No. 78

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March 1993

MART/AZR PROJECT RESEARCH REPORTS

This research report series is issued by the Management of Agricultural Research and Technology Project/Arid Zone Research Component (MART/AZR). This project is sponsored financially by the Mission to Pakistan of the United States Agency for International Development (USAID).

The project contract is implemented by the International Center for Agricultural Research in the Dry Areas (ICARDA) at the Pakistan Agricultural Research Council's Arid Zone Research Institute (AZRI).

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Economics of Water-Harvesting Trials with Cereal Crops in Highland Balochistan

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Abstract

As an attempt to demonstrate better utilization of rain water in *khushkaba* agricultural systems, AZRI has been growing different crops under water-harvesting techniques since 1986. The preparation of small catchment areas on rainfed valley bottom soils represents a low-cost method of generating run-off and increasing crop yields within the cropped areas. The proportions of water catchment area and cropped area investigated were as follows: for the control treatment the entire area is planted to the crop; in the 1:1 treatment one half of the area is used for water catchment and one half for planting; in the 2:1 treatment, two thirds of the area is used for water catchment and one third for planting. The objectives of this study were: i) to compare water-harvesting techniques with the existing farming practices and ii) to determine to what extent economic benefits are increased and their associated risks decreased. Data from six seasons of wheat trials and four seasons of barley trials were used in this study. Partial budgets were developed for each crop, season, location and trial, to calculate net benefits and costs associated with the treatments.

Results from wheat trials showed that the 1:1 treatment had 22 percent higher net benefits (Rs422/ha) than the control (Rs345/ha) with a 22 percent reduction in the coefficient of variation. The 2:1 treatment had 33 percent lower net benefits (Rs230/ha) than the control and reduced the variation in net benefits by 10 percent. In contrast, barley trials showed that the 1:1 treatment yielded 18 percent lower net benefits (Rs291/ha) than the control (Rs421/ha) but increased by 6 percent the variation in net benefits. Treatment 2:1 had 14 percent lower net benefits (251 Rs/ha) than the control and 19 percent more variation. Even though gross revenues of wheat straw and grain under the 1:1 treatment were lower than the control, the reduction in total costs under the 1:1 treatment resulted in higher net benefits than the control.

Under conditions where land suitable for cultivation is limited, the increases in yields of both straw and grain in the cropped area resulting from water-harvesting has to be offset by the opportunity cost of the catchment area. Moreover, less than proportional decreases in total costs of the water-harvesting treatments as the catchment to cropped area changes can limit the economic performance of the technique. The data available for the analysis does not represent the entire spectrum of weather conditions in highland Balochistan; therefore, it is desirable to incorporate the probabilities of different quantities of rainfall into the economic analysis. Simulation techniques are suggested to generate probability distributions of net benefits of these cereal crops grown under water-harvesting. The assessment of the adoption potential of these technologies will be facilitated by these simulations in conjunction with the quantification of farmers' perceptions of the benefits associated with water-harvesting practices.

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Introduction

Highland Balochistan is located in the north central part of Balochistan province and has a continental semi-arid climate with hot summers and cold winters. Cereal crops, in particular wheat, are grown by most dryland farmers as dual-purpose crops, the grain being used for human consumption and the straw for animal feed (Buzdar *et al.*, 1989). If monsoon rains occur, crops are sown in September/October and survive on residual soil moisture until the winter rainy season, December-March. The same crops are sown in January/February if the monsoon rains are insufficient for autumn sowing. The crops are harvested by hand in May/June and threshed using animal draft power.

The most limiting factor for crop production in rain-fed areas of Balochistan is the skewed distribution of rainfall in both time and space (Kidd *et al.*, 1988). Annual rainfall in highland Balochistan ranges from 175 to 200 mm in the southern districts of Khuzdar and Kalat and 300 to 350 mm in the northern districts of Loralai and Zhob. Crop production in non-irrigated areas is either totally dependent on rainfall (*khushkaba*) or dependent on run-on water collected from non-cultivable land to supplement rainfall (*sailaba*).

A survey conducted in the summer of 1986 (Rees *et al.*, 1987) showed that 60 to 80 percent of the total cropped land is planted to wheat, 20 to 40 percent is planted to barley and from 0 to 20 percent is planted to lentils. A "good" agricultural year is expected 2 to 3 years out of ten, and both "normal" and "poor" years are expected 3 to 5 years out of ten. The frequency of agricultural years in different areas of highland Balochistan determine the farmers' source of income. In a "good" year 10 to 15 percent of the farmers had an off-farm income, in a "normal" year 18 to 34 percent had an off-farm income and in a "bad" year 33 to 65 percent had an off-farm income. Thus, weather variability determines not only cereal production in highland Balochistan but the *employment* pattern of the rural population.

Under *khushkaba* conditions wheat grain yields in a "good" year ranged from 400 to 500 kg/ha, in a "normal" year they were 300 kg/ha and in a "poor" year they ranged from 100 to 200 kg/ha. Similarly, barley grain yields were 300 kg/ha in a "good" year and ranged from 200 to 300 kg/ha in a "normal' year. All respondents mentioned that in a "poor" year no barley is sown. Under *sailaba* conditions wheat grain yields ranged from 800 to 900 kg/ha in a "good" year, from 600 to 700 kg/ha in a "normal" year, and 300 to 400 kg/ha in a "bad" year. Likewise, barley grain yields in a "good" year were 500 to 600 kg/ha, 400 kg/ha in a "normal" year, and 200 kg/ha in a "bad" year (Rees *et al.*, 1987).

The minimum water requirement for wheat grain production is about 300 mm and the probability of receiving more than this amount varies from 10 to 50% (Rees *et al.*, 1989a). In contrast, the minimum requirements for barley are 225 mm, barley has a higher water-use-efficiency than wheat (Rees *et al.*, 1989b), and there are higher probabilities of receiving this lower amount of rainfall. However, barley is not widely grown in highland Balochistan. Most of the farmers grow wheat instead of barley for food security reasons, because they perceive there is a poor market for barley, and because there may be a land shortage in certain areas (Nagy *et al.*, 1989).

"Farmers have long practiced water-harvesting by constructing bunds. These are high banks of soil and gravel which hold back water which flows from steep and mountainous land on to the level valley bottoms. This water supplements actual rainfall to produce the *sailaba* system of crop production. The growing demand for food and feed crops from both (*sic*) an expanding human and animal population in Balochistan necessitates the more complete use of the estimated 0.8 million ha of cultivable land" (Khan, 1990).

In an attempt to demonstrate better utilization of rain water, AZRI has been growing cereals, lentils and forage legumes under water-harvesting techniques in highland Balochistan since 1986. The preparation of small catchment basins on rainfed valley bottom soils represents a low-cost method of generating run-off and of increasing crop yields within the cropped areas (Rees *et al.*, 1991). The run-off area is formed by ploughing, cultivation with a tinned implement to physically disintegrate the soil aggregates, levelling with a wooden beam and sprinkling of water, the impact of the drops sealing the soil surface into a crust.

The proportions of water catchment area to cropped area investigated at AZRI were as follows: for the control treatment the entire area is planted; in the 1:1 treatment half the area is used for water catchment and half is planted; lastly, in the 2:1 treatment, two thirds is used for water catchment and one third for planting. The observed run-off efficiencies of 55 percent for the 1:1 treatment and 43 percent for the 2:1 treatment are not particularly high for the silty clay loam soils (Rees *et al.*, 1991). Higher efficiencies could be induced by compaction and/or surface treatment with water repellant chemicals. However, the need for better management of the water on the cropped area to reduce water-logging damage, is clearly of much higher priority (Rees *et al.*, 1991).

The objectives of this study were two fold: i) to compare water-harvesting techniques with the existing farming practices and ii) to determine to what extent the economic benefits are increased and their associated risks are decreased.

The Economics of Water-harvesting

Water-harvesting techniques can increase soil moisture by transferring run-off water from the catchment area onto the cropped area, thus, increasing plant growth. However, to be economically feasible the crop gains due to the additional moisture must be larger than the cost of not planting in the catchment area.

The economic feasibility of water-harvesting depends on the following inter-related questions:

1) Whether or not the crop area of a water-harvesting treatment yields more than that of both the crop area without treatment (control). For example, does the 1:1 treatment yield more than double the control area, or does the 2:1 treatment yield more than triple the control area?
2) Whether there are reductions in the fixed and variable costs associated with the proportions of the crop and catchment areas, and

3) Whether there is an increase in the price of outputs (grain and straw) relative to the costs of inputs or a decrease in the cost of inputs relative to the price of outputs.

