PN-ABX-676

USE OF WATER HARVESTIG T. ENHANCE CROP PRODUCTION IN ARID AND SEMI-ARID AREAS OF HIGHLAND BALOCHISTAN, PAKISTAN

TRADITIONAL WATER HARVESTING PRACTICES

Water harvesting practices have been carried out in Pakistan for centuries in both upland and low land Balochistan, and parts of NWFP, Punjab and Sind provinces.
The annual average rainfall of 150 to 350 mm in the barani winter wheat areas of Balochistan is not sufficient to reliably produce a good crop of wheat. Traditional farming practices have apparently adapted to the environment and attempt to increase the water supply to the crop by a number of means:

1. Ridging

Ridging is accomplished with the help of "desi plough" which form a ridge-furrow system with ridges 8 to 15 cm high. The desi plough enables the farmers to place the seed in the moist soil by planting 4 to 6 cm below the bottom of the furrow.

2. Ephemeral stream diversion

A common practice in upland Balochistan is to terrace stony land along side ephemeral streams, at the top of the valleys near the mountains, and divert some of the stream flow into the fields by dams extending into the stream beds. However, this form of water harvesting is dependent on the summer monsoon rains, which are unreliable in upland Balochistan.

3. Bunding

Large areas of land in the valley bottoms do not receive any water from the streams, but do have gentle slopes. Field ownership is demarcated by bunds which have the additional purpose of trapping runoff water.These bunds range from 0.5 to 3 m in height, depending upon the topography of the land. On the heavier soils of the valley bottoms infiltration rates are low, and runoff frequently occurs during the gentler winter rains from surrounding fallow areas and from the top of the fields themselves, to be trapped by the bunds and so is available to the crops in only part of the fields near the bunds.

CATCHMENT BASIN WATER HARVESTING AS A MEANS OF IMPROVING THE PRODUCTIVITY OF RAINFED LAND IN UPLAND BALOCHISTAN.

Small catchment basins of different size were prepared within bunded fields on gentle slope on silty valley bottom soils in upland Balochistan. The ratios of catchment areas to cropped area were 1:1 or 2:1. Seasonal rainfall were 282, 102 and 239 mm in the 1985/86, 1986/87 and 1988/89 seasons, respectively.

Increased water storage in the cropped areas of 55% and 43% of the rain falling on the catchments were observed in the water 1:1 and 1:2 treatments. Yields were considerably increased on a cropped area basis by the water harvesting treatments, but not always sufficiently to compensate for the loss of cropped land. The 2:1

CONSOLIDATED BRIEF REPORT ON WATER HARVESTING IN UPLAND BALOCHISTAN

INTRODUCTION

Situated in the desert belt between 25 N and 32 N Balochistan has an arid or semi-arid climate, with annual precipitation varying from 50 mm in the west to 400 mm in the East. Physically it consist of extensive plateau of rough terrain divided into basins by ranges of sufficient height and ruggedness to pose obstacles to air movement. Rain fall generally occurs in two seasons: winter (November to March /April) and summer (July to September /October). Most of the Balochistan is on the fringes of the monsoon area, and so dose not receive large or reliable amount of summer rainfall. The proportion of annual rainfall received as summer rains varies from less than 10% to over 60%, increasing in a North-South and West-East direction.

Balochistan has been divided into two major ecological zones by Rafique (1976). Based principally on location of the mountain ranges, the Northern areas , and a large "extrusion of high elevation area into the hot subtropical desert zone (Kalat and most of Khuzdar districts), have been classified as continental semi-arid mediterranean, where rain fall varies from 200 to 350 mm and principal land usage is range land grazing, irrigated cropping and barani (or dry land) cropping. The Arid Zone Research Institute (AZRI) is currently focussing its efforts in Balochistan on this continental semi-arid mediterranean zone.

The higher elevation areas are also more northerly and receive most of the rain during the winter months, whilst Khuzdar receives mainly summer rainfall. The normal cropping pattern for winter wheat in the higher elevation areas is: (1) plough the soil following July/August monsoon rains, and then level the soil to reduce evaporative losses; (2) plant in September; (3) cut the green wheat for fodder in November /December if the good growth has occurred; (4) crop dormancy from December to February; (5) renewed crop growth from mid- February; (6) harvest the crop in June. In Kalat the lower temperatures can delay the harvest until July, whilst in Khuzdar the higher temperatures result in a shorter crop season and a limited dormancy period(if any), with planting in October and harvesting in May.

It is clear from the above that attempting to grow wheat for grain in this environment is a high risk, low return exercise. However , the practice of growing wheat as a dual purpose crop, providing both fodder for animals, and if conditions are favorable ,grain for human consumption increases the chances of getting some return from this enterprise. The need for farming practices that make the most efficient use of the scanty rainfall resource in upland Balochistan is apparent.

treatments suffered from water logging damage, even in the low rainfall year.

The cost of catchment set-up was low compared to the reduced seed and ploughing costs in water harvesting treatments, resulting in 21 and 34% reduction in overall cost for the 1:1 and 1:2 treatments. Net benefits were 33% higher than the control for the 1:1 treatment overall, but 27% lower for the 2:1 treatment. Labour inputs were less for the water harvesting treatments, with the result that overall, returns to labour were more than doubled by water harvesting.

Within-field water harvesting with a 1:1 crop:catchment ratio thus reduced risk by reducing investments in seed, animal draft and labour, whilst maintaining yields, suggesting that it could be of considerable benefit to farmers in an environment with a high risk of crop failure. The potential for forming catchments on adjacent unused land, and further research aimed at reducing water-logging damage, could both lead to further improvements in farmer circumstances in upland Balochistan.

ECONOMICS OF WATER HARVESTING TRIALS WITH CEREAL CROPS IN HIGH LAND BALOCHISTAN

Economics of applying WH was studied based on budgeting costs and benefits. Since part of the land is not cultivated but used as catchment area economist divided the yield obtained from the cultivated area by that of both cultivated plus catchment for the purpose of the analysis. Results showed little or no advantage of practicing WH for wheat in terms of not benefits under present conditions. Similar results were obtained from barley. However, an improvement in wheat yield stability over the years of the study ranged from 4% to 23%.

Result from wheat trials showed that the 1:1 treatment has 22% higher benefits (Rs.422/ha) than the control (Rs.345/ha) with a 22 percent reduction in the coefficient of variation. The 2:1 treatment had 33% lower benefits (Rs.230/ha)than the control and reduce the variation by 10 percent. In contrast, barley trials showed that the 1:1 treatment yielded 18 percent lower net benefits (Rs.291/ha) than the control (Rs.421/ha) but increased by 6 percent the variation in net benefits. Treatment 2:1 had 14 percent lower net benefits (Rs.251/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 from water-harvesting has to be offset by the opportunity cost of catchment area. Moreover, less than proportional decreases in total costs of the water-harvesting treatments as the catchment to crop area changes can limit the economic performance of the technique.

The data available for the analysis dose not represent the entire spectrum of weather condition in high land Balochistan; therefore it is desirable to incorporate the probabilities of different quantities of rainfall into the economic analysis. Simulation techniques are suggested to generate probabilities 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 farmer's perception of the benefits associated with water-harvesting practices.

The reasons for low production are not limited to water supply but also include soil which is problematic. Soil texture, structure and fertility are not favorable for high production. The rate of yield increase may become high only if WH is associated with improving soil, farming practices and varieties.

References:

1. ICARDA/AZRI Research Reports Nos.6,40,48 and 78.

2. Tour reports submitted by Dr. T. Oweis i.e;
   i) Visit to Quetta, 17-20 Dec. 1991
   ii)Visit to Quetta, 15-19 Dec. 1992.

1. Background

Pakistan is an agricultural country situated between longitudes 60^{0}-76^{0} east and latitudes 24^{0}-37^{0} north with 117 million population living in an area of 834,000 Sq. Km (Government of Pakistan, 1992). It consists of four provinces Punjab, Sindh, North West Frontier and Balochistan. Balochistan is the largest province by size (347,190 Sq. Km) and the smallest in number of inhabitants which is 9 million (Gil and Baig, 1992). It lies to west of the Indus valley and south and east of Afghanistan border (Figure 1.1). The majority of the population in the province are subsistence farmers. The major stress limiting crop production in Balochistan is inadequate and poorly distributed rainfall. Annual rainfall varies from 100 to 400 mm. Highland Balochistan is located in the north central part of the Balochistan province (Figure 1.2) and has a continental Mediterranean climate with hot summer and cold winter. Altitudes generally exceed 1000 m and crop production is affected by both low rainfall and seasonal extremes of temperature. In winter, when most of the rainfall occurs and crops have usually been sown, minimum temperatures fall below freezing and this prevent crops from exploiting the available moisture.

In order to protect from freezing temperature farmer living in extreme cool areas of highland Balochistan, migrate during winter to warm areas of the province and even to Sindh province. They return to their premises during spring. These farmers practice dry sowing farming. These "opportunistic" farmers, before migrating to hotter places, start sowing their crop without waiting the rain. The yield is lower but highly dependent upon the rainfall.

These extreme climatic conditions restrict non-irrigated crop production to sites totally dependent on rainfall (kushkaba) or areas where the run-off water from uncultivable land can be collected to supplement rainfall (sailaba). It has been noted that the full area of 'kushkaba' land is rarely, if ever, completely planted in upland Balochistan. Even in 1986/87, a good year, only about 50-70 % was planted, almost exclusively to wheat (ICARDA, 1989).

In an earlier survey conducted in the summer of 1986 in Kalat and Khuzdar areas (Rees et al., 1987) reported 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 lentil. A "good" agricultural year is expected 2-3 years out of ten, and both "normal" and "poor" years are expected 3-5 years out of ten. The distributions 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 of the farmers 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 the duel-purpose cereal production in highland Balochistan but the employment pattern of the rural population.

