: 4
Runoff and soil loss reduction effectiveness of different geo–textiles at 60% and 90% slopping land

Year	500 GSM synthetic non–woven geo textiles		500 GSM non–woven JGT		500 GSM open weave JGT	
	60% slope	90% slope	60% slope	90% slope	60% slope	90% slope
			RRE %			
2013	6.79	8.43	20.26	19.90	29.20	29.44
2014	16.97	12.78	30.36	22.00	41.61	27.01
2015	31.34	33.44	44.19	50.30	53.02	58.62
Mean	18.37	18.22	31.60	30.73	41.28	38.36
			SLRE %			
2013	66.67	66.07	81.90	81.25	80.95	83.93
2014	79.76	79.78	85.71	86.52	90.48	89.89
2015	53.49	73.33	69.77	81.67	88.37	86.67
Mean	66.64	73.06	79.13	83.15	86.60	86.83

respectively (Table 4). Increased RRE and SLRE is due to higher infiltration process of JGT by absorbing more water and support the erosion control and reduce the overland flow (Beven, 2011; Jana *et al.,* 2016).

Nutrient Loss

Nutrient loss in runoff is directly proportional to volume of runoff and soil erosion. Major soil nutrients like nitrogen, phosphorous, potassium and organic carbon lost through runoff were estimated under 60% and 90% slope (Table's 5 and 6). Among the geotextiles, open weave JGT was more effective in reducing the nutrient losses as compared to non−woven JGT and synthetic geo−textiles and considerable amount of nutrients were saved by open weave JGT. The Open Weave JGT saved 68.6% total nutrients in 60% slope and 55.7% in 90% slope from the loss through runoff compared to the plot without JGT. These results confirmed the hypothesis that natural geotextiles are very effective in soil erosion control and vegetation establishment (Davies *et al.,* 2006).

Soil Moisture Retention

The application of jute geotextile on sloppy land increases moisture retention in the soil at various depths (Table's 7 and 8). The soil moisture content in different soil depths (0−15 cm, 16−30 cm and 31−45 cm) is higher under all JGT applied plots than the control plot in both rainy and dry season. Among the two types of JGT, the soil moisture retention was highest under 500 GSM open weave JGT followed by 500 GSM non woven JGT and 500 GSM synthetic geo−textiles. Similar significant differences in soil moisture retention was noticed in dry season under open

Table: 5
Nutrient losses in runoff under different types of JGT and synthetic geo−textiles in 60% slopping land

Treatment	Year	Nutrient Loss (kg ha^{-1})					Nutrient saved (%)
		N	P	K	OC	Total	
500 GSM synthetic non−woven geo−textiles	2013	29.9	0.1	3.3	5.7	39.0	17.8
	2014	11.6	0.1	3.1	3.1	17.9	
	2015	4.5	0.1	3.1	3.0	10.7	
	Mean	15.3	0.1	3.2	3.9	22.5	
500 GSM non−woven JGT	2013	16.2	0.2	4.8	3.2	24.4	43.4
	2014	7.8	0.1	3.4	2.2	13.5	
	2015	3.8	0.1	2.6	2.1	8.6	
	Mean	9.3	0.1	3.6	2.5	15.5	
500 GSM open weave JGT	2013	10.1	0.1	2.4	1.9	14.5	68.6
	2014	3.5	0.1	1.5	1.6	6.7	
	2015	2.5	0.1	1.3	0.7	4.6	
	Mean	5.4	0.1	1.7	1.4	8.6	
Control	2013	8.3	0.1	5.8	18.3	32.5	−
	2014	7.8	0.1	5.5	14.9	28.3	
	2015	7.5	0.1	5.0	8.9	21.5	
	Mean	7.9	0.1	5.4	42.1	27.4	

Table: 6
Nutrient losses in runoff under different types of JGT and synthetic geo−textiles in 90% slopping land

