Hydrol. Earth Syst. Sci. Discuss., 2, 2327–2348, 2005
www.copernicus.org/EGU/hess/hessd/2/2327/
SRef-ID: 1812-2116/hessd/2005-2-2327
European Geosciences Union

Hydrology and Earth System Sciences Discussions

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Experimental study using coir geotextiles in watershed management

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Received: 15 August 2005 – Accepted: 10 October 2005 – Published: 10 November 2005

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Abstract

This paper presents the results of a field experiment conducted in Kerala, South India, to test the effectiveness of coir geotextiles for embankment protection. In the context of sustainable watershed management, coir is a cheap and locally available material that can be used to strengthen traditional earthen bunds or protect the banks of village ponds from erosion. Particularly in developing countries, where coir is abundantly available and textiles can be produced by small-scale industry, this is an attractive alternative for conventional methods.

1. Introduction

In the rural areas of Kerala, India, small streams and village ponds are the main source of water for irrigation and domestic use. However, during monsoon, the side banks of these ponds erode and the ponds get silted up. The same silt from the pond is subsequently used to restore the side banks but it is often eroded before vegetation can establish. Hence continuous maintenance is required for deepening and desilting of ponds to maintain their water holding capacity. Neither the local government nor the community may have enough funds for these labour intensive works. Ultimately the ponds get filled up and deteriorate and the area will become subject to water shortage during the summer season. Most watershed projects meant to support communities propose conventional stone bunds for soil and water conservation. However, the majority of the people cannot afford these structures without support from the government. Hence it is interesting to look for an alternative material which is effective in reducing soil erosion, enhancing soil moisture and vegetation growth, and which at the same time is economically attractive.

The aim of the experiment was to study the conditions under which coir geotextiles can be used for embankment protection of ponds and provide an alternative, cost effective, option for watershed management to reduce soil erosion, increase vegetation growth and increase soil moisture availability.

2. Background

Coir geotextile is made from coconut fibre extracted from the husk of the coconut fruit. It is available in different mesh matting with international trade names such as: MMA1, MMV1, etc., where MM stands for mesh matting and A or V stands for the place of origin. Coir fibres are of different types and are classified according to varying degree of colour, length and thickness. Length of coir varies from 50 mm to 150 mm and diameters vary from 0.20 mm to 0.60 mm. It is a lignocelluloses polymeric fibre with 45% lignin and 43% cellulose (Ayyar et al., 2002). Coir has the highest tensile strength of any natural fiber and retains much of its tensile strength when wet. It is also very long lasting, with infield service life of 4 to 10 years (English, 1997). The reason for the greater strength of coir is its high lignin content (Ayyar et al., 2002). Because of its high tensile and wet strength, coir matting can be used in very high flow velocity conditions (English, 1997). Tests conducted by Schurholz (1991), cited in: Banerjee (2000), for material testing on jute, sisal, coir and cotton over a prolonged period of time in highly fertile soil maintained at high humidity (90%) and moderate temperature revealed that coir retained 20% of its strength after one year whereas cotton degraded in six weeks and jute degraded in eight weeks. Rao and Balan (2000), in their erosion control study, showed that coir geotextile (MMA3 and MMV2) is capable to prevent surface erosion of particles along the surface of a slope and facilitates in sedimentation of soil on previously exposed rock surfaces. Even after seven months, the matting retained 56% of its original strength against the reported value of 56% reduction in strength in six months by Oostbuizer and Kruger (1994), cited in: Rao and Balan (2000). Anil and Sebastian (2003) in their study using coir geotextile (MMV1) on different slopes show that there is considerable reduction in soil erosion in the treatment plots. In the treatment plots with a slope of 20%, soil conservation was 77 times higher compared to control plots; on a slopes of 30–40% it was 17 times higher.

