Efficacy of Water Conservation Techniques for the Afforestation of Watersheds in the Scrub Zone of Pakistan

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Abstract

To evaluate the efficacy of water conservation techniques for the establishment of forest plantation, an experiment was laid out at two sites, Kharian and Raisan (Kohat). Microcatchments, conservation trenches, gradonii and simple pits were used for planting *Eucalyptus camaldulensis, Leucaena leucocephala, Acacia nilotica* and A. *modesta* seedlings.

Preliminary results based on the two years data are presented in this article. All the three techniques proved effective for the establishment of tree species. Both the survival as well as growth rate of seedlings planted with water conservation techniques was almost double as compared to those planted in simple pits at both sites. At Kharian the seedlings of *E. camaldulensis* showed highly positive response to water conservation techniques by attaining three times height of seedlings planted in simple pits. The response of *A. modesta* was however, low. *A. nilotica* suffered frost damage at Raisan.

Introduction

Afforestation of watershed areas in arid and semiarid zones is generally not possible without hand watering. The submountainous tracts of Pakistan fall in semi-arid climatic zone with the average annual precipitation ranging from 350 mm to 850 mm with 60 to 70% of the total precipitation received in monsoon season. The indigenous tree species of the area are phulai (*Acacia modesta*) and kao (*Olea cuspidata*) and are managed under coppice system. Both species are slow growing and have only fuelwood and forage value.

Afforestation programmes of commercial tree species are in progress in this zone for increasing wood production as well as for protection of the important catchment areas of Tarbela, Mangla, Warsak and Tanda reservoirs. The planting of phulai poses no problem but that of commercial tree species such as *Eucalyptus camaldulensis, A. nilotica, A. cynophylla* and *L. leucocephala* is not successful without hand watering. Hand watering is not only expensive but it is also not practical in the hilly terrain. On the other hand, water harvesting and conservation techniques can be used to successfully establish forest plantations.

Different types of water conservation techniques have been used for the establishment of tree plantations in arid and semi-arid zone of the world. Chris Reig et al, (1988) have reviewed work done on water harvesting for plant growth including water harvesting on short slopes. Similarly, Shanon and Tadmor (1976) have identified four types of water harvesting techniques on short slopes viz catchment basin (Negarim), contour runoff strips (Shananine), contour bench terraces and microcatchments. The Negarim microcatchment have been used in Nigev desert with border check and a basin in one corner with slope towards the basin (Shanon and Tadmor 1979, Finkl et al, 1987, Evernari et al , 1971). A V-shaped microcatchment was successfully used in Niger for establishment of forest trees (Chase, 1986). Semi-circular basins "Demi lunes" have also been used in Niger and Kenya for the production of crops on gentle slopes (Moald 1984). The height of the bunds of demi lunes is usually less than 30 cm (Chris et al , 1988) and diameter 4 m, which are 8 m spaced.

Since 1975, considerable research in water harvesting and conservation has been done in India. The research in Jodhpur focussed on the size and shape of microcatchments and the yield of runoff (Jain and Singh, 1980, Sharma, 1986, Sharma, Pareek and Singh, 1986). Bhushan (1979) has described the research on conservation bench terraces with varying catchment crop ratios (CCR's) in the subhumid region of Dehra Dun . Nag et al, (1989) has also described the mechanization of gradonii (conservation benches) for large scale afforestation in the subhumid southern hill region of Rajasthan state in India.

Contour ridges were successfully used in Kenya for the establishment of fuel and fodder tree species (Robert, 1985; Critchley, 1987). A water conservation technique known as "Zay" was used in Burkina Faso for the establishment of vegetation (Wright, 1985). These are simple pits with 30 cm depth and 30 cm diametre filled with a mixture of soil, manure and organic matter. The spacing of pits is 1 × 1 m on flat or gentle slopes for the conservation of moisture to produce crops. A similar technique is used in Cape Verde Island, namely, "Covas" (Reijntjes, 1986, quoted by Chris et al, 1988).

