PRELIMINARY OBSERVATIONS ON EFFICACY OF BIO-TECHNICAL TECHNIQUES FOR ROAD FILL SLOPE STABILIZATION

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Abstract

Preliminary data on the efficacy of biotechnical techniques for critical slope stabilization at two sites are presented in the paper. Six biotechnical techniques viz; brush layering, brush hedge layering, brush wattles, sodding, saccharum hedges and contour trenches with Ipomea cuttings were compared with simple planting and control at one site and only three biotechnical techniques were tested along with simple planting and control at the second site. All techniques were quite successful in the latter.

Introduction

New roads are being constructed in the hilly areas of Pakistan for development of these regions. With the introduction of intensive forest management, new forest roads are also being constructed in northern part of NWFP for scientific management of natural forests. Although roads are essential for the development but these have also created land slides and erosion problem in the hills. Properly designed roads do not have problem of erosion on the upper side but downhill fill slopes always need special treatment for stabilization. Mere planting does not stop the process of rilling and gullying on steep fill slopes because the soil is loose, and exposed to rain drop splash and sheet erosion. Generally rills are formed followed by gully formation even in the presence of tree seedlings. This is due to the fact that newly planted seedlings do not have large canopy to cover the exposed loose soil. In the first few years before the canopy closure of the plantation, the soil is exposed to rain drop impact and sheet erosion which results in the formation of rills and gullies. Once the process of gully formation starts, it does not stop even if there is complete canopy cover of the plantation on the site subsequently.

The same problem is on the upper cut slopes of the roads if the cut is not made vertical. In addition to road cut and fill slopes, land slide also create the condition of critical slopes. There is continous movement of loose earth on road causing road blockage during wet season from the slides above the roads. For clearing the road for traffic, the loose soil is pushed down the slope by the buldozers. This continous supply of loose soil on the down hill side of the road create unstable slope. The same condition is of debris avalanches. Such slopes are not easy to stabilize without special techniques. Similarly heavily denuded steep slopes are also difficult to stabilize with simple planting. The engineering control structures such as retaining walls, crib walls, concrete slabs are very expensive. Vegetation stabilization is economical, easy, permanent, have less maintenance

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problem and also have better aesthetic value. The slopes stabilized by vegetation also become productive by providing fuel wood, timber and forage.

Many biotechnical techniques have been used in various parts of the world for stabilizing critical slopes particularly the fill slopes of newly constructed roads in mountainous areas. Among these, brush matresses, wattle fences, sodding, hodroseeding mulch seeding, wattling, hedge layering, hedge brush layering have been found effective in some countries. Gray and Leiser (1982) have reviewed the work done on use of various biotechnical techniques. Kracbel (1936), Horton (1949), Leiser (1974) and Gray (1982) reported numerous wattling installations on road cut and fill slopes in southern California and other parts of U.S.A. Countour brush layering is another technique which has proved successful for stabilizing fill slopes of newly constructed roads, earth dams and levees in U.S.A., England and Austria (Scheehtl, 1978; Doran; 1948, Bower 1950; Horton, 1949; Howel, 1979; Bertos, 1979).

A number of biotechnical techniques of varying nature are used for road fill stabilization. For instance hedge layering is similar to brush layering, the only difference is that in the former, rooted seedlings are used instead of brush for slope stabilization. It requires a large number of seedlings for its construction and therefore brush hedge layering is preferred. However, brush hedge layering is the combination of brush as well as rooted seedlings. Sodding is another technique which has been successfully used for slope stabilization (FAO Conservation Guide, 1985). Only those plant species are used in these biotechnical techniques which can be vegetatively propagated. The basic aim in this regard is to develop mechanical barrier on the slope with living plant material for trapping sediment and reducing the velocity of runoff water.

Unfortunately no work has been done on this important aspect of soil conservation in Pakistan so far. Therefore a study was conducted at two sites to test the efficacy of different biotechnical techniques using local plant materail for stabilizing critical slopes.

Material and Method

Two experiments were laid out in February, 1989. One experiment was established at Ahmad Nagar near Harrow Bridge (Larence pur) on Islamabad-Peshawar Road and the other at Rarha Basnara on Kohala Road about 15 km from Muzaffarabad, Azad Jammu and Kashmir (AJK). Ahmad Nagar is in scrub zone with annual average rainfall of about 400 mm while the study area in A.J.K. is also in scrub zone but has much higher annual precipitation of 1400 mm.