The rationale behind the first question is that there is an opportunity cost if there is no planting in the catchment area, and this cost needs to be accounted for. The method used to supply additional water uses land which could be used to grow crops instead of "catching" water. After the catchment area is levelled and planked this land can be either cultivated or used for harvesting water. So, the additional soil moisture accumulated in the planted area is not external to the system as would be the addition of fertilizer. Rees *et al.* (1989a and 1991) are not very clear about reducing the operating costs related to smaller cropped areas without accounting for the opportunity cost of the catchment areas. Data on land tenure, as reported in Nagy and Farid Sabir (1987), Masood *et al.* (1988) and Farid-Sabir *et al.* (1991), does not suggest that kuskhaba land is unlimited, and the only information available on cropping intensity in highland Balochistan (Rees *et al.*, 1987, p. 9) is not very complete. This prevented the consideration that the opportunity cost of *khushkaba* land is very low or negligible.

The Trials

Six seasons of wheat trials (1986/87 season to 1991/92 season) and four seasons of barley trials (1988/89 season to 1991/92 season) were used in this study. The local wheat landrace was planted during the first two seasons, Pak-81 was planted in the following two seasons, Punjab-85 was used in the fifth season and Pak-81 was used again in the last season. Rainfall during the trials and wheat yields of grain and straw are shown in Table 1. Yields for the 1:1 and 2:1 treatments were adjusted for the total area, i.e., crop plus catchment area (ICARDA 1989, p. 42), to account for the opportunity cost of not planting the catchment area.

Table 1. Rainfall at each location, and wheat grain and straw yields (kg/ha), **adjusted to the total area**[1], under different water-harvesting treatments in highland Balochistan

Treatment		Season													
		86/87	87/88			88/89				89/90	90/91	91/92			
		D/1[2]	D/1	D/2	M/3	D/1	D/2	M/3	K/4	M/1	M/1	M/1	M/2	D/1	D/2
Rainfall (mm)		282	102	102	96	239	239	167	227	224	240	281	281	278	278
Control	Grain	562	25	12	8	196	130	166	159	303	88	82	70	114	126
	Straw	1531	105	75	108	392	192	324	388	1404	1124	631	552	464	278
1:1	Grain	608	48	11	5	112	119	122	130	261	105	54	48	66	85
	Straw	1283	140	73	70	292	169	345	338	1066	799	346	406	186	227
2:1	Grain	397	30	15	8	106	116	126	80	92	47	76	38	114	89
	Straw	904	117	90	87	261	209	406	205	903	306	258	280	385	161

[1]Yields in the cropped area (kg/ha) were divided by 2 in the 1:1 treatment and by 3 in the 2:1 treatment.
[2]Location/trial: denotes the location (D=Dasht, M=Mastung and K=Kovak) and the trial number.
Source: Rees et al. (1991), AZRI/ICARDA (1991) and AZRI Agronomy Section.

The local barley landrace was planted in the 1988/89 season and *Arabi Abiad*, a Syrian landrace, was used in the last three seasons. Rainfall during the trials and barley yields of grain and straw are shown in Table 2. As with wheat, the yields were adjusted for the total area.

Table 2. Rainfall at each location, and barley grain and straw yields (kg/ha), adjusted to the total area[1], under different water-harvesting treatments in highland Balochistan

Treatment		Season									
		88/89				89/90	90/91	91/92			
		D/1[2]	D/2	M/3	K/4	M/1	M/1	M/1	M/2	D/1	D/2
Rainfall (mm)		239	239	167	227	224	240	281	281	278	278
Control	Grain	119	97	189	168	418	119	186	128	135	203
	Straw	239	108	619	358	1278	1322	839	773	477	625
1:1	Grain	104	68	152	133	317	71	137	147	74	96
	Straw	192	123	470	331	1146	639	430	462	228	334
2:1	Grain	75	60	162	83	238	31	104	88	204	102
	Straw	126	119	539	249	1205	340	447	366	572	138

[1]Yields in the cropped area (kg/ha) were divided by 2 in the 1:1 treatment and by 3 in the 2:1 treatment.
[2]Location/trial denotes the location (D=Dasht, M=Mastung and K=Kovak) and the trial number.
Source: Rees (personal communication), AZRI/ICARDA (1991), and AZRI Agronomy Section.

Partial Budgets

Partial budgets were developed for each crop, season, location and trial to calculate the benefits and the costs associated with the treatments. They reflect the conditions of traditional farming in rainfed areas of highland Balochistan, where camels are used for the preparation of the land, ploughing, harvesting and threshing.

Fixed costs

Stone and shrub removal, layout of plots, levelling, planking and bund building were included in the set-up costs. The costs of catchment set-up were as low as Rs203/ha in the 1:1 and Rs271/ha in the 2:1 treatment in the 1986/87 season and as high as Rs345/ha in the 1:1 and Rs469/ha in the 2:1 treatment in the 1991/92 seasons (Table 3). These costs were amortized over a ten year period at 12 percent annual interest rate. With appropriate care, the structures are supposed to last for a long time. However, a ten year period should give a more realistic figure to account for the set-up costs.

Variable costs

Estimated labor for maintenance of the catchment structures and weeding added up to 10 hr/yr for the 1:1 treatment and 15 hr/yr for the 2:1 treatment. Labor of

Table 3. Fixed costs of wheat and barley trials under water-harvesting treatments from 1986 to 1992

			Set up		Seed		Grain		Straw	
	Labor	Camel	1:1	2:1	Wheat	Barley	Wheat	Barley	Wheat	Barley
Season	--- (Rs/hr) --		--- (Rs/ha) --		---------- (Rs/kg) ----------					
86/87	2.50	5.50	203.4	271.2	2.00	----	2.00	----	0.75	----
87/88	2.80	6.00	226.0	299.5	2.00	----	2.06	----	0.75	----
88/89	3.20	6.50	254.3	339.0	2.06	2.00	2.13	2.00	0.88	0.50
89/90	3.75	7.00	282.5	378.6	2.13	2.00	2.40	2.50	0.63	0.50
90/91	4.20	7.50	313.6	420.2	2.40	2.50	3.68	2.75	1.00	1.00
91/92	4.60	8.10	344.6	469.0	3.68	2.75	4.50	3.75	1.25	1.25

Source: AZRI Agricultural Economics Section.

the camel operator and camel rental were incorporated using values from Table 3. Planting was done by camel because it is the usual practice in rainfed areas of highland Balochistan. Similarly, tillage costs were separately calculated for the camel operator and the camel. The seed rate was 100 kg/ha for both wheat and barley. Wheat and barley seed prices for the different seasons are shown in Table 3, as are the wheat and barley straw prices. Harvesting costs are 10 percent of the sales value of the grain and straw production, and threshing costs are 10 percent of the sales value of the grain production (Agricultural Economics Research Unit, Pakistan Agricultural Research Council, Sariab, unpublished survey results).

Gross and net benefits

The grain and straw yields were multiplied by their respective prices to calculate the gross benefits. Total costs were subtracted from the gross benefits to calculate the net benefits.

Results and Discussion

Wheat

Table 4 shows the gross benefits, total costs and net benefits of each season during 1986-92. [Tables A1-A14 in the Appendix show the budgets for each location, year and trial]. Averages were calculated for the seasons 1987/88, 1988/89 and 1991/92 to assign equal weight to each season. The average of all seasons was calculated, as well as its coefficient of variation.

The 1:1 treatment showed an improved net benefit over the control, except in the 1989/90 season. Negative net benefits in all treatments during the 1987/88 season show the effect of very low rainfall at Dasht and Mastung, which caused low yields of straw and grain (Table 1). However, the less negative net returns of treatments 1:1 and 2:1 compared with the control show that these water-harvesting practices could reduce the magnitude of losses in seasons with

low rainfall (96 to 102 mm). Treatment 2:1 yielded less negative net benefits than the 1:1 treatment during the 1987/88 season and higher net benefits than the 1:1 treatment during the 1988/89 and 1991/92 seasons. Water-logging explained the lower performance of the 2:1 treatment in the 1986/87, 1989/90 and 1990/91 seasons compared with the 1:1 treatment.

All treatments in the first and the fourth season had high yields and net benefits but the first season had the highest values due to the 60 mm higher and better distribution of rainfall. Kolpur 4 (K/4) in the 1988/89 season shows how average rainfall (227 mm) but bad distribution results in low yields and net benefits (Table A8). The high net benefits of the first and fourth season, and to some extent the fifth season, had a marked effect when the results were averaged for all the seasons (Table 4). The 1:1 treatment was better than the control and the 2:1 treatment showed inferior performance due to water-logging effects in the first, fourth and fifth seasons. Furthermore, the coefficient of variation of the 1:1 and 2:1 water-harvesting treatments (138 and 160 percent) was slightly less than that of the control (177 percent).

Table 4. Gross benefits, total costs and net benefits (Rs/ha) of wheat grown under different water-harvesting treatments for the years 1986-1992 in highland Balochistan

		Average for each season						All seasons	
Treatment		86/87	87/88	88/89	89/90	90/91	91/92	Avg[1]	CV[1]
Control	GB[2]	2272	103	632	1612	1448	1043	1185	59
	TC[2]	876	583	711	898	909	1049	839	19
	NB[2]	1397	-480	-77	713	539	-7	345	177
1:1	GB	2178	115	509	1298	1168	647	986	67
	TC	668	369	460	612	617	651	564	20
	NB	1510	-254	49	686	551	-4	422	138
2:1	GB	1472	110	466	790	478	697	669	63
	TC	491	299	382	446	447	558	438	19
	NB	981	-190	84	344	31	139	230	160

[1]Avg=average; CV=coefficient of variation (percent).
[2]GB=gross benefits; TC=total costs; NB=net benefits.