Treatment	Year	Nutrient Loss (kg ha^{-1})					Nutrient saved (%)
		N	P	K	OC	Total	
500 GSM synthetic non−woven geo−textiles	2013	27.3	0.1	5.0	6.3	38.7	20.5
	2014	11.6	0.1	3.2	5.5	20.4	
	2015	6.0	0.1	3.0	5.1	14.2	
	Mean	15.0	0.1	3.7	5.6	24.4	
500 GSM non−woven JGT	2013	21.4	0.1	3.4	5.8	30.7	38.0
	2014	10.8	0.1	3.4	3.9	18.2	
	2015	3.8	0.1	2.5	1.8	8.2	
	Mean	12.0	0.1	3.1	3.8	19.0	
500 GSM open weave JGT	2013	18.9	0.1	2.6	4.7	26.3	55.7
	2014	3.5	0.1	1.6	4	9.2	
	2015	2.1	0.1	1.5	1.7	5.4	
	Mean	8.2	0.1	1.9	3.5	13.6	
Control	2013	20.7	0.2	10	14.1	45.0	−
	2014	12.7	0.1	5.3	9.4	27.5	
	2015	10.9	0.1	2.8	5.8	19.6	
	Mean	14.8	0.1	6.0	9.8	30.7	

Table: 7
Impact of jute geo–textiles and synthetic geo–textile on soil moisture retention in 60% slope

Treatment	Soil depth	Soil moisture (%)											
	(cm)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
500 GSM synthetic	0–15	15.2	14.6	13.5	14.2	21.5	28.4	20.6	21.2	24.6	21.4	24.2	17.3
non–woven geo–textiles	16–30	18.4	17.1	17.2	21.0	25.5	30.8	22.8	25.5	28.0	25.5	29.7	20.1
	31–45	23.9	21.3	19.3	23.2	30.0	32.4	26.7	29.7	32.0	32.2	34.2	26.0
500 GSM non–oven JGT	0–15	18.6	16.6	14.2	16.4	23.2	29.3	22.6	22.9	26.1	24.2	28.2	20.0
	16–30	20.7	18.4	18.4	20.4	26.1	31.5	24.2	26.2	30.9	28.4	30.1	22.8
	31–45	26.5	24.1	20.9	23.8	31.2	33.6	29.7	34.6	34.0	33.6	36.4	28.1
500 GSM open weave JGT	0–15	22.5	20.4	12.6	17.0	26.6	30.4	24.2	24.7	28.1	26.8	33.1	24.8
	16–30	26.9	24.3	16.8	23.8	29.5	32.6	28.3	28.2	32.5	29.0	35.9	28.3
	31–45	28.1	26.4	18.7	30.0	32.9	35.1	32.1	36.0	36.2	34.3	38.6	31.7
Control	0–15	14.6	14.1	12.6	13.0	18.1	26.2	19.5	19.9	22.3	20.0	21.4	15.9
	16–30	17.9	16.4	16.8	18.9	24.2	28.4	21.1	22.3	27.6	24.3	23.5	18.4
	31–45	18.3	18.3	18.7	21.3	26.5	30.9	25.5	26.4	30.4	31.1	31.1	20.6

Table: 8
Impact of jute geo–textiles and synthetic geo–textile on soil moisture retention in 90% slope

Treatment	Soil depth	Soil moisture (%)											
	(cm)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
500 GSM synthetic	0–15	14.8	14.5	13.9	13.8	21.4	28.3	20.5	21.1	24.5	21.3	24.1	16.9
non–woven geo–textiles	16–30	18.0	16.7	15.0	20.5	25.3	30.6	22.7	25.4	27.9	23.0	29.5	19.7
	31–45	23.3	21.0	19.1	23.5	30.3	32.2	26.5	29.5	30.0	30.0	32.8	25.0
500 GSM non–oven JGT	0–15	18.1	16.8	14.0	16.3	23.8	29.2	22.5	22.8	26.0	23.0	28.1	19.8
	16–30	22.0	17.0	17.6	18.6	27.8	31.3	24.1	26.1	30.0	25.0	29.9	22.3
	31–45	25.9	23.9	20.5	22.0	31.0	33.4	29.5	34.4	31.0	29.0	34.9	27.0
500 GSM open weave JGT	0–15	23.0	20.0	16.1	16.8	26.3	30.2	24.1	24.6	28.0	25.0	32.9	24.6
	16–30	25.6	22.0	18.0	22.0	30.6	32.4	28.2	28.1	31.0	27.0	35.6	27.7
	31–45	27.8	23.0	24.0	29.5	33.4	34.9	31.9	35.8	34.0	32.0	37.1	30.4
Control	0–15	13.9	13.6	12.3	12.9	18.0	26.1	19.4	19.8	22.2	19.9	21.3	15.7
	16–30	17.6	16.5	16.0	18.0	23.5	28.3	21.0	22.2	24.0	22.0	23.3	18.0
	31–45	19.8	17.7	18.1	19.1	26.1	30.7	25.3	26.2	26.0	29.0	29.9	19.8