Also there is considerable reduction in the time that it takes for the different treatments to achieve slope stabilisation. Plots with geotextiles alone are stabilised earlier, followed by plots with geotextile and crops and then control plots. Reduction in soil loss is mainly due to the coir matting, which reduces the raindrop impact as it intercepts the direct contact with soil. Balan (2003), in his study using coir geotextile (MMV1) for gully plugging in the high land region of Kerala shows that gullies on the upstream side have a siltation of 45 cm and on the downstream side a siltation of 10 cm after one monsoon season. Lekha (2004), in her field trial using coir geotextile (MMA3) for slope stabilisation, observed that after seven months of laying, coir retained 22% of the strength of a fresh sample. Also the reduction in soil erosion and increase in vegetation is significant in plots treated with geotextile. Thomson and Ingold (1986) through their study revealed that geotextiles can be used in combination with vegetation to provide a composite solution of soil erosion control.

Coir matting has an open area of 40 to 70%. Hence it allows the growth of grass and provides a large number of miniature porous check dams per square metre of soil. It slows down and catches runoff so that sediment settles and water either passes through the matting or percolates into the underlying soil. As geotextiles degrade, they provide mulch and conserve moisture for plant growth.

On impact with an unprotected soil surface, raindrops loosen the soil particles, causing an incremental movement of the suspended particles down slope. Soils are susceptible to erosion by flowing water even at very low flow rates. If the energy of falling rain can be absorbed or dissipated by vegetation or some other soil cover or surface obstruction, the energy transfer to the soil particles will be reduced and hence soil erosion. When geotextiles are used, they absorb the impact and kinetic energy of raindrops and reduces surface runoff. Also seeds and vegetations are kept protected from being washed away (Anil, 2004).

3. Study area

The Amachal watershed in the Trivandrum District, in the Western Ghat region of Kerala, India, has been selected for the experiment. The watershed lies in the midland region between the latitudes 77°6′26″ E and 77°7′16″ E and the longitudes 8°28′57″ N and 8°29′44″ N. The watershed is characterized by moderately sloping to steep hills intervened by very gently sloping valleys. The area experiences a humid tropical climate with two distinct monsoons (Northeast and Southwest) and an average mean annual temperature of 26.53°C. The relative humidity varied from 62 to 100% (GoK, 2002). The Southwest monsoon commences by the first week of June and continues up to September and the Northeast monsoon sets in by the middle of October and extends up to December. Annual rainfall amounts to 1500 mm/year. Peak rainfall in the experimental period was observed in the month of October (429 mm/month) followed by June (243 mm/month).

4. The experiment

4.1. Materials

Coir matting selected for the study was MMV1 with the smallest mesh opening of $6\times6\,\mathrm{mm}^2$ and a density $0.74\,\mathrm{kg/m}^2$. Tensile strength of fresh coir matting was 13.75 kN/m. The selection of material was based on the steepness of the slopes. Literature shows that for higher slopes, geotextiles with small mesh openings are better to reduce soil erosion and absorb the impact of raindrops.

4.2. Field layout and installation techniques

A village pond in the watershed was selected for the field experiment. The side banks of this pond get eroded even during summer showers. The type of soil is silty sand. The size of the pond is 48 m×123 m. The slope of the embankment is 70°. The experiment consists of three treatments (a) coir geotextiles with planted grass (CGG), (b) Coir geotextile alone (CG) and (c) control plot (CP); replicated four times. The length of the embankment varies from 3.10 m to 3.50 m. Each side was divided equally in three parts for the three treatments.

The coir was laid during 17–22 May 2004, just before the onset of the monsoon. The installation procedure followed was generally similar to that used for surface erosion control. All the vegetation was removed and the soil on the surface of the slope was well graded to remove unevenness; since any irregularity may allow water to flow under the matting and thus cause undercutting (Rao and Balan, 2000). Trenches were dug of 30 cm×30 cm, at the top of the slope to anchor the geotextile. Rolls of the matting were first anchored in the top trench and then unrolled along the slope. Anchoring was done using bamboo pins cut to a length of 25–30 cm, instead of iron hooks used in conventionally. Pins were driven at right angles to the slope and up to a depth of the failure plane. Each roll was given an overlap of a minimum of 15 cm and anchored firmly with bamboo pins spaced to form a grid of 1 m spacing. Bamboo pins were also driven at the joints with a spacing of 1 m. At the bottom, matting was rolled in two layers and anchored with bamboo pins to hold the soil eroded if any and also to reduce the intensity of runoff. In the conventional practises trench were also dug at the bottom of the slope. After installation, matting was tampered to closely follow the soil surface. Trenches were backfilled and compacted.

