KFRI Research Report 433 ISSN 0970-8103

Potential of using coir geo-textiles in highly degraded areas for improving the soil and the productivity

(Final report of the project KFRI 430/04)

M. Balagopalan
(Soil Science Department)
P. Rugmini
(Forest Statistics Department)

Kerala Forest Research Institute
An Institution of Kerala State Council for Science, Technology and Environment
Peechi 680 653, Kerala, India

June 2012

PROJECT PROPOSAL

1. Code	:	KFRI 430/04
2. Title	:	Potential of using coir geo-textiles in highly degraded areas for improving the soil and the productivity
3. Objectives	:	To estimate the quantity of soils eroded and the loss in soil nutrients in degraded areas as brought about by coir geo- textiles To find out the changes in soil physical properties To assess the establishment and growth of teak stumps/ root trainer seedlings To evaluate the economics of using coir geo-textiles in degraded lands
4. Date of commencement	:	April 2004
5. Date of completion	:	March 2007
6. Funding agency	:	Planning and Economic Affairs (E) Dept. Govt. of Kerala
7. Investigators		
Principal Investigator	:	M. Balagopalan
Associate Investigator	:	P.Rugmini

CONTENTS

ACKNOWLEDGEMENTS

We have great pleasure to record our deep gratitude to Dr. J. K. Sharma, Former Director for constant encouragement and valuable suggestions in the initial stages of the project and the Planning and Economic Affairs (E) Dept. Govt. of Kerala for financial assistance. We are also very grateful to Dr. K. V. Sankaran, Director for the kind support for publication of the Report. We are thankful to the Staff at the Forest Station, Vettukkad for assistance in the field work. We express our sincere thanks to Drs. Thomas P. Thomas, K. V. Bhat and S. Sandeep for the editorial comments and the valuable suggestions for the improvement of the report. Finally, we owe very much to Mrs. Reneela, Research Fellow for her earnest help in the field and laboratory without which this project would not have been accomplished.

ABSTRACT

It is estimated that in India, 6000 million MT of precious topsoil is lost annually whereas it takes around 1000 years to build one inch of topsoil. Over the past 20 years, coir has proved its worth as a geo-textile in soil engineering, erosion control, soil re-enforcement, filtration etc. Coir geo-textile currently enjoys a high demand across the world. But in India its demand is very low. In the agricultural fields of Kerala, coir geo-textiles are in use on a smaller scale. However, it is yet to make a beginning in forestry sector in Kerala.

In Kerala, teak (*Tectona grandis* Linn. f.) occupies an area of about 57, 855 ha and the planting operations after one rotation have to be carried out in areas, which once were very fertile and now due to continuous plantation activities with monoculture, degraded. Thus, the present project was undertaken to evaluate the potential of using coir geo-textiles in highly degraded area for controlling soil erosion, improving the soil and thus the productivity of the area and also to assess the economics of using coir geo-textiles in degraded lands.

The study was carried out at Vettukkad in the Wadakkancherry Range, Thrissur Forest Division in 2004. The experiment was conducted in split plot design with two nutrient combinations *viz*., control (T_0) and high input management (T_1) as the main plot treatments and three coir geo-textiles size levels *viz*., without coir geo-textiles (A); 1 cm x 1cm mesh size coir geo-textile (B) and 2 cm x 2 cm mesh size coir geo-textile (C) as the subplot treatments.

The high input management is the one prescribed for the soil nutrient management. The root trainer seedlings and stumps collected from the Central Nursery, Chettikkulam were planted in plots of 20 m x 20m size in 2.5 m x 2.5 m and 2 m x 2 m spacing, respectively. The experiment was replicated six times.

The soils were medium acid in all layers and sandy loam in the surface and loam in deeper layers. The organic carbon and total N as well as available P, K, Ca and Mg contents were low.

It was seen that, in general, soil erosion and the quantity of nutrients eroded were low in plots where coir geo-textiles were spread. Among the two plots where coir geo-textiles were spread, erosion and loss of nutrients were lower in plots where coir geo-textiles of 1cm x 1cm mesh size was spread.

There was considerable increase in the soil moisture and decrease in the soil temperature in all the months in plots with coir geo-textiles. Soil moisture and soil temperature were substantially lower in the plots where coir geo-textiles of 1cm x 1cm mesh size was spread.

It was found that the two factor interaction between coir mesh size and nutrient treatment was highly significant, indicating that the effect of nutrient treatment differed significantly between the different mesh size treatments in their height growth. The growth of root trainer seedlings was better than that of stump planted seedlings in the early stages and the root trainer and stump planted seedlings receiving the fertilizers and mesh size of 1cm x 1cm attained the maximum height.

The Relative Treatment Effectiveness and Relative Economic Effectiveness values in the treatment receiving the fertilizers and mesh size of 1cm x 1cm were considerably higher when compared with the other treatments for the root trainer trees as well as stumps. As no new areas are available, future planting has to be done in highly degraded areas. Hence, it would be wiser to consider spreading of closely knitted coir geo-textiles as well as application of fertilizers as part of integrated silvicultural management for maximizing productivity.

1. INTRODUCTION

Soil erosion is one of the most serious problems faced by mankind today. In India, about 27 per cent of the land is subject to severe erosion. It is estimated that 6000 million MT of precious topsoil is lost annually whereas it takes around 1000 years to build one inch of topsoil. Deforestation, unsustainable methods of land use, mining, road laying and construction accelerate the rate of soil erosion (Rao and Balan, 2000).

Over the past 20 years, coir has proved its worth as a geo-textile in soil engineering, erosion control, soil reinforcement, filtration etc. This shows that it has great diversity when it comes to different application. Coir takes 15 times longer than cotton and seven times longer than jute to degrade. Where it does so, it is 100% biodegradable and eco-friendly (Schurholz, 1991).