weave JGT which is due to the fact that it checked the velocity of flowing water, increased the time of concentration and allowed higher infiltration into the soil consequently reduced the runoff and soil loss (Manivannan *et al*., 2018). Several earlier investigations showed the higher moisture retention capacity by the application of the different types of geo–textile due to gyroscopic property of jute textile (Jankauskas *et al.,* 2012; Rahul and Ravisankar, 2018).

Growth Parameters of Grass

Grass height after two years of planting in 60% slope (Fig. 3) was the highest (128.4 cm) under 500 GSM open weave JGT which was followed by 500 GSM non woven JGT (120.4 cm) and synthetic geo–textiles (119.8 cm). The highest plant height (125.2 cm) was observed with open weave JGT in 90% slope (Fig. 4) which was followed by non woven JGT (122.2 cm). The growth rate of grass was higher in case of non woven JGT in 60 % slope and open weave JGT in case of 90% slope (Fig's 5 and 6). This may be due to the optimum growing condition provided in terms of better soil and moisture conservation. The growth rate of grass under different treatments were the highest during the fourth month after planting and started declining from the six months as the dry season commenced.

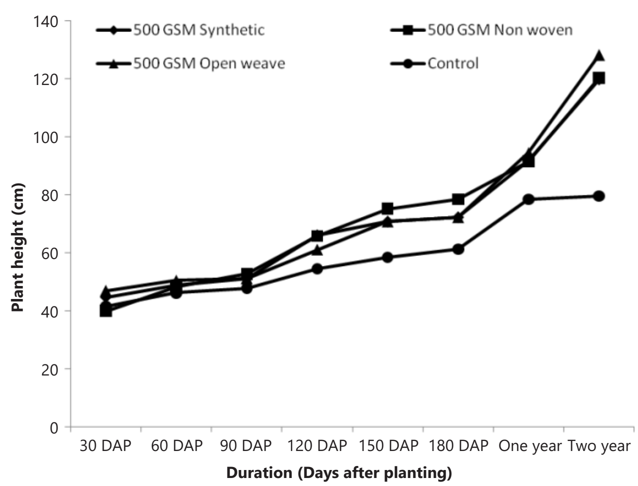

Fig. 3. Height of grass at different stages in 60% slope

In 60% slope, number of tillers per clump of grass was the highest (163.5 cm) in open weave JGT (Fig. 7) which was followed by non woven JGT (155.3 cm). However, the highest tiller numbers were observed under synthetic geo–textiles and it was on par with other JGT treatment. The least tiller number was observed under the control treatment. In