4.3. Planting of grass

The common grass species *Axonopus compressus* was selected for the study. This species is used as fodder in this watershed. It was planted in the treatment plots at a spacing of 10 cm.

5. Monitoring

Rainfall was measured using a self-recording rain gauge installed in the field. Soil moisture, vegetation, nutrient loss and bio-degradation of coir were measured from all the three treatments directly. Since the pond is used for domestic purposes by the people, it was not possible to install equipment for directly measuring the soil loss. Hence sixty people living in the vicinity of the pond were selected to monitor and evaluate the performance of the different treatments. They monitored the density and uniformity of the established vegetation, and the soil erosion from the upper and lower portion. Data sheets were provided for scoring.

6. Results and discussions

6.1. Soil moisture

Soil moisture was determined by gravimetric method from different treatment plots. Soil samples from the root zone were collected monthly and its initial weight was recorded as (w_1). Subsequently samples were dried in sunlight until a constant weight was obtained, which was considered as the oven-dry weight (w_2). It can be clearly seen in Fig. 1 that soil moisture recorded in plots laid with coir geotextile was significantly higher than in the control plots.

Soil moisture in CGG is 21% higher than in the control plot during the dry period. In CG, soil moisture is less than in CGG. This is because in CGG, *Axonopus compressus* is well established as a canopy reducing solar radiation. Whereas in CG, the area was invaded with the same natural vegetation as in the control plot and most of this vegetation consists of shrubs and broad-leaved plants. These plants dried up from December onwards, and less moisture was retained than in CGG. In CP, the density and uniformity of vegetation was much less along with the occurrence of soil erosion and runoff. Hence moisture retention was least in these plots. Soil moisture retained during the dry period in CGG, CG and CP experiments are in the ratio 1:0.75:0.21. Variation in soil moisture in different treatments with respect to rainfall is presented in Fig. 1.

6.2. Soil erosion

As the pond is in used by the community for both domestic use and irrigation, a participatory approach was adopted to measure soil erosion. People living near the pond were selected and data sheets were provided monthly to compare the erosion in the different plots. The response of the participants shows that the erosion in the treated plots is significantly less compared to the control plot. It varied in response to the rainfall. Treatment with CGG was stabilised first followed by CG. The control plot was not stabilised during the monitoring period.

Figure 2 shows the mean and standard deviation of the scores given by the participants with respect to soil erosion in the different plots. People could give a scoring from 10 to 50, where 50 represent maximum reduction in soil erosion. In the plots with CGG, scoring lies in the range of 40–50 and in CG the scoring ranges from 30–40. The graph clearly shows that an immediate effect was seen in plots treated with geotextiles. It can be seen that there was some erosion in the plot treated with CG alone during the initial stage, but that thereafter erosion decreased with the growth of vegetation. Both CGG and CG stabilised within nine months. Whereas erosion persisted in the control plot.

6.3. Vegetation

Coir matting installed to cover the soil surface provides ample opportunity for the growth of vegetation. Even degraded geotextile contributes to the organic composition of the soil and promotes vegetation. Length of grass, weed intensity, uniformity and density of grass has been considered as measures for vegetation growth. Within nine months, vegetation was well established and the slope was stabilised in the area covered with geotextiles. Figure 3 shows the variation in height of the vegetation at all plots. Growth of vegetation in CGG shows greater values than in CG. The control plot shows the lowest value. In CGG, vegetation established well before it started at CG and CP. In CG and CP, vegetation established with different varieties of weeds, whereas in CGG only *Axonopus compressus* was grown. This vegetation started drying up in December and even at that time the control plots were not stabilised. Weed intensity per square metre were also noted and it seen that *Axonopus compressus* and *Heteropogon contortus* alone survived after December.

