EFFECT OF DIFFERENT ENGINEERING SOIL CONSERVATION MEASURES ON WATER AND SEDIMENT YIELD AND FARM PRODUCTIVITY

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ABSTRACT

An experiment was laid out at Pabbi forest Kharian to find out the suitable soil conservation measure for soil and water conservation enhancement of farm productivity. Four catchments were treated one each with strip cropping, conservation benches with planting of trees on slopes, conservation benches with natural grass on slopes and bench terraces. On the risers of bench terraces and conservation benches ipil ipil was planted. In strip cropping *Eucalyptus camaldulensis*, *Acacia modesta* and *L. leucocephalla* were planted in 3 rows at 1 x 1 m spacing along the contour.

At the outlet of each catchment, detension dams with circular splitter and siltation tanks for monitoring water and sediment yield were constructed. The water and sediment yield data showed that there was no surface runoff and sediment yield from the catchment treated with bench terraces,while it was maximum from the catchment treated with only strip cropping. There was no significant difference in water and sediment yield from the other two catchments treated with conservation benches with trees and grasses on slopes respectively.

The crop, forage, and the biomass production of Ipil ipil data showed that maximum farm productivity is from the catchment treated with bench terraces. Ipil Ipil on the risers of the terraces was found to be most fruitful not only for increasing the fertility of soil and stability of risers but also for increasing the farm income by production of fuelwood and fodder from the riser of bench terraces. Therefore bench terraces were found to the most suitable soil conservation measure for soil and water conservation and increasing the farm productivity in the scrub zone.

INTRODUCTION

The scrub zone is situated in the foothill areas of northern Pakistan having annual rainfall ranging from 400-1000 mm. Therefore, it is fit for barani (rainfed) agriculture. The Potwar plateau although has potential for barani agriculture but is one of the highest sediment producing areas in Pakistan because of the fact that maximum land area is under agriculture. Some agriculture fields are well terraced but most of the agriculture lands are without any technical soil conservation measure. As a result the watershed areas of potwar region are yielding high rate of sediment.

Natural vegetation of area is scrub forest having *Olea cuspidata* and *Acacia modesta* the major tree species. Both these species are slow growing but the area have potential for afforestation with fast growing tree species. Experiments on tree species trials showed that some fast growing tree species such as *Eucalyptus camaldulensis, Acacia nilotica, A. elata, A. saligna, A. stenophylla, A.albida and Leucanea leucocephala* can be successfully planted. (Annon, 1994, Shah, 1990, Shah, 1991)/ Results of a comparative watershed management study laid out at Missa Keswal, Distt. Gujar Khan showed that afforestation, protection from grazing and gully control measures can reduce the water and sediment yield by 50% within 15 years of treatment. (Hanif 1977, Hanif, 1987, Masrur 1972 and Subhan, 1986). An other study was also conducted at Fateh Jhang to compare the *E.camaldulensis* and Ipil ipil plantations and agriculture practice on sediment yield (Anwar, 1987) by PARC. No work has been conducted to evaluate the effect of different soil conservation measures on agriculture land for reducing sediment yield and enhancing the crop production. It was also necessary to develop an agroforestry model for the sub mountain areas of scrub zone for enhancing the farm productivity as well as sustainable agriculture production.

MATERIAL AND METHOD

An experiment was laid out at Pabbi Forest Kharian to evaluate the proper soil conservation method to develop an agroforestry model for the scrub zone. The experimental area lies near 73.8° East Longitude and 33.0° North Latitude. The annual precipation of the area is about 800 mm, out of which 70% is received during monsoon. There are long dry spell, from April to Mid July and mid September to January. The soil of study site is sandy loam.