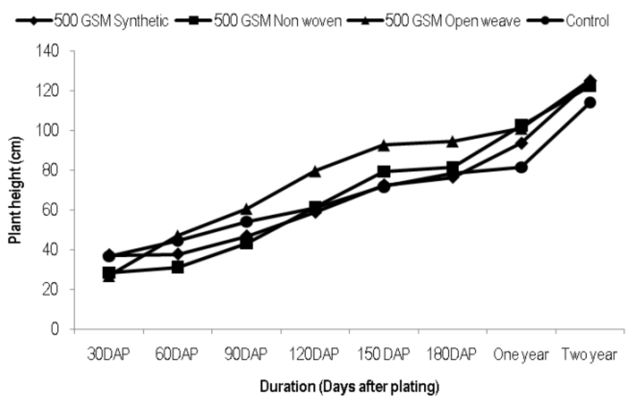

Fig. 4. Height of grass at different stages in 90% slope

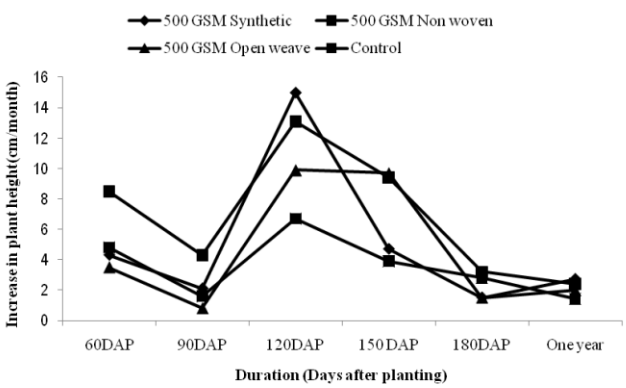

Fig. 5. Growth rate at different stages in 60% slope

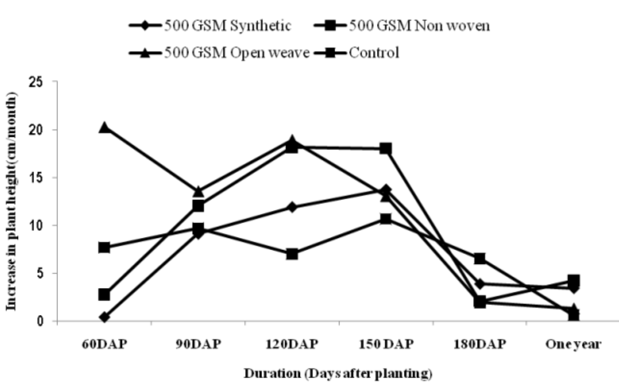

Fig. 6. Growth rate at different stages in 90% slope

90% slope, the highest tiller number was observed under open weave JGT (Fig. 8) after one and two year of planting. The less number of tillers was observed under synthetic compared to open weave JGT and it may be due the mechanical resistance given by the synthetic materials for tillering. The least tiller number was observed under control. Biomass produced was the highest in 500 GSM open weave JGT after one year (3.84 t ha^{-1}) and two years (10.7 t ha^{-1}) of planting, which was followed by 500 GSM non−woven JGT and synthetic geo−textiles which were on par with each other (Table 9). In 90% slope the highest biomass was observed under open weave JGT after one year

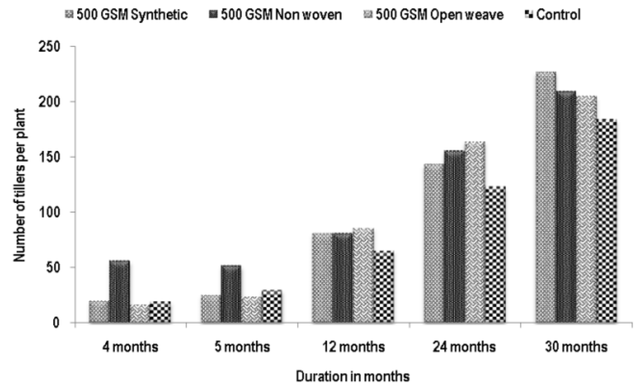

Fig. 7. Number of tillers per clump of grass in various growth stages in 60% slope

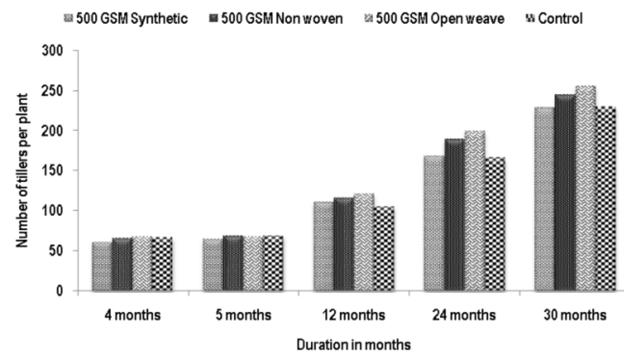

Fig. 8. Number of tillers per clump of grass in various growth stages in 90% slope

(11.16 t ha^{-1}) and two years (35.3 t ha^{-1}) after planting which was followed by non−woven JGT and synthetic geo−textiles. Similarly, grass and other herbs produced higher biomass of in between tea when covered with open weave jute geo−textiles in 22% slope (Manivannan *et al.*, 2019). The lowest biomass at one and two year after planting was observed under control.