At Ahmad Nagar slope strips, 5 metre wide and 10 metre long were demarcated by planting *Saccharum munja* tufts. The slope was a fill slope of a newly developed land in a gullied areas of loess soil. The experiment was laid out in Randomized Complete Block Design with eight treatments and three replications. The treatments were as follows:

Brush Wattles (Slope Fascines)

Fascines of living plant material which could root were prepared. These were 0.2-0.3 m in diameter and 3 m in lenght. Branches of *Tamarix*, mulbery and *Ipomea* were mixed for making fascines. The branches were arranged in bundles and tied lossely at 1 m interval. Pegs of *Tamarix aphylla* of 0.5 m lenght and 7-10 cm diameter were also prepared. Trenches were excavated along the contour having 0.3 m width and about 20 cm depth for these fascines. The soil of the trenches was placed on both upper and lower sides of the trench. The pegs were fixed in the soil at 1 meter spacing along the contour on the down hill side of trench. Only 15 cm of each peg was exposed on the soil surface. The pegs were driven at right angle to slope. The fascines were placed horizontally in the trench. Pegs of 0.5 m length were driven through the fascines in the ground. The fascines were covered with the soil which was pressed by feet. Only a small section of branches in the fascines were kept above the ground.

The installation of wattles was started from the top. The interval between two adjacent fascines was 2 meters along the slope. The area between two adjacent wattles was planted with *Eucalyptus camaldulensis* at 1.3 × 1.3 m spacing. The plan is shown in Fig. 1.

Brush Layering

Begining at the toe of the slope of 1 m wide terraces were dug out. The platform of the terrace was given reverse slope of 20 percent. The branches were about 1.3 m long. About one fourth of the branches were extended from the edge of the terraces. The branches of different species such as *Ipomea, Tamarix* and *Mulbery* were mixed and were placed parallel and diagonal to the slope.

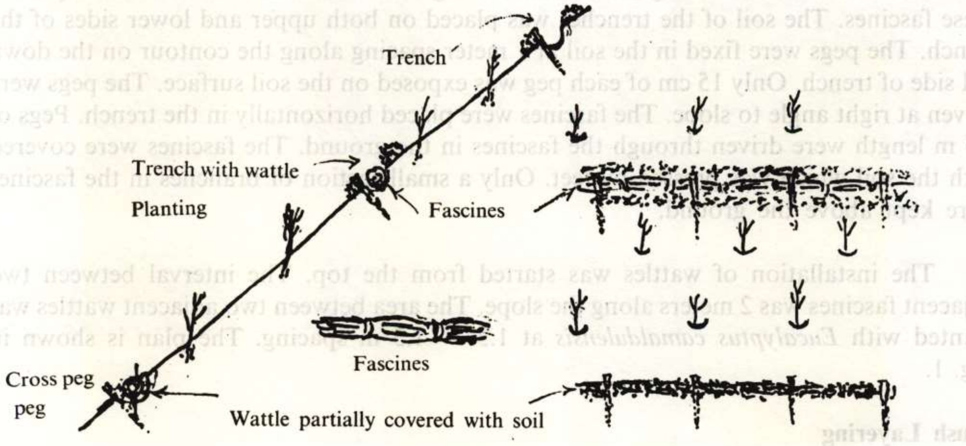
The brush layer construction was started at the bottom and continued upward. The lower ditch was filled with the soil from the ditch above it. In the area between brush layers, *Eucalyptus camalculensis* was planted at 1.3 × 1.3 m spacing (Fig. 2).

Hedge Brush-layer Construction

Rooted plants of Ipil Ipil were planted 0.4 m apart alongwith the brush layers. the treatment is identical to brush-layer construction with the exception that rooted plants are also used in this case. The rooted plants were covered with soil upto three quarters of their entire length in terrace. Subsequently, adventicious roots developed along the length of the stem which was covered by soil. The hedge brush layer construction was carried out at 2 m slope distance interval. In the area between the adjacent hedges planting of Eucalyptus was done at 1.3 × 1.3 m spacing.