In Pakistan sloping catchments (roaded catchments) have proved quite effective *in situ* water harvesting and conservation techniques for planting of *A. modesta, A. tortalis, A. albida* and *A. victoria* in Thal desert (Sheikh et al, 1984). Eyebrow pits have also been successfully used for planting *E. camaldulensis* in Fateh Jhang in scrub zone (Shahid et al, 1989).

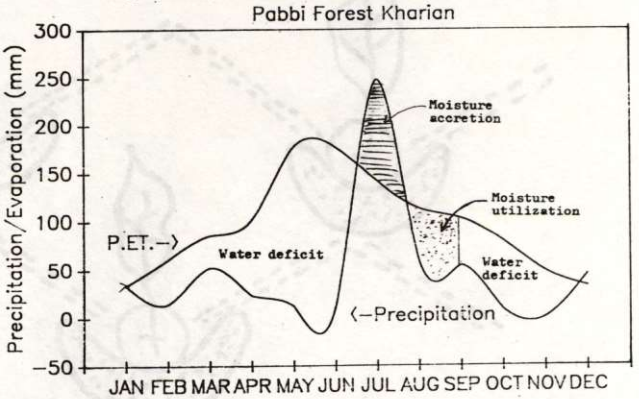
No systematic study has been conducted for evaluating the efficiency of different water conservation techniques for the afforestation of arid and semi-arid watershed areas of Pakistan. Experiments have been initiated in the arid and semi-arid areas of the country to develop effective technique for water conservation in order to rehabilitate the watersheds in such areas. The paper presents the preliminary results of such experiments.

Meterial and Method

The experiments were laid out at two sites, one at Pabbi Forest, Compartment-63 Kharian (Punjab) and other at Raisan on Kohat-Hangu Road (NWFP). Both sites are in the scrub zone with *Acacia modesta* and *Olea cuspidata* as dominant tree species. At Kharian the experiment was laid on hill slopes with varying degrees of erosion. The top and middle part of the slopes were heavily eroded while the foot of the hillocks have good soil. The soil is sandy loam with sand stone as parent rock. The average annual precipitation of the area is 550 mm. Out of total precipitation 60-70% is received in monsoon (Fig. 1)

The experiment at Raisan was laid out on hill slopes having very stony and gravely soil and in denuded condition. The area is a community land with heavy grazing pressure, which is being planted under an income generating project for Afghan refugees financed by World Bank. The mean annual precipitation is less than that in Kharian and about 50% of it is received in spring.