The study site was occupied by *A. modesta* and also invaded by *P.juliflora.* During 1988, the area was cleared from the natural vegetation and soil conservation treatments were given. Looking at the annual average precipitation and pattern, four types of soil conservation treatments were proposed in the study plan. For this purpose four small catchments having gentle to moderately steep slopes were selected in compartment No.63 of Pabbi forest, Kharian Range. The first catchment having 10% slope was taken up for strip cropping and no engineering soil conservation treatment was given. The biological treatment given was planting of two strips of trees along the contour, one in the middle the catchment while the other near the outlet. In each strip rows of three different tree species was planted at 2 m spacing. The first row was planted with *Eucalyptus camaldulensis,* middle with *Acacia modesta* and third with *Leucanea leucocephala* (Ipil ipil). The spacing of rows was also 2 meters. The first row of trees (*E. camaldulensis*) was established by planting in

a trench having 0.3 m width and depth with a berm on down hill side. The upper two rows were established by planting in the pits without disturbing the natural grass.

The other catchment having an area of 1.38 ha was treated by bench terraces with the help of a bulldozer and tractor blade. Four series of terraces were developed at a vertical interval of 1-2 meters and with spillways (outlets) for disposal of outflow from one terrace to the other. Each terrace was provided with a berm of 0.5 m height on the risers. The height of spillway was 0.15 m. The spillway was treated with stone pitching. The risers were planted up with tufts of *Cenchrus ciliaris* and Ipil ipil while the level benches were used for agriculture crop production.

The 3rd catchment having an area of 1.15 ha was treated with conservation benches (hill side ditches). In this catchment upper one fourth sloping area was planted up with forest trees and then a bench terrace was developed along the contour for agriculture crops. Again slope having 5 - 10 m width was left for planting and a bench terrace was developed near the outlet of the catchment for crop production. The slopes were planted up in 1988 - 89 with *E. camaldulensis, A. nilotica, A. modesta and L. leucocephala* in mixture. The risers of conservation benches were planted with Ipil ipil and tufts of *Cenchrus ciliaris*. The conservation benches were developed for trapping surface runoff from the slopes for collecting extra runoff water to enhance the crop production.

The fourth catchment was also treated with conservation benches as described above with the only difference of keeping the slope under grass cover for producing more runoff for crop production. Any how the risers of the benches were planted with Ipil Ipil for their stabilization and fodder production.

For the first three years agriculture crops such as sunflower, taramira, mash beans, were cultivated in both seasons. As the study site is situated with in the forest, the crops were being damaged by wild animals such as wild boar, porcupine and rabbits, therefore ultimately the crops were replaced by perennial grasses. In the first catchment *Panicum antidotale* was sown and in the other three catchments *Cenchrus ciliaris* was sown. During 1991-92 the ipil ipil trees were coppiced at 40 cm height from ground level. The data on biomass was recorded from each catchment and it was processed and tabulated. The data on grass production was also recorded at the end of each growing season.

For recording data on sediment yield, detension ponds were developed at the outlet of each catchment. There was outflow from the ponds and therefore a circular splitter system was installed during 1990. The data on sediment was processed and tabulated.

The meteorological data are also recorded of the study area by establishing meteorological observatory near the substation office in Pabbi Forest Kharian.

RESULTS AND DISCUSSION

The hydrological data on water and sediment yield are being collected regularly since completion of the treatments in 1989. The surface runoff data for the last five years is summarized in Table-1, while the sediment yield data is presented in Table-2.

In the first three years the total water yield could not be measured because the data

on outflow from the detension dams could not be collected while in the last two years the outflow was also measured through the splitter system. The runoff was higher in the initial years when agriculture crops were cultivated and it was reduced with the replacement of agriculture crops with perennial grasses. From the Table-1 it can be seen that maximum hydrological response was from the catchments treated with only biological conservation measures i.e. strip cropping inspite of the fact that the catchment has minimum slope gradient. On average hydrological response was 10.4% from the catchment treated with strip cropping and it was 3.84 and 2.14 percent from the catchment treated with conservation benches with slopes planted with trees and grass respectively. While from the catchment treated with bench terraces, no surface runoff could be recorded during the last five years of data collection even with the highest intensity rainstorms.

It is interesting to note that the hydrological response was gradually reduced by replacement of annual crops with perennial grass vegetation. No significant difference in hydrological response was observed amongst the two different types of conservation benches. During 1993, not a single rainstorm could produce surface runoff from all the four catchments.