In an age of growing environmental awareness, the use of eco-friendly biodegradable material as geo-textile started gaining momentum. In fact, the concept of geo-textile is not very new. According to historical findings, wood, bamboo, straw, reed etc. were used as geo-textiles in ancient times too. In industrial age, synthetic materials like polyester, polyamide, polypropylene and polyethylene took their place as geo-textiles for engineering applications due to their long life. These geo-textiles, however, had their own disadvantages. Their production caused air and water pollution while their non-biodegradability was responsible for increasing soil pollution (Rao and Balan, 2000).

Natural geo-textiles like cotton and jute were used but their performance was not upto the mark. Coir fibre with very high lignin content comparable to that present in softwood became the ideal choice as a geo-textile material. The lignin content in a fibre determines the resistance to microbial attack. Coir geo-textile with a lignin content of about 46 per cent scores heavily above jute and leaf fibre having 12 and 10 per cent of lignin, respectively (Banerjee and Unni, 2000).

Coir geo-textiles, a generic member of the geo-synthetic family are made from coconut fibre extracted from the outer husk of the coconut fruit. A variety of composites can be manufactured from coir fibres. The coir fibre has a length 6-8 inches, density 1.4 g/cc, tenacity 10 g/tex, breaking elongation 30%, swelling in water 5% diameter, water solubles 5.50%, pectin and related compounds 3%, hemicellulose 0.50%, lignin 45.84%, cellulose 43.44% and ash 2.22%.

Coir geo-textile has very high tensile strength, water absorption capabilities and ability to break up run off topsoil. It can promote new vegetation by absorbing water and by preventing the topsoil from drying out. Coir geo-textile has the ability to absorb solar radiation. One of the most outstanding aspects of coir geo-textile is that due to its eco-friendliness and bio-degradability, it need not be painstakingly removed. Coir geo-textile currently enjoys a high demand across the world. But in India its demand is very poor. About 90 per cent of the production in the country is exported (Banerjee, 1996).

Experimental studies have proved that while cotton and jute degrade within six months, coir retains its 20 per cent strength even after one year. It provides good support on slopes for about five years and is resistant to saline water. Its greatest advantage is its ecological niche for a rapid re-establishment of the vegetation cover by absorbing water and preventing the topsoil from drying. Once the natural vegetation takes over, the fibre decomposes gradually and eventually disintegrates, leaving nothing but humus. Similarly, like natural soil, coir has the capacity to absorb solar radiation (Banerjee, 1996).

The coir geo-textiles are used for stabilization of soil slope, reinforced soil wall, stabilization of road, rail-road track bed stabilization, embankment of soft soil, land fills, erosion control in slopes, land reclamation and river bank protection. The main functions of coir geo-textiles when used for the above purposes are re-enforcement, erosion control, drainage, filtration, separation, confinement, protection and encapsulation (Rao and Balan, 2000).

Based on the method of manufacture, coir geo-textiles are classified as woven and non-woven. The woven ones are those with coir mesh matting of two shafts weaves, coir woven fabric with loop construction and coir bags made with latex backed coir matting. The non woven ones are coco logs, coir fibre beds and coir needled felts.

In the agricultural fields in Kerala, coir geo-textiles are in use on a small scale. But, this has not yet been used in forestry sector in Kerala. In Kerala, teak (*Tectona grandis* Linn. f.) occupies an area of about 57, 855 ha and constitute about 50 per cent of man made forests. For planting teak and other forestry species in future, no new areas will be available. The planting operations after one rotation have to be carried out in areas, which once were very fertile and now due to continuous plantation activities with monoculture, degraded. This project, thus, was undertaken to evaluate the potential of using coir geo-textiles in highly degraded areas for controlling soil erosion, improving the soil and thus the productivity of the area and also to assess the economics of using coir geo-textiles in degraded lands.

2. MATERIALS AND METHODS

2.1. Study area

The study was carried out at Vettukkad in the Wadakkanacherry Range, Thrissur Forest Division. A hilly area, 3 ha in extent, having a slope of 30^0, was selected (Fig. 1).

2.2. Design of the experiment

The experiment was conducted in split plot design with two nutrient combinations *viz.*, Control (T_0) and High input management (T_1) as the main plot treatments and three coir geo-textiles size levels *viz.*,

1. Without coir geo-textiles (A);
2. 1 cm x 1cm size and (B) and
3. 2 cm x 2 cm size (C) as the subplot treatments (Fig. 2).