A summary of the economic analysis is presented in Table 5, comparing the averages and coefficients of variation of the net benefits of treatments for all seasons. The 1:1 treatment had 22 percent higher net benefits than the control with a 22 percent reduction in the coefficient of variation. The 2:1 treatment had 33 percent lower net benefits than the control and reduced the variation in net benefits by 10 percent.

Barley

Table 6 shows the gross benefits, total costs and net benefits of each trial planted with barley during four seasons. [Tables A15-A24 in the Appendix show

Table 5. Summary of the net benefits for wheat grown with different water-harvesting treatments relative to the control (percentages) in highland Balochistan, years 1986-1992 (data from Table 4)

Treatment	All seasons	
	Avg[1]	CV[1]
Control	100	100
1:1	122	78
2:1	67	90

[1]Avg=average; CV=coefficient of variation (percent).

the budgets for each location and trial]. As with the wheat, averages by season were calculated for the seasons 1988/89 and 1991/92 to assign equal weight to each season. The average of all seasons and the coefficient of variation were also estimated. Only in the 1988/89 season did the 1:1 and 2:1 treatments show an improvement over the control with regard to the net benefits, even though they were all negative. Negative net returns in the 1988/89 season were due to water-logging (Table 2). The 1:1 treatment had a negative impact on the net benefits in the last three seasons, and this effect was accentuated with the 2:1 treatment in the 1989/90 and 1990/91 seasons. Only in the 1988/89 and the 1991/92 seasons was the 2:1 treatment above the 1:1 treatment.

Table 6. Gross benefits, total costs and net benefits (Rs/ha) of barley grown with different water-harvesting treatments for the years 1988-1992 in highland Balochistan

Treatment		Average for each season				All seasons	
		88/89	89/90	90/91	91/92	Avg[1]	CV[1]
Control	GB[2]	452	1684	1649	1459	1311	38
	TC[2]	681	924	939	1015	890	14
	NB[2]	-229	760	710	444	421	94
1:1	GB	368	1366	833	880	862	41
	TC	440	620	571	642	571	14
	NB	-72	736	262	238	291	99
2:1	GB	319	1198	425	944	721	50
	TC	361	520	436	563	470	16
	NB	-42	678	-11	381	251	118

[1]Avg=average; CV=coefficient of variation (percent).
[2]GB=gross benefits; TC=total costs; NB=net benefits.

A summary of the economic analysis for barley is presented in Table 7. The 1:1 treatment generated a 31 percent lower net benefit than the control and

increased by 6 percent the variation in net benefits. Treatment 2:1 had a 14 percent lower net benefit than the control and 19 percent more variation.

Figure 1 depicts the economic results of the water-harvesting treatments for both cereals. The gross benefits decreased as more area was allocated to water catchment. While the gross benefits of barley were higher than those of wheat in the control treatment, the gross benefits of wheat were higher than

Table 7. Summary of the net benefits for barley grown with different water-harvesting treatments relative to the control (percentages) in highland Balochistan, years 1988-1992 (data from Table 6)

Treatment	All seasons	
	Avg[1]	CV[1]
Control	100	100
1:1	69	106
2:1	86	119

[1]Avg=average; CV=coefficient of variation (percent).

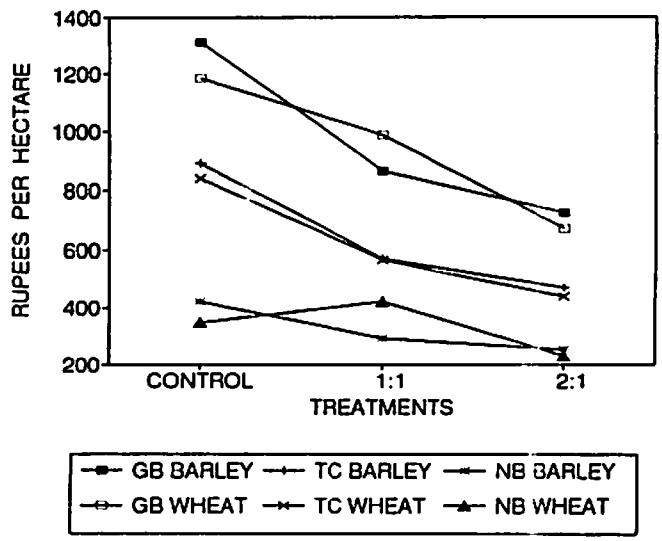

Figure 1. Gross benefits (GB), total costs (TC) and net benefits (NB) of cereals under different water-harvesting treatments.

those of barley in the 1:1 treatment. This better response of wheat to the 1:1 treatment explains why the net benefits of wheat were higher than barley, given the fact that the total costs for both cereals followed the same trend. This figure leads to the first two inter-related questions presented on page 4, viz: biological yields adjusted to total area and reductions in total costs relative to the cropped area.

It was mentioned earlier (page 3) that barley had a higher water use efficiency than wheat. Thus one would expect both the straw and grain yields of barley to be higher than the wheat yields (Figure 2). This was not necessarily the case. The lower than expected yields of barley compared to wheat may possibly be due to a gradual decrease in water-use-efficiency above the critical minimum water requirement. The relative responses of the local landraces and improved varieties of wheat and barley to higher than average rainfall (above 250 mm) under the conditions that prevail in highland Balochistan, are not clear. The water-use-efficiency coefficients estimated by Rees *et al.* (1989a, 1989b) for wheat and barley were derived from data on local landraces where only 28 percent of the observations had a water-availability-index (soil water at planting plus rainfall during the rest of the season) between 250 and 350 mm. To evaluate these water-harvesting trials the variety effect had to be ignored but it could explain the lower than expected yields of barley and the response of both wheat and barley to above average soil moisture conditions. Given the additional water collected in the catchment areas, it would be worthwhile to estimate the response of these local and improved varieties to above-average moisture supplies.

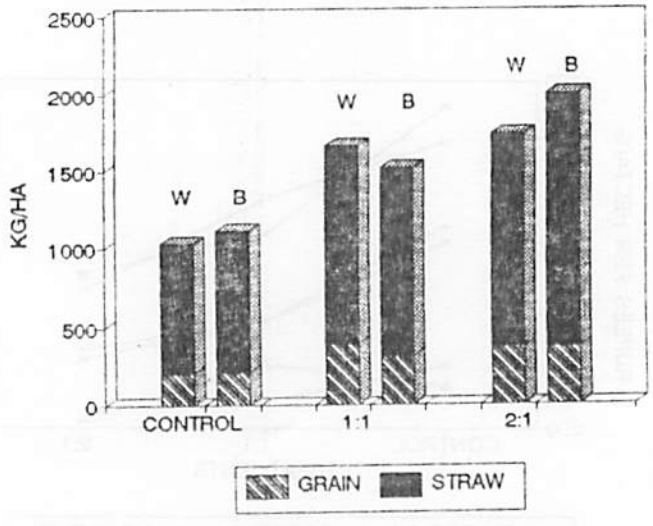

Figure 2. Unadjusted grain and straw yields of wheat (W) and barley (B) under different water-harvesting treatments.

The results of these wheat and barley trials suggest that there are still some technical problems which must be overcome before the technology has a chance of being adopted by farmers. Either too little or too much water is harvested and transferred to the cropped area, and only a small reduction in economic risk is achieved. At best, the treatment 1:1 increased wheat net benefits by 22 percent compared to the control with a 22 percent reduction in economic risk. ***Are these figures appealing for khushkaba farmers? And how many years are enough to determine the effectiveness of a new technology in an extremely variable weather environment?*** Because of the adjustment for the catchment area (Tables 1 and 2), the yields in the 1:1 treatment need to be twice as high as the control and three times as high for the 2:1 treatment to be superior to the control, assuming proportional total costs for the treatments. However, the total costs for different treatments did not decrease proportionally to the cropped area (one half or one third for the 1:1 or 2:1 treatments, respectively). Adjusted yields and costs per hectare compounded the low economic performance of the water-harvesting technique in situations where land suitable for cultivation is limited. Thus, factors such as land tenure and availability of land, labour and capital to set-up the catchment area are likely to hinder the adoption of AZRI's water-harvesting methods, more than technical factors.

It is clear that the data available for the analysis does not represent the entire spectrum of weather conditions in highland Balochistan. In situations where rainfall variability so closely determines crop performance, it is desirable to incorporate the probabilities of different rainfall amounts into the economic analysis. Thus, simulation techniques must be used to generate probability distributions of net benefits of these cereal crops grown under water-harvesting techniques and different price scenarios. The assessment of the adoption potential of this technology will be facilitated by these simulations in conjunction with the quantification of farmers' perceptions of the benefits associated with water-harvesting practices. AZRI has already started research towards this assessment (Khan *et al.*, 1993).