Fig. 1 Precipitation Vs. Potential Evapotranspiration
Pabbi Forest Kharian

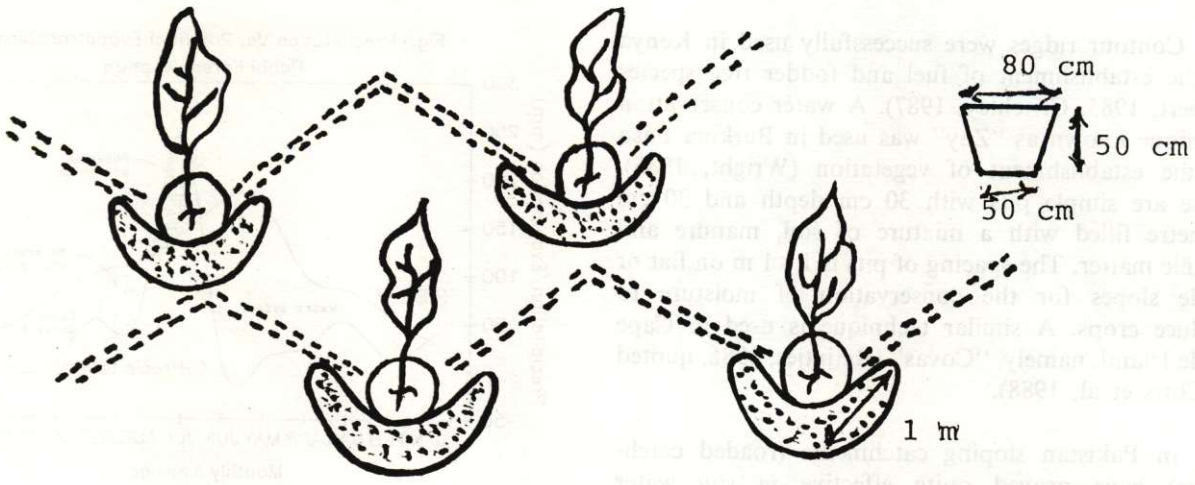


The experiment was laid out on split plot design with tree species as major treatment and water conservation treatments as minor treatment. The experiment was replicated three times with 20 plants as plot size at both sites. The tree species were *E. camaldulensis, L. leucocephala, A. nilotica* and *A. modesta* and water conservation treatments were V-shaped microcatchments, gradonii, conservation trenches and conventional plant pits.

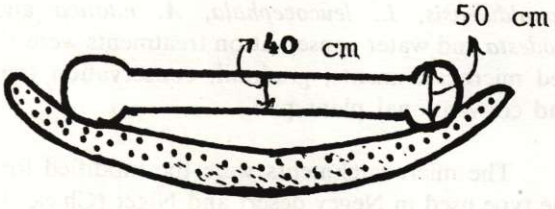
The microcatchments were the modified form of the type used in Negev desert and Niger (Chase, 1986). A plant pit of 0.8 m diametre at the top, 0.5 m at the bottom and 0.5 m depth was excavated. A drain 15 cm deep as well as wide was also excavated from both sides of the pit extending up and outward upto 4 m. The excavated soil of the pit and the drain was piled on the down hill side of the pit in a semi-circle extending from the down hill side mid point of the pit upto only 1 m length along the drain (Fig. 2a). The microcatchments were staggered in rows.

The conservation trenches were specially designed for the conservation of rain water for plant growth. Contour trenches were excavated having 4 m length and 0.4 m width. At both ends plant pits of 0.5 m diameter and depth were excavated. The depth at the centre of the trench was kept only 0.15 m sloping towards end pits. The excavated soil was piled on the down hill side of the trench in a crescent shape mound extending about 0.4 m on both ends (Fig. 2b). The contour trenches were staggered in the rows. Planting was done in the plant pits.

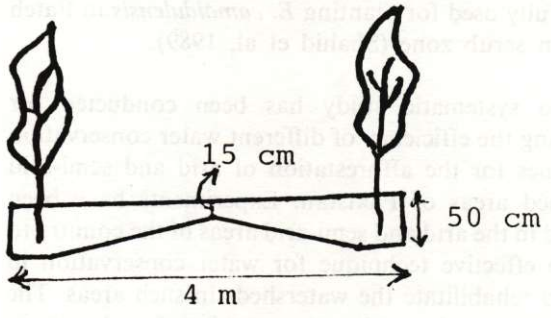
The gradoni are narrow bench terraces excavated along the contour having 1 m width and 0.3 m high berm on the down hill side. Plant pits of 0.5 m diameter and 0.3 m depth were excavated at 4 m spacing in the centre



a. MICROCATCHMENTS

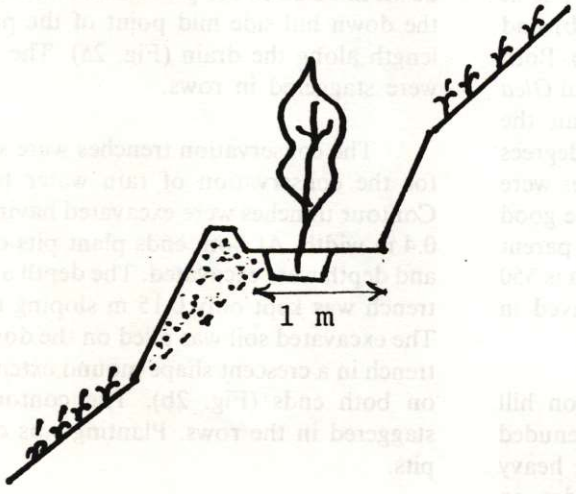


PLAN



L. SECTION

b. CONSERVATION TRENCHES



c. GRADONI

Fig-2 Design of Water Conservation Structures

of gradoni (Fig. 2c).