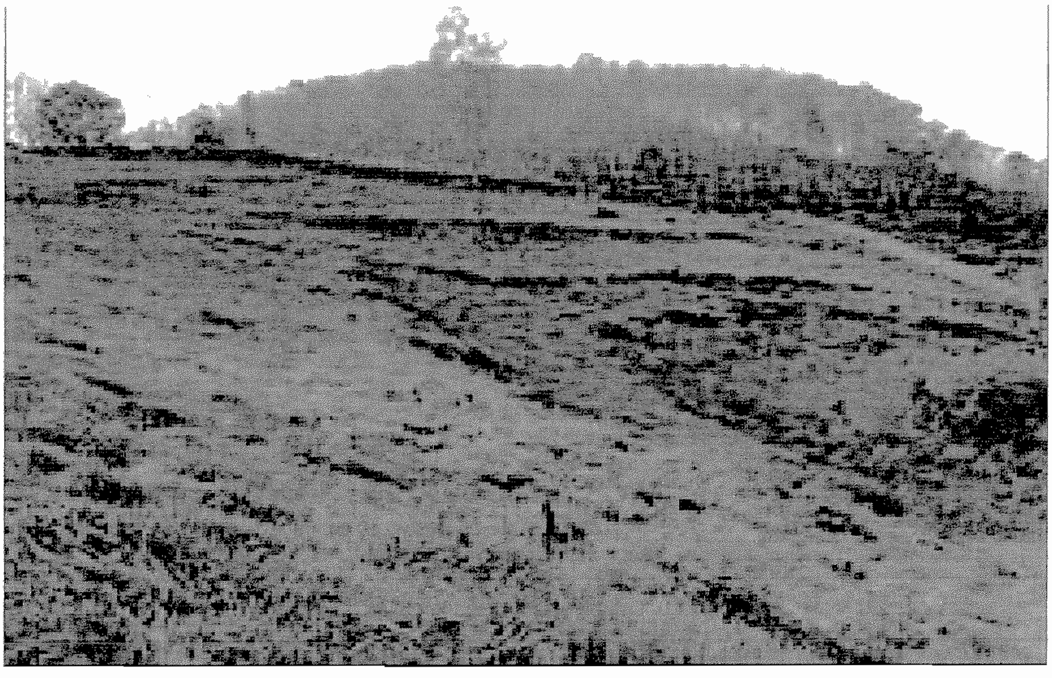

Fig. 1. Location of study area

The high input management is as per the soil nutrient management prescribed by Balagopalan *et al.* (1998). The root trainer seedlings and stumps collected from the Central Nursery, Chettikkulam were used for the study. Plots of 20 m x 20m size were laid out for planting. The root trainer seedlings and stumps were planted in 2.5 m x 2.5 m spacing and 2 m x 2 m spacing, respectively. In the root trainer experiment, in each subplot, there were 64 plants (8 x 8) while for stumps, there were 100 plants. The different treatments were T_0 A, T_0 B, T_0 C and T_1 A, T_1 B, T_1 C where T_0 represents control and T_1 represents high input management. A, B and C are for treatments without coir geo-textiles, coir geo-textiles having a mesh size of 1 cm x 1cm size and 2 cm x 2 cm size, respectively. The experiment was replicated six times. Hence, there were 18 plots, each, for the root trainer seedlings and stumps. The planting was over in July 2004.

Fig. 2. Plots with and without coir geo-textiles

2.3. Soil sampling

In order to find out the general soil characteristics, three soil pits each were dug in plots where root trainer and stumps were planted and soils were collected from 0-20, 20-40 and 40-60cm layers. The soils were characterized and the mean values are given in Table 1.

2.4. Soil and nutrient erosion studies

For evaluating the quantity of soils eroded and estimating the nutrients in the eroded soils, galvanized iron traps 2m x 1m x 1m size were placed across the slope in all the plots. The run off water were collected in the traps and when the traps were full, the supernatant water was decanted. The quantity of the supernatant water decanted was measured every time. Each time, five litre of the decanted water was evaporated and the quantity of the soils in this part was found out. From this, the total quantity of soil in the decanted water at different times was calculated. The soils deposited in the traps after the south west and north east monsoon periods in 2004, 2005 and 2006 were weighed. From the quantity of soils in the decanted water from the traps as well as in the traps after the south west and north east monsoon periods in 2004, 2005 and 2006, the total quantity of soils eroded was found out. The N, P, K, Ca and Mg contents in the eroded soils were found out as per standard procedures in ASA (1965) and Jackson (1958) which are presented in Tables 2 and 3.

2.5. Soil moisture and temperature

Soil moisture contents were recorded by collecting soils during mid day from six selected plots every day in the months of September, November and December 2004, January, February, March 2005, September, November and December 2005, January, February, March, September, November and December 2006 and the average soil moisture content was computed for one month. The soil moisture contents during the months when there was heavy showers were not recorded as the water holding capacity of the soils were above the saturation level. The mean values are given in Tables 4 and 5.

To find out soil temperature on all days in the months of September, November and December 2004, January, February, March 2005, September, November and December 2005, January, February, March, September, November and December 2006 during early morning (7.00 am), mid day (12.00 noon) and evening (5.00 pm), soil thermometer was inserted upto 10cm into the soil of selected plots and the temperature was recorded. The average for one month at different periods was computed and given in Tables 6 and 7.

2.6. Application of fertilizers

First dose of fertilizers was not done at the time of planting in June 2004 as it was heavily raining. Second and third doses of fertilizers were given in October 2004 and June 2005.

2.7. Growth measurements

Initial growth measurements of all the root trainer seedlings and stump planted seedlings were taken at the time of planting. Subsequent growth of root trainer seedlings and stump planted seedlings was recorded leaving two rows and columns on the periphery in order to avoid border effect. Data on growth measurements of root trainer seedlings were obtained from the net plot containing 16 plants (4 x 4) from each gross plot of 64 plants. In the case of stumps, growth measurements were recorded from 36 plants (6 x 6) from each gross plot of 100 plants. The second, third and fourth growth measurements were noted in June 2005, and June and December 2006. Thus, from each plot, heights of 16 root trainer seedlings and 36 stumps were measured at different periods. For the purpose of statistical analysis, data from only the net plots were considered.

2.8. Statistical analyses

The data on height measured over different periods were subjected to split plot analysis of variance separately for root trainer seedlings and stumps. The computational procedure and structure follow that for a split-split-plot analysis of variance. The height values were subjected to logarithmic transformation before subjecting to analysis of variance (Gomez and Gomez, 1976). The analysis of variance conformed to that of a univariate mixed model analysis. Analysis of variance of data on height of teak root trainer seedlings and stumps measured at different periods are given in Tables 10 and 11.

2.9. Survival of seedlings

The survival of all the root trainer and stump planted seedlings was recorded in June 2005 and 2006 and December 2006. The per cent survival of root trainer and stump planted seedlings are presented in Tables 12 and 13.

2.10. Volume of trees

In order to evaluate the economics of using coir geo-textiles in degraded lands, the volume of trees was calculated using the prediction equation reported by Chathurvedi and Pande (1973) which is

$$V = -0.0009 + 0.3360\, D^2 H$$

where V - the volume of trees (m^3)

D - the diameter at breast height (m)

H – the tree height (m).

2.11. Relative Treatment Effectiveness (RTE)

On the basis of the volume of trees in the control and different treatments, the Relative Treatment Effectiveness (RTE) was calculated as

$$RTE = \frac{(\text{Volume in treatment} - \text{Volume in control})}{\text{Volume in control}}$$

2. 12. Relative Economic Effectiveness (REE)

From the values of the RTE, the Relative Economic Effectiveness (REE) was calculated as

$$REE = RTE \times \frac{\text{Cost in control}}{\text{Cost in treatment}}$$

The mean values of RTE and REE for the root trainer and stump planted trees are given in Tables 13 and 14. From the values of the REE, the economics of using coir geo-textiles in degraded lands for root trainer seedlings and stumps are calculated.