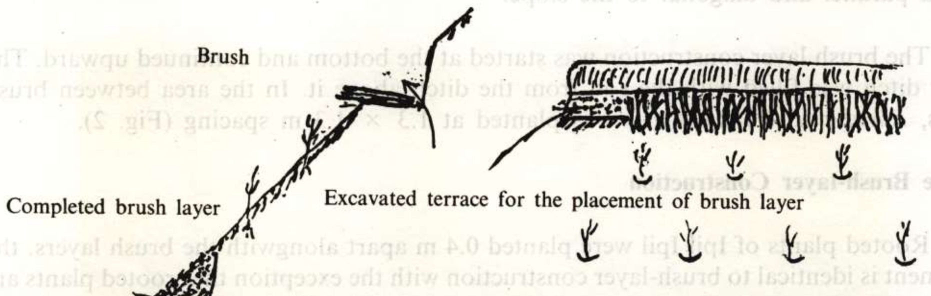
Sodding and Grass Tuft Planting

Slabs of sod (grass and soil) of 0.3 × 0.3 meter were dug out from a nearby meadow



A - Cross Section of slope treated with wattles B - Plan of slope treated with wattles

Fig. 1. BRUSH WATTLE CONSTRUCTION



A - Cross Section of slope treated with brush layering B - Plan of slope treated with brush layering

Fig. 2. Brush layer construction

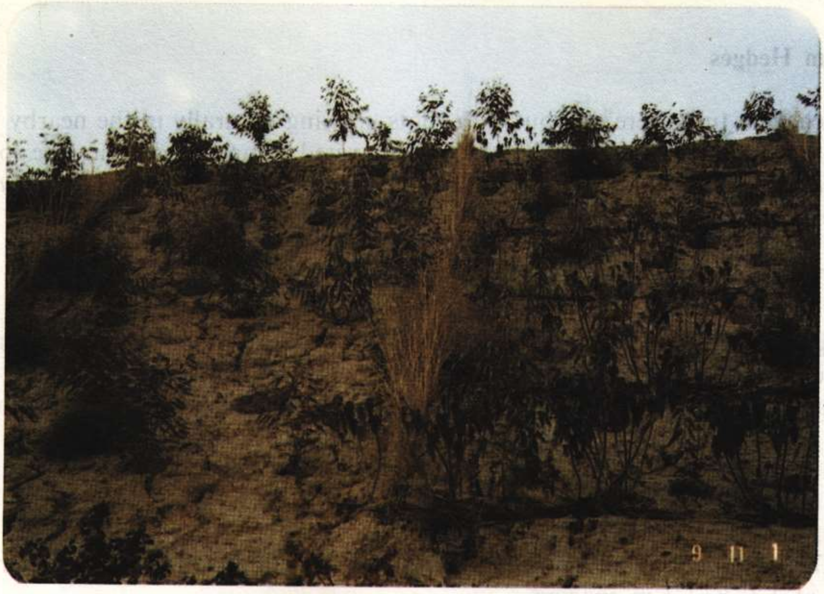


Fig. 3. Photograph showing brush wattles on right side plot and planting in pits on left side.

Fig. 4. Photograph showing staggered contour trenches on right side plot and brush layering on left.

and were placed in trenches of 0.15 m depth dug at 2 meter spacing. The space between the sod slabs was planted with grass tufts of local species in the first week of February, 1989.

Saccharum Hedges

Saccharum tufts were dug out with roots growing naturally in the nearby vicinity. The tufts were planted closely in the trenches excavated along the contour. The spacing of *Sacchrum* hedges was 2.0 m. The area in between the hedges was planted with *Eucalyptus camaldulensis* at 1.3 × 1.3 m spacing.

Contour Trenches with *Ipomea* Cuttings

Staggered contour trenches (2 × 0.4 × 0.4 m) were excavated at 1.5 m spacing in the rows. The interval between the rows was 1 meter. The trenches were staggered. At both ends of each trench *Eucalyptus* was planted and rest of the trench was planted with *Ipomea* cuttings.

Planting in Pits

In this treatment, planting of *Eucalyptus* was done in pits of 0.4 m diameter and 0.3 m depth at 1.3 × 1.3 m spacing.

Control

The strip was kept untreated without any of above planting or biotechnical slope stabilization techniques.

At the base of each slope strip, a siltation tank of 2 × 1 × 1 m dimension was constructed for sediment. Sediment trapped was measured at the end of monsoon season for evaluating the efficinecy of biotechnical treatments.

At Kohala Road, A.J.K. The experiment was laid out in January 1989 in Randomized Complete Block design with five treatments including simple planting and control. The experiment was replicated three times. The treatments were brush wattles, brush layering, brush hedge layering, planting without biotechnical techniques and control without planting biotechnical techniques. The width of the strips was 3 meters. The experimental site was fill slope on the main Kohala Road. There was a slide on the uphill side. The earth coming on the road from the slide had been pushed down by the crawler tractor. So the treated slope had loose material on steep gradient of more than 100%

Fresh cut branches of *Salix*, poplar and *Ipomea* were used for preparing wattle fascines, brush and brush hedge layer construction while *Robinia pseudocasia* and *Ailanthus* sp. were planted at 1.3 m × 1.3 m spacing in between the wattles, brush layering and brush hedge layering.