Under kushkaba conditions wheat grain yields in a "good" year ranged from 400 to 500 kg/ha, in a "normal" year were 300 kg/ha and in a "poor" year 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 in a "normal" year. All respondents mentioned that in a "poor" year no barley is sown. Under sailaba conditions wheat grain yields ranged from 800 900 kg/ha in a "good" year, from 600 to 700 kg/ha in a "normal" year, and 300 to 400

Location of Balochistan.

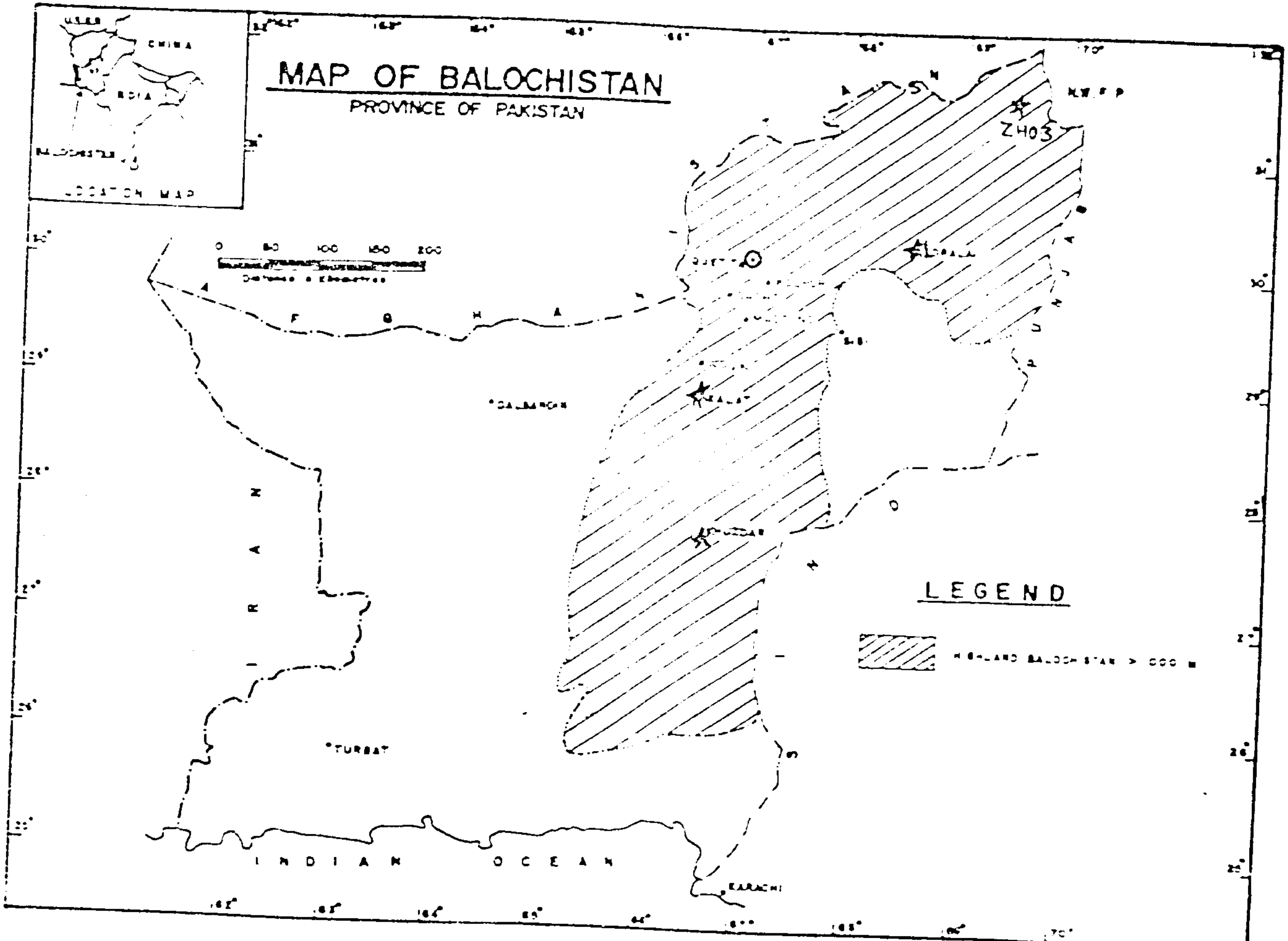

MAP OF BALOCHISTAN
PROVINCE OF PAKISTAN
CHINA
LOCATION MAP
N.W.F.P
KARACHI
TURBAT
INDIAN OCEAN
LEGEND

Figure 1.2

kg/ha in a "bad" year. Likewise, barley grain yields in "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). Where as, the minimum requirements for barley are 225 mm, which has a higher water use efficiency than wheat (Rees et al., 1989b) but it is not a major crop. Wheat is the staple crop of the region. It is very clear that rainfed barley yield was less variable (risky) than rainfed wheat production. Thus farmer's reasons for growing less barley than wheat may have to do more with growing wheat for food security and with the present small uncertain barley market than with the production problems (Rees et al., 1989).

The demand for increased crop production in West Asia and North Africa is expected to lead to increase cropping on marginal lands. There is a need to harness the limited available water resources and maximize the benefit from the uncertain and skewed distribution of rainfall. Water harvesting seems to be an attractive practice as it reduces the risk of crop failure. Farmers have long practiced water harvesting by constructing bunds. This water supplements actual rainfall to produce the sailaba system of crop production. The growing demand for food and feed crops from both 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).

1.1. Water Harvesting Research at Arid Zone Research Institute

The Arid Zone Research Institute (AZRI) is one of the federal agricultural research organization which forms part of Pakistan Agricultural Research Council's national network of agricultural support agencies. AZRI's mandate is to conduct agricultural research in order to generate appropriate technologies for improving agricultural production in the arid and semi-arid zones where the potential for irrigation is either undeveloped or non-existent. Forty million ha or about half of Pakistan's area is nominally serviced from the Institute.

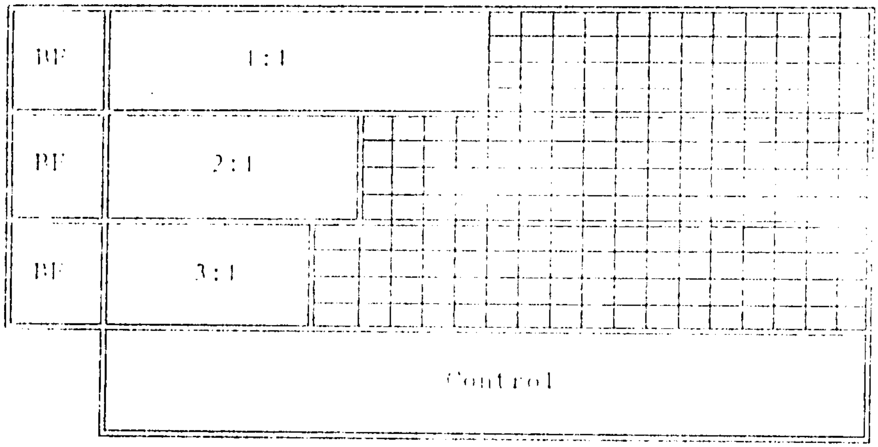
As an attempt to demonstrate improved utilization of rain water, AZRI has been growing cereals, lentils and forage legumes with catchment basin water harvesting (CBWH) techniques (trials) in highland Balochistan since 1986. Accordingly a practice that concentrated the water from one part of field to another, to permit better crop growth should be acceptable in the local farming systems in many areas. Attention has been focused on kushkaba systems because it was considered that the farmers who practice agriculture in the valley bottoms have most need for technological improvement.

The CBWH trials consist of preparing catchment areas at the top of gentle sloping fields (0.5 - 1% slope) to encourage incident rainfall to run off onto the bund, cropped areas. The preparation of small catchment basins on rainfed valley bottom soils represents a low-cost method of generating run-off and increasing crop yields within the cropped areas (Rees et al., 1990). Catchment areas preparation consist simply of tractor-ploughing to remove weeds and then pulverizing the soil with a heavy wooden plank dragged behind the tractor, so that it should form a solid "capped" layer following on the experimental plots sprinkling of water, the impact of drops sealing the soil surface in to a crust. These catchments will last indefinitely if undisturbed, and should in fact become more solid and impervious with time and repeated wetting. Occasional weeding is required (ICARDA, 1989).

The proportions of water catchment area and crop area investigated by AZRI scientist are as follows: for the control treatment the entire area is occupied by the crop; in the 1:1 treatment one half of the area is used for water catchment and one half for planting, lastly, in the 2:1 treatment, two thirds of the area is used for water catchment and one third for planting. The observed run-off efficiencies of 55% for the 1:1 treatment and 43% for the 2:1 treatment are not particularly high for the silty clay loam soils (Khan, 1990). Higher efficiencies could be induced by compaction and/or surface treatment with water repellant chemicals (Dutt, 1981; Fink and Ehrler, 1981). 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).

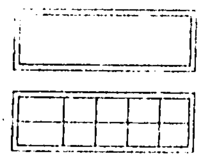
During 1990-91 AZRI Agronomy Section made some modifications in CBWH trials (Figure 1.3). An additional treatment of 3:1 (Catchment-to-crop area) has been added to try and capture more water in very dry seasons. To get over the waterlogging problem on the 2:1 and 3:1 treatments, an additional "buffer" plot has been added below the cropped plot. Excessive water on the cropped plot will be drained on to the buffer plot where fourwing saltbush will be planted. This drought-resistant forage shrub will utilize any surplus water drained off from above plot. The buffer plot is intended to overcome the reluctance of local farmers to drain off

Figure 1.3
EXPERIMENTAL LAYOUT OF CBWE



Cropped Area

Catchment Area



Beffer Zone BF

excessive water which stands on the lower parts of cropped fields and reduces yields (AZRI/ICARDA, 1991).