3. RESULTS AND DISCUSSION

The soils were medium acid in all layers and sandy loam in the surface and loam in deeper layers. The organic carbon and total N as well as available P, K, Ca and Mg contents were low (Table 1).

3.1. Quantity of soils and nutrients eroded

It was seen that the quantity of soils eroded during the years 2004, 2005 and 2006 was maximum in the plots where fertilizer was added and coir geo-textiles were not spread (Table 2). The control plots where coir geo-textiles of 1cm x 1cm were spread (T_0B) had the minimum soils eroded. It could be seen that, in general, soil erosion was low in plots where coir geo-textiles were spread. Among the two plots where coir geo-textiles were spread, it was found that the quantity of soils eroded was lower in plots where coir geo-textiles of 1cm x 1cm was spread. In other words, the protection against the rain splash erosion and the reduction in the velocity as well as the erosive effect of runoff is more in closely woven geo-textiles. This could be adduced to the absorption of impact and kinetic energy of falling raindrops and checking runoff (Palmer, 1992). Moreover, the drapability of geo-textiles allows it to conform closely to the terrain (Thomson and Ingold, 1986). This observation is in agreement with those of Cammack (1988) and Schurholz (1988). As the ultimate objective of any erosion control measure is to establish a dense network of root system and vegetative cover to the desired degree of growth in the shortest possible time, the use of 1cm x 1cm coir geo-textile in sloppy areas for protection of soils against runoff is highly warranted.

The quantity of nutrients in the eroded soils during the years 2004, 2005 and 2006 was maximum in the plots where fertilizer was added and coir geo-textiles were not spread (T_1A). Control plots where coir geo-textiles of 1cm x 1cm were spread (T_0B) had the minimum nutrients eroded (Table 3). This is in conformity with the soils eroded.

Table 1. Physical and chemical characteristics of soils in the experimental plot at Vettukkad in the Wadakkancherry range

Layers (cm)	Gravel %	Sand %	Silt %	Clay %	Water holding capacity %	Soil pH	Organic carbon %	Exch. bases me/100g	Total N ppm	P ppm	K ppm	Ca ppm	Mg ppm
0-20	23	76	14	10	42	5.9	1.74	15	1712	5	89	118	71
20-40	21	72	16	12	44	6.0	0.89	11	834	3	61	58	48
40-60	13	67	19	14	47	6.1	0.65	9	615	trace	43	44	30

Table 2. Quantity of soils eroded (kg/ha) from different plots

Year	Sub treatment	Soils eroded (kg/ha)		
		Without coir geo-textile	1cm x 1cm coir geo-textile	2cm x 2cm coir geo-textile
2004	Control	348	243	274
	Fertilizer	372	245	278
2005	Control	302	230	256
	Fertilizer	317	237	259
2006	Control	289	223	243
	Fertilizer	303	229	246

Table 3. Quantity of nutrients in the eroded soils (g/ha) from different plots

Year	Sub treatment	Nutrients (g/ha)		
		Without coir geo-textile	1cm x 1cm coir geo-textile	2cm x 2cm coir geo-textile
2004	Control	851	634	692
	Fertilizer	1190	1032	1114
2005	Control	772	543	594
	Fertilizer	1054	921	983
2006	Control	714	490	642
	Fertilizer	973	844	892

3.2. Soil moisture and temperature

The soil moisture contents were measured in all the plots where the root trainer seedlings and stumps were planted in the months of September and November to March in the first two years and September, November and December 2006 (Tables 4 and 5). It was found that there was considerable increase in the soil moisture contents in the plots with coir geo-textiles in all the months. This also revealed that the soils retained more moisture in

Table 4. Soil moisture content in the plots of root trainer seedlings at different periods in the various treatments

Main plot	Sub plot	Sept 2004	Nov 2004	Dec 2004	Jan 2005	Feb 2005	Mar 2005	Sep 2005	Nov 2005	Dec 2005	Jan 2006	Feb 2006	Mar 2006	Sep 2006	Nov 2006	Dec 2006
T_0	A	16	18	13	10	9	8	17	19	14	11	10	9	15	16	12
T_0	B	21	22	17	12	11	10	21	23	18	13	12	11	22	20	16
T_0	C	18	20	14	11	10	9	19	21	15	12	11	10	20	19	14
T_1	A	17	19	16	12	11	8	19	20	17	12	12	9	17	16	12
T_1	B	22	23	19	15	13	11	22	23	20	16	14	12	23	21	17
T_1	C	20	21	17	13	12	10	20	22	18	14	12	11	21	20	15

Table 5. Soil moisture content in plots of stump planted seedlings at different periods in the various treatments

Main plot	Sub plot	Sept 2004	Nov 2004	Dec 2004	Jan 2005	Feb 2005	Mar 2005	Sep 2005	Nov 2005	Dec 2005	Jan 2006	Feb 2006	Mar 2006	Sep 2006	Nov 2006	Dec 2006
T_0	A	15	16	11	8	8	5	16	17	12	9	7	6	16	18	10
T_0	B	20	20	16	11	11	8	20	22	17	11	10	8	21	20	14
T_0	C	17	18	13	11	10	6	18	20	14	10	9	7	20	19	12
T_1	A	16	18	15	12	10	7	18	19	15	10	9	6	18	19	11
T_1	B	20	21	18	15	13	10	21	23	18	13	11	9	22	22	15
T_1	C	18	19	16	13	11	9	20	21	16	12	10	8	21	21	13

the plots with coir geo-textiles for a longer period. Among the two coir geo-textile plots (B and C), there was substantial difference in the soil moisture contents in the plots where coir geo-textiles of 1cm x 1cm was spread. It was also noticed that moisture absorption capacity of the coir geo-textiles was found to be increasing with degradation process. The higher moisture contents in the soils where coir geo-textiles were spread is due to the capacity of the geo-textiles to absorb even up to five times of their own weight (Rao and Balan, 2000).