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Appendix-Partial Budgets Water-harvesting Trials

Table A1. Labor hours and costs of wheat water-harvesting at Dasht 1 (D/1), 1986/87 season.

	Treatments		
	control	1:1	2:1
	hr/ha		
Tillage (camel)	28.0	14.0	9.3
(man)	28.0	14.0	9.3
Planting (camel)	14.0	7.0	4.7
(man)	14.0	7.0	4.7
Catchment maintenance	0.0	10.0	15.0
	Rs/ha		
Tillage[1] (man & camel)	224.0	112.0	74.7
Planting (man & camel)	112.0	56.0	37.3
Harvesting[2]	227.2	217.8	147.2
Threshing[3]	112.4	121.6	79.4
Catchment maintenance	0.0	25.0	37.5
Set-up cost[4]	0.0	36.0	48.0
Seed cost[5]	200.0	100.0	66.7
Total costs	875.6	668.4	490.8
Grain yield (kg/ha)	562.0	608.0	397.0
Straw yield (kg/ha)	1531.0	1283.0	904.0
Gross benefits (Rs/ha)[6]	2272.3	2178.3	1472.0
Net benefits (Rs/ha)[7]	1396.6	1509.8	981.2

Control=crop in entire area; 1:1=catchment:crop area; 2:1=catchment:crop area.

[1]Labor cost=2.50 Rs/hr and camel cost=5.50 Rs/hr.

[2]Harvesting cost @ 4 kg/40 kg of grain and straw yields.

[3]Threshing cost @ 10 % of grain yield.

[4]203.4 and 271.2 Rs/ha amortized over 10 years at 12% annual interest for the 1:1 and 2:1 treatments, respectively.

[5]Seed rate (100 kg/ha) * seed price (2.00 Rs/kg).

[6]Grain yield (kg/ha) * grain price (2.00 Rs/kg) + straw yield (kg/ha) * straw price (0.75 Rs/kg).

[7]Gross benefits - total costs.

Table A2. Labor hours and costs of wheat water-harvesting at Dasht 1 (D/1), 1987/88 season.

	Treatments		
	control	1:1	2:1
	hr/ha		
Tillage (camel)	28.0	14.0	9.3
(man)	28.0	14.0	9.3
Planting (camel)	14.0	7.0	4.7
(man)	14.0	7.0	4.7
Catchment maintenance	0.0	10.0	15.0
	Rs/ha		
Tillage[1] (man & camel)	246.4	123.2	82.1
Planting (man & camel)	123.2	61.6	41.1
Harvesting[2]	13.0	20.4	15.0
Threshing[3]	5.2	9.9	6.2
Catchment maintenance	0.0	28.0	42.0
Set-up costs[4]	0.0	40.0	53.0
Seed cost[5]	200.0	100.0	66.7
Total costs	587.8	383.1	306.0
Grain yield (kg/ha)	25.0	48.0	30.0
Straw yield (kg/ha)	105.0	140.0	117.0
Gross benefits (Rs/ha)[6]	130.3	203.9	149.6
Net benefits (Rs/ha)[7]	-457.5	-179.2	-156.5

Control=crop in entire area; 1:1=catchment:crop area; 2:1=catchment:crop area.

[1]Labor cost=2.80 Rs/hr and camel cost=6.00 Rs/hr.

[2]Harvesting cost @4 kg/40 kg of grain and straw yields.

[3]Threshing cost @ 10% of grain yield.

[4]226.0 and 299.5 Rs/ha amortized over 10 years at 12% annual interest for the 1:1 and 2:1 treatments, respectively.

[5]Seed rate (100 kg/ha) * seed price (2.00 Rs/kg).

[6]Grain yield (kg/ha) * grain price (2.06 Rs/kg) + straw yield (kg/ha) * straw price (0.75 Rs/kg).

[7]Gross benefits - total costs.

Table A3. Labor hours and costs of wheat water-harvesting at Dasht 2 (D/2), 1987/88 season.

	Treatments		
	control	1:1	2:1
	hr/ha		
Tillage (camel)	28.0	14.0	9.3
(man)	28.0	14.0	9.3
Planting (camel)	14.0	7.0	4.7
(man)	14.0	7.0	4.7
Catchment maintenance	0.0	10.0	15.0
	Rs/ha		
Tillage[1] (man & camel)	246.4	123.2	82.1
Planting (man & camel)	123.2	61.6	41.1
Harvesting[2]	8.1	7.7	9.8
Threshing[3]	2.5	2.3	3.1
Catchment maintenance	0.0	28.0	42.0
Set-up cost[4]	0.0	40.0	53.0
Seed cost[5]	200.0	100.0	66.7
Total costs	580.2	362.8	297.8
Grain yield (kg/ha)	12.0	11.0	15.0
Straw yield (kg/ha)	75.0	73.0	90.0
Gross benefits (Rs/ha)[6]	81.0	77.4	98.4
Net benefits (Rs/ha)[7]	-499.2	-285.4	-199.4

Control=crop in entire area; 1:1=catchment:crop area; 2:1=catchment:crop area.

[1]Labor cost=2.80 Rs/hr and camel cost=6.00 Rs/hr.

[2]Harvesting cost @4 kg/40 kg of grain and straw yields.

[3]Threshing cost @ 10% of grain yield.

[4]226.0 and 299.5 Rs/ha amortized over 10 years at 12% annual interest for the 1:1 and 2:1 treatments, respectively.

[5]Seed rate (100 kg/ha) * seed price (2.00 Rs/kg).

[6]Grain yield (kg/ha) * grain price (2.06 Rs/kg) + straw yield (kg/ha) * straw price (0.75 Rs/kg).

[7]Gross benefits - total costs.

Table A4. Labor hours and costs of wheat water-harvesting at Mastung 3 (M/3), 1987/88 season.

	Treatments		
	control	1:1	2:1
	--- hr/ha ---		
Tillage (camel)	28.0	14.0	9.3
(man)	28.0	14.0	9.3
Planting (camel)	14.0	7.0	4.7
(man)	14.0	7.0	4.7
Catchment maintenance	0.0	10.0	15.0
	--- Rs/ha ---		
Tillage[1] (man & camel)	246.4	123.2	82.1
Planting (man & camel)	123.2	61.6	41.1
Harvesting[2]	9.7	6.3	8.2
Threshing[3]	1.6	1.0	1.6
Catchment maintenance	0.0	28.0	42.0
Set-up cost[4]	0.0	40.0	53.0
Seed cost[5]	200.0	100.0	66.7
Total costs	581.0	360.1	294.7
Grain yield (kg/ha)	8.0	5.0	8.0
Straw yield (kg/ha)	108.0	70.0	87.0
Gross benefits (Rs/ha)[6]	97.5	62.8	81.7
Net benefits (Rs/ha)[7]	-483.5	-297.3	-213.0

Control=crop in entire area; 1:1=catchment:crop area; 2:1=catchment:crop area.

[1]Labor cost=2.80 Rs/hr and camel cost=6.00 Rs/hr.

[2]Harvesting cost @4 kg/40 kg of grain and straw yields.

[3]Threshing cost @ 10% of grain yield.

[4]226.0 and 299.5 Rs/ha amortized over 10 years at 12% annual interest for the 1:1 and 2:1 treatments, respectively.

[5]Seed rate (100 kg/ha) * seed price (2.0 Rs/kg).

[6]Grain yield (kg/ha) * grain price (2.06 Rs/kg) + straw yield (kg/ha) * straw price (0.75 Rs/kg).

[7]Gross benefits - total costs.

Table A5. Labor hours and costs of wheat water-harvesting at Dasht 1 (D/1), 1988/89 season.

	Treatments		
	control	1:1	2:1
	hr/ha		
Tillage (camel)	28.0	14.0	9.3
(man)	28.0	14.0	9.3
Planting (camel)	14.0	7.0	4.7
(man)	14.0	7.0	4.7
Catchment maintenance	0.0	10.0	15.0
	Rs/ha		
Tillage[1] (man & camel)	271.6	135.8	90.5
Planting (man & camel)	135.8	67.9	45.3
Harvesting[2]	76.2	49.6	45.5
Threshing[3]	41.7	23.9	22.6
Catchment maintenance	0.0	32.0	48.0
Set-up cost[4]	0.0	45.0	60.0
Seed cost[5]	206.0	103.0	68.7
Total costs	731.4	457.1	380.6
Grain yield (kg/ha)	196.0	112.0	106.0
Straw yield (kg/ha)	392.0	292.0	261.0
Gross benefits (Rs/ha)[6]	762.4	495.5	455.5
Net benefits (Rs/ha)[7]	31.0	38.4	74.9

Control=crop in entire area; 1:1=catchment:crop area; 2:1=catchment:crop area.