Results and Discussion

Preliminary observations were made on plant survival and sediment yield in both experiments. There was 100% sprouting of live plants in wattles, brush layering and brush hedge layering treatments conducted at Kohala Road, A.J.K. Plants of *Robinia pseudocasia* and *Ailanthus* sp. were also successfully established. There was complete closure of the canopy and seedlings attained 2-3 meter height in one growing season. Data on sediment yield could not be collected because siltation tank were constructed in November, 1989 after monsoon season. However, observation showed that all biotechnical techniques of wattles, brush layering and brush hedge layering were quite successful in stabilizing road fill slope. The untreated plots and plots with simple planting had rill formation while there was no rill formation in plots treated with biotechnical treatments.

At Ahmad Nagar near Harrow bridge, only 5-10% of brush material used in brush layering and wattles sprouted because of prolonged drought. The tuft planting of grasses also failed. Only sodding was successful. All treatments were repeated at the end of January 1990 in the dormant season.

Observations on the sediment yield of each plot were made by measuring the volume of sediment trapped in the earthen tanks at the foot of each plot. The data are presented in Table 1. A minimum sediment yield of 141 tons/ha was found in the plots treated with brush layering. The sediment yield from plots treated with brush wattles, brush hedge layering, sodding, *Saccharum* hedges and contour trenches with Ipomia cuttings was 145, 165, 149 and 181 tons per ha. respectively. Maximum sediment yield was observed in the control plots without any treatment and in plots with planting only; 197 and 192 tons per ha. respectively. There are some missing data in the table due to leakage in some of the siltation tanks and sediment could not be trapped fully. The siltation tanks and sediment could not be trapped fully. The siltation tanks are being lined with bricks for making the tanks leak proof.

Although the sprouting of the plant material used in wattles, brush layering, brush hedge layering and Ipomea cuttings treatments was only 5-10 percent due to drought even then there is indication of the effectiveness of these treatments for slope stabilization. The sediment yield was less in the treated plots as compared to the untreated plots by 42-52 tons/ha/yr. It was also evident that planting of *Eucalyptus camaldulensis per se* had no effect on erosion on fill slopes of newly built roads. Further, both Saccharum hedges and sodding treatments were equally effective in slope stabilization. *Saccharum* spp. grow naturally in the area and are easily available for road stabilization work. It is also a hardy species and can withstand long droughts. *Saccharum* hedge treatment was the cheapest treatment, amongst all treatments in this experiment.

TABLE 1

SEDIMENT YIELD FROM 150 M^2 SLOPE PLOTS TREATED WITH DIFFERENT BIOTECHNICAL TECHNIQUES (CUBIC METER)

S. No.	Treatments	Replications				**
		R-I	R-II	R-III	Average	Tons/ha
1.	Brush layering	1.00	1.3	1.7	1.33	141.70
2.	Brush Hedge Layering	*	1.4	1.7	1.55	165.33
3.	Wattles	1.06	1.5	1.6	1.36	145.00
4.	Saccharum Hedges	1.40	*	*	1.40	149.30
5.	Sodding	1.10	1.5	1.6	1.40	149.30
6.	Contour trenches with Ipomea cutting	1.60	1.8	*	1.70	181.30
7.	Planting in pits	*	1.8	1.8	1.80	192.00
8.	No treatment (control)	*	1.8	1.9	1.85	197.30

* No sediment was trapped due to leakage in the siltation tank.

** Sediment yield in tons per hectare was computed by using 1.6 gm/cm^3 density of mineral soil for the sediment.

Conclusion

From the preliminary observations it may be concluded that biotechnical techniques are quite effective in critical slope stabilization. These are not only useful for newly constructed road cut and fill slope stabilization but can be equally effective for stabilizing land slides, debris avalanches and heavily denuded slopes with loose and ravelling soil.

Acknowledgement

M.Sc and B.Sc. Forestry students of 1987-89 course helped in the layout of the experiment at Ahmed Nagar. They took keen interest in the work and their assistance is appreciated. I am also thankful to Mr. M. Fayyaz Joya and Ch. Abdul Khalique, Research Officers for their help in the lay out of the study. Thanks are also due to the Divisional Forest Officer Research muzaffarabad, A.J.K. and his staff for successfully laying out the study and for their continued interest in it. I am grateful to Dr. K.M. Siddiqui, Director General, Pakistan Forest Insitute, Peshawar for his encouragement and assistance for this study.

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