The sediment yield data (Table -2, Bar Diagram-1) also showed the same trend that highest sediment yield was from the catchment treated only with strip cropping without technical soil conservation measure while there was no sediment yield from the catchment treated with bench terraces. The sediment yield from the catchment under strip cropping was 15.87, 11.5, 26.0 and 37.56 tonnes per hectare during 1990, 1991, 1992, 1993 and 1994 respectively. the low figures of sediment yield during the initial years was due to the fact that suspended sediment with the over flow from the detension dams could not be measures.

On average the sediment yield was 22.63, 7.92 and 5.58 from the catchment treated with strip cropping, conservation benches with trees on slope and conservation benches with grasses on slopes respectively. The sediment yield, from the catchment treated with conservation benches with trees on slopes, reduced gradually with the growth of seedlings planted on slopes. In the initial years the sediment yield from planted catchment was higher than that from the catchment with natural grass vegetation on slopes, but during 1994 it was reverse.

Both water and sediment yield data shows that bench terraces are most suitable soil conservation measure for soil and water conservation in the scrub zone with annual means precipitation of 800 mm and with sandy loam soil.

The agriculture crop production data collected during 1989, 1990 and 1991 is presented in Table-3. Both winter and summer crops were cultivated under rainfed conditions. The crops were taramira (Brasica sp.), Mash beans, and sunflower. Production of Taramira was highest as compared to other crops. The average crop production was 116.6, 167, 132 and 118 kg per hectare from the catchments treated with strip cropping, conservation benches with trees on slopes, conservation benches with grasses on slopes and bench terraces respectively. Although there was 11 to 40% overall increase in crop production in the conservation benches but during summer the crops could not grow according to their capacity due to flooding by the surface runoff from slopes in conservation benches. The crop

production per unit area of the catchment was also lower because almost 50% area in the conservation benches is not used for agriculture crops and is used for water production. On the newly constructed bench terraces crop production is always low in the initial few years because top soil is removed during earth work.

As the crops were also being damaged by wild boar, porcupine and rabbits, perennial grasses were established in the cropping area of all the four catchments.

Biomass data was taken after three years of growth on Ipil Ipil planted on the risers of bench terraces, conservation benches and in strip cropping area in different catchments. The data is presented in Table-4A. The biomass data shows that growth of Ipil Ipil on risers of bench terraces and conservation benches was extremely impressive as compared to the seedlings planted in the strip cropping in simple pits. The biomass production of single tree on average ranged from 44.3 to 54.1kg in conservation benches and terraces and only 29.4 kg in strip cropping. Per unit area biomass production of Ipil Ipil was highest in the catchment treated with bench terraces (6075 kg/ha) and lowest in catchment with strip cropping (1342 kg per ha). While biomass production of Ipil ipil in the catchment treated conservation benches with trees on slopes and grasses on slopes was 2660 kg and 1688 kg/ha respectively. The average single tree annual biomass growth was 9.8 kg in strip cropping catchment and 18 kg in the catchment with conservation benches which is almost double.

The Ipil ipil trees were cut at 40cm height to get coppous growth for forage and fire wood production. After two years of growth biomass data was taken during December 1994. The data is present in Table 4-b.

The average two years growth of copous single tree was 39.6, 60, 65.4 and 77.5 kg of Ipil Ipil planted in strip cropping, conservation benches with trees on slopes, conservation benches with grass on slopes and bench terraces respectively. The annual copous growth was almost double than the average annual growth of 3 years old seedlings. The maximum annual per biomass production of Ipil ipil was of the catchment with bench terraces (14258 kg/ha) and minimum (2812 kg/ha) from the catchment with strip cropping. While from the catchment treated with conservation benches with trees on slopes and grass on slopes it was 4435 and 4016 kg/ha respectively. The plantation of Ipil ipil on the risers of terraces proved quite beneficial for increasing the farm productivity because risers area in the terraces is considered to be out of production. This is the unique example that the productivity from risers is almost the same as the cropping area of terraces.