[1]Labor cost=3.20 Rs/hr and camel cost=6.50 Rs/hr.

[2]Harvesting cost @ 4 kg/40 kg of grain and straw yields.

[3]Threshing cost @ 10% of grain yield.

[4]254.3 and 339.0 Rs/ha amortized over 10 years at 12% annual interest for the 1:1 and 2:1 treatments, respectively.

[5]Seed rate (100 kg/ha) * seed price (2.06 Rs/kg).

[6]Grain yield (kg/ha) * grain price (2.13 Rs/kg) + straw yield (kg/ha) * straw price (0.88 Rs/kg).

[7]Gross benefits - total costs.

Table A6. Labor hours and costs of wheat water-harvesting at Dasht 2 (D/2), 1988/89 season.

	Treatments		
	control	1:1	2:1
	hr/ha		
Tillage (camel)	28.0	14.0	9.3
(man)	28.0	14.0	9.3
Planting (camel)	14.0	7.0	4.7
(man)	14.0	7.0	4.7
Catchment maintenance	0.0	10.0	15.0
	Rs/ha		
Tillage[1] (man & camel)	271.6	135.8	90.5
Planting (man & camel)	135.8	67.9	45.3
Harvesting[2]	44.6	40.2	43.1
Threshing[3]	27.7	25.3	24.7
Catchment maintenance	0.0	32.0	48.0
Set-up cost[4]	0.0	45.0	60.0
Seed cost[5]	206.0	103.0	68.7
Total costs	685.7	449.3	380.3
Grain yield (kg/ha)	130.0	119.0	116.0
Straw yield (kg/ha)	192.0	169.0	209.0
Gross benefits (Rs/ha)[6]	445.9	402.2	431.0
Net benefits (Rs/ha)[7]	-239.8	-47.1	50.7

Control=crop in entire area; 1:1=catchment:crop area; 2:1=catchment:crop area.

[1]Labor cost=3.20 Rs/hr and camel cost=6.50 Rs/hr.

[2]Harvesting cost @ 4 kg/40 kg of grain and straw yields.

[3]Threshing cost @ 10% of grain yield.

[4]254.3 and 339.0 Rs/ha amortized over 10 years at 12% annual interest for the 1:1 and 2:1 treatments, respectively.

[5]Seed rate (100 kg/ha) * seed price (2.06 Rs/kg).

[6]Grain yield (kg/ha) * grain price (2.13 Rs/kg) + straw yield (kg/ha) * straw price (0.88 Rs/kg).

[7]Gross benefits - total costs.

Table A7. Labor hours and costs of wheat water-harvesting at Mastung 3 (M/3), 1988/89 season.

	Treatments		
	control	1:1	2:1
	hr/ha		
Tillage (camel)	28.0	14.0	9.3
(man)	28.0	14.0	9.3
Planting (camel)	14.0	7.0	4.7
(man)	14.0	7.0	4.7
Catchment maintenance	0.0	10.0	15.0
	Rs/ha		
Tillage[1] (man & camel)	271.6	135.8	90.5
Planting (man & camel)	135.8	67.9	45.3
Harvesting[2]	63.9	56.4	62.6
Threshing[3]	35.4	26.0	26.8
Catchment maintenance	0.0	32.0	48.0
Set-up cost[4]	0.0	45.0	60.0
Seed cost[5]	206.0	103.0	68.7
Total costs	712.6	466.0	401.9
Grain yield (kg/ha)	166.0	122.0	126.0
Straw yield (kg/ha)	324.0	345.0	406.0
Gross benefits (Rs/ha)[6]	638.7	563.5	625.7
Net benefits (Rs/ha)[7]	-73.9	97.4	223.8

Control=crop in entire area; 1:1=catchment:crop area; 2:1=catchment:crop area.

[1]Labor cost=3.20 Rs/hr and camel cost=6.50 Rs/hr.

[2]Harvesting cost @ 4 kg/40 kg of grain and straw yields.

[3]Threshing cost @ 10% of grain yield.

[4]254.3 and 339.0 Rs/ha amortized over 10 years at 12% annual interest for the 1:1 and 2:1 treatments, respectively.

[5]Seed rate (100 kg/ha) * seed price (2.06 Rs/kg).

[6]Grain yield (kg/ha) * grain price (2.13 Rs/kg) + straw yield (kg/ha) * straw price (0.88 Rs/kg).

[7]Gross benefits - total costs.

Table A8. Labor hours and costs of wheat water-harvesting at Kolpur 4 (K/4), 1988/89 season.

	Treatments		
	control	1:1	2:1
	hr/ha		
Tillage (camel)	28.0	14.0	9.3
(man)	28.0	14.0	9.3
Planting (camel)	14.0	7.0	4.7
(man)	14.0	7.0	4.7
Catchment maintenance	0.0	10.0	15.0
	Rs/ha		
Tillage[1] (man & camel)	271.6	135.8	90.5
Planting (man & camel)	135.8	67.9	45.3
Harvesting[2]	68.0	57.4	35.1
Threshing[3]	33.9	27.7	17.0
Catchment maintenance	0.0	32.0	48.0
Set-up cost[4]	0.0	45.0	60.0
Seed cost[5]	206.0	103.0	68.7
Total costs	715.3	468.8	364.6
Grain yield (kg/ha)	159.0	130.0	80.0
Straw yield (kg/ha)	388.0	338.0	205.0
Gross benefits (Rs/ha)[6]	680.1	574.3	350.8
Net benefits (Rs/ha)[7]	-35.2	105.5	-13.8

Control=crop in entire area; 1:1=catchment:crop area; 2:1=catchment:crop area.

[1]Labor cost=3.20 Rs/hr and camel cost=6.50 Rs/hr.

[2]Harvesting cost @ 4 kg/40 kg of grain and straw yields.

[3]Threshing cost @ 10% of grain yield.

[4]254.3 and 339.0 Rs/ha amortized over 10 years at 12% annual interest for the 1:1 and 2:1 treatments, respectively.

[5]Seed rate (100 kg/ha) * seed price (2.06 Rs/kg).

[6]Grain yield (kg/ha) * grain price (2.13 Rs/kg) + straw yield (kg/ha) * straw price (0.88 Rs/kg).

[7]Gross benefits - total costs.

Table A9. Labor hours and costs of wheat water-harvesting at Mastung 1 (M/1), 1989/90 season.

	Treatments		
	control	1:1	2:1
	hr/ha		
Tillage (camel)	28.0	14.0	9.3
(man)	28.0	14.0	9.3
Planting (camel)	14.0	7.0	4.7
(man)	14.0	7.0	4.7
Catchment maintenance	0.0	10.0	15.0
	Rs/ha		
Tillage[1] (man & camel)	301.0	150.5	100.3
Planting (man & camel)	150.5	75.3	50.2
Harvesting[2]	161.2	129.8	79.0
Threshing[3]	72.7	62.6	22.1
Catchment maintenance	0.0	37.5	56.3
Set-up cost[4]	0.0	50.0	67.0
Seed cost[5]	213.0	106.5	71.0
Total costs	898.4	612.2	445.8
Grain yield (kg/ha)	303	261.0	92.0
Straw yield (kg/ha)	1404.0	1066.0	903.0
Gross benefits (Rs/ha)[6]	1611.7	1298.0	789.7
Net benefits (Rs/ha)[7]	713.3	685.8	343.9

Control=crop in entire area; 1:1=catchment:crop area; 2:1=catchment:crop area.

[1]Labor cost=3.20 Rs/hr and camel cost=6.50 Rs/hr.

[2]Harvesting cost @ 4 kg/40 kg of grain and straw yields.

[3]Threshing cost @ 10% of grain yield.

[4]282.5 and 378.6 Rs/ha amortized over 10 years at 12% annual interest for the 1:1 and 2:1 treatments, respectively.

[5]Seed rate (100 kg/ha) * seed price (2.13 Rs/kg).

[6]Grain yield (kg/ha) * grain price (2.40 Rs/kg) + straw yield (kg/ha) * straw price (0.63 Rs/kg).

[7]Gross benefits - total costs.

Table A10. Labor hours and costs of wheat water-harvesting at Mastung 1 (M/1), 1990/91 season.

	Treatments		
	control	1:1	2:1
	hr/ha		
Tillage (camel)	28.0	14.0	9.3
(man)	28.0	14.0	9.3
Planting (camel)	14.0	7.0	4.7
(man)	14.0	7.0	4.7
Catchment maintenance	0.0	10.0	15.0
	Rs/ha		
Tillage[1] (man & camel)	372.6	163.8	109.2
Planting (man & camel)	163.8	81.9	54.6
Harvesting[2]	144.8	116.8	47.8
Threshing[3]	32.4	37.0	17.2
Catchment maintenance	0.0	42.0	63.0
Set-up cost[4]	0.0	56.0	75.0
Seed cost[5]	240.0	120.0	80.0
Total costs	908.5	617.5	446.8
Grain yield (kg/ha)	88.0	100.5	46.7
Straw yield (kg/ha)	1124.0	798.5	306.3
Gross benefits (Rs/ha)[6]	1447.6	1168.0	477.9
Net benefits (Rs/ha)[7]	539.1	550.6	31.2

Control=crop in entire area; 1:1=catchment:crop area; 2:1=catchment:crop area.