The conventional plant pits having 0.5 m diametre and 0.3 m depth were used for planting as control for comparison with the water conservation techniques.

Earth work for water conservation treatments was done in October-November 1988 while planting was conducted in January 1989 with hand watering. Restocking was done in monsoon of 1989 and 1990. The data on survival was recorded at the time of restocking during monsoon 1989 at Kharian and Raisan and are presented in Table 1 and Table 2 respectively, while two years height data were recorded in Spring 1991 at both Kharian and Raisan as given in Table 3 and Table 4. The data on both survival and height growth were statistically analysed by applying ANOVA and LSD test on a personal computer (IBM).

Results and Discussion

The preliminary observations on the survival and growth rate of seedlings of the four tree species planted with water conservation techniques and in conventional plant pits have shown that water conservation techniques are quite effective for the establishment of forest tree species in the scrub zone of Pakistan. The survival of seedlings planted with water conservation tehniques was much higher than the seedlings planted in pits (Table 1 and Table 2). At Kharian, the survival of seedlings planted with conservation trenches, microcatchments and gradoni was 60%, 57% and 57% respectively while in simple plant pits, it was only 35% .

Table 1

Survival of Tree Seedlings Planted with and without Water Conservation Techniques at Kharian, Survival out of 60 Plants in Three Replications.

Water Conservation Technique	*E. camaldulensis* Survival		*L. leucocephala* Survival		*A. nilotica* Survival		*A. modesta* Survival		Average percentage
	No.	%cent	No.	%cent	No.	%cent	No.	%cent	
C. Trenches	43	72	39	65	27	45	36	60	61
Micorcatchment	33	55	39	65	24	40	39	65	56
Gradoni	23	38	37	62	29	48	46	77	56
Average of W.C.T	33	55	38	64	27	44	40	67	58
Simple pits	15	25	30	50	14	23	26	43	35

Table 2

Survival of Tree Seedlings Planted with and without Water Conservation Techniques at Raisan, Survival out of 60 Plants in Three Replications.

Water Conservation Technique	*E. camaldulensis* Survival		*L. leucocephala* Survival		*A. nilotica* Survival		*A. modesta* Survival		Average percentage
	No.	%cent	No.	%cent	No.	%cent	No.	%cent	
C. Trenches	44	73	48	80	17	28	57	95	69
Micorcatchment	37	62	48	80	26	43	58	97	71
Gradoni	43	72	54	90	42	70	52	87	80
Average	41	69	50	83	28	47	57	93	73
Simple pits	15	25	42	70	11	18	44	73	46

At Raisan the survival of seedlings was better as compared to Kharian due to the fact that at both sites the planting was done in spring, a season in which there is more rainfall at Raisan than Kharian, The survival data in Table 2 show that maximum survival of 80% was observed in case of seedlings planted in the gradoni. The survival in both microcatchments and conservation trenches was 70% while in plant pits it was only 47%.

Among the species *A. modesta* being a native species gave maximum survival at both sites and *A. nilotica* showed minimun survival. The mortality of *A. nilotica* was mainly due to frost. At Kharian on average the survival of *A. modesta, L. leucocephala, E. camaldulensis* and *A. nilotica* seedlings planted with water conservation techniques was 67, 64, 55 and 44% respectively, while in simple plant pits it was 43, 50, 25 and 23% respectively. At Raisan the survival of *A. modesta, L. Leucocephala, E. camaldulensis* and *A. nilotica* seedlings planted with water conservation techniques was 93, 83, 69 and 47% and in conventional plant pits it was 73, 70, 25 and 18 percent respectively.