The forage production data was also collected from the all the four catchments during 1993 and 1994 and presented in the Table-5. On average the highest forage production was recorded from the terraced catchment, sown with *Cenchrus ciliaris* while the minimum production was recorded from strip cropping catchment sown with *Panicum antidotale* (3817 kg/ha). The forage production from the catchment, treated with conservation benches with trees on slope and grasses on slopes was 3916 and 4740 kg per ha respectively.

The annual production of the perennial vegetation of each the catchment was assessed and value presented in Table-6. Considering the harvesting and extraction expenditure and the value of fuel wood and fodder of Ipil Ipil a modest rate of Rs.0.25 per kg of green biomass was used for the assessment of income from Ipil ipil. Similarly twenty five paisa per kg of air dry

grass is also reasonable estimated value of grass production. From the Table-6 it can be seen that maximum annual income of Rs.6851.00 per ha. is from terraced catchment. The annual income from the catchment with strip cropping, conservation benches with trees on slopes and conservation benches with grass on slopes is Rs.3817, Rs.3915 and Rs.4740 per hectare respectively.

The combination of agriculture crops with Ipil ipil on the risers of terraces can be more productive. The foliage of Ipil ipil can be used as green manure for enhancing the agriculture crop production. Ipil ipil should be managed under coppous system every year so that there should be minimum shade effect on the crop but at the same time being a nitrogen fixing tree can add fertility to the agriculture land by fixing atmospheric nitrogen by the bacteria in their root system. Ipil ipil is being used extensively in the cultivated land as hedge rows and in Slopirg Agriculture Land Technology (SALT) i Phillipines, Malasia, Srilanka and other trc ,ical countries for the maintenance of soil fertility of agriculture land as well as conservation of soil. Although it will take time to introduce SALT in Pakistan after experimentation but Ipil ipil can be introduced for intercropping with agriculture crops by planting it an risers of terraces under copping system.

CONCLUSION

Both the water and sediment yield data as well as data on crop production, grass production and biomass production of Ipil ipil planted on the risers of conservation benches and bench terraces has shown that bench terraces is the best soil conservation treatment for soil and water conservation as well as for increasing the farm productivity in the scrub zone having 700 - 800 mm annual rainfall and sandy loam soil. The use of Ipil ipil on the risers of bench terraces can enhance agriculture crop production by improving the soil fertility. It can also add farmer's income by providing firewood and fodder of the value almost equal to agriculture crops in the cropping area. Ipil ipil should be coppiced every year during winter season to get fuelwood as well as fodder at a time when natural grasses are not available.

It can be concluded that in the scrub zone bench terraces with Ipil ipil on the riser are quite useful for soil and water conservation as well as increasing the farm income and should be adopted by the farmers. This is the best agroforestry system for the undulating and foot hill areas of the country.

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Table-1. Summary of surface runoff data from the catchments treated with different conservation treatments at Kharian.

Year	Precipitation which produced runoff(mm)	No of storms	Strip cropping		Conservation benches with trees on slopes		Conservation benches with grass on slopes		Bench Terraces	
			Run off (mm)	Hydrological response (%)	Runoff (mm)	Hydrological Response (%)	Runoff (mm)	Hydrological Response (%)	Runoff (mm)	Hydrological Response (%)
1990	551	9	48.94	8.8	20.54	3.7	14.5	2.6	-	-
1991	426	10	94.77	22.25	14.43	3.4	13.0	3.1	-	-
1992	396	4	21.0	5.3	17.8	4.4	13.0	3.3	-	-
1993	-	-	-	-	-	-	-	-	-	-
1994	329	11	12.35	3.8	12.6	3.8	10.4	3.2	-	-
Total	1702	34	177.06	10.4	65.37	3.84	36.4	2.14	-	-

Table 2. Summary of the sediment yield data from the catchments treated with different soil conservation treatments (Tonnes/ha).