[1]Labor cost=4.20 Rs/hr and camel cost=7.50 Rs/hr.

[2]Harvesting cost @ 4 kg/40 kg of grain and straw yields.

[3]Threshing cost @ 10% of grain yield.

[4]313.6 and 420.2 Rs/ha amortized over 10 years at 12% annual interest for the 1:1 and 2:1 treatments, respectively.

[5]Seed rate (100 kg/ha) * seed price (2.40 Rs/kg).

[6]Grain yield (kg/ha) * grain price (3.68 Rs/kg) + straw yield (kg/ha) * straw price (1.00 Rs/kg).

[7]Gross benefits - total costs.

Table A11. Labor hours and costs of wheat water-harvesting at Mastung 1 (M/1), 1991/92 season.

	Treatments		
	control	1:1	2:1
	hr/ha		
Tillage (camel)	28.0	14.0	9.3
(man)	28.0	14.0	9.3
Planting (camel)	14.0	7.0	4.7
(man)	14.0	7.0	4.7
Catchment maintenance	0.0	10.0	15.0
	Rs/ha		
Tillage[1] (man & camel)	355.6	177.8	118.5
Planting (man & camel)	177.8	88.9	59.3
Harvesting[2]	115.8	67.3	66.6
Threshing[3]	36.9	24.1	34.4
Catchment maintenance	0.0	46.0	69.0
Set-up cost[4]	0.0	61.0	83.0
Seed cost[5]	367.7	183.9	122.6
Total costs	1053.8	648.9	553.4
Grain yield (kg/ha)	82.0	53.5	76.3
Straw yield (kg/ha)	631.0	345.5	258.3
Gross benefits (Rs/ha)[6]	1157.8	672.6	666.4
Net benefits (Rs/ha)[7]	104.0	23.7	113.1

Control=crop in entire area; 1:1=catchment:crop area; 2:1=catchment:crop area.

[1]Labor cost=4.60 Rs/hr and camel cost=8.10 Rs/hr.

[2]Harvesting cost @ 4 kg/40 kg of grain and straw yields.

[3]Threshing cost @ 10% of grain yield.

[4]344.6 and 469.0 Rs/ha amortized over 10 years at 12% annual interest for the 1:1 and 2:1 treatments, respectively.

[5]Seed rate (100 kg/ha) * seed price (3.68 Rs/kg).

[6]Grain yield (kg/ha) * grain price (4.50 Rs/kg) + straw yield (kg/ha) * straw price (1.25 Rs/kg).

[7]Gross benefits - total costs.

Table A12. Labor hours and costs of wheat water-harvesting at Mastung 2 (M/2), 1991/92 season.

	Treatments		
	control	1:1	2:1
	hr/ha		
Tillage (camel)	28.0	14.0	9.3
(man)	28.0	14.0	9.3
Planting (camel)	14.0	7.0	4.7
(man)	14.0	7.0	4.7
Catchment maintenance	0.0	10.0	15.0
	Rs/ha		
Tillage[1] (man & camel)	355.6	177.8	118.5
Planting (man & camel)	177.8	88.9	59.3
Harvesting[2]	100.5	72.3	52.3
Threshing[3]	31.5	21.6	17.3
Catchment maintenance	0.0	46.0	69.0
Set-up cost[4]	0.0	61.0	83.0
Seed cost[5]	367.7	183.9	122.6
Total costs	1033.1	651.4	521.9
Grain yield (kg/ha)	70.0	48.0	38.3
Straw yield (kg/ha)	552.0	405.5	280.3
Gross benefits (Rs/ha)[6]	1005.0	722.9	522.9
Net benefits (Rs/ha)[7]	-28.1	71.4	1.0

Control=crop in entire area; 1:1=catchment:crop area; 2:1=catchment:crop area.

[1]Labor cost=4.60 Rs/hr and camel cost=8.10 Rs/hr.

[2]Harvesting cost @ 4 kg/40 kg of grain and straw yields.

[3]Threshing cost @ 10% of grain yield.

[4]344.6 and 469.0 Rs/ha amortized over 10 years at 12% annual interest for the 1:1 and 2:1 treatments, respectively.

[5]Seed rate (100 kg/ha) * seed price (3.68 Rs/kg).

[6]Grain yield (kg/ha) * grain price (4.50 Rs/kg) + straw yield (kg/ha) * straw price (1.25 Rs/kg).

[7]Gross benefits - total costs.

Table A13. Labor hours and costs of wheat water-harvesting at Dasht 1 (D/1), 1991/92 season.

	Treatments		
	control	1:1	2:1
	hr/ha		
Tillage (camel)	28.0	14.0	9.3
(man)	28.0	14.0	9.3
Planting (camel)	14.0	7.0	4.7
(man)	14.0	7.0	4.7
Catchment maintenance	0.0	10.0	15.0
	Rs/ha		
Tillage[1] (man & camel)	355.6	177.8	118.5
Planting (man & camel)	177.8	88.9	59.3
Harvesting[2]	109.3	52.9	99.6
Threshing[3]	51.3	29.7	51.5
Catchment maintenance	0.0	46.0	69.0
Set-up cost[4]	0.0	61.0	83.0
Seed cost[5]	367.7	183.9	122.6
Total costs	1061.7	640.1	603.4
Grain yield (kg/ha)	114.0	66.0	114.3
Straw yield (kg/ha)	464.0	185.5	385.0
Gross benefits (Rs/ha)[6]	1093.0	528.9	995.8
Net benefits (Rs/ha)[7]	31.3	-111.3	392.4

Control=crop in entire area; 1:1=catchment:crop area; 2:1=catchment:crop area.

[1]Labor cost=4.60 Rs/hr and camel cost=8.10 Rs/hr.

[2]Harvesting cost @ 4 kg/40 kg of grain and straw yields.

[3]Threshing cost @ 10% of grain yield.

[4]344.6 and 469.0 Rs/ha amortized over 10 years at 12% annual interest for the 1:1 and 2:1 treatments, respectively.

[5]Seed rate (100 kg/ha) * seed price (3.68 Rs/kg).

[6]Grain yield (kg/ha) * grain price (4.50 Rs/kg) + straw yield (kg/ha) * straw price (1.25 Rs/kg).

[7]Gross benefits - total costs.

Table A14. Labor hours and costs of wheat water-harvesting at Dasht 2 (D/2), 1991/92 season.

	Treatments		
	control	1:1	2:1
	hr/ha		
Tillage (camel)	28.0	14.0	9.3
(man)	28.0	14.0	9.3
Planting (camel)	14.0	7.0	4.7
(man)	14.0	7.0	4.7
Catchment maintenance	0.0	10.0	15.0
	Rs/ha		
Tillage[1] (man & camel)	355.6	177.8	118.5
Planting (man & camel)	177.8	88.9	59.3
Harvesting[2]	91.5	66.3	60.1
Threshing[3]	56.7	38.0	40.1
Catchment maintenance	0.0	46.0	69.0
Set-up cost[4]	0.0	61.0	83.0
Seed cost[5]	367.7	183.9	122.6
Total costs	1049.3	661.9	552.6
Grain yield (kg/ha)	126.0	84	89.0
Straw yield (kg/ha)	278.0	226	160.7
Gross benefits (Rs/ha)[6]	914.5	663	601.3
Net benefits (Rs/ha)[7]	-134.8	1.5	48.8

Control=crop in entire area; 1:1=catchment:crop area; 2:1=catchment:crop area.

[1]Labor cost=4.60 Rs/hr and camel cost=8.10 Rs/hr.

[2]Harvesting cost @ 4 kg/40 kg of grain and straw yields.

[3]Threshing cost @ 10% of grain yield.

[4]344.6 and 469.0 Rs/ha amortized over 10 years at 12% annual interest for the 1:1 and 2:1 treatments, respectively.

[5]Seed rate (100 kg/ha) * seed price (3.68 Rs/kg).

[6]Grain yield (kg/ha) * grain price (4.50 Rs/kg) + straw yield (kg/ha) * straw price (1.25 Rs/kg).

[7]Gross benefits - total costs.

Table A15. Labor hours and costs of barley water-harvesting at Dasht 1 (D/1), 1988/89 season.