The soil temperature also followed the opposite pattern as that for soil moisture (Tables 6 and 7). One of the advantages of the coir geo-textiles is to mitigate the extremes of soil temperature (Rao and Balan, 2000) and this has been very much seen in plots where coir geo-textiles were spread. Among the two plots where coir geo-textiles of 1cm x 1cm and 2cm x 2cm were spread, the soil temperature was relatively lower in the closely knit coir geo-textile plots.

3.3. Statistical analyses

The effects due to nutrient treatment, coir size, period and all interactions turned out to be highly significant with regard to height in root trainer seedlings and teak stumps (Tables 8 and 9). The two factor interaction between period and nutrient treatment was highly significant, showing that the effect of nutrient treatment differed significantly between different periods in their height growth. The two factor interaction between period and coir size was highly significant, indicating that the effect of coir size differed significantly between the different periods in their height growth.

Table 6. Soil temperature in plots of root trainer seedlings at different periods in the various treatments

Main plot	Sub plot	Sept 2004	Nov 2004	Dec 2004	Jan 2005	Feb 2005	Mar 2005	Sep 2005	Nov 2005	Dec 2005	Jan 2006	Feb 2006	Mar 2005	Sep 2005	Nov 2005	Dec 2005
T_0	A	26	28	30	31	31	32	27	29	29	31	32	32	26	27	30
T_0	B	24	26	27	27	28	29	25	26	27	28	29	29	24	24	26
T_0	C	25	27	29	29	30	31	26	27	29	30	31	30	25	25	28
T_1	A	27	27	30	30	31	32	28	30	31	32	31	30	27	28	31
T_1	B	25	25	27	27	28	29	25	27	28	29	28	28	24	25	28
T_1	C	26	26	28	28	29	30	27	28	30	30	30	30	25	26	29

Table 7. Soil temperature in plots of stump planted seedlings at different periods in the various treatments

Main plot	Subplot	Sept 2004	Nov 2004	Dec 2004	Jan 2005	Feb 2005	Mar 2005	Sep 2005	Nov 2005	Dec 2005	Jan 2006	Feb 2006	Mar 2005	Sep 2005	Nov 2005	Dec 2005
T_0	A	28	26	23	28	29	30	26	27	24	27	30	32	27	28	25
T_0	B	25	24	21	22	25	27	23	24	22	24	27	28	25	25	23
T_0	C	27	28	22	25	27	28	25	26	23	26	29	30	26	26	24
T_1	A	27	28	25	27	29	31	28	29	25	28	29	31	28	29	26
T_1	B	25	22	23	25	26	28	24	25	23	25	26	28	25	25	23
T_1	C	26	25	24	26	28	30	26	27	24	26	28	30	27	27	24

Table 8. Analysis of variance of data on height of teak root trainer seedlings measured at different periods.

Source of variation	Degrees of freedom	Sum of squares	Mean sum of squares	F- ratio
Block	5	0.00	0.00	0.51ns
Nutrient treatment	1	0.04	0.04	47.23**
Nutrient treatment x block	5	0.00	0.00	
Coir size	2	0.43	0.21	471.12**
Coir size x nutrient treatment	2	0.03	0.01	30.18**
Block x Coir size within nutrient treatment	20	0.01	0.00	
Period	3	115.24	38.41	125190.89**
Nutrient treatment x period	3	0.09	0.03	101.34**
Coir size x period	6	0.20	0.03	110.56**
Nutrient treatment x Coir size x period	6	0.03	0.00	15.20**
Residual	90	0.03	0.00	

** - Significant at P= 0.01, ns- Nonsignificant: Zero values for sum of squares and mean sum of squares are only a consequence of number of digits displayed

The two factor interaction between coir size and nutrient treatment was highly significant, indicating that the effect of nutrient treatment differed significantly between the different coir size treatments in their height. Mean values at each stage corresponding to each nutrient treatment and coir size are given in Tables 10 and 11.

3.4. Growth pattern

The growth pattern of root trainer seedlings and stumps in different treatments are shown in Figures 3 and 4. The height of root trainer seedlings varied from 20 to 22cm at the time of planting. After one year in June 2004, the height varied from 105 to 125cm and then to 115cm in the treatment T_0 in the control, 1cm x 1cm and 2cm x 2cm size coir geo-textiles, respectively. In the treatment T_1, the height varied from 105 to 144 and then to 134cm after one year in June 2005 in the control, 1cm x 1cm and 2cm x 2cm size coir geo-textiles, respectively (Table 10).

Table 9. Analysis of variance of data on height of teak stumps measured at different periods

Source of variation	Degrees of freedom	Sum of squares	Mean sum of squares	F- ratio
Block	5	0.00	0.00	0.42ns
Nutrient treatment	1	0.49	0.49	239.11**
Nutrient treatment x block	5	0.01	0.00	
Coir size	2	0.98	0.49	371.48**
Coir size x nutrient treatment	2	0.00	0.00	1.53ns
Block x Coir size within nutrient treatment	20	0.03	0.00	
Period	3	176.23	58.74	58111.63**
Nutrient treatment x period	3	0.50	0.17	164.12**
Coir size x period	6	0.41	0.07	68.25**
Nutrient treatment x coir size x period	6	0.05	0.01	8.21**
Residual	90	0.09	0.00	

** - Significant at P= 0.01, ns- Nonsignificant; Zero values for sum of squares and mean sum of squares are only a consequence of number of digits displayed

Table 10. Mean values of height of root trainer seedlings in different treatments at various periods

Main plot treatment	Subplot treatment	Mean Height(cm)			
		June 2004	June 2005	June 2006	December 2006
T_0	A	21.19	104.71	153.01	183.20
T_0	B	20.75	124.66	174.19	204.38
T_0	C	21.98	115.24	164.71	194.70
T_1	A	20.39	105.09	154.59	183.18
T_1	B	20.39	144.09	183.68	214.00
T_1	C	20.45	134.13	174.19	204.23