The average height attained in two years by the different tree species planted with water conservation techniques and conventional plant pits at Kharian is presented in Table 3. The average height growth of the four species planted in conservation trenches, microcatchments, gradoni and simple pits was 133, 132, 137 and 72 cm respectively. The height growth of seedlings planted with water conservation techniques was almost double as compared to those planted with conventional method (Fig 3) Maximum positive response to the conservation techniques was observed in *E. camaldulensis* which gained three times more height when planted with water conservation techniques (184 cm) as compared to those seedlings planted in simple pits (59 cm). The average height growth of *L. leucocephala* and *A. nilotica* with water conservation techniques was 176 and 125 cm and in pits 122 and 60 cm respectively. While the average height growth of *A. modesta* seedlings with and without water conservation techniques was only 52 and 42 cm respectively which is not significantly different from each other.

Table 3

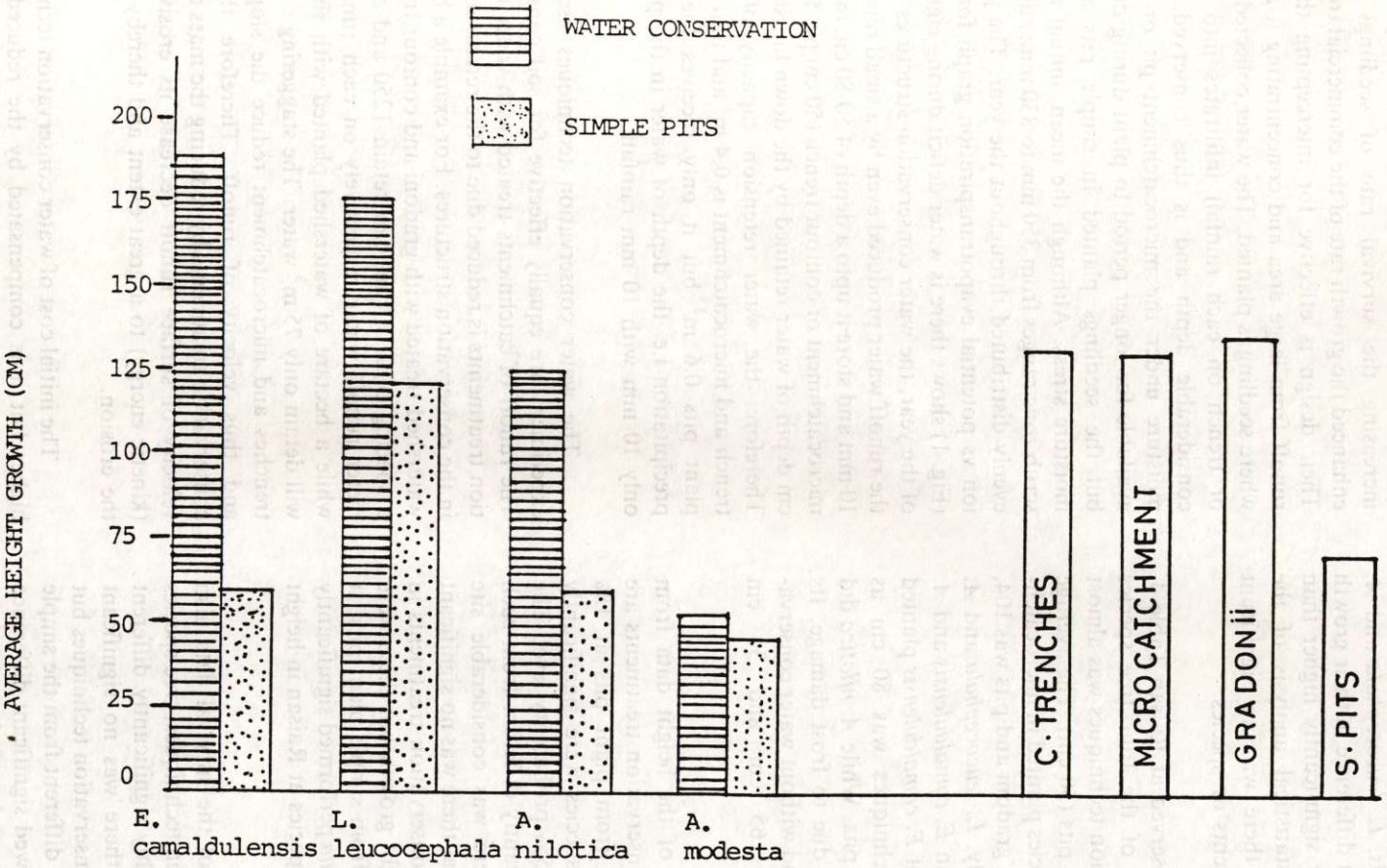
Average Height Growth in Two Years by Tree Species Planted with and without Water Conservation Techniques at Kharian, Average of Three Replications in cm.