The community monitored and evaluated the growth of vegetation in the treatment plots. Response of the community with respect to the three treatments in terms of uniformity and density are shown in Figs. 4 and 5, respectively. Figures 6a, 6b, 7 and 8 show the difference in growth of vegetation in CGG, CG and CP.

6.4. Bio degradation of coir

Bio degradation of coir was studied based on ultimate tensile strength of the matting collected from the field during the period. Figure 9 shows the degradation curve of the geotextile with respect to time. The coir retained 19% of the strength of a fresh sample after 9 months. By this period, however, slopes were stabilised and vegetation was well established. The loss of strength of the coir matting was no reason for concern as it had served its purpose until vegetation established.

6.5. Nutrient losses

Nutrient loss through surface runoff and soil erosion can be very high in tropical regions. This is mainly because of the soil erosion due to high rainfall. Soil samples were periodically collected from the field and tested in the laboratory for Nitrogen, Phosphorous, Potassium and organic carbon. In all the plots, it was seen that loss in NPK and organic carbon was higher in CP than in the plots treated with coir geotextiles. This is mainly due to the protective covering of the geotextiles. Also biodegradation of coir fabric contributes to the increase in nutrient content in the treated plots (Lekha, 2004). The net loss of nutrients in CGG, CG and CP are in the ratio 1:1.3:6.2 for Nitrogen, 1:1.4:3.5 for Phosphorous and 1:1.4:4.9 for Potassium. The loss in organic carbon in the three plots is in the ratio 1:1.4:2.8. Difference in values in CGG and CG may be due to leaching of nutrients in CG during the initial stage. Figures 10 and 11 show variation in loss of NPK and organic carbon during the study period in the three treatments.

7. Conclusions

Field experiments, involving a local community in Kerala, have clearly demonstrated the effectiveness of coir geotextiles to stabilize banks of hydraulic structures and particularly the steeply sloping banks of a pond. The community was very enthusiastic about the effectiveness of the coir, particularly in combination with a local grass variety. The coir with grass appeared to be the most effective to prevent erosion, to retain moisture and nutrients and to facilitate grass growth. Moreover the slope with grass was productive in providing fodder. The degradation of the natural fibres over time did not result in any loss of effectiveness. On the contrary: the fibre contributed to the natural fertility of the soil after the vegetation cover was well established and the geotextile was no longer needed for bank stability. The relative cheapness of the material and the potential for producing and laying the matting with local labour makes the use of coir geotextiles a very attractive option for sustainable development scenarios in watershed management.

Acknowledgements. The authors express their sincere thanks to the watershed community and watershed committee members for their help throughout the experiment. The first author expresses sincere gratitude to the technical assistants who helped her to conduct the survey and to monitor the field data.

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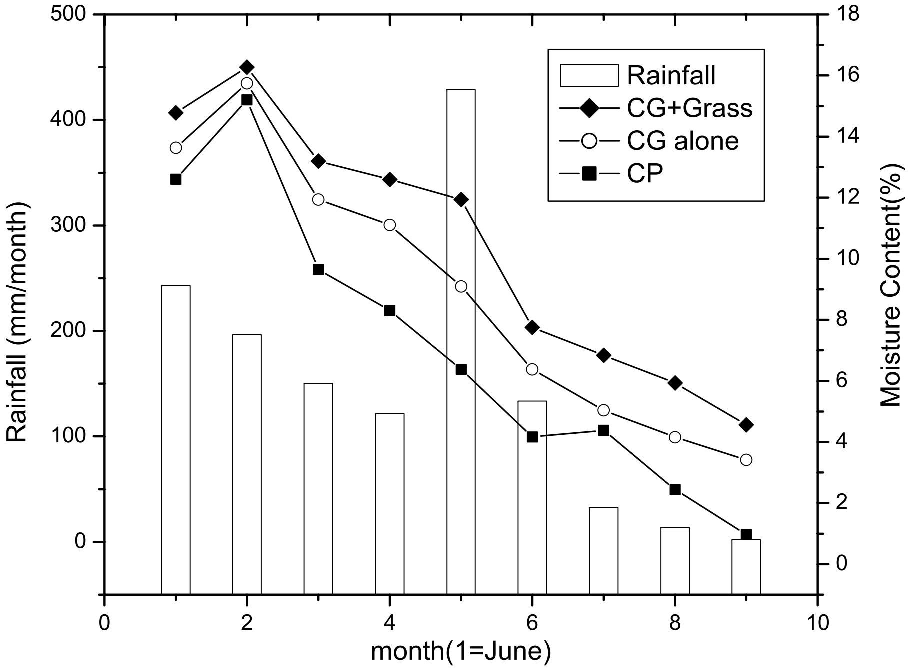