Contour strip cropping seems to hold promise and in 1992-93 replicated trial has been laid out at three sites. The technology is used in many countries with semi-arid climates and requires sloping land. The ratio 1:1 and 1.5:1 catchment to cropped land, has been investigated in the experiment. However, natural slopes are so small that the slope of the catchment strips has to be increased mechanically. A new trial "wide row spacing to reduce competition for moisture in the rooting zone" (Figure 5) was also initiated during 1992-93 (Khan et al., 1992).

1.2 Objective of the Study

The overall objective of the present case study is to enhance the supply of food and feed crops in highland Balochistan of Pakistan using the sustainable water harvesting techniques that increase the frequency of economic crop yield.

Specifically, the study has the following objectives:

1. To compare water harvesting techniques with the existing farming practices.

2. To determine to what extent crop production is increased and production risks are decreased.

3. To work out the economic implications of the practices, and

4. To assess the adoption potential of water harvesting techniques by farmers in highland Balochistan.

1.3 Organization of the Study

Proceeding from the objective, this study is organized this way: second part, which follows, results of the trials (Agronomic analysis), yields on cropped area basis i.e there is no shortage of kushkaba land, and yields on total area basis i.e there is an opportunity cost of using land for catchment basin. Section 3 and 4 presents the economic analysis of the trials, where gross benefits, costs and net benefits are discussed. In section 4, rainfall variability is incorporated into the economic analysis using historical rainfall data in simulation of yields and net benefits over a 50 year period. Section 5 reports the methodology and results of the farmers' perception about CBWH, their practices about land cultivation, etc. This section will also include the problems with interpreting agronomic trials data. The last section 6 concludes the study. In this section, results are summarized and recommendations for future research/activity pointed out which should improve the income of subsistence farmers in highland Balochistan, Pakistan.

2. Analysis of CBWH Trials

The field trials were conducted at 3 sites around Quetta by the Agronomy Section of AZRI since 1986 i.e Dasht, Mastung and Kovak valleys. Each trial consisted of three replicates, with the four water-harvesting treatment as the main plots. The soils in these broad flat valleys are alluvial yermosols, light to medium in texture, high in lime percentage and pH, low to medium in available phosphate content and low to very low in organic matter and nitrogen (AZRI/ICARDA, 1992).

Soil water content to 1 m depth, sampled gravimetrically at three different positions within each plot (near to the bund, in the center of the cropped area, and at the end of the cropped area) of Dash water harvesting field 1 on 21 March 1988, after 78 mm rain in five showers had fallen. In each position soil water content was increased significantly ($P<0.1\%$) by the water harvesting treatments. The data indicate that overall the 1:1 treatment resulted in an additional 41 mm being stored in the cropped area, and an additional 67 mm in the 2:1 treatment (ICARDA, 1989).

Although a number of crops i.e wheat, barley, lentil and woolly pod vetch were grown in the CBWH field trials, Agronomy Section also introduced one more treatment 3:1 in CBWH trials since 1990-91 but for simplicity only wheat results and 1:1 and 2:1 treatments are presented. Local wheat land race was planted during the first two seasons, Pak-81 was planted in the next two following seasons, Punjab-85 was used in the fifth season and Pak-81 was used again in the last season.

2.1 Yields on Crop Area Basis

These results based on premise that kushkaba land is rarely ever completely planted i.e there is not a shortage of kushkaba land and that catchment basins can be constructed on adjacent unutilized land. Table 2.1 shows the wheat and straw yields (kg/ha), grown with different treatments of water-harvesting in highland Balochistan. Rainfall for each location/trial is also presented. This table showed that there were significantly better increase in yield in 1:1 and 2:1 treatments in all the six seasons, only except during 1989-90 trials at Mastung there was a decrease in yield in 2:1 treatment. During these seasons the rain came late and then was heavy enough to cause some waterlogging, especially in the 2:1 treatment. This apparently affected grain and straw production in the wheat (AZRI/ICARDA, 1990). Table 2.1 also indicated that treatment 2:1 produce the best results. The increase in yield was the highest in this treatment during the season of 1987-88 at Dash 2 and Mastung locations. It is worth mentioning that there was very poor rainfall (102 mm and 96 mm) during this season.

Table 2.1. Average wheat and straw yields (kg/ha), grown with different treatments of water-harvesting in highland Balochistan. Rainfall for each location/trial is also presented.

Season		86/87	87/88			88/89				89/90	90/91	91/92			
Treatment		D/1[1]	D/1	D/2	M/3	D/1	D/2	M/3	R/4	M/1	M/1	M/1	M/2	D/1	D/2
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	1216	96	22	10	224	238	244	260	522	210	108	96	132	170
	Straw	2566	280	146	140	584	338	690	676	2132	1598	692	812	372	454
2:1	Grain	1191	90	45	24	318	346	378	240	276	141	228	116	342	267
	Straw	2712	351	270	261	783	627	1218	615	2709	918	774	840	1155	483
Rainfall (mm)		282	102	102	96	239	239	167	227	224	240	281	281	278	278

[1] Location/trial: denotes the location (D=Dash, M=Mastung and R=Kovak) and the trial number.
Source: Rees et al. (1991), AZRI/ICARDA (1991) and AZRI Agronomy Section.

Summary of wheat grain and straw yields (kg/ha of cropped area) average over years and location is presented in Table 2.1. This table revealed that in treatment 2:1 there were an increased of 196% in grain and 181% in straw production as of control. The over all increased in both grain and straw was 184% as of control. and also have the lowest co-efficient of variation (C.V) in this treatment. These results indicated that treatment 2:1 is performing better in production and also there was less possibilities of risk.

These trials revealed that if we calculate yield on crop area basis assuming that availability of land is no problem in kushkaba land, the results are very promising. Treatment 2:1 produce higher yields of grain, straw and also both together as of control (Table 2.2). Further more this treatment was found better off because the C.V value was also lower as of 1:1 and control indicating that it has less risk.

Table 2.2. Summary of wheat grain and straw yields (kg/ha of cropped area) average over years and location.

	Grain	% of control	Straw	% of control	Total	% of control
Control						
Mean	146	100	541	100	686	100
CV %	95		85		83	
1:1						
Mean	253	173	820	152	1073	156
CV %	116		88		92	
2:1						
Mean	285	196	981	181	1266	184
CV %	95		78		77	

2.2. Yields on Total Area Basis (cropped + catchment basin)

In this section CBWH trials were analyzed on premise that kushkaba land is completely planted i.e. that there is shortage of kushkaba land and that catchment basins can not be constructed on adjacent land or simply the hypothesis that land is scared. There is an opportunity cost of using land for catchment basin - foregone production i.e., yields may be considerably increased on a cropped area basis but not always sufficiently to compensated for loss of cropped land in catchment basin. To be economically feasible the crop gains due to additional soil moisture must be larger than the cost of not planting in the catchment area. Wheat grain and straw yields (kg/ha), adjusted to total area grown with different treatments of water-harvesting in highland Balochistan are presented in Table 2.3. Rainfall for each location is also presented.

Only during 1986-87, 1987-88 and 1990-91 the adjusted yield was increased in treatment 1:1 at Dash1, Dash1 and Mastung1 respectively (Table 2.3). It was also increased in 1:1 and 2:1 during 1987-88 in both grain and straw at Dash1 but 2:1 adjusted yield were lower as 1:1. Dash2 location during the same season showed increased yields of both grain and straw as control. This may be contributed due to the low rainfall during this season. There was also increased straw yield during 1988-89 in both 1:1 and 2:1 treatment as of control. All other treatments indicated lower yields.

In general if we calculate wheat yields adjusted to total area basis the results were poor. There was no increased in grain, straw and both grain and straw as of control (Table 2.4). Only the C.V was found lower in 2:1 treatment as of 1:1 and control.

It is worth mentioning that in the above analysis we have not considered different costs and benefits which were incurred in different water harvesting trials. There was a need to consider variable and fixed costs which were incurred in construction of catchment area and there were also benefits as less inputs were required in treatment. Keeping all these in mind, for better under standing the true picture of catchment basin water harvesting we need to do economic analysis for measuring gross benefits, costs and net benefit. Next section will deal with the economic analysis.

Table 2.3. Wheat grain and straw yields (kg/ha), adjusted to total area[1] grown with different treatments of water-harvesting in highland Balochistan. Rainfall for each location is also presented.

Season		86/87	87/88			88/89				89/90	90/91	91/92			
Treatment		D/1[2]	D/1	D/2	M/3	D/1	D/2	K/3	K/4	M/1	M/1	M/1	M/2	D/1	D/2
Control	Grain	562	25	12	8	196	130	166	159	303	88	82	70	114	126
	Straw	1531	105	75	108	392	192	324	[illegible]	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	141	73	70	292	169	345	338	1066	799	340	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
Rainfall (mm)		282	102	102	96	239	239	167	227	224	240	281	281	278	278

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=Dash, M=Mastung and K=Kovak) and the trial number.

Source: Rees et al. (1991), AZRI/ICARDA (1991) and AZRI Agronomy Section.

Table 2.4. Summary of wheat grain and straw yields (kg/ha of total area) average over years and location.

	Grain	% of control	Straw	% of control	Total	% of control
Control						
Mean	146	100	541	100	686	100
CV %	95		85		83	
1:1						
Mean	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
CV %	115		88		92	
2:1						
Mean	95	65	326	60	421	62
CV %	95		78		77	

3. Economic Analysis of CBWH Trials

Run-off from the catchment basins increased water storage in the cropped areas. Thus, increasing the plant growth potential. However, to be economically feasible the crop gains due to the additional soil moisture must be larger than the cost of not planting in the catchment area. Partial budgets were developed for each trial to calculate the benefits and cost associated to the treatments. In calculating the benefits and cost data were used from a survey conducted by the Economics and Farming Systems Section of AZRI through out the highland Balochistan during 1992.