Water Conservation Techniques	*E. camaldulensis*	*L. leucocephala*	*A. nilotica*	*A. modesta*	*Average*
C. Trenches	206	172	108	48	133
Micorcaschment	169	168	132	59	132
Gradoni	177	189	135	49	137
Average of W.C.T	184	176	125	52	134
Simple pits (Control)	59	122	60	46	72

Table 4

Average Height Growth in Two Years by Tree Species Planted with and without Water Conservation Techniques at Raisan, Average of Three Replications in cm.

Water Conservation Techniques	*E. camaldulensis*	*L. leucocephala*	*A. nilotica*	*A. modesta*	*Average*
C. Trenches	64	134	52	80	82
Micorcatchment	87	171	64	93	104
Gradoni	88	140	79	84	98
Average of W.C.T	80	148	65	86	95
Simple pits	46	74	30	51	50



Average Height growth of tree species with and without water conservation

Average Height of the 4 tree species with different water conservation treatments

Fig.3 BAR DIAGRAM SHOWING AVERAGE HEIGHT GROWTH OF TREE SPECIES PLANTED WITH WATER CONSERVATION TREATMENTS AT KHARIAN.

The statistical analysis of the height growth data from Kharian showed that both treatments and species were highly significantly different from each other while replications showed no significant difference. The LSD test indicated that water conservation techniques were highly significantly different from simple pits in respect of their effect on height growth but there was no significant difference among them. LSD test also showed that *E. camaldulensis*, *L. leucocephala* and *A. nilotica* showed no significant difference in their growth but their growth was highly significantly higher than that of *A. modesta*. The statistical analysis of the survival data showed that there was no significant difference among the treatments or species.

A similar trend was observed at Raisan Table 4. The average height growth of the four tree species planted with water conservation techniques was almost double (95 cm) than those in pits (50 cm). The average height growth of four tree species planted in microcatchments, conservation trenches, gradoni and pits was 104, 82, 98, and 50 cm respectively. *L. leucocephala* and *A. modesta* performed better than *E. camaldulensis* and *A. nilotica*. The average height of *E. camaldulensis* planted with water conservation techniques was 80 cm as compared to 46 cm in simple pits. While *A. nilotica* did not perform well at the site due to frost damage. Its average height growth with and without water conservation techniques was only 65 cm and 30 cm respectively.

The statistical analysis of the height data from Raisan showed that water conservation treatments are highly significantly different from plant pits at 1% probability level while tree species were significantly different from each other at 5% probability level. The replications were also significantly different from each other, which shows that there was considerable site variation. LSD test showed that there was no significant difference among the water conservation treatments in respect of their effect on height growth but these were highly significantly different from simple plant pits. It also showed that *L. leucocephala* performed significantly different from the other tree species at Raisan in height growth.

The statistical analysis of the survival data also showed that water conservation techniques, tree species and the replications were highly significantly different from each other. Although there was no significant difference among the water conservation techniques but these were highly significantly different from the simple pits. The tree species also showed significant difference among each other. The LSD test classified *A. Modesta* and *L. leucocephala* in one group showing better survival followed by *E. camaldulensis*, and *A. nilotica* showed lowest survival.