Fig. 1. Variation in moisture content with respect to rainfall.

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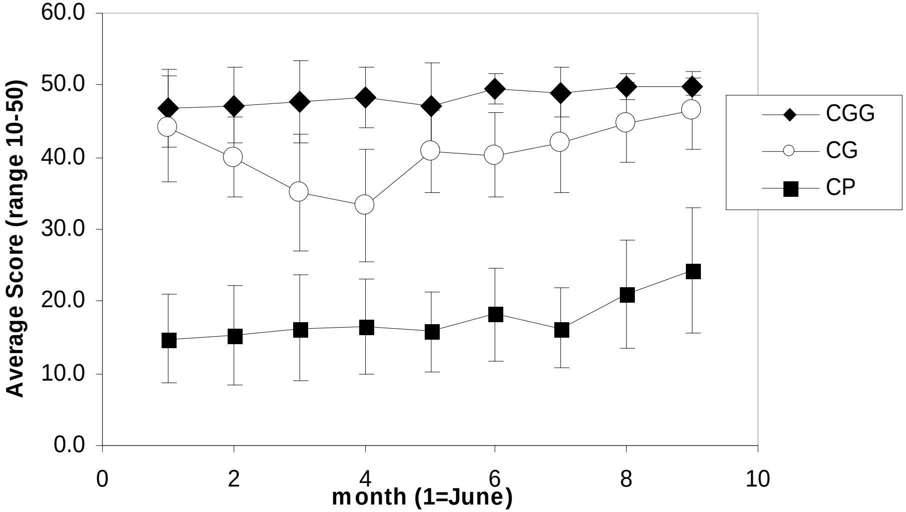

Fig. 2. Soil Erosion, people's response.

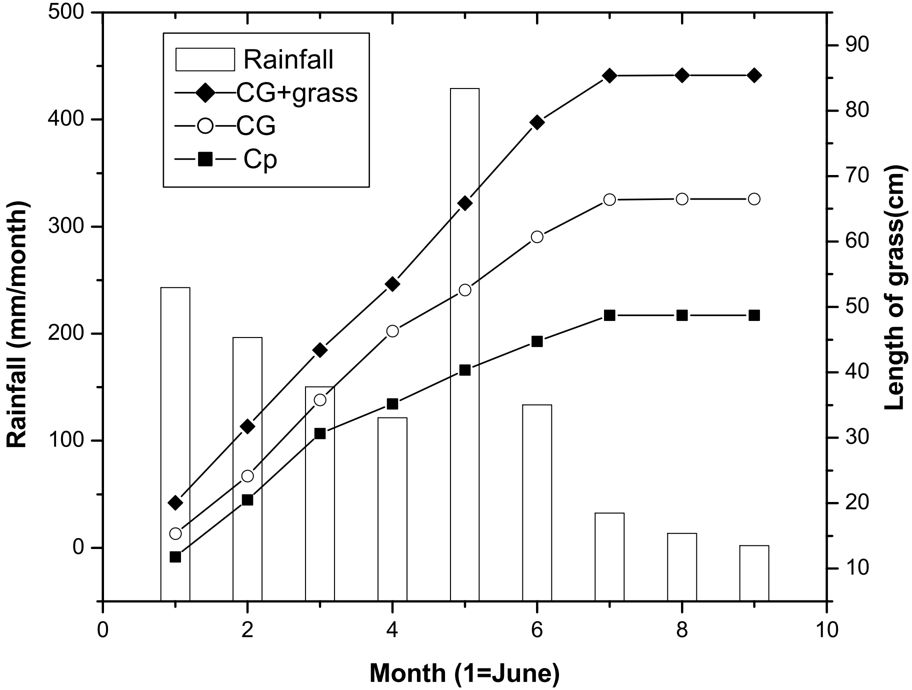

Fig. 3. Length of grass (measured).