Years	Strip cropping	Conservation bench with trees on slopes.	Conservation benches with grasses on slopes	Bench terraces.
1990	15.87	6.26	2.38	-
1991	11.28	8.26	5.90	-
1992	26.0	9.30	3.90	-
1993	-	-	-	-
1994	37.56	7.86	10.16	-
Average	22.63	7.92	5.58	-

Table 3. Production of Agriculture crops in catchments treated with different soil conservation measures (Kg/hectare).

Cropping season	Crop	Strip cropping	Conservation benches with trees on slopes	Conservation benches with grass on slopes	Bench Terraces
Winter 1989	Sunflower	26	34	15	43.5
Winter 1990	Brassica sp.	302	447.5	287.0	288.4
Summer 1990	Mash	44.5	56.0	49.5	31.0
Winter 1991	Brassica	940	132	175.0	108.6
Average		116.6	167.4	131.6	118

Table 4-A. Biomass (40cm above ground) of *L. leucocephala* at 3 years age planted under soil conservation experiment at Kharian.

Catchment Treatment	No.of tree sampled	Average D.B.H.	No. of Branches	Average green weight per tree (kg)				Annual biomass production (kg)		
				Stem	Branches	Leaves/ pods	Total	Per tree	Per catchment	Per hectare
Strip cropping	5	5.3	2	13.0	9.4	7.0	29.4	9.8	696	1392
Conservation Benches with trees on slopes	7	8.2	1.7	32.0	14.4	7.7	54.1	18.0	3060	2660
Conservation benches with grass on slopes		6.2	2.3	23.1	8.4	9.8	44.3	13.7	2329	1688
Terraces Ipil ipil on risers	20	7.5	2.0	27	9.15	12.5	48.75	16.2	7776	6075

Table 4-B. Biomass (40 cm above ground) of *L.leucocephala* of 2 years coppous, planted under soil conservation experiment at Kharian.

Catchment treatment	No. of trees sampled	Average Height (m)	No. of coppous stems	Average D.B.H. of stems (cm)	Average green weight per tree (kg)				Annual biomass (kg)		
					Stem	Branches	Leans	Total	Per tree	Per catchment	Per ha.
Conservation Benches with trees on slopes	17	7.0	4.0	5.0	35.0	8.0	17	60.0	30	5100	4435
Conservation benches with grass on slopes	17	6.8	5.2	5.2	41	8.2	16.2	65.4	32.6	5542	4016
Bench Terraces	48	7.0	6.0	5.36	51.7	8.4	17.2	77.5	38.75	18251	14258

Table 5. Forage production from the catchments treated with different soil conservation measures.

Year	Strip Croping		Conservation benches with trees on slopes		Conservation benches with grass on slopes		Bench Terraces.	
	Panicum antidotale		*Cenchrus ciliaris*		*Sorghum almum*		*Cenchrus ciliaris*	
	Cover %	Forage production kg/ha.	Cover %	Forage production kg/ha	Cover %	Foreage production kg/ha	Cover %	Forage production kg/ha
1993	64.6	4440	55	3438	61	4830	84.2	7595
1994	70.0	3194	64.95	4393.6	65	4650	76.46	6108
Total	134.6	7634	119.95	7831.6	126	9480	160.66	13703
Average	67.3	3817	59.98	3915.8	63	4740	80.33	6851