The labor requirement and costs of wheat production are summarized in Appendix Table 1 and 2 for total area (crop + catchment) and cropped area basis. Majority of the farmers in highland Balochistan are preparing their land with tractors and planting is done by animal (camel or bullocks).

Labor and tractor time for plowing one hectare of land was 1.5 hours. For animal planting 18.00 hr/ha was used and for the maintenance of catchment areas the labor time was Rs 20.00/ha.

In order to calculate the catchment set-up cost, 3.0 hr/ha for tractor and 12.00 hr/ha for man were used and amortized over 10 years at 12% annual interest rate. This structure can stand more than ten years if there is an appropriate care but for average basis a ten year period looks more appropriate. Labor cost and tractor costs were 5.6 Rs/hr (45.00 Rs/day) and Rs 90.00 Rs/hr. Where as camel cost was Rs 6.25 Rs/hr (50 Rs/day).This cost was Rs 64.00 in 1:1 treatment and Rs 96.00 in case of 2:1 treatment. Harvesting cost was calculated at the rate of 10 percent of total grain and straw value. Where as threshing cost was calculated at the rate of 15% of total grain production. Seed and grain prices were kept same (3.75 Rs/kg) for convenient.

Gross benefit were calculated as the value of crop products on both total and cropped area basis, and net benefits as the difference between gross benefits and cost of inputs (Table 3.1 and 3.2).

Summary of gross benefits, costs and net benefits of wheat production with CBWH (Rs/ha of total area) averaged over years and locations are presented in Table 3.1. Appendix Table 1 shows average budgets over years and locations for wheat production (Total area basis). The 1:1 treatment showed higher net benefits over control and 2:1 treatment. There was 26% more net benefit as of control in case of adopting 1:1 CBWH treatment. The net benefit decreased by 20% if we adopt 2:1 treatment as of control (Table 3.1). Higher gross benefit in control as of 1:1 and 2:1 treatments give an illusion of good performance but also the higher cost of inputs made it less beneficial as of 1:1 treatment. The risk in production was reduced as there was larger source of run-off as 27% and 26% less C.V values in 1:1 and 2:1 treatments (Table 3.1).

Table 3.2 shows the gross benefits, costs and net benefits of wheat

Table 3.1. Summary of net benefits (Rs/ha of total area) averaged over years and locations.

	Gross Benefit	% of Control	Total Cost	% of Control	Net Benefit	% of Control
Control						
Mean	1224	100	974	100	250	100
CV%	84	100	18	100	343	100
1:1						
Mean	989	81	675	69	314	126
CV%	98	117	26	144	252	73
2:1						
Mean	765	62	566	58	199	80
CV%	80	95	20	111	253	74

Table 3.2. Summary of net benefits (Rs/ha of cropped area) averaged over years and locations.

	Gross Benefit	% of Control	Cost	% of Control	Net Benefit	% of Control
Control						
Mean	1224	100	974	100	250	100
CV%	84	100	18	100	343	100
1:1						
Mean	1974	161	845	87	1129	451
CV%	98	117	42	233	139	41
2:1						
Mean	2295	188	826	85	1469	588
CV%	80	95	40	222	103	30

production with CBWH (Rs/ha of cropped area) averaged over years and locations.
Average budget over years and locations for control and treatments for wheat
production (cropped area basis) are presented in Appendix Table 2. Both treatment

1:1 and 2:1 shows higher net benefits in wheat production as of control if we calculate it on cropped area basis. The net benefits are positively increased with the increased in run-off or catchment areas. There were 588% and 451% increased in net benefits in 2:1 and 1:1 treatments as of control (Table 3.2). Fall in risk was also coincided with the increased in catchment areas. C.V were 70% and 59% lowered in 2:1 and 1:1 treatments as of control.

There is an increased in net benefits by adopting CBWH techniques both in case of calculating it on the basis of total or crop area basis. This increased was found maximum (588%) in treatment 2:1 as of control estimated on crop area basis and the c.v in net benefits decreased from 345 (control) to 139 (treatment 2:1). If we estimate net benefits on total area basis treatment 1:1 shows 26% and 59% higher and less variability in net benefit as of control.

It is clear that the data available for the analysis does not represent the entire spectrum of weather conditions in highland Balochistan. In situation where rainfall variability so closely governs crop performance, it is necessary to incorporate the probabilities of different rainfall amount in the economic analysis. Thus, simulation techniques must be used to find probability distributions of net benefits of these cereal crops grown under water-harvesting techniques (AZRI/ICARDA, 1992). Next section had incorporated the rainfall variability into the economic analysis using historical rainfall data in simulation of yields and net benefits over 50 years period.

4 Simulation

4.1 CATCHMENT AREA PRODUCTIVITY EVALUATION (CAPE): A Crop Simulation Model

In this section crop simulation model is developed. This model estimated the wheat yield and net benefits in Quetta, Balochistan.

4.1.1 Basic Description about CAPE

The catchment area productivity evaluation model estimates the crop yield of Wheat, Barley, and Lentil in the micro-catchment water harvesting systems using only the daily rainfall as an input parameter. Currently the model estimates yields when the cropped to catchment area ratios are 1:1, 2:1, and 3:1. But if the model proved useful it can be enhanced very easily for any kinds of catchment to cropped area ratios.

Initially, the experimental layout shown in Figure 1.3 is the base of this model, because the same experimental design is used for the research purposes by the Arid Zone Research Institute Quetta in Balochistan, Pakistan for last seven years, from 1986-87 to 1992-93. When the experiment was started in 1986-87 it was observed that after a rain shover of greater than 50mm the pounding of water occurs at the very down slope end in the low infiltrated (42 mm/day), cropped area of the water harvesting treatments, particularly in the 2:1 treatment. This pounded water damaged the cropped in the bottom end of the cropped area by sealing the soil surface, which affected the emergence of wheat plants. This is why in later studies of 1991-192 to onward a buffer zone (Fig. 1.3), was added so that any water which stays longer than two days on the cropped area can over flow towards the buffer zone.

By Including a buffer zone effect in the model it is assumed that no water stands on the surface of cropped area longer than two days in the water harvesting treatments and thus no crop damage eventuates due the pounding of water in the cropped areas.

The model imitates the flow diagram shown in Figure 4.1. It has been tried that proper instructions should be labeled during the use of the CAPE model. The following are the components of the model:

1. The driving variable for the model is the daily rainfall from the historical records. This data can easily be stored in compact form on a file using any of the file editor available in different computer programs. This data must be in the units of INCHES.

2. Daily runoff can be estimated by using computer program CARE (Catchment Area Runoff Evaluation), written by Dr. E.R. Perrier. This program calculates the runoff by using the CURVE NUMBER method, for different types of surface treatments, developed by the United States Department of Soil Conservation Department. A descriptive operating manual is available from the ICARDA office in Aleppo, Syria or Arid Zone Research Institute in Quetta Pakistan.

3. The total water receipt (TWR), in the cropped area of the catchment treatments is the summation of the daily rainfall and the resulted daily runoff less the water transferred to the buffer zone (WTBZ).

   TWR = Rainfall + Runoff - WTBZ

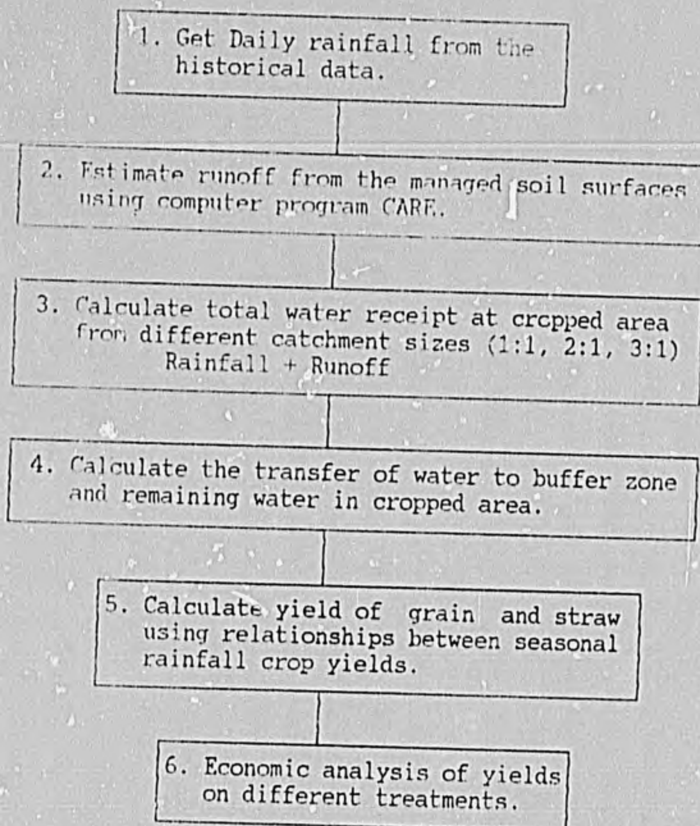
4. The water infiltration rate at the experimental site is about 42mm/day for the silt clay loam soil (USSCS). Therefore, if the total water receipt is greater than 84 mm then that must transfer to the Buffer zone (BF), to avoid crop damage due to water pounding.

   If TWR > 84mm,
   Transfer to BF = TWR - 84mm

5. Yields were predicted using the relationships were developed between seasonal rainfall and the crop grain and straw yields. Table 1. in the Appendix A shows an example of the final outputs from the model, for the Quetta area in Pakistan.

6. The economic analysis used the input data collected from a farmer perception survey performed by Agric. Economics Section of AZRI in the highland areas of Balochistan, during 1992.

Figure 4.1. Different Steps of Model Development.