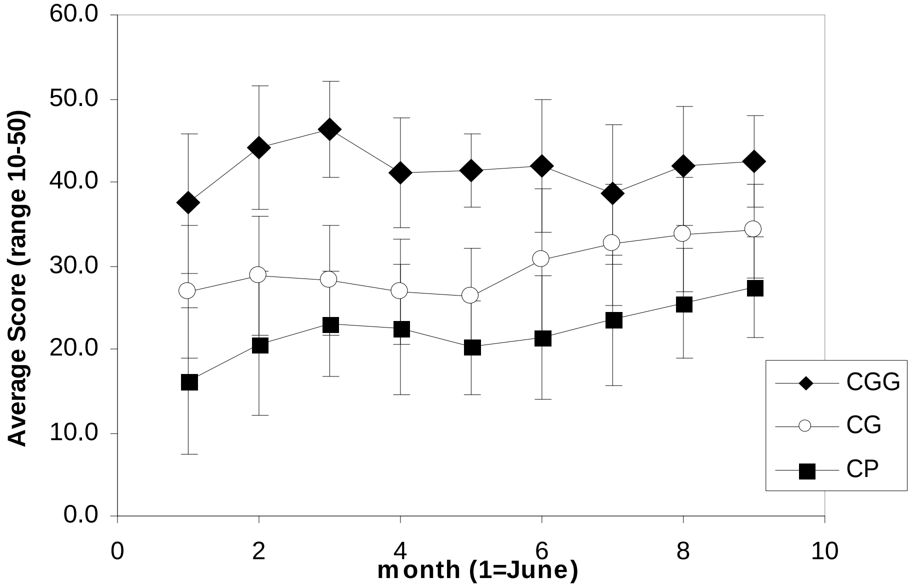

Fig. 4. Uniformity of grass, people's response.

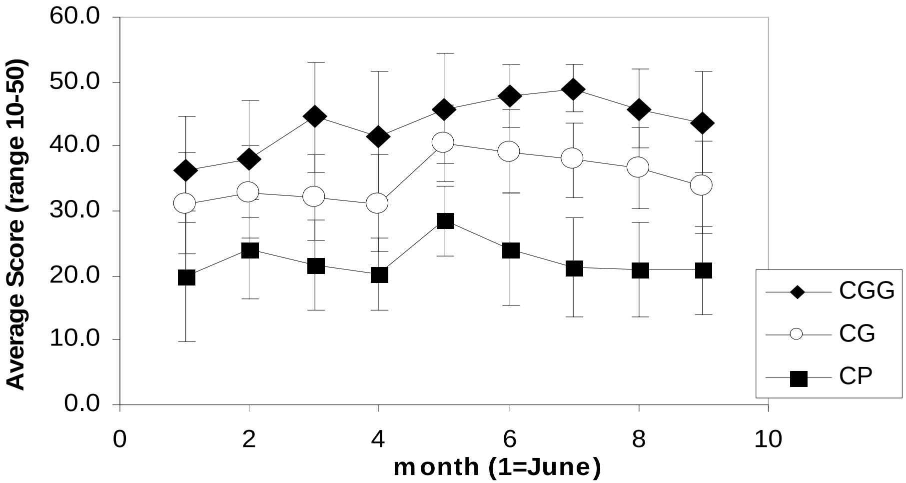

Fig. 5. Density of grass, people's response.