The surface area protected by the grass was more under 500 GSM open weave JGT followed by 500 GSM non−woven JGT due to higher plant height compared to synthetic geo−textiles and it was the least in case control plot without any geo−textiles. In 90% slope, there was clear−cut trend among various jute geo−textiles. The highest value for surface area protection (16733 cm^2) was recorded in 500 GSM open weave JGT because of higher tiller number and foliage lateral spread. Surface area protected by the grass was the least in case of control.

Rooting Characters

The highest root depth of 46 cm was recorded under open weave JGT after one year of planting in 60% slope, which was followed by non−woven JGT (Table 10). However, root lateral spread (37.6 cm) and volume of soil bind by the root (130956 cc) was the highest under non−woven JGT and it was on par with open weave JGT. In 90% slope, the

Table: 9
Biomass, foliage spread and surface area protection given by the grass

Treatments	Biomass after one year (t/ha)	Biomass after two year (t/ha)	Foliage lateral spread after one year (cm)	Foliage lateral spread after two year (cm)	Surface area protected by grass after one year (cm^2)	Surface area protected by grass after two year (cm^2)
			60% slope			
500 GSM synthetic non–woven GT	3.54^{ab}	9.6^{bc}	69.7^{bc}	133^{a}	3813^{bc}	13886^{a}
500 GSM non–woven JGT	3.62^{ab}	10.7^{ab}	78.2^{ab}	135^{a}	4800^{ba}	14307^{a}
500 GSM open weave JGT	3.84^{a}	11.2^{a}	86.2^{a}	142^{a}	5833^{a}	15829^{a}
Control	3.12^{b}	8.6^{c}	58.1^{c}	106^{b}	2649^{c}	8820^{b}
			90% slope			
500 GSM synthetic non–woven GT	10.3^{ab}	31.2^{a}	109^{ab}	129^{bc}	9331^{ba}	13063^{bc}
500 GSM non–woven JGT	10.5^{ab}	32^{a}	116^{a}	138^{ba}	10659^{ba}	14950^{ba}
500 GSM open weave JGT	11.16^{a}	35.3^{a}	118^{a}	146^{a}	10935^{a}	16733^{a}
Control	9.16^{b}	29.6^{b}	105^{b}	115^{c}	8659^{b}	10382^{c}

Note: Numbers with the same letter are not significantly different (P = 0.05)

Table: 10
Root growth of grass under different treatments and slopes after one year

Treatments	Root depth (cm)	Root lateral spread (cm)	Root weight / plant	Root volume (cc)	Root mass density (gm cc^{-1})	Volume of soil bind by the root (cc)
			60% slope			
500 GSM synthetic non–woven GT	23.0^{c}	31.8^{ab}	5.2^{ab}	32^{ab}	0.16^{a}	72802^{b}
500 GSM non–woven JGT	29.5^{b}	37.6^{a}	6.0^{a}	35^{a}	0.16^{a}	130956^{a}
500 GSM open weave JGT	46.0^{a}	30.1^{ab}	5.8^{a}	35^{a}	0.17^{a}	130864^{a}
Control	26.0^{bc}	26.5^{b}	4.8^{b}	30^{b}	0.14^{b}	57332^{c}
			90% slope			
500 GSM synthetic non–woven GT	31.0^{b}	26.6^{b}	5.9^{bc}	35^{b}	0.15^{ab}	68873^{b}
500 GSM non–woven JGT	39.0^{a}	35.6^{a}	6.6^{ab}	45^{a}	0.19^{a}	155200^{a}
500 GSM open weave JGT	37.0^{a}	40.3^{a}	7.7^{a}	50^{a}	0.19^{a}	188686^{a}
Control	33.0^{b}	24.8^{b}	4.8^{c}	25^{c}	0.13^{b}	63730^{c}

Note: Numbers with the same letter are not significantly different (P = 0.05)

highest root lateral spread (40.3 cm) and volume of soil bind by the root (188686 cc) was observed under open weave JGT followed by non–woven JGT which was on par with each other. In 60% slope two years after planting the highest root depth was observed in case of open weave JGT followed by open weave JGT (Table 11). The volume of soil bind by the root was more under open weave JGT due to higher root lateral spread (49 cm). The root volume and root weight were higher under open weave and non–woven JGT, followed by synthetic geo–textiles. In 90% slope, the highest root depth (34 cm) was observed in non–woven JGT which was followed by the synthetic geo–textiles. However, the volume of soil bind (391073 cc) by the root was more under 500 GSM open weave JGT due to the higher root lateral spread (62 cm) which was followed by 500 GSM non–woven JGT (359140 cc) and synthetic geo–textiles. Overall, the root and growth characters in 500 GSM open weave and non–woven JGT were better as compared to synthetic geo–textiles.