	Treatments		
	control	1:1	2:1
	hr/ha		
Tillage (camel)	28.0	14.0	9.3
(man)	28.0	14.0	9.3
Planting (camel)	14.0	7.0	4.7
(man)	14.0	7.0	4.7
Catchment maintenance	0.0	10.0	15.0
	Rs/ha		
Tillage[1] (man & camel)	271.6	135.8	90.5
Planting (man & camel)	135.8	67.9	45.3
Harvesting[2]	35.8	30.4	21.3
Threshing[3]	23.8	20.8	15.0
Catchment maintenance	0.0	32.0	48.0
Set-up cost[4]	0.0	45.0	60.0
Seed cost[5]	200.0	100.0	66.7
Total costs	667.0	431.9	346.8
Grain yield (kg/ha)	119.0	104.0	75.0
Straw yield (kg/ha)	239.0	192.0	126.0
Gross benefits (Rs/ha)[6]	357.5	304.0	213.0
Net benefits (Rs/ha)[7]	-309.5	-127.9	-133.8

Control=crop in entire area; 1:1=catchment:crop area; 2:1=catchment:crop area.

[1]Labor cost=3.20 Rs/hr and camel cost=6.50 Rs/hr.

[2]Harvesting cost @ 4 kg/40 kg of grain and straw yields.

[3]Threshing cost @ 10% of grain yield.

[4]254.3 and 339.0 Rs/ha amortized over 10 years at 12% annual interest for the 1:1 and 2:1 treatments, respectively.

[5]Seed rate (100 kg/ha) * seed price (2.00 Rs/kg).

[6]Grain yield (kg/ha) * grain price (2.00 Rs/kg) + straw yield (kg/ha) * straw price (0.50 Rs/kg).

[7]Gross benefits - total costs.

Table A16. Labor hours and costs of barley water-harvesting at Dasht 2 (D/2), 1988/89 season.

	Treatments		
	control	1:1	2:1
	hr/ha		
Tillage (camel)	28.0	14.0	9.3
(man)	28.0	14.0	9.3
Planting (camel)	14.0	7.0	4.7
(man)	14.0	7.0	4.7
Catchment maintenance	0.0	10.0	15.0
	Rs/ha		
Tillage[1] (man & camel)	271.6	135.8	90.5
Planting (man & camel)	135.8	67.9	45.3
Harvesting[2]	24.8	19.8	18.0
Threshing[3]	19.4	13.6	12.0
Catchment maintenance	0.0	32.0	48.0
Set-up cost[4]	0.0	45.0	60.0
Seed cost[5]	200.0	100.0	66.7
Total costs	651.6	414.1	340.4
Grain yield (kg/ha)	97.0	68.0	60.0
Straw yield (kg/ha)	108.0	123.0	119.0
Gross benefits (Rs/ha)[6]	248.0	197.5	179.5
Net benefits (Rs/ha)[7]	-403.6	-216.6	-160.9

Control=crop in entire area; 1:1=catchment:crop area; 2:1=catchment:crop area.

[1]Labor cost=3.20 Rs/hr and camel cost=6.50 Rs/hr.

[2]Harvesting cost @ 4 kg/40 kg of grain and straw yields.

[3]Threshing cost @ 10% of grain yield.

[4]254.3 and 339.0 Rs/ha amortized over 10 years at 12% annual interest for the 1:1 and 2:1 treatments, respectively.

[5]Seed rate (100 kg/ha) * seed price (2.00 Rs/kg).

[6]Grain yield (kg/ha) * grain price (2.00 Rs/kg) + straw yield (kg/ha) * straw price (0.50 Rs/kg).

[7]Gross benefits - total costs.

Table A17. Labor hours and costs of barley water-harvesting at Mastung 3 (M/3), 1988/89 season.

	Treatments		
	control	1:1	2:1
	hr/ha		
Tillage (camel)	28.0	14.0	9.3
(man)	28.0	14.0	9.3
Planting (camel)	14.0	7.0	4.7
(man)	14.0	7.0	4.7
Catchment maintenance	0.0	10.0	15.0
	Rs/ha		
Tillage[1] (man & camel)	271.6	135.8	90.5
Planting (man & camel)	135.8	67.9	45.3
Harvesting[2]	68.8	53.9	59.4
Threshing[3]	37.8	30.4	32.4
Catchment maintenance	0.0	32.0	48.0
Set-up cost[4]	0.0	45.0	60.0
Seed cost[5]	200.0	100.0	66.7
Total costs	714.0	465.0	402.2
Grain yield (kg/ha)	189.0	152.0	162.0
Straw yield (kg/ha)	619.0	470.0	539.0
Gross benefits (Rs/ha)[6]	687.5	539.0	593.5
Net benefits (Rs/ha)[7]	-26.5	74.0	191.3

Control=crop in entire area; 1:1=catchment:crop area; 2:1=catchment:crop area.

[1]Labor cost=3.20 Rs/hr and camel cost=6.50 Rs/hr.

[2]Harvesting cost @ 4 kg/40 kg of grain and straw yields.

[3]Threshing cost @ 10% of grain yield.

[4]254.3 and 339.0 Rs/ha amortized over 10 years at 12% annual interest for the 1:1 and 2:1 treatments, respectively.

[5]Seed rate (100 kg/ha) * seed price (2.00 Rs/kg).

[6]Grain yield (kg/ha) * grain price (2.00 Rs/kg) + straw yield (kg/ha) * straw price (0.50 Rs/kg).

[7]Gross benefits - total costs.

Table A18. Labor hours and costs of barley water-harvesting at Kolpur 4 (K/4), 1988/89.

	Treatments		
	control	1:1	2:1
	hr/ha		
Tillage (camel)	28.0	14.0	9.3
(man)	28.0	14.0	9.3
Planting (camel)	14.0	7.0	4.7
(man)	14.0	7.0	4.7
Catchment maintenance	0.0	10.0	15.0
	Rs/ha		
Tillage[1] (man & camel)	271.6	135.8	90.5
Planting (man & camel)	135.8	67.9	45.3
Harvesting[2]	51.5	43.2	29.1
Threshing[3]	33.6	26.6	16.6
Catchment maintenance	0.0	32.0	48.0
Set-up cost[4]	0.0	45.0	60.0
Seed cost[5]	200.0	100.0	66.7
Total costs	692.5	450.5	356.1
Grain yield (kg/ha)	168.0	133.0	83.0
Straw yield (kg/ha)	358.0	331.0	249.0
Gross benefits (Rs/ha)[6]	515.0	431.5	290.5
Net benefits (Rs/ha)[7]	-177.5	-19.0	-65.6

Control=crop in entire area; 1:1=catchment:crop area; 2:1=catchment:crop area.

[1]Labor cost=3.20 Rs/hr and camel cost=6.50 Rs/hr.

[2]Harvesting cost @ 4 kg/40 kg of grain and straw yields.

[3]Threshing cost @ 10% of grain yield.

[4]254.3 and 339.0 Rs/ha amortized over 10 years at 12% annual interest for the 1:1 and 2:1 treatments, respectively.

[5]Seed rate (100 kg/ha) * seed price (2.00 Rs/kg).

[6]Grain yield (kg/ha) * grain price (2.00 Rs/kg) + straw yield (kg/ha) * straw price (0.50 Rs/kg).

[7]Gross benefits - total costs.

Table A19. Labor hours and costs of barley water-harvesting at Mastung 1 (M/1), 1989/90 season.

	Treatments		
	control	1:1	2:1
	hr/ha		
Tillage (camel)	28.0	14.0	9.3
(man)	28.0	14.0	9.3
Planting (camel)	14.0	7.0	4.7
(man)	14.0	7.0	4.7
Catchment maintenance	0.0	10.0	15.0
	Rs/ha		
Tillage[1] (man & camel)	301.0	150.5	100.3
Planting (man & camel)	150.5	75.3	50.2
Harvesting[2]	333.9	297.7	183.5
Threshing[3]	205.5	168.5	98.0
Catchment maintenance	0.0	37.5	56.3
Set-up cost[4]	0.0	50.0	67.0
Seed cost[5]	200.0	100.0	66.7
Total costs	1190.9	879.5	621.9
Grain yield (kg/ha)	418.0	317.0	238.0
Straw yield (kg/ha)	1278.0	1146.0	1205.0
Gross benefits (Rs/ha)[6]	1684.0	1365.5	1197.5
Net benefits (Rs/ha)[7]	759.6	736.5	677.8

Control=crop in entire area; 1:1=catchment:crop area; 2:1=catchment:crop area.

[1]Labor cost=3.75 Rs/hr and camel cost=7.00 Rs/hr.

[2]Harvesting cost @4 kg/40 kg of grain and straw yields.

[3]Threshing cost @ 10% of grain yield.

[4]282.5 and 378.6 Rs/ha amortized over 10 years at 12% annual interest for the 1:1 and 2:1 treatments, respectively.

[5]Seed rate (100 kg/ha) * seed price (2.00 Rs/kg).

[6]Grain yield (kg/ha) * grain price (2.50 Rs/kg) + straw yield (kg/ha) * straw price (0.50 Rs/kg).

[7]Gross benefits - total costs.

Table A20. Labor hours and costs of barley water-harvesting at Mastung 1 (M/1), 1990/91 season.