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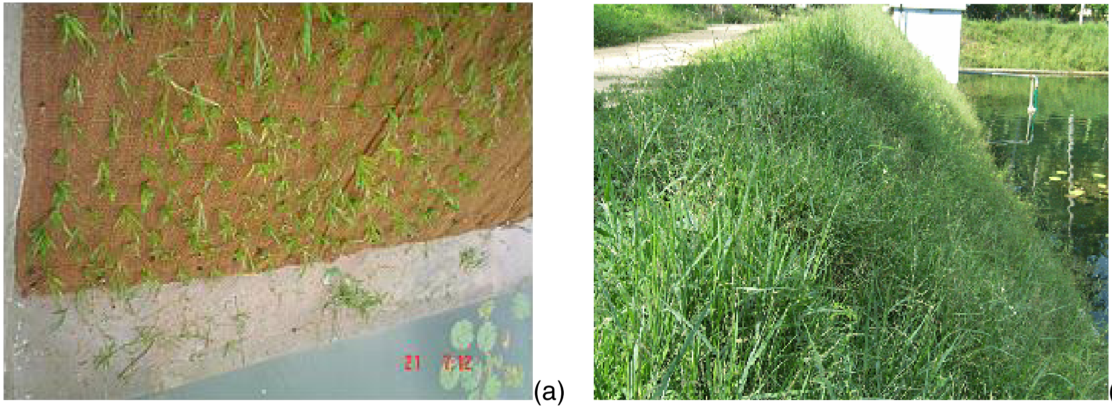

(a) (b)

Fig. 6. (a) CGG, third day of installation. **(b)** CGG thick vegetation after 7 months.

Fig. 7. CG, natural vegetation after 7 months.

Fig. 8. CP-less density, non uniform vegetation with soil erosion, after 7 months.

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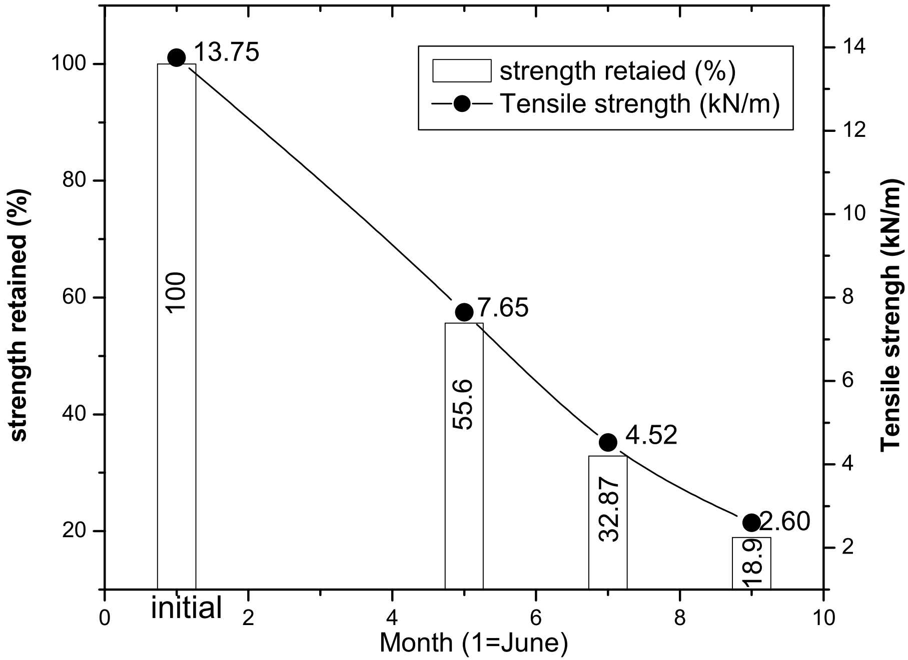

Fig. 9. Biodegradation of coir with time.

