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Bioengineering measures for erosion and sediment control

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ABSTRACT

Soil is formed at a rate of only 1 cm every 100 to 400 years and it takes 3,000 to 12,000 years to build enough soil to form productive land which makes soil a non-renewable resource. It is important therefore to treat soil, especially topsoil, as a living entity. Erosion on farm fields reduces potential crop production and sediment which leaves the field can result in subsequent sedimentation problems which in turn can cause off-site environmental problems. In this study an attempt has been made to evaluate the effectiveness of different bioengineering control measures in reducing the soil loss from agricultural fields and the soil loss measured from standard runoff plots was compared with a bare land plot of the same size. The different bioengineering measures adopted in this particular study were coir geotextile, jute geotextile and vegetative cover. Among all the three measures, coir geotextile was found to be the most effective in reducing soil loss due to erosion which reduced soil loss by 99.95 per cent compared to bare land plot of the same size.

Keywords: Soil; erosion; bioengineering; coir geotextile

INTRODUCTION

Soil is one of the most fundamental and essential resources of our earth. It provides ecosystem services critical for life. Prime soil resources of the world are finite over the human time frame and prone to degradation. Facing ongoing soil degradation at European and global level, General Assembly of the United Nations proclaimed 2015 as the International Year of Soils (IYS) to highlight the importance of sustainable soil management. Soil erosion is one of the most severe environmental problems in the earth and ecosystem and one of the most significant forms of land degradation greatly influenced by land use and management. Soil erosion along degraded hill slopes has been a problem of serious concern throughout the world (Lekha 2004). In India, it has been estimated that a total area of over 175 million hectares out of total geographical area of 328 million hectares suffers from various forms of erosion hazards. Estimation shows that 6,000 million tonnes of top soil is eroded every year. Soil quality, structure, stability and texture can be affected by the loss of soil. Soil erosion would remain an imperative global issue for the 21st century because of its adverse impact on agronomic productivity, the environment and its effect on food security and the quality of life; so conservation of soil is very essential (Macdonald et al 2001). Soil erosion can be minimized by maintaining a protective cover on the soil surface creating a barrier to the erosive agent. There are numerous treatments, combinations of treatments and various emerging techniques for effective control of soil erosion. Presence of vegetative cover on the surface of earth protects the soil from heavy rainfall striking the surface and thereby reduces soil erosion. In highly slope areas, geotextiles are found to be effective for slope stabilization and for reducing sediment yield. They may be natural (jute, coir, sisal etc) or synthetic (nylon, polypropylene etc) materials (Luo et al 2013). Coir geotextiles are found to be economical for the effective control of soil erosion. It is a biodegradable organic fibre material which is coarse, rigid and strong. Natural water absorbing capacity and enrichment of soil with organic nutrients makes jute geotextile one of the good measures for reducing soil loss through various agents. In view of the above facts, the present study was undertaken on the lateritic terrain in the farm area of KCAET, Tavanur of Malappuram district in Kerala state. The specific soil erosion control measures were taken on the natural soil demarcated into standard soil erosion study plots of size 22 m x 1.8 m with 9 per cent slope with the main objective to compare the effectiveness of imparted bioengineering erosion control measures.

MATERIAL and METHODS

The experiment was conducted at the KCAET campus, Tavanur in Malappuram district of Kerala between June and December 2014. The selected area is situated at 5°52'30'' N latitude and 76° E longitude. The soil profile at the study stage was composed of laterite, clay and alluvial formations. The experimental area falls within the border line of north zone, central zone and Kole zone. Climatologically the area is in high rainfall zone.

Four standard runoff plots with a dimension of 22 m x1.8 m, each with a slope gradient of 9 per cent were constructed. The plots were prepared for different field conditions like barren, grass and geotextiles. For the barren condition, the land was prepared to the required grade and kept as such without any covering. Among the other three plots one was laid with coir geotextile, second with jute geotextile and the third with grass. At the lower end of each runoff plot, provisions were made for inserting the collector tray along with a pit of almost 60 cm depth for holding the collecting cans to measure the soil loss.

Coir mat of 900 gsm (Grade III) and jute bags in the form of mat were the geotextile measures considered for the study. The mats were of 22 m length and 2 m width. These mats were inserted in the grooves to a considerable depth of approximately 10 cm. Hybrid Napier grass was selected as a vegetative measure. The stem cuttings were planted at slanting position at one side of the ridges with one node buried in the soil at a spacing of 60 cm x 60 cm with a total of 108 plants in one plot area of 40 m².

A pressurized nozzle type rainfall simulator was fabricated with micro-sprinkler to create the rainfall simulation. The frame of the simulator was constructed using PVC pipe of 25 mm diameter. The diameter of coverage of the selected sprinklers was 1.8 m. The sprinklers were connected to a riser pipe of 50 cm height using FTA and were fitted on the PVC pipe. The angle of coverage of the sprinklers was adjusted to 180° and the frame was placed at the boundary of each plot along the length of the plot.

The experimental plots were exposed to simulated rainfall using the rainfall simulator to measure the soil loss. The soil loss from the control plot was measured for four different intensities viz 8.16, 8.18, 8.21 and 8.26 cm/h by adjusting the pressure of water supply. The samples were collected at the end of 10, 20 and 30 minutes of supply of water. The measurement of soil loss in the treated plots was done with two intensities viz 8.21 and 8.26 cm/h. The collected samples were dried and the weights were noted.

RESULTS and DISCUSSION

Soil erosion can be minimized by maintaining a protective cover on the soil surface creating a barrier to the erosive agent. Various treatments and combinations of treatments were applied to the plots with the objective to minimize the soil erosion. The effects of three different bioengineering measures viz coir geotextiles, jute geotextile and vegetation to control erosion and sedimentation were studied and these were compared with a barren plot of same size and specification.