4.2 Model development

As described above the runoff is calculated using the already available computer program CARE. Spreadsheet LOTUS 123 is used as the main carrier for the development of the model. The daily rainfall and the daily runoff resulted form the CARE is then imported in LOTUS 123 for different kinds of manipulation and choices. A portrait of the different steps involved in the development of the CAPE is shown in the form of a flow chart in Figure 4.2. The resulted Graphs of grain yields, straw yields, and the net benefit are shown in the Figures 4.3, 4.4, and 4.5 respectively.

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. In the next section farmers' perception and methods of water harvesting had been discussed.

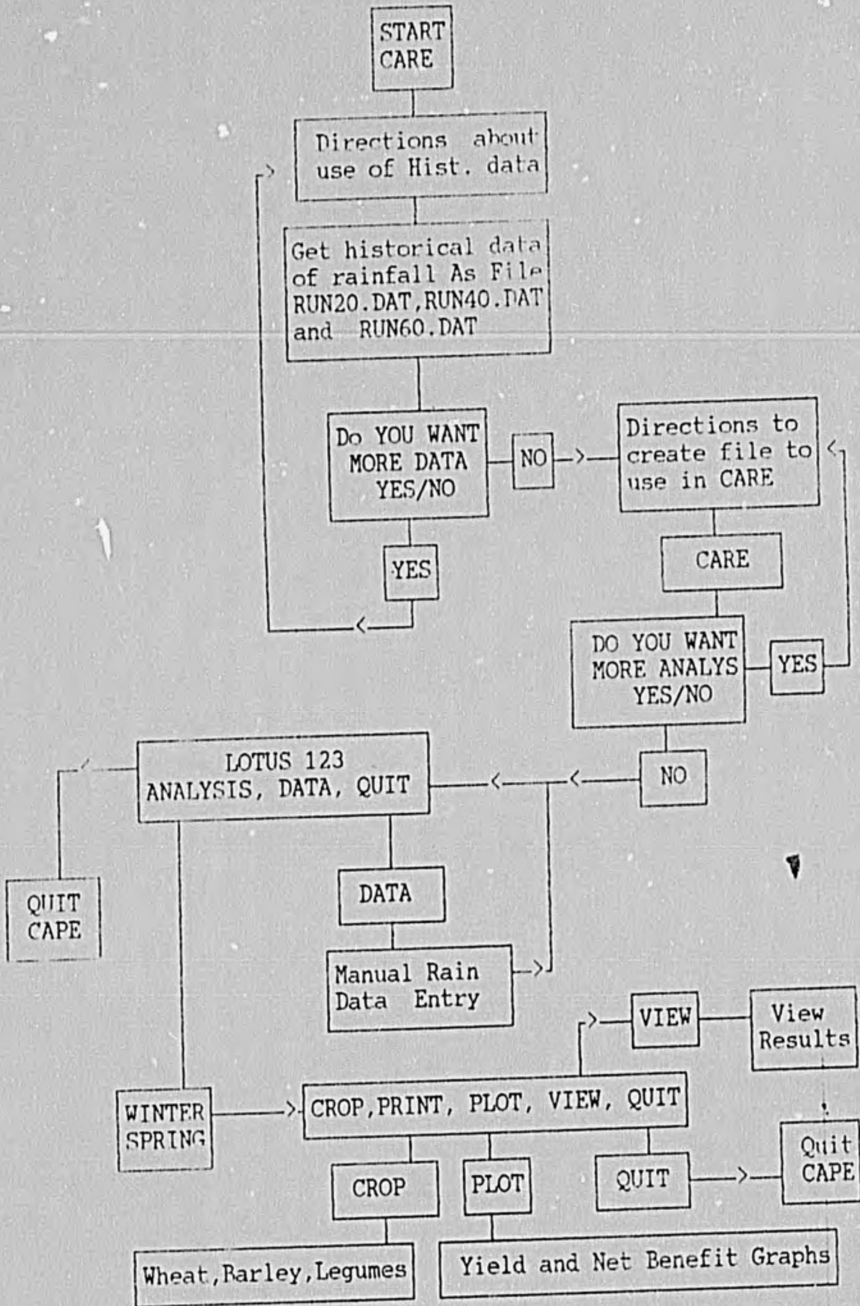


Figure 4.2. Flow Chart of Model Catchment Area Productivity Evaluation (CAPE).

Figure 4.3

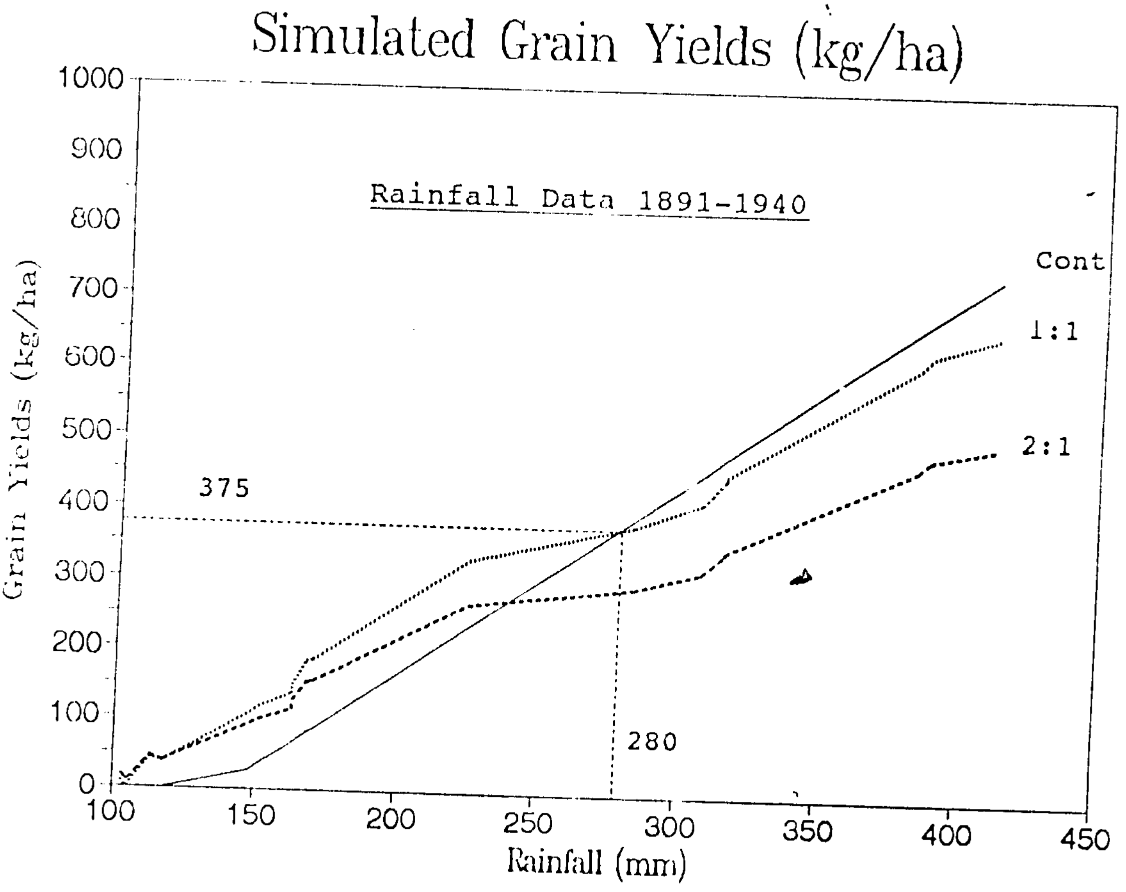
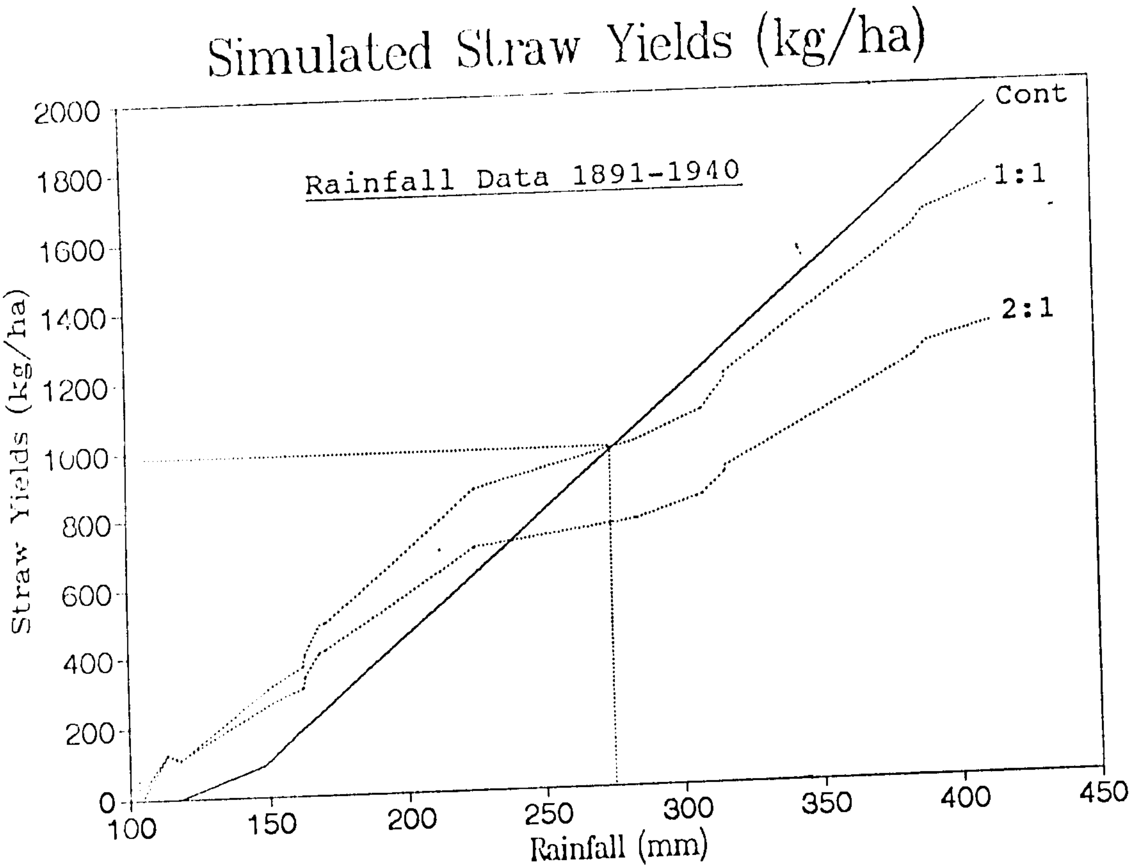
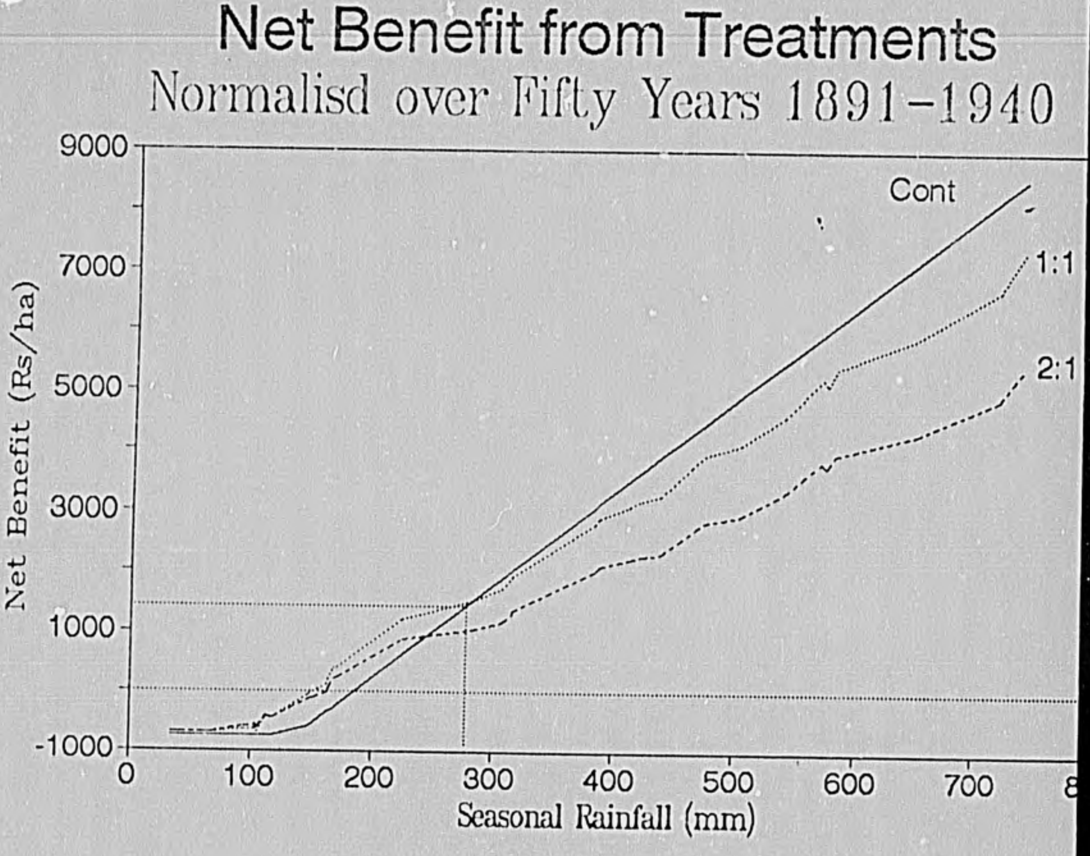