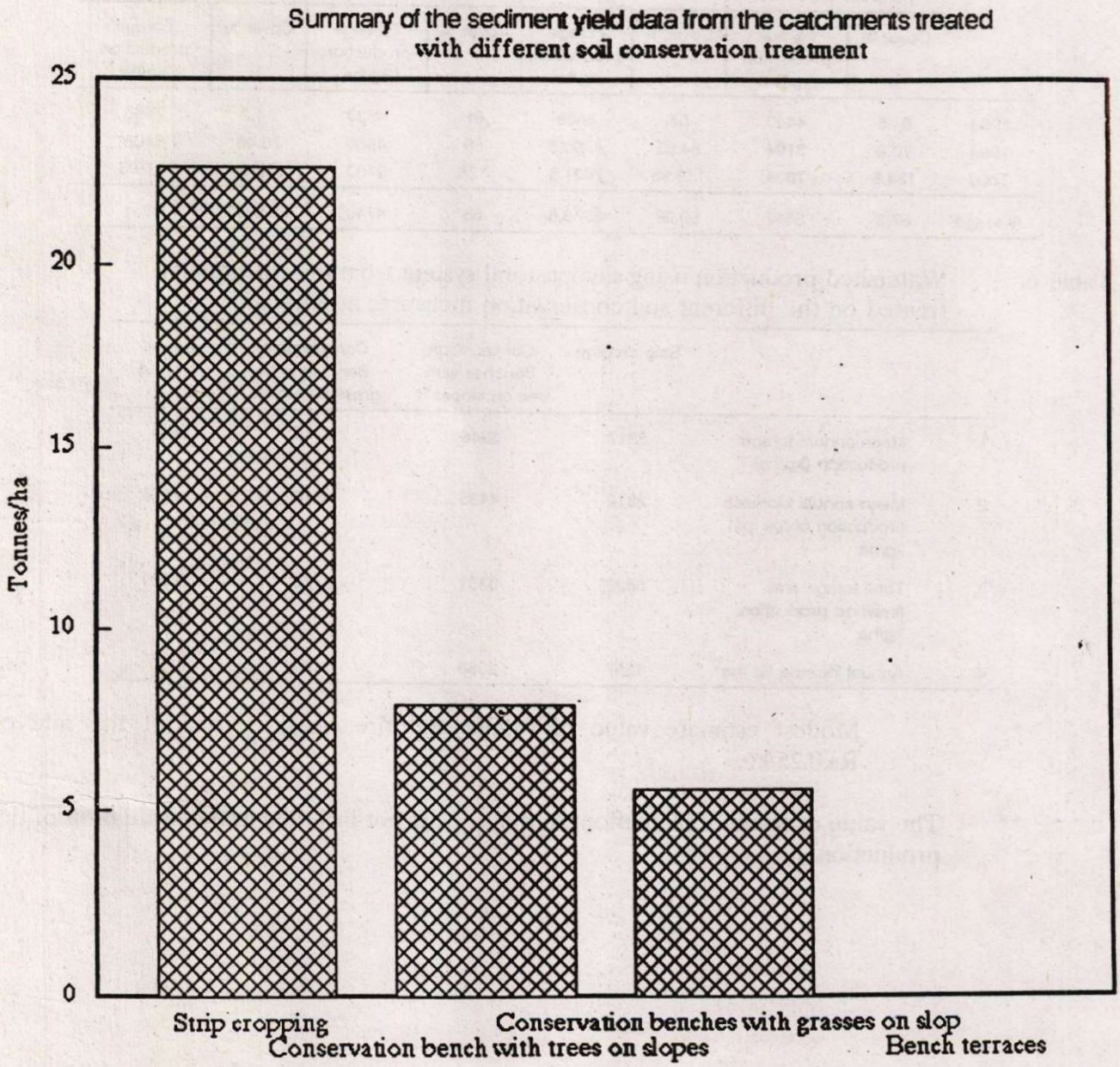
Table 6. Watershed production using silvopastoral system from the catchments treated on the different soil conservation measures at Kharian.

		Strip croping	Conservation Benches with tree on slopes**	Conservation Benches with grass on slopes	Bench Terraces.
1.	Mean annual forage production (kg/ha)	3817	3916	4740	6851
2.	Mean annual biomass production of Ipil ipil kg/ha	2812	4435	4016	14258
3.	Total forage and firewood production kg/ha	6629	8351	8756	21109
4.	Annual income Rs./ha*	1657	2088	2189	5277

* Modest estimate value of forage and fire wood is used at the rate of Rs.0.25/kg.

** The value of wood of plantation on the slope is not included in the evaluation of the production.

Graph


Summary of the sediment yield data from the catchments treated with different soil conservation treatment
Tonnes/ha
25
20
15
10
5
0
Strip cropping
Conservation bench with trees on slopes
Conservation benches with grasses on slop
Bench terraces