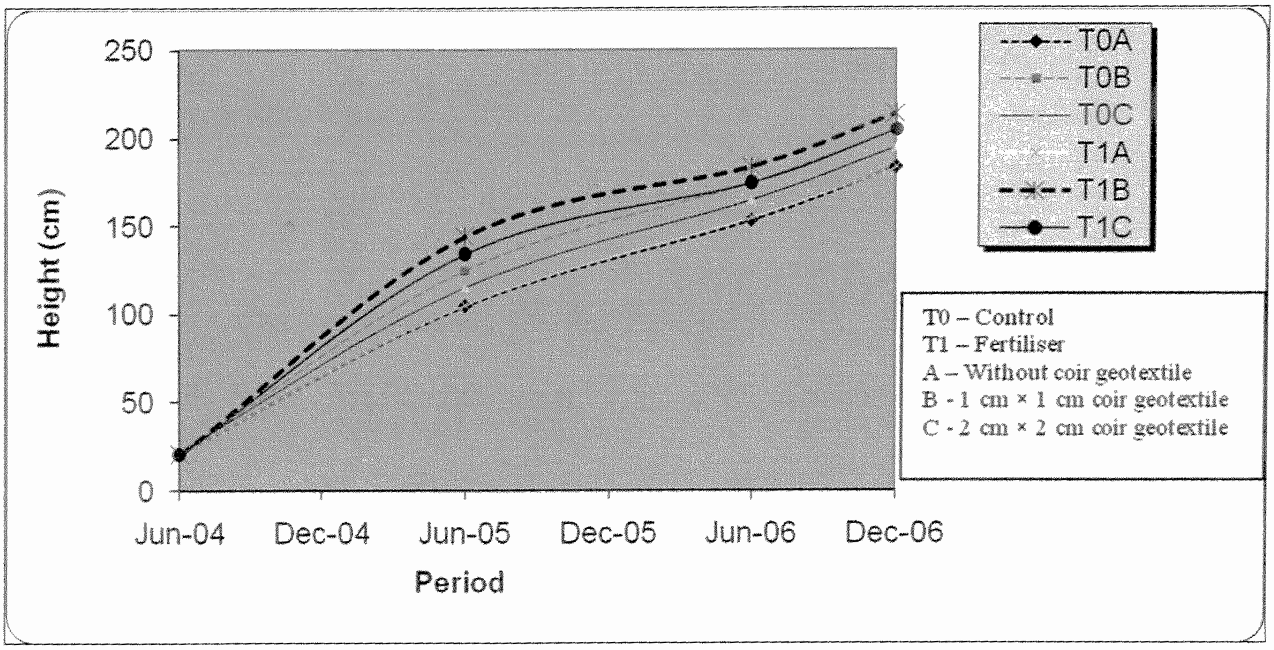

Fig.3. Growth pattern of root trainer seedlings at different periods

In the second year in June 2006, the height was 153cm in the control in T_0 while it was 174 and 165cm in 1cm x 1cm and 2cm x 2cm size coir geo-textiles, respectively. With respect to T_1 in June 2006, the height in the control was 155cm whereas in 1cm x 1cm and 2cm x 2cm size coir geo-textiles, the heights were 184 and 174cm, respectively (Table 10). The height of seedlings in T_0 varied from 183cm in the control in December 2006 to 204 and to 195cm in the 1cm x 1cm and 2cm x 2cm size coir geo-textiles, respectively (Table 10). In the treatment T_1, the height was 183cm in the control while it was 214cm in the 1cm x 1cm and 2cm x 2cm size coir geo-textile and 204cm in the 2cm x 2cm size coir geo-textiles.

The height of stump planted seedlings varied from 10 to 11cm at the time of planting. The height varied from 64 to 93 and to 75cm in the treatment T_0 in the control, and 1cm x 1cm and 2cm x 2cm size coir geo-textiles, respectively after one year of planting in June 2005. The corresponding values in the treatment T_1 were 84, 115 and 104cm after one year in June 2005 (Table 11).

In the second year in June 2006, the height was 104cm in the control in T_0 while it was 135and 123cm in 1cm x 1cm and 2cm x 2cm size coir geo-textiles, respectively. With respect to T_1 in June 2006, the height in the control was 123cm whereas in 1cm x 1cm and 2cm x 2cm size coir geo-textiles, the height was 164 and 144cm, respectively (Table 11). The height was 153cm in the control whereas, it was 184 and 174cm in the 1cm x 1cm and 2cm x 2cm size coir geo-textiles, respectively in the month of December 2006 in the treatment T_0 (Table 11). With respect to the treatment T_1, corresponding values were 165, 204 and 184 cm.

Table 11. Mean values of height of stumps in different treatments at various periods

Main plot treatment	Subplot treatment	Mean height(cm)			
		June 2004	June 2005	June 2006	December 2006
T_0	A	10.75	64.43	104.39	153.43
T_0	B	10.39	93.46	134.71	184.50
T_0	C	11.21	74.76	123.86	174.79
T_1	A	10.33	84.15	123.17	164.66
T_1	B	10.56	115.32	163.81	203.91
T_1	C	9.97	103.90	144.30	184.00

It was found that the growth of root trainer seedlings was better than that of stump planted seedlings in the early stages. There was consistent increase in the height of plants in the plots with coir geo-textiles. This could be due to the effect of the coir geo-textiles on the soils. It is also clear from the Tables 10 and 11 that root trainer and stump planted seedlings receiving the nutrient treatment T_1 and coir size 1cm x 1cm attained the maximum height. Pair- wise comparison between treatments *vs* different coir size showed that the two different coir sizes used for the study differed significantly from each other. Also, the coir size 1cm x 1cm showed higher mean height than the other two treatments. Moreover, the nutrient treatment recommended by Balagopalan *et al* (1998) showed higher mean height than the control at each coir size.