The preliminary results of the experiments at both the sites have shown that water conservation techniques prove quite effective tool in the afforestation programme of watersheds in the scrub zone of the country. The techniques have proved not only useful in increasing the survival rate of seedlings but also enhanced the growth rate of the commercial tree species. Their design is effective for intercepting the surface runoff from large area and concentrating it at a point where seedling is planted. The water collected in the pit or trench on each rainfall infiltrates into soil upto considerable depth and is thus conserved. The soil moisture under the microcatchment pit or trench is available for longer period to plant during dry period, but the seedlings planted in simple pits are under moisture stress. Although the mean annual rainfall of scrub zone ranges from 350 mm to 830 mm, still, it is not evenly distributed throughout the year. The precipitation vs potential evapotranspiration graph for Kharian (Fig. 1) shows there is water deficit during eight months of the year, the water conservation structures intercepts the runoff water produced even by a small rain storm of 10 mm and store it upto a depth of 50-80 cm in the pit of microcatchment or contour trench (50 cm pit depth + 30 cm depth of water retained by the down hill side berm). Therefore, the water retension capacity of contour trench and microcatchment is 0.4 m^3 and that of simple plant pits 0.6 m^3 but it only receives the incident precipitation i.e. the depth of water in the pit will be only 10 mm with 10 mm rainfall.

The water conservation techniques used in the experiment are equally effective for soil conservation. The runoff of catchments treated with water conservation treatmemts is reduced due to the retention of water in the conservation structures. For example a hectare of watershed treated with gradoni and contour trenches at a spacing of 2 $\times$4 m, can retain 1250 and 500 cubic meter runoff water respectively on each runoff event while a hectare of watershed planted with simple pits will detain only 75 m^3 water. The staggering of contour trenches and microcatchment reduce the slope length and thus velocity of runoff. Therefore the water conservation treatments by reducing the mass as well as velocity of surface runoff decrease its erosive power (kinetic energy) to a great extent and thereby prevents the erosion.

The initial cost of water conservation techniques is higher but it is compensated by the reduced cost of restocking due to higher survival rate of seedlings as compared to those in pits. The earth work required for

installing microcatchments, gradoni, conservation trenches and simple pits is 0.26, 1.0, 0.26 and 0.6 m^3 respectively. Comparative statement on the cost of establishment of *Eucalyptus* plantation with and without water conservation techniques is presented in Table 5. Conservation trenches are considered for this assesment. The cost of earth work, plantation, restocking and maintenance is based on the prevailing schedule of expenditure of the Forest Department. The cost of restocking is estimated according to the average mortality rate of seedlings observed in the experiment.

Although the cost of establishment of a hectare of *Eucalyptus* plantation with water conservation is Rs. 1457 higher than the plantation with the conventional method but the production of *Eucalyptus* wood would be increased by 200 to 300 percent, if the growth continues at the rate observed in the last two years. Thus, by increasing the cost of establishment by 22%, wood production can be doubled or even tripled.

Table 5
Comparative Establishment Cost Statement of One Hectare Eucalyptus Plantation with and without Water Conservation Techniques

	Conservation Trenches	Simple Pits
i. Earth work	Rs. 4017.00	Rs. 927.00
ii. Plantation (including seedling cost, transport and plantation)	Rs. 2125.00	Rs. 2125.00
iii. Restocking in two years (according to mortality rate)	Rs. 797.00	Rs. 2430.00
iv. Maintenance (2 years)	Rs.1112.00	Rs. 1112.00
Total	Rs. 8051.00	Rs. 6594.00
Dierence	Rs. 1457.00	

Percent increase in cost with water conservation 22%

Conclusion

From the preliminary results it can be concluded that water conservation techniques are quite effective and economical for the establishment of forest plantations of commercial tree species in the scrub zone. The techniques have not only proved effective in increasing the survival rate and enhancing the growth rate of commercial tree species but are equally useful for reducing soil erosion as well as in regulating the stream flow. Although all the three types of techniques employed in the experiments have shown similar results, but considering the cost of treatment, microcatchments and conservation trenches in their modified form are economical.

At Kharian *E. camaldulensis, L. leucocephala* and *A. nilotica* performed well but at Raisan the performance of *A. nilotica* was discouraging due to frost damage. The employment of conservation trenches or microcatchments for large scale plantation of *E. camaldulensis, L.leucocephala* and *A. nilotica* in the scrub zone can increase fuelwood and timber production as well rehabilitate the denuded watersheds.

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