Simulated Grain Yields (kg/ha)
Rainfall Data 1891-1940
Cont
1:1
2:1
375
280
Grain Yields (kg/ha)
1000
900
800
700
600
500
400
300
200
100
0
100
150
200
250
300
350
400
450
Rainfall (mm)

Figure 4.4


Simulated Straw Yields (kg/ha)
Rainfall Data 1891-1940
Cont
1:1
2:1
2000
1800
1600
1400
1200
1000
800
600
400
200
0
Straw Yields (kg/ha)
100
150
200
250
300
350
400
450
Rainfall (mm)

Fugure 4.5



Net Benefit from Treatments
Normalisd over Fifty Years 1891-1940
Net Benefit (Rs/ha)
9000
7000
5000
3000
1000
-1000
0
100
200
300
400
500
600
700
Seasonal Rainfall (mm)
Cont
1:1
2:1

24

5. Farmers' Perceptions About Water-harvesting

A survey was undertaken at evaluating farmers' agricultural systems, perceptions and practices about water-harvesting technology and to assess the adoption potential of CBWH techniques in rainfed agricultural of highland Balochistan.

5.1 Methodology

In pursuit of these objectives, a comprehensive questionnaire was developed. This questionnaire compromised a number of sections relating to the general socio-economics information of the farmer and his family, soil, water and land use, climate, adoption potential of CBWH, crop and livestock production, etc. The questionnaire was pre-tested before proceeding to the survey. A multi-disciplinary team consisting of social scientists, chemist and agronomist interviewed one hundred and forty five farmers at their premises. A three stage stratified random sampling technique was used to get information from farmers. At the first stage, highland Balochistan and four regions viz Loralai, Zhob, Khuzdar and Kalat were selected. In the 2nd stage, sample villages from each region were selected with the consultation of local people and agricultural department for maximum representation. Whereas at the 3rd stage farmers were randomly selected from each villages according to their population size.

Regions selected for survey on an average have rainfall from 138 mm to 279 mm and altitude of 1238 meters to 1704 meters. There were 36, 37, 35 and 37 respondents from Loralai, Zhob, Khuzdar and Kalat regions, respectively. The number of respondents, average rainfall and altitude are presented in and Table 5.1.

Table 5.1. Sample regions with number of sample, average rainfall and height of the survey area of highland Balochistan.

Region	Respondent	Average Rain * (mm)	Height * (M)
Loralai	36	244	1433
Zhob	37	279	1385
Khuzdar	35	138	1238
Kalat	37	240	1704

* Government of Balochistan, 1991.
Source: Agri. Econ. Group of AZRI, Farmers Perception Survey, 1992.

5.2 Characteristics of the Highland Balochistan Kushkaba Farmers

Majority of the farmer interviewed (72%) were the head of the farm, 23% were son of the head and rest are brother or close relative. On an average farm were situated at a distance of 17 km from metaled road. Khuzdar region farms were at the longest distance (28 km) followed by Kalat region (17 km) Zhob region (12 km) and Loralai region (11 km). The availability of head of the farm and road distance were highly co-related. Literacy rate was found very low, on an average

28% respondent farmers could read. This was found the lowest amongst
respondents belongs to Loralai and Zhob regions (Table 5.2).

5.2.1 Land Utilization

On an average total land holding amongst the sample farmers were 19.5 hectar
This also include land which is not suitable (banjar) for cultivation which
5 hectares. In Zhob region the highest banger land (7 hectares) was noticed

Table 5.2 Sample regions, farmers age (years), literacy rate (%), experie (years) and distance from mettled road (km).

Region	Farmer Age	Literacy Rate	Experience	Distance from Metaled Road
Loralai	45	22	26	11
Zhob	46	30	29	12
Khuzdar	43	26	25	28
Kalat	41	27	26	17
Overall	44	28	27	17

Source: Agri. Econ. Group of AZRI, Farmers Perception Survey, 1992.

followed by Loralai (5 hectares), Khuzdar (4 hectares), and Kalat (3 hectares
On an average respondents own 14.9 hectares of land while they have 2.7; 0.
0.9 and 0.1 hectares of share crop, rented in, communal and lease in la
respectively. The maximum land holding of 23.4 hectares on an average w
observed in Loralai region. It was the lowest in Khuzdar and Kalat region, whe
the farmer on an average hold only 16.5 and 16.1 hectares. Only lease in la
was observed in Loralai region and communal lands in Zhob and Khuzdar region
The other land distributions in survey area are described in Table 5.3. On
average cropping intensity was found 38 percent and it was the highest in t
north-east part of the highland Balochistan i.e. Zhob (57%) and Loralai (47%
and the lowest in south parts i.e. Kalat (21%) and Khuzdar (23%). It is wor
mentioning that cropping intensity and rainfall are highly co-related. Croppi
intensity calculated on the available Government data of 1985-86 of highla
Balochistan, it was found very low i.e. 14% (AZRI/ICARDA, 1988).

5.2.2 Demographic

Average family member (house holds) were 16 in the sample area, with simila
gender ratio. Highest family members 19 were observed in Zhob region with highe
(53 %) female members. Zhob district was also reported having the highest hous
hold numbers by the population census (Government of Balochistan, 1992). Wherea
the smallest family size of 14 members with equal proportional of gender we
noticed in Kalat region. On an average 3 family member were full time worki
at farm. Similar number were reported at Loralai and Zhob regions where as
an average only 2 persons were full time engaged in farm activities at Khuzda
and Kalat regions (Table 5.4).

Table 5.3. Land distribution and other related information amongst the sample farmers (hectares) of the survey area of highland Balochistan.

Region	Total	Own	Share Crop	Other* Lands	Ranger Land	Under Wheat	land Parcel	Cropping Intensity (%)
Loralai	23.4	16.9	5.8	0.7	5	5.5	2	47
Zhob	21.9	16.9	0.5	4.5	7	4.3	3	57
Khuzdar	16.5	12.5	2.5	1.5	4	2.7	4	23
Kalat	16.1	13.5	2.3	0.3	3	2.0	6	21
Overall	19.5	14.9	2.7	1.9	5	3.6	4	38

* Include communal, rented and lease in lands
Source: Agri. Econ. Group of AZRI, Farmers Perception Survey, 1992.