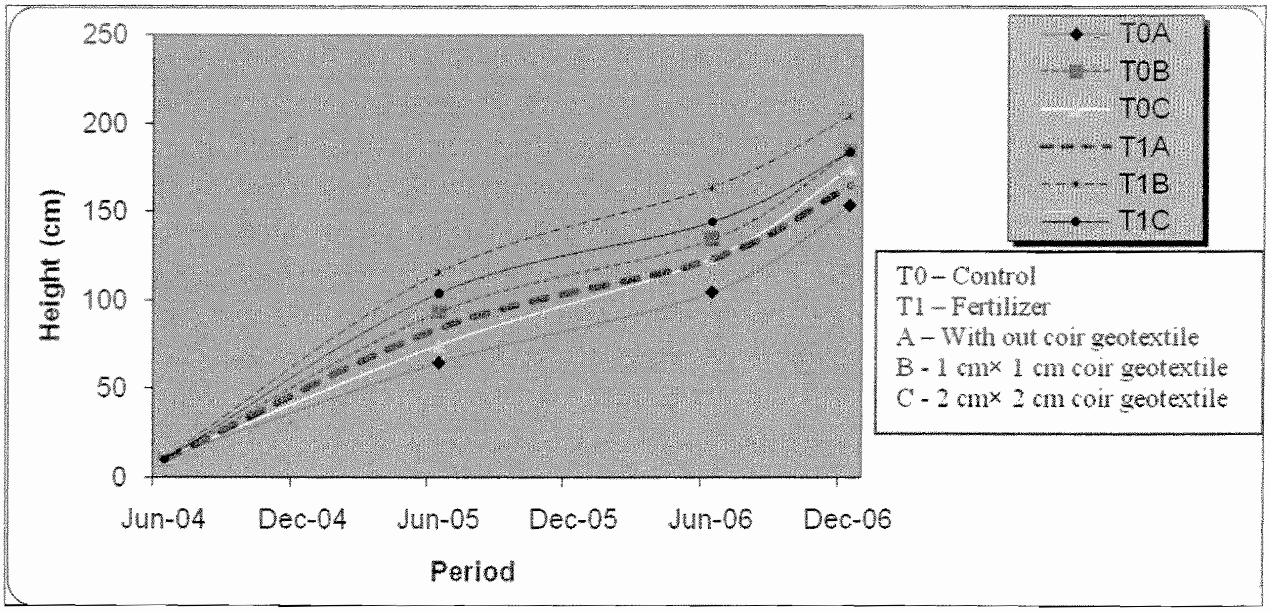

Fig.4. Growth pattern of stumps at different periods

It was also found that there was a mortality of 10.5% for the root trainer seedlings during the first year which gradually increased to 15% at the end of the experiment in December 2006 (Table 12). This revealed that the survival per cent was 85% at the end of the experiment. In the case of stump planted seedlings, the mortality was 13% in the first year which also gradually increased to 18% in December 2006. In other words, the survival was 82 per cent in the case of stumps at the end of the experiment (Table 13).

The low survival per cent for stumps could be due to the fact that the planting was done when it was heavily raining. Actually teak stumps should have been planted prior to the monsoon which could not be done due the delay in allocation of the area for planting. It was also noticed that the mortality was lower in treatments receiving 1m x 1m size coir geo-textiles when compared with other treatments.

Table 12. Mortality of root trainer seedlings at different periods in the various treatments

Main plot treatment	Subplot treatment	June 2004	June 2005	June 2006	December 2006
T_0	A	13	14	17	21
T_0	B	10	12	14	19
T_0	C	11	13	15	20
T_1	A	11	13	15	18
T_1	B	10	11	12	15
T_1	C	10	12	14	16

Table 13. Mortality of stump planted seedlings at different periods in the various treatments

Main plot treatment	Sub plot treatment	June 2004	June 2005	June 2006	December 2006
T_0	A	15	17	18	20
T_0	B	13	15	15	17
T_0	C	14	15	16	18
T_1	A	13	15	16	17
T_1	B	11	13	14	15
T_1	C	12	14	15	16

3.5. Volume of trees

The volume of trees was computed based on the equation of Chathurvedi and Pande (1973). It was found that the volume was highest in T_1B and lowest in the control plots in the case of root trainer and stump planted seedlings (Tables 14 and 15). As the volume is computed from the height and GBH data, the pattern for these is also seen in the case of volume.

Table 14. Volume of root trainer trees at the end of the experiment and the cost of planting in the various treatments

Main plot treatment	Sub plot treatment	Height of the trees (cm)	Gbh at breast height (cm)	Volume of trees (m^3)	Volume of trees per hectare (m^3/ha)	Cost of planting per hectare
T_0	A	183.20	15.52	0.0006038	0.96608	20,000
T_0	B	204.38	19.54	0.001759	2.8144	1,20,000
T_0	C	194.70	17.63	0.001162	1.8592	1,00,000
T_1	A	183.18	15.10	0.0005234	0.83744	26,000
T_1	B	214.00	21.19	0.002375	3.80	1,26,000
T_1	C	204.23	19.40	0.001719	2.7504	1,06,000

Table 15. Volume of stump planted trees at the end of the experiment and the cost of planting in the various treatments

Main plot treatment	Sub plot treatment	Height of the trees (cm)	Gbh at breast height (cm)	Volume of trees (m^3)	Volume of trees per hectare (m^3/ha)	Cost of planting per hectare
T_0	A	153.43	14.56	0.0002084	0.521	17,700
T_0	B	184.50	16.54	0.0008201	2.0503	1,17,700
T_0	C	174.79	15.63	0.0005552	1.388	97,700
T_1	A	164.66	14.62	0.0002994	0.35225	26,700
T_1	B	203.91	18.19	0.001399	3.4975	1,26,700
T_1	C	184.00	17.40	0.0009984	2.496	1,06,700

3.6. Relative Treatment Effectiveness (RTE)

The Relative Treatment Effectiveness (RTE) values for root trainer and stumps are depicted in Table 16. The values for root trainer trees were 191.32 and 92.45 for T_0B and T_0C, respectively. With respect to T_1B and T_1C, the values were 353.76 and 228.43, respectively. This shows that there was considerable increase in the RTE values in the T_1B treatment when compared with the other treatments for the root trainer trees. In the case of stump planted trees, the RTE values were 293.53 and 166.41 for T_0B and T_0C, respectively. They were 892.90 for T_1B and 608.59 for T_1C. The RTE values for stumps also followed the same pattern as that for root trainer trees.