Cost of Geo–Textiles Application

Economics of application of geo–textiles was worked out and found that the cost of open weave jute geo–textiles is cheapest in the market followed by non woven jute geo–textiles and synthetic jute geo–textiles (Table 12). Cost of application for the 700 GSM open weave jute geo–textiles recommended for grass will be ₹ 34/- sq m^{-1} including geo–textiles cost.

4. CONCLUSIONS

It is concluded that various types of jute geo–textiles and synthetic geo–textiles on 60% and 90% sloppy land had erosion control and it is observed that the natural jute geo–textiles have performed with higher efficiency in controlling soil erosion. Out of open weave and non–woven JGT, open weave JGT is more effective in reducing runoff and soil loss, nutrient loss and also increased soil moisture retention and plant growth parameters. Higher runoff reduction efficiency of 41.3% and 38.4% was attained by

Table: 11
Root growth of grass under different treatments and slopes after two year

Treatments	Root depth (cm)	Root lateral spread (cm)	Root weight / plant	Root volume (cc)	Root mass density (gm cc^{-1})	Volume of soil bind by the root (cc)
			60% slope			
500 GSM synthetic non−woven GT	32b^{a}	42^{bc}	13.8^{ba}	51^{a}	0.27^{ba}	177247^{b}
500 GSM non−woven JGT	32b^{a}	45^{ba}	16.2^{a}	55^{a}	0.29^{ba}	200292^{ba}
500 GSM open weave JGT	38^{a}	49^{a}	18.0^{a}	58^{a}	0.31^{a}	286487^{a}
Control	29^{b}	38^{c}	10.0^{b}	42^{b}	0.24^{b}	131490^{b}
			90% slope			
500 GSM Synthetic non−woven GT	33.6^{a}	50^{b}	15.5^{b}	52^{b}	0.30^{ba}	263760^{b}
500 GSM non−woven JGT	34.0^{a}	58^{a}	22.3^{a}	55^{ab}	0.41^{a}	359140^{a}
500 GSM open weave JGT	32.4^{a}	62^{a}	24.6^{a}	62^{a}	0.40^{a}	391073^{a}
Control	31.6^{a} (1.49)	48^{b} (1.20)	12.4^{b} (1.23)	48^{b} (2.64)	0.26^{b} (0.019)	228612^{b}

Note: Numbers with the same letter are not significantly different (P = 0.05); Figures in parenthesis denotes the standard error

Table: 12
Cost of geo−textiles application

Type of geo−textiles	Specification	Cost of application with grass	
		(₹ m^{-2})	(₹ ha^{-1})
Open weave JGT	500 GSM	25.50	2,55,000
	600 GSM	31.25	3,12,500
	700 GSM	33.80	3,38,000
Non woven JGT	500 GSM	42.00	4,20,000
Non woven synthetic GT	500 GSM	86.14	8,61,400

open weave JGT in 60% and 90% slope, respectively. Similarly, maximum soil loss reduction efficiency of 86.6% and 86.8% was also attained by open weave jute geo−textiles under 60% and 90% slopes, respectively. Maximum surface area protected by the grass was obtained under 500 GSM open weave JGT, followed by 500 GSM non−woven JGT due to higher plant height compared to synthetic geo−textiles and it was the least in case control plot without any geo−textiles. Growth and root parameters of grass (*E. curvula)* also showed that maximum was attained by open weave jute geotextiles. Thus, the study concludes that the natural JGT outperformed the synthetic geo−textiles and natural JGT can be effectively utilized for slope stabilization by establishing grass species when compared to synthetic geo−textiles. Open weave JGT with establishment of grasses is recommended for slope stabilization in the degraded land having the slopes upto 90%.