Table 5.4. Average family size of the population, income from agricultural, migration, dry sowing practices, per capita land holding and minimum land needed for their wheat consumption (ha) of the survey area of highland Balochistan.

Region	Family Size (No)	Income from Agric. (%)	Migrat-ion (%)	Dry Sowing (%)	Per Capita Land (ha)	Minimum Land for Wheat Con* (ha)
Loralai	16	76	8	-	1.4	15
Zhob	19	72	7	-	1.2	16
Khuzdar	17	70	14	-	1.0	13
Kalat	14	63	22	22	1.2	12
Overall	16	70	13	6	1.3	14

* Con.= consumption.
Source: Agri. Econ. Group of AZRI, Farmers Perception Survey, 1992.

5.2.3 Source of income

Majority of the farmers (70%) source of income is from agricultural which consists of crop (mainly wheat) production, followed by sheep and goat rearing, farmers living nearby towns also earn from providing their services as labors. There was very close relation ship between annual rainfall and income, which looks obvious because all crop production depends on rains. In Kalat the farmers were getting 63% of their income through agriculture farming it was highest (76%) in Loralai region (Table 5.4). In order to understand farmer's economic/financial standing, one questionnaire was asked about the minimum land required for fulfilling their family wheat consumption. In response to this 14 hectares of wheat could supply enough wheat flour for consumption to an average family in the overall sample areas. It is worth mentioning that in general farmer get only one crop in a year and they also rotate their land i.e thei cropping pattern w.r.t wheat is wheat fallow and fallow wheat. This was highest amongst the respondents of Zhob region. It is important to note that Zhob region also have the highest household size. On an average only 3.6 hectares of wheat was grown in the sample area. This was found highest in Loralai (5.5 hectares and Zhob (4.3 hectares) regions. Whereas it was the lowest in Kalat (2. hectares) and Khuzdar (2.7 hectares). So mostly the farmers purchase wheat for their home consumption (Table 5.3). Overall per capita land holding on ar average was 1.3 hectares. This was reported highest in Loralai (1.4 hectares and the lowest (1.0 hectare) in Khuzdar region (Table 5.4).

5.2.4 Migration to Lower Areas During Winter

This is a practice found in extreme cold areas of highland Balochistan where a number of farmers migrated to warmers areas mostly to Sibi, Balochistan and Sindh province to protect them from freezing temperature. On an average they start moving to lower areas in November when the temperature started below freezing and returned to their houses during April. The migration to lower areas is not only due to the freezing temperature and non availability of heating arrangements but also the scarcity of shrubs and grasses to feed their animals, all these motivate them to move from cooler to warmer places. Some farmers have their houses at both the places. Although migration trend was found in all the sample regions but the trend was highest (22%) in Kalat region. Overall 13% farmers reported migration to lower areas.

5.2.5 Decisions to Plant on Kushkaba Land

The decisions to plant on kushkaba land mainly depends on the availability of rain, some farmers showed that availability of tractor for land preparation also played significant role. They could bring more areas under cultivation with the help of tractor.

5.2.6 Good, Normal and or Poor Agricultural Years and Wheat Grain Yield in Ten

An important question about the intensity and average yield of wheat (grain) in "good", "normal" and "poor" agricultural years in ten years was asked to the respondents during the survey. On an average 2, 3 and 5 "good", "normal" and "poor" agricultural years are expected out of ten in kushkaba conditions of highland Balochistan, respectively. Under Kushkaba conditions wheat grain yields on an average in a "good" year was 551 kg/ha and ranged from 101 to 1200 kg/ha, in a "normal" year it was 255 kg/ha and ranged from 40 to 998 kg/ha, and in poor year it was 99 kg/ha and ranged from 7 to 398 kg/ha in highland Balochistan (Table 5.5).

Wheat grain yield was reported lowest in the Southern areas (Khuzdar and Kalat) of highland Balochistan where on an average in a "good" year it was 536 kg/ha and ranged from 131 to 820 kg/ha, in a "normal" year it was 201 kg/ha and ranged from 45 to 386 kg/ha, and in poor year it was only 63 kg/ha and ranged from 12 to 45 kg/ha. It was highest in the Northern areas (Loralai and Zhob) of highland Balochistan where on an average in a "good" year it was 562 kg/ha and ranged from 236 to 1200 kg/ha, in a "normal" year it was 351 kg/ha and ranged from 149 to 898 kg/ha, and in poor year it was 134 kg/ha and ranged from 24 to 349 kg/ha. This is understandable because in Northern areas the average rainfall is higher as of the Southern areas (Table 5.1).

The average wheat grain yield reported by Rees et.al., 1987 for Kushkaba was quite high. Present results are more realist and representative for highland Balochistan compared to Rees et. al., 1987 who surveyed only Southern parts of highland Balochistan.

Table 5.5. Intensity and average grain yield of wheat (kg/ha) in Good, Normal and Poor agricultural years in ten of highland Balochistan.

Region	Years			Yield								
				Good			Normal			Poor		
	Good	Normal	Poor	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min
Loralai	3	3	4	1200	618	200	998	343	79	398	158	40
Zhob	3	3	4	1200	507	279	798	259	119	299	109	7
Khuzdar	2	3	5	801	499	161	400	193	40	200	69	12
Kalat	2	3	5	840	576	101	371	220	49	198	57	12
Overall	2	3	5	1200	551	101	998	255	40	398	99	7

Source: Agri. Econ. Group of AZRI, Farmers Perception Survey, 1992.

5.3 Water Harvesting Practices in Highland Balochistan

Water harvesting practices were noticed amongst all the farmers. They have been practicing this since very long time. There were a number of methods or practices used both in Kushkaba and Sailaba irrigation systems.

5.3.1 Kushkaba Irrigation Systems:

It is purely rainfed land on valley bottom: such fields are marked by small embankments which not only demarcate ownership but also catch any runoff within-field.

5.3.1.1 Dry Sowing: This is the practice concentrated only in very high altitude of highland Balochistan in Kalat region where due to the freezing temperature during winter period farmers migrated to lower areas and returned during spring. They plant their seed without waiting for the moisture and when ever the seeds got enough moisture started growing. There was no damage to the seed due to the prevailing cold temperature. This practice is not practical in warn areas because high temperature of soils damage the seed for germination. The yield heavily depends upon the rainfalls.

5.3.1.2 Availability of Moisture: This is very common practice of kushkaba farmers. farmers do not plant their whole fields. they plant in areas where moisture has accumulated (at bottom of field) and, presumably the crop receives some run-on from the rest of the field. i.e. note that the farmers practice is "opportunistic". They plant their wheat where ever they got good moisture for germination or they plant at their best lands. All the rest areas remains without planting. This land is normally at the lower elevations.

5.3.1.3 CBWH Practice W/O Any Specific Ratio of Catchment Basin: This practice was also found amongst most of the kushkaba farmers in highland Balochistan. Here farmers are adopting the CBWH techniques but without any specific ratio between catchment and cropped areas. It may be of 1:1, 2:1 or even higher or lower catchment area. It was found mostly in those area of Dasht, Kovak and other big valleys where the land scape is better and there is also natural slope. Farmers have not design nor maintaining the catchment areas, it is a natural land scape. Area planted varies with the availability of rainfall. But they were getting better yields them other farmers who does not have any water harvesting catchment areas.

5.3.1.4 Planting the Best Suitable Crop: This practice of crop production under kushkaba farming systems was mostly observed in the Northern part of highland Balochistan. Under this practice farmers maximize the utilization of the rainfalls. Crops and their planting decision heavily depends upon the availability of moisture and season of crop plantation. Their system is very flexible - they may replant, or plant further areas later if more rain received, and if rains are good they may plant a summer crop later on the previously not cropped part of the field. If the rains are available during wheat growing season they grow wheat, if it is late they try to cover more area under spring wheat (if seed available), if there is no spring wheat available then they will plant cumin or sorghum or even if the rains are further delayed some farmers also grow water mellon to utilize the available moisture and boost his subsistence income.

5.3.2 Sailaba Irrigation Systems:

Land receiving additional run-on water from adjacent hillsides and uncultivated rocky areas or water diverted from ephemeral streams and rivers. Under sailaba system there are natural runoff, and located near the hill sides. There are also stream which are not perineal but depends only upon the rains. Rod Kohi sailaba systems is also practices on the extreme Southern parts where water is partially diverted from the ephemeral stream or rivers. In some areas small seasonal dam are also constructed under sailaba systems. They does not guaranty continue supply of water as dam under canal irrigated systems but at least increasing the supply of irrigation water for some days. Under each sailaba system there are a number of distribution systems.

5.4 Adoption of CBWH

Fifty percent of the respondents were interesting to adopt modern water harvesting techniques (CBWHT's) which increased yields and have less production risks. A large number of 65% respondent showed positive response for adoption of this technology in Zhob areas whereas it was reported only 40% in Kalat areas (Table 5.5).

Out of the respondents who did not adopt this technology, one third of overall respondents did not believe it and it was the highest (46%) amongst Khuzdar region followed by Zhob (44%), Loralai (42%) and it was the lowest (11%) in Kalat region. Thirty one percent farmers said that they did not have resources for levelling or preparation of catchment area, financial constraint

Table 5.6. Sample population view about adoption of modern water harvesting technology (percentage) of the survey area of highland Balochistan.