The plots taken as control was tested with four different intensities of rainfall and the soil loss was measured for each intensity of rainfall and for a time period of 10, 20 and 30 minutes. Observations showed a general trend of increased soil loss with increase in intensity of rainfall as well as the time. Soil loss increased drastically from the rainfall intensity of 8.21 to 8.26 cm/h.

In order to measure the soil loss from plots treated with elephant grass, rainfall intensities of 8.21and 8.26 cm/h were selected as these values of intensity gave higher soil loss in the bare land plots. Graphical representation of observed soil loss measured from the above said plots showed that soil loss had increased with increase in intensity initially and after certain time period, the soil loss was found to show a declining trend due to establishment of vegetation (Fig 1).

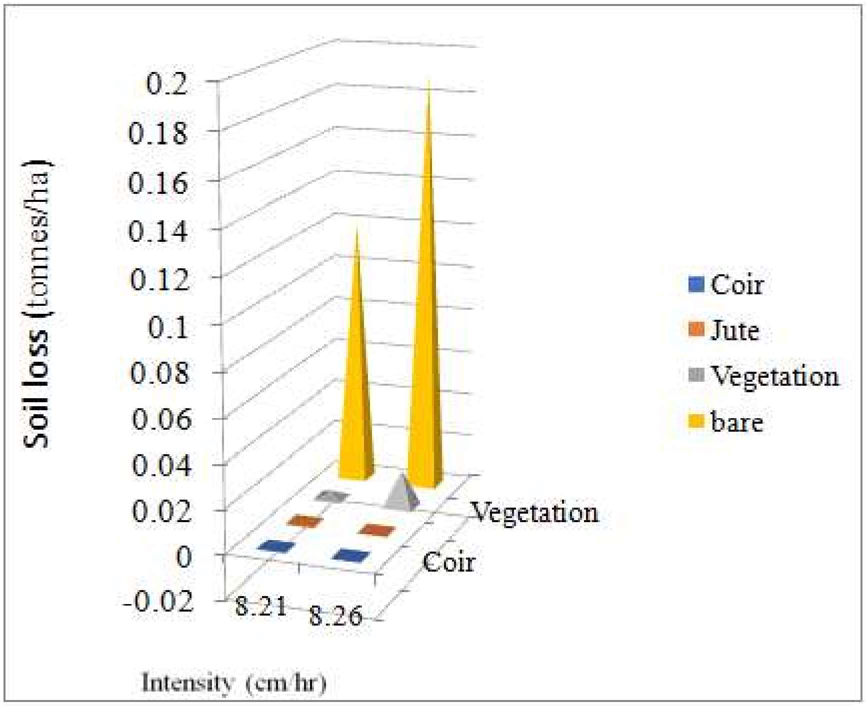

Fig 1. Comparison of soil loss from different runoff plots

The runoff plots treated with jute gunny bags as jute geotextiles showed relatively less erosion. The plots with jute geotextile was also tested with intensities of 8.21 and 8.26 cm/h. The results showed that soil loss decreased considerably for both the intensities of 8.21 and 8.26 cm/h with increase of time. The maximum values of soil losses were 0.41 and 0.65 kg/ha for intensities 8.21 and 8.26 cm/h respectively and it was obtained during the initial period. With elapsed time, soil loss was found to be decreased and it was due to the thorough fixing of jute mat on to the ground surface.

Plots treated with coir geotextiles were also tested with same two intensities of rainfall. The observations displayed a decreased trend of soil loss as time was increased for each intensity of rainfall but an increased soil loss with increase in intensity of rainfall. Maximum soil loss of about 0.09 tonnes/ha was received for the rainfall intensity of 8.26 cm/h.

A comparative study was done based on the soil loss obtained from all the plots considered for the study and the result of comparison of soil loss from each plot is depicted in the Fig 1. While considering the percentage reduction in soil loss in each of the treated plots, plots treated with coir and jute geotextiles showed the maximum percentage reduction. Among coir and jute laid plots, maximum reduction in soil loss was obtained in the plots treated with coir which reduced soil loss by 99.9 per cent.

Vegetation also reduced soil loss by 91 per cent but as it takes long time to get fully established, it cannot be preferred for immediate erosion control. The study invariably proved coir geotextile as the most effective bioengineering soil erosion control measure and its effectiveness increases as vegetation gets established on it as time proceeds. The properties of coir geotextile such as 100 per cent biodegradability, eco-friendliness and better adherence to the soil makes it the most recommended soil erosion control measure.

Earlier Bhattacharyya (2010) reported that geotextile cover was significantly more effective in reducing soil loss ratio on shorter plots than longer ones for both interrill and rill and interrill erosion processes.

Choudhury and Tapobrata (2010) laid jute geotextiles on National Highway, NH-2 Allahabad bypass, on the slope followed by spreading of grass seeds before the rainy season.Sprouting started within 2-3 weeks; the fibrous root system of grass took care of the slope soil and the whole area was fully stabilized within one year of laying jute geotextiles. Kurien et al (2014) reported that the soil loss and runoff increased with increase in the rainfall intensity for different slopes studied.

Permanent and self-propagating vegetal cover is found to be an ideal solution to 90 per cent of the erosion problems. Natural and biodegradable fibres such as coir and jute in the form of nettings can aid in vegetative turfing along the slopes. The coir netting spread over seeded slopes shields the soil and seeds from the impact of rain drops, minimise runoff and slows down its velocity, maintains the capacity of soil to absorb water, holds the soil particles and seeds in place and retains soil moisture. This technology is applicable to highly erodable slopes where mechanical methods such as tillage or terracing prove unsuitable (Lekha 2004).

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