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REFERENCES

Alvarez−Mozos, J., Abad, E., Giménez, R., Campo, M.A., Goñi, M., Arive, M., Casalí, J., Díez, J. and Diego, I. 2013. Evaluation of erosion control geotextiles on steep slopes, Part 1: Effects on runoff and soil loss. *Catena,* 118: 168−178.

Beven, K.J. 2011. Rainfall−runoff modeling. The primer, John Wiley and Sons, 449p.

Bhattacharyya, R., Smets, T., Fullen, M. A., Poesen, J. and Booth, C.A. 2010. Effectiveness of geotextiles in reducing runoff and soil loss: A synthesis. *Catena,* 81: 184–19.

Bray, R.H. and Kurtz, L.T. 1945. Determination of total organic and available forms of phosphorus in soils. *Soil Sci.,* 59: 39−45.

Brooker, E.W. and Ireland, H.O. 1965. Earth pressure at rest related to stress history. *Can. Geotech. J.,* 2 (1–2): 1–15.

Choudhury, P. and Sanyal, T.K. 2010. Embankment slope stabilization with jute geo−textiles: A case study in NH−2 Allahabad by−pass. In Indian Geotechnical Conference, Mumbai, pp 731−734.

Davies, K., Fullen, M.A. and Booth, C.A. 2016. A pilot project on the potential contribution of palm−mat geotextiles to soil conservation. Earth Surf. *Process Landf.,* 1: 561–569.

Deb, K., Chandra, S. and Basudhar, P.K. 2013. Design of geosynthetic−reinforced earth using equivalent thickness concept. *Indian J. Geosyn. Ground Improv.,* 2(1): 4–6.

Fullen, M.A., Booth, C.A. 2006. Grass ley set−aside and soil organic matter dynamics on sandy soils in Shropshire, U.K. Earth Surf. *Process Landf.,* 31: 570–578.

Ghosh, P., Samanta, A.K. and Das, D. 1994. Effect of selective pre−treatments and different resin post−treatments on jute−viscose upholstery fabric. *Indian J. Fibre Textile Res.,* 19(4): 277–280.

Harrold, L.L. and Krimgold, D.B. 1968. Devices for measuring rates and amounts of runoff employed in soil conservation research. U.S. Soil Conservation Service, 51p.

Ingold, T.S. 1994. Geotextiles and geomembranes manual. Elsevier Science Publishers Ltd, Oxford, 199p.

Jackson, M.L. 1973. Soil chemical analysis, Printice Hall, New Delhi.

Jana, K., Lukas, J. and Jan, P. 2016. The effectiveness of jute and coir blankets for erosion control in different field and laboratory conditions. *Solid Earth.* 7: 469–79.

Jankauskas, B., Jankauskiene, G., Fullen, M.A. and Booth, C.A. 2008. Utilizing palm−leaf geotextiles to control soil erosion on roadside slopes in Lithuania. *Lith. J. Sci.,* 3: 22–28.

Jankauskas, B., Jankauskiene, G. and Fullen, M.A. 2004. Erosion preventive crop rotations and water erosion rates on undulating slopes of Lithuania. *Can. J. Soil Sci.,* 84(2): 177–186.

Jankauskas, B., Jankauskiene, G. and Fullen, M.A. 2012. Soil conservation on road embankments using palm−mat geotextiles: Field studies in Lithuania. *Soil Use Manag.,* 28: 266–275.

Majumder, A., Samajpati, S., Ganguly, P.K., Sardar, D. and Das Gupta, P.C. 1980. Swelling of jute Heterogeneity of crimp formation. *Text. Res. J.,* 50(9): 575–8.

Manivannan, S., Khola, O.P.S., Kannan, K., Kasthuri Thilagam, V. and Choudhury, P.K. 2019. Application of jute geo textiles (JGT) for sustainable management of hill slopes. *Acta Scient. Agric.,* 3(7): 163−166.

Manivannan, S., Khola, O.P.S., Kannan, K., Choudhury, P.K., Kasthuri Thilagam, V. 2018. Efficacy of open weave jute geotextiles in controlling soil erosion and its impact on hill slope stabilization. *Indian J. Agric. Sci.,* 88(5) : 679–84.