3.7. Relative Economic Effectiveness (REE)

The Relative Treatment Effectiveness (RTE) values for root trainer trees were found to be highest in T_1B (73.00) followed by T_1C (56.03) and T_0B (31.89) and the lowest was in T_0C (18.49). For the stump planted trees, the REE values were 188.16 and 152.29 for T_1B and T_1C, respectively. They were 44.14 for T_0B and 30.15 for T_0C (Table 16). This revealed that on economic and volume basis, the treatment, T_1B was found to be the best.

Table 16. RTE and REE values of root trainer and stump planted trees in the various treatments

Main plot treatment	Subplot treatment	RTE		REE	
		Root trainer	Stumps	Root trainer	Stumps
T_0	A				
T_0	B	191.32	293.53	31.89	44.14
T_0	C	92.45	166.41	18.49	30.15
T_1	A				
T_1	B	353.76	892.90	73.00	188.16
T_1	C	228.43	608.59	56.03	152.29

The study indicated that during the years prior to canopy closure, tree growth was very much dependent on the current uptake of nutrients. In other words, the trees in the closely knit coir geo-textiles spread plots along with fertilizers added overtook the trees in the other treatments. In the long run, these trees are expected to produce more volume than the other trees. It is obvious that spreading of coir geo-textiles as well as application of fertilizers are costly and therefore, required to be investigated on economic grounds. It should be emphasized that as no new areas are available, future planting has to be done in highly degraded areas. Hence, it would be wiser to consider spreading of coir geo-textiles as well as application of fertilizers as part of integrated silvicultural management for maximizing productivity.

4. CONCLUSIONS

The study in the highly degraded area at Vettukkad in the Wadakkancherry Forest Range where teak root trainer seedlings and stump plants are planted in plots under different treatments of coir geo-textiles and fertilizers showed that:

1. the quantity of soils and nutrients eroded during the years 2004, 2005 and 2006 was lowest in the plots where coir geo-textiles of 1cm x 1cm was spread. The quantity of nutrients in the eroded soils was maximum in the plots where fertilizer was added and coir geo-textiles were not spread.

2. soils retained more moisture for a longer period and the soil temperature was less in the plots with coir geo-textiles. Among the two coir geo-textiles of 1cm x 1cm and 2cm x 2cm spread plots, there was substantial difference in the soil moisture contents and soil temperature in the plots where coir geo-textiles of 1cm x 1cm were spread.

3. the two factor interaction between coir size and nutrient treatment was highly significant, indicating that the effect of nutrient treatment differed significantly between the different coir size treatments in their height growth.

4. there was consistent increase in the height of plants in the plots with coir geo-textiles and the growth of root trainer seedlings was better than that of stump planted seedlings in the early stages.

5. root trainer and stump planted seedlings receiving the fertilizers and coir size 1cm x 1cm attained the maximum height.

6. the mortality was lower in treatments receiving 1cm x 1cm size coir geo-textiles

7. there was considerable increase in the RTE and REE values in the treatment receiving the fertilizers and coir size 1cm x 1cm when compared with the other treatments for the root trainer trees as well as stumps

8. as no new areas are available, future planting has to be done in highly degraded areas. Hence, it would be wiser to consider spreading of closely knitted coir geo-textiles as well as application of fertilizers as part of integrated silvicultural management for maximizing productivity.

5. REFERENCES

ASA. 1965. Methods of Soil Analysis. Parts 1 & 2. Black, C. A. *et al.* (eds.), Madison, Wisconsin, USA. 1572p.

Balagopalan, M., Rugmini, P. and Chand Basha, S. 1998. Soil nutrient management for teak plantations of Kerala. KFRI Research Report 138. 40p.

Banerjee, P. K. 1996. Development of new geo-synthetic products through blends of natural fibres. Proceedings of the International Seminar and Technomeet on Environmental Geo-technology with Geo-synthetics, New Delhi. pp.337-346.

Banerjee, P. K. and Unni, E. B. 2000. Growth prospects of natural geo-textiles. In: Coir Geotextiles - Emerging Trends. G. Venkatappa Rao and K. Balan (Eds.). Avenir Publishers, Delhi. pp.15-30.

Cammack, A. 1988. A role of coir fibre geo-fabrics in soil stabilization and erosion control. Proceeding of the Workshop on Coir Geo-grids and Geo-fabrics in Civil Engineering Practice, Coimbatore, India. pp.28-31.

Chathurvedi, A. N. and Pande, G. C. 1973. General volume tables for *Eucalyptus grandis.* Vol. 12. No. 17. FRI New Series Silviculture. Dehra dun, India. 8p.

Gomez, K.A. and Gomez, A.A. 1976. Statistical Procedures for Agricultural Research. Wiley Inter Science publications, John Wiley & Sons, New York, 680p.

Jackson, M. L.1958 Soil Chemical Analysis. Prentice –Hall Inc., Englewood Cliffs, NJ, USA. 498p.

Palmer, P. J. 1992. The use of biodegradable geofabrics to control highway slope erosion. Proceedings of the UK coir geo-textile Seminar, West Midland.

Rao, G. V. and Balan, K. 2000. Coir geo-textiles – A perspective. In: Coir Geotextiles - Emerging Trends. G. Venkatappa Rao and K. Balan (Eds.). Avenir Publishers, Delhi. pp. 5-14.

Thomson, J. C. and Ingold, T. S. 1986. Use of jute fabrics in erosion control. Report to the Jute market promotion project. International Jute Organisation, International Trade Center, UNCTAD/GATT. 30p.

Schurholz, H.1988. Utilization potential of coir fabrics as geo-textile material. Proceeding of the Workshop on coir geo-grids and geo-fabrics in civil engineering practice, Coimbatore, India pp. 36-44.

Schurholz, H. 1991. Use of woven coir geo-textiles in Europe. *Coir* 35: 18-25.