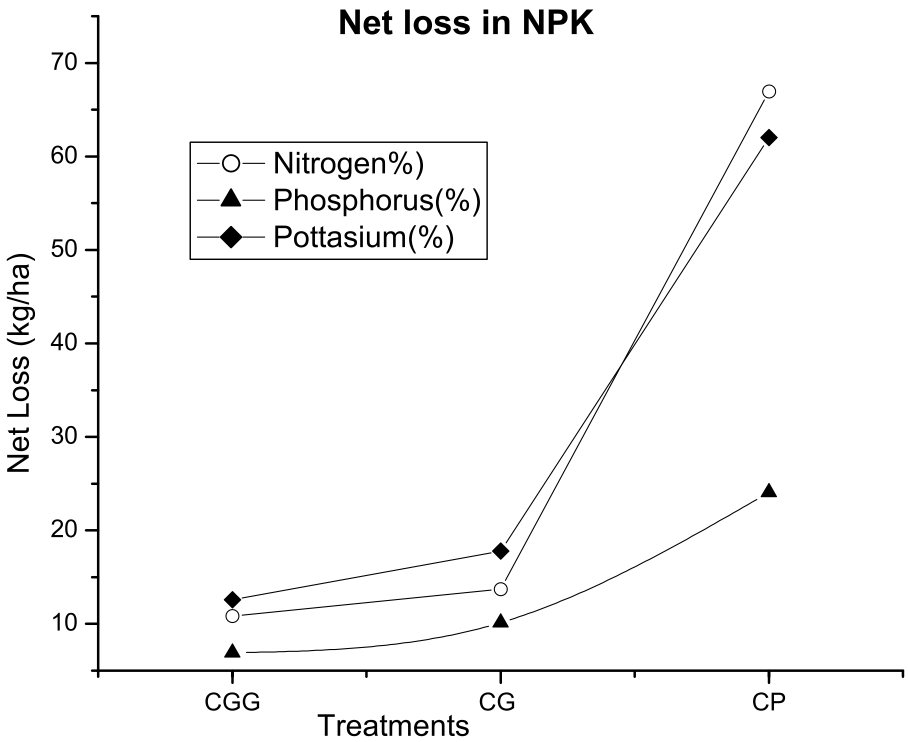

Fig. 10. Net loss in NPK.

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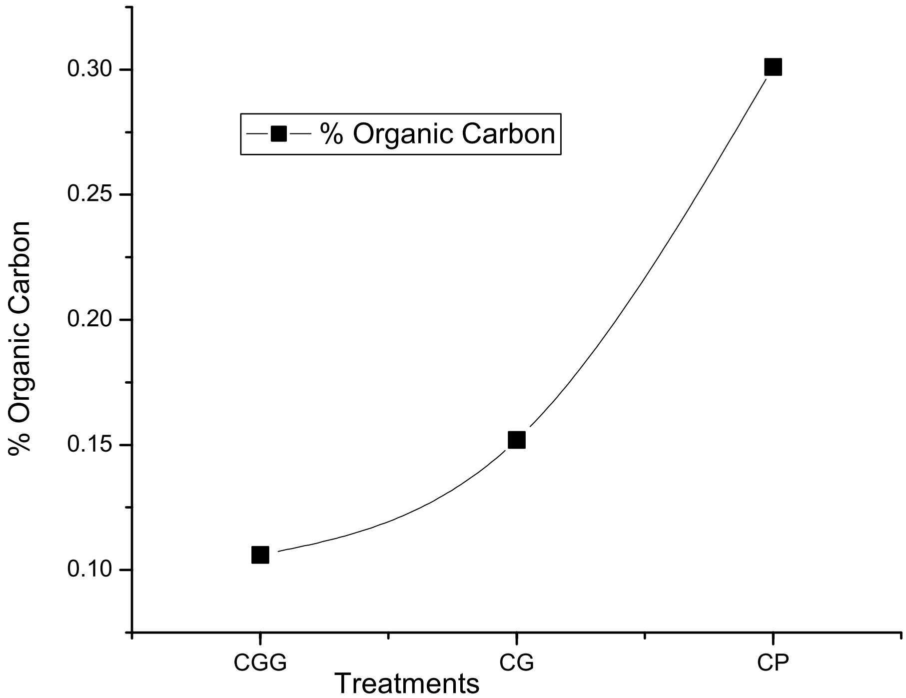

Fig. 11. Percentage loss in organic carbon in different treatments.

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