	Treatments		
	control	1:1	2:1
	hr/ha		
Tillage (camel)	28.0	14.0	9.3
(man)	28.0	14.0	9.3
Planting (camel)	14.0	7.0	4.7
(man)	14.0	7.0	4.7
Catchment maintenance	0.0	10.0	15.0
	Rs/ha		
Tillage[1] (man & camel)	327.6	163.8	109.2
Planting (man & camel)	163.8	81.9	54.6
Harvesting[2]	164.9	83.3	42.5
Threshing[3]	32.7	19.4	8.5
Catchment maintenance	0.0	42.0	63.0
Set-up cost[4]	0.0	56.0	75.0
Seed cost[5]	250.0	125.0	83.3
Total costs	939.1	571.4	436.2
Grain yield (kg/ha)	119.0	70.5	31.0
Straw yield (kg/ha)	1322.0	639.0	340.0
Gross benefits (Rs/ha)[6]	1649.3	832.9	425.3
Net benefits (Rs/ha)[7]	710.2	261.5	-10.9

Control=crop in entire area; 1:1=catchment:crop area; 2:1=catchment:crop area.

[1]Labor cost=4.20 Rs/hr and camel cost=7.50 Rs/hr.

[2]Harvesting cost @4 kg/40 kg of grain and straw yields.

[3]Threshing cost @ 10% of grain yield.

[4]313.6 and 420.3 Rs/ha amortized over 10 years at 12% annual interest for the 1:1 and 2:1 treatments, respectively.

[5]Seed rate (100 kg/ha) * seed price (2.50 Rs/kg).

[6]Grain yield (kg/ha) * grain price (2.75 Rs/kg) + straw yield (kg/ha) * straw price (1.00 Rs/kg).

[7]Gross benefits - total costs.

Table A21. Labor hours and costs of barley water-harvesting at Mastung 1 (M/1), 1991/92 season.

	Treatments		
	control	1:1	2:1
	hr/ha		
Tillage (camel)	28.0	14.0	9.3
(man)	28.0	14.0	9.3
Planting (camel)	14.0	7.0	4.7
(man)	14.0	7.0	4.7
Catchment maintenance	0.0	10.0	15.0
	Rs/ha		
Tillage[1] (man & camel)	355.6	177.8	118.5
Planting (man & camel)	177.8	88.9	59.3
Harvesting[2]	174.6	105.1	95.0
Threshing[3]	69.8	51.4	39.1
Catchment maintenance	0.0	46.0	69.0
Set-up cost[4]	0.0	61.0	83.0
Seed cost[5]	275.0	137.5	91.7
Total costs	1052.8	667.7	555.6
Grain yield (kg/ha)	186.0	137.0	104.3
Straw yield (kg/ha)	839.0	430.0	447.3
Gross benefits (Rs/ha)[6]	1746.3	1051.3	950.4
Net benefits (Rs/ha)[7]	693.5	383.6	394.8

Control=crop in entire area; 1:1=catchment:crop area; 2:1=catchment:crop area.

[1]Labor cost=4.60 Rs/hr and camel cost=8.10 Rs/hr.

[2]Harvesting cost @4 kg/40 kg of grain and straw yields.

[3]Threshing cost @ 10% of grain yield.

[4]344.6 and 469.0 Rs/ha amortized over 10 years at 12% annual interest for the 1:1 and 2:1 treatments, respectively.

[5]Seed rate (100 kg/ha) * seed price (2.75 Rs/kg).

[6]Grain yield (kg/ha) * grain price (3.75 Rs/kg) + straw yield (kg/ha) * straw price (1.25 Rs/kg).

[7]Gross benefits - total costs.

Table A22. Labor hours and costs of barley water-harvesting at Mastung 2 (M/2), 1991/92 season.

	Treatments		
	control	1:1	2:1
	hr/ha		
Tillage (camel)	28.0	14.0	9.3
(man)	28.0	14.0	9.3
Planting (camel)	14.0	7.0	4.7
(man)	14.0	7.0	4.7
Catchment maintenance	0.0	10.0	15.0
	Rs/ha		
Tillage[1] (man & camel)	355.6	177.8	118.5
Planting (man & camel)	177.8	88.9	59.3
Harvesting[2]	144.6	112.8	78.7
Threshing[3]	48.0	55.1	32.9
Catchment maintenance	0.0	46.0	69.0
Set-up cost[4]	0.0	61.0	83.0
Seed cost[5]	275.0	137.5	91.7
Total costs	1001.0	679.1	533.0
Grain yield (kg/ha)	128.0	147.0	87.7
Straw yield (kg/ha)	773.0	461.5	366.3
Gross benefits (Rs/ha)[6]	1446.0	1128.1	786.7
Net benefits (Rs/ha)[7]	445.2	449.0	253.7

Control=crop in entire area; 1:1=catchment:crop area; 2:1=catchment:crop area.

[1]Labor cost=4.60 Rs/hr and camel cost=8.10 Rs/hr.

[2]Harvesting cost @4 kg/40 kg of grain and straw yields.

[3]Threshing cost @ 10% of grain yield.

[4]344.6 and 469.0 Rs/ha amortized over 10 years at 12% annual interest for the 1:1 and 2:1 treatments, respectively.

[5]Seed rate (100 kg/ha) * seed price (2.75 Rs/kg).

[6]Grain yield (kg/ha) * grain price (3.75 Rs/kg) + straw yield (kg/ha) * straw price (1.25 Rs/kg).

[7]Gross benefits - total costs.

Table A23. Labor hours and costs of barley water-harvesting at Dasht 1 (D/1), 1991/92 season.

	Treatments		
	control	1:1	2:1
	hr/ha		
Tillage (camel)	28.0	14.0	9.3
(man)	28.0	14.0	9.3
Planting (camel)	14.0	7.0	4.7
(man)	14.0	7.0	4.7
Catchment maintenance	0.0	10.0	15.0
	Rs/ha		
Tillage[1] (man & camel)	355.6	177.8	118.5
Planting (man & camel)	177.8	88.9	59.3
Harvesting[2]	110.3	56.3	148.1
Threshing[3]	50.6	27.8	76.6
Catchment maintenance	0.0	46.0	69.0
Set-up cost[4]	0.0	61.0	83.0
Seed cost[5]	275.0	137.5	91.7
Total costs	969.3	595.3	646.2
Grain yield (kg/ha)	135.0	74.0	204.3
Straw yield (kg/ha)	477.0	228.5	572.0
Gross benefits (Rs/ha)[6]	1102.5	563.1	1481.3
Net benefits (Rs/ha)[7]	133.2	-32.1	835.0

Control=crop in entire area; 1:1=catchment:crop area; 2:1=catchment:crop area.

[1]Labor cost=4.60 Rs/hr and camel cost=8.10 Rs/hr.

[2]Harvesting cost @4 kg/40 kg of grain and straw yields.

[3]Threshing cost @ 10% of grain yield.

[4]344.6 and 469.0 Rs/ha amortized over 10 years at 12% annual interest for the 1:1 and 2:1 treatments, respectively.

[5]Seed rate (100 kg/ha) * seed price (2.75 Rs/kg).

[6]Grain yield (kg/ha) * grain price (3.75 Rs/kg) + straw yield (kg/ha) * straw price (1.25 Rs/kg).

[7]Gross benefits - total costs.

Table A24. Labor hours and costs of barley water-harvesting at Dasht 2 (D/2), 1991/92 season.

	Treatments		
	control	1:1	2:1
	hr/ha		
Tillage (camel)	28.0	14.0	9.3
(man)	28.0	14.0	9.3
Planting (camel)	14.0	7.0	4.7
(man)	14.0	7.0	4.7
Catchment maintenance	0.0	10.0	15.0
	Rs/ha		
Tillage[1] (man & camel)	355.6	177.8	118.5
Planting (man & camel)	177.8	88.9	59.3
Harvesting[2]	154.3	77.8	55.6
Threshing[3]	76.1	36.0	38.4
Catchment maintenance	0.0	46.0	69.0
Set-up cost[4]	0.0	61.0	83.0
Seed cost[5]	275.0	137.5	91.7
Total costs	1038.8	625.0	515.4
Grain yield (kg/ha)	203.0	96.0	102.3
Straw yield (kg/ha)	625.0	334.0	137.7
Gross benefits (Rs/ha)[6]	1542.5	777.5	555.8
Net benefits (Rs/ha)[7]	503.7	152.6	40.4

Control=crop in entire area; 1:1=catchment:crop area; 2:1=catchment:crop area.

[1]Labor cost=4.60 Rs/hr and camel cost=8.10 Rs/hr.

[2]Harvesting cost @4 kg/40 kg of grain and straw yields.

[3]Threshing cost @ 10% of grain yield.

[4]344.6 and 469.0 Rs/ha amortized over 10 years at 12% annual interest for the 1:1 and 2:1 treatments, respectively.

[5]Seed rate (100 kg/ha) * seed price (2.75 Rs/kg).

[6]Grain yield (kg/ha) * grain price (3.75 Rs/kg) + straw yield (kg/ha) * straw price (1.25 Rs/kg).

[7]Gross benefits - total costs.