Nagami, T. and Yong, T.Y. 2003. Load−settlement analysis of geosynthetic− reinforced soil with a simplified model. *Soils Found.,* 43(3): 33–42.

Ogbobe, O. and Essien, K.S. 2018. A study of biodegradable geotextiles used for erosion control. *Geosynth. Int.,* 5: 545–553.

Oosthuizen, D. and Kruger, D. 1994. The use of Sisal fibre as natural geotextile to control erosion. (In) Rao, G.V., Balan, K., (eds.). Coir Geotextiles–Emerging Trends. Proc. of the 5th International Conference on Geotextiles, Geo–membranes and Related Products. Singapore, pp 18–23.

Pang, W., Crow, W.T., Luc, J.E., McSorley, R., Giblin−Davis, R.M., Kenworthy, K.E. and Kruse, J.K. 2011. Comparison of water displacement and WinRHIZO software for plant root parameter assessment. *Plant Dis.,* 95: 1308−1310.

Rahul, A. and Ravisankar, L. 2018. Use of geotextiles for improving crop productivity on groundnut in Inceptisols. *Int. J. Chem. Stud.,* 6(5): 2673−2678.

Ramaswamy, S.D. and Aziz, M.A. 1989. Jute geotextile for roads. *Proc. of the Workshop on Geotextiles, Bangalore*. pp 259–66.

Rickson, R.J. 2006. Controlling sediment at source: An evaluation of erosion control geotextiles. *Earth Surf. Process Landf.,* 31: 550–560.

Rickson, R.J., Moore, H.M., Fox, H. and Elliott, S. 2003. Geotextiles in land reclamation: Applications for erosion control and vegetation establishment. *Proc. of 7th International Conference of the International Affiliation of Land Reclamationists.* Runcorn, U.K. pp 305–14.

Rickson, R.J. 1988. The use of jute geotextiles in soil erosion control. *Proc. of the 15th International Soil Consolidation Conference.* Bangkok, Thailand, pp 627−633.

Sanyal, T. and Chakraborty, K. 1993. Application of bitumen coated jute textile in bank protection works in the Hooghly estuary. *Geotext. Geomembr.,* 13: 127–32.

Sanyal, T. 2011. *Control of bank erosion naturally − A pilot project in Nayachar island in the river Hugli and appraisal of performance, Jute Geotextiles*. National Jute Board, Ministry of Textiles, GoI, Kolkata. pp 219–26.

Sanyal, T. 2004. *Proc. of seminar workshop Geosynthetics India.* Indian Institute of Technology, New Delhi, India, 362p.

Subbiah, B.V. and Asija, G.L. 1956. A rapid procedure for the determination of available nitrogen in soils. *Curr. Sci.,* 25: 259−260.

Sutherland, R.A. 1998. Rolled erosion control systems for hill slope surface protection: A critical review, synthesis and analysis of available data. I. Background and formative years. *Land Degrad. Dev.,* 9: 465–486.

Thomson, A.M. 2001. Shear stress partitioning for vegetation and erosion control blankets. Ph.D. Dissertation. Department of Bio–systems and Agricultural Engineering, University of Minnesota, St. Paul, Minnesota. (UMI Number: 3032015).

Thomson, J.C. and Ingold, T.S. 1986. Use of jute fabrics in erosion control, report of the international trade centre. United Nations Conference on Trade and Development, Geneva.

Vishnudas, S., Hubert, H.G., Savenije, Pieter, Van der Zaag and Anil, K.R. 2012. Coir geotextile for slope stabilization and cultivation – A case study in a highland region of Kerala, South India. *Phys. Chem. Earth.,* 47−48: 135–138.

Vivek, G., Neeraj, M., Hareesh, H., Ajith, G., Gireesh Kumar, G., Kumar, K., Renjith, K., Ravindranath and Das, A. 2019. Development of fully automatic power looms (*Anugraha Tejas*) for coir geo–textiles. *Indian J. Fibre Text. Res.,* 44 (3): 358−359.

Walkley, A. and Black, I.A.1934. An examination of degtjareff method for determining soil organic matter and a proposed modification of the chromic acid titration method. *Soil Sci.,* 37: 29−37.