REGION	ADOPTION Yes	ADOPTION No	IF NOT REASONS: Money (1)	Labor (2)	Don't believe (3)	Other (4)	No reply (5)	Combi.* (6)
Loralai	53	47	25	-	42	28	5	-
Zhob	65	35	5	16	44	16	19	-
Khuzdar	40	60	43	3	46	6	9	-
Kalat	41	59	51	-	11	3	11	24
Overall	50	50	31	5	33	14	11	6

* Combi= combination 1 to 5.
Source: Agri. Econ. Group of AZRI, Farmers Perception Survey, 1992.

was reported highest (51%) in Kalat region while it was the lowest only 5% in Zhob region. Whereas 14% farmers gave other reasons for not adoption of the AZRI technology for water harvesting, due to the reasons of shortage of land, heavy rain or land near the foot of hill with large area as catchment, they have already invested heavily by constructed bunds, some farmer did not want to invest because if their would be no rain all investment will be wasted, some farmers were practicing dry sowing and during winter they migrate to low land areas, etc. Eleven percent overall farmers reported no reason, they were illiterate and believe what is going on is their faith. This type of feeling were the highest in Zhob and the lowest in Loralai regions. There were a number of respondents who reported more them one reasons for not adoption of CBWHT's and even they did not believe it. Only 5 % respondent showed labor shortage as the problem, in Loralai and Kalat region no one reported this as a cause for not adoption of CBWHT's. There were overall 6% respondents which gave combination of previous reasons for not adoption of this technology and were only found in Kalat region (Table 5.5).

Although Table 5.6 revealed that 50% of the respondents accepted that they would try this technology (CBWH). But it didn't indicate their belief in the technology because they also indicated that in case of sufficient moisture availability they would even cultivate the catchment area so that they could hope to increase production probabilities against low precipitation.

It is important to relate farmers practices of water harvesting and adoption of CBWH technology developed by AZRI. Farmers are opportunistic and their practices are flexible. They do not plant their whole fields or any fixed ratio. They plant in areas where moisture has accumulated. Where as AZRI's CBWH technology trials has fixed ratio, and permanent nature of catchment area.

A number of overall farmers who did not believe on CBWH would believe (46%) if there would be demonstration plots, 34% gave no reply, this might be they either we were not able to explain them well or they were illiterate and have no interest, and 10% if neighbor farmers adopt it, the rest ten percent showed combination of the previous reasons (Table 5.6). Demonstration plots were the major factor motivating the majority (56%) of Kalat region farmers followed by Loralai (44%), Khuzdar (43%) and as the lowest (38%) in Zhob region (Table 5.6).

Table 5.7. Sample population who don't believe on CBWHT's would adopt this, if there would be demonstration plots of CBWHT's and or if neighbor farmer would adopt of the survey area of highland Balochistan.

REGION	Demo. Plots	Neighbor Farmer's	Combination	No Reply
Loralai	44	3	3	50
Zhob	38	11	16	35
Khuzdar	43	14	14	29
Kalat	56	14	8	22
Overall	46	10	10	34

Source: Agri. Econ. Group of AZRI, Farmers Perception Survey, 1992

5.5 Limitation with the available agronomic data:

Local wheat landrace was planted during the first two seasons, Pak-81 was planted in the next two following seasons, Punjab-85 was used in the fifth season and Pak-81 was used again in the last season. So the affects of wheat variety in estimating the cost and net benefits of CBWH trials was assumed to be constant.

Farmer's in dry land area are opportunistic. Farmers do not plant their whole fields. They plant in areas where moisture has accumulated. But the control in the trial does not represent farmer's true practices. So we are not comparing the "improved" technology with what farmers are doing. So almost all observations give little bit higher weight to control as of treatments.

Farmers water harvesting system is flexible - they may replant, or plant further area later if more rain received, and if rain are good they may plant a summer crop later on the previously not cropped part of the field. This would not be possible given the fixed ratio, permanent nature of AZRI's CBWH technology trials.

AZRI, CBWH trials mainly concentrated on wheat and barley plantation and there is a problem of non availability of spring wheat and barley varieties. If there were late (spring) rainfall no other choice except to plant winter wheat and barley variety. Winter varieties have less production as of spring varieties.

6. Summary, Conclusion and Recommendation

Highland Balochistan is located in the north central part of Balochistan Pakistan and has a continental semi-arid climate with hot summers and cold winters. The most limited factor for crop production in rain-fed areas of Balochistan is the skewed distribution of rainfall in both time and space. Annual rainfall in highland Balochistan averages 200 mm in the southern parts and 300 mm in the northern parts. Crop production in non-irrigated areas is either totally dependent on rainfall (kushkaba) or dependent on run-off water collected from uncultivated land to supplement rainfall (sailaba).

Present study was initiated to enhance the supply of food and feed crops in highland Balochistan of Pakistan using the sustainable water harvesting techniques that increase the frequency of economic crop yield. Catchment techniques that increase the frequency of economic crop yield. Catchment basins water harvesting (CBWH) techniques increased run-off from catchment basin and also increased water storage in the cropped areas.

As an attempt to demonstrate improved utilization of rain water, AZRI has been growing cereals, lentils and forage legumes with CBWH techniques (trials) in highland Balochistan since 1986. The CBWH trials consist of preparing catchment areas at the top of gentle sloping fields (0.5 - 1% slope) to encourage incident rainfall to run off onto the bund, cropped areas. The proportions of water catchment area and crop area investigated by AZRI scientist are as follow: for the control treatment the entire area is occupied by the crop; in the 1:1 treatment one half of the area is used for water catchment and one half for planting, lastly, in the 2:1 treatment, two thirds of the areas is used for water catchment and one third for planting.

In pursuit of the objectives of the study, results of the AZRI's CBWH trials were discussed and analyzed, probabilities of different rainfall amount in economic analysis was also incorporated by simulation techniques, farmers practices and adoption potential of CBWH technology was also addressed. Following are the summery and conclusions of the findings:

6.1 Summaary and Conclusions

Following are the summary and conclusions of the study:

- The results of wheat grain and straw yields based on the premise that kushkaba land is rarely ever completely planted i.e. there is not a shortage of kushkaba land and catchment basins can be constructed on adjacent unutilized land revealed very promising. Treatment 2:1 produce 184% higher yield as of control and less production risk.

- The conclusion based on the assumption that there is an opportunity cost of using land for catchment basin- foregone production or lands are scare produced very poor results as of control. There was no increased in grain, straw and both grain and straw as of control.

- It is important to consider different costs and benefits which were incurred in different water harvesting trials. There is a need to consider variable and fixed costs which were incurred in construction of catchment area and there were also gain as less inputs were required as of treatment. Economic analysis is critical to understand the net benefits and losses from CBWH technology.

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In order to calculate the benefits and cost basic data were used from a survey conducted by the Economic and Farming Systems Section of AZRI through out the highland Balochistan during 1992.

- There is an increase in net benefits by adopting CBWH techniques both in case of calculating it on the total or crop area basis. This increased was found maximum (588%) in treatment 2:1 as of control, estimated on crop area basis and variability in net benefits decreased from 343% (control) to 139% (2:1). If we estimate total net benefits on total area basis treatment 1:1 shows 26% higher and 59% less variability in net benefit as of control.

- It is clear that the six years data available for the analysis does not represent the entire spectrum of weather conditions in highland Balochistan. In situation where rainfall variability so closely governs crop performance, it is necessary to incorporate the probabilities of different rainfall amount in the economic analysis. Thus, simulation techniques must be used to find probability distributions of net benefits of these cereal crops grown under water-harvesting techniques.

- Rainfall variability was incorporated into the economic analysis using historical rainfall data in simulation of yields and net benefits over 50 years period.

- In order to understand farmer's practices and adoption potential about CBWH technology, a survey was under taken by a multidiciplinary team in highland Balochistan during 1992. Three stage stratified random sampling technique was adopted to interviewed 145 respondents at their premises of four regions of highland Balochistan viz Loralai, Zhob, Khuzdar and Kalat.

- The farmers were mostly illiterate in the area. The literacy rate was 28% amongst the respondents which consists of only men. The literacy rate amongst women is very low. The farmers have combine family system and on an average family member (house holds) were 16 in the sample area with equal gender ratio. Only 3 family member are full time engaged with the farm activities. Majority of dry land farmers (70%) source of income is from agricultural which consists of wheat only.

- On an average total land holding amongst the sample farmers were 19.5 hectares. This also include land (5 hectares) which is not suitable for cultivation. Wheat is the major and dominant crop in highland Balochistan. Out of the total cropped land 95% land went under wheat plantation.

- The farmers in highland Balochistan are very poor. In order to understand farmer's economic/financial standing, one questionnaire was asked about the minimum land required for fulfilling their family wheat consumption. In response to this 14 hectares of wheat could supply enough wheat flour for consumption to an average family in the overall sample areas.

- Cropping intensity of highland Balochistan calculated from 1992 surveyed data was only 38%. It was the highest in the northern part and the lowest in the southern parts of highland Balochistan. The low cropping intensity revealed the scarcity of available water for crop production.

- In order to protect from freezing temperature and scarcity of fodder for animals during the winter period, motivated the farmers to migrate to lower areas. The over all migration trend was 13% in the sample areas. This was observed the highest in southern cold and high elevation areas as of northern areas.

- On an average 2, 3 and 5 "good", "normal" and "poor" agricultural years are expected out of ten in kushkaba conditions of highland Balochistan, respectively. Under Kushkaba conditions wheat grain yields on an average in a "good" year was 223 kg/ha and ranged from 41 to 486 kg/ha, in a "normal" year it was 103 kg/ha and ranged from 16 to 404 kg/ha, and in poor year it was 40 kg/ha and ranged from 3 to 161 kg/ha in highland Balochistan.

- Dry sowing practice concentrated only in very high altitude of highland Balochistan in Kalat region (22% farmers) where due to the freezing temperature during winter period farmers migrated to lower areas and returned during spring. They plant their seed without waiting for the moisture and when ever the seeds got enough moisture started growing.

- Fifty percent of the respondents were interesting to adopt modern water harvesting techniques (CBWHT's) which increased yields and have less production risks. A large number of 65% respondent showed positive response for adoption of this technology in Zhob areas whereas it was reported only 40% in Kalat areas.

- Out of the respondents who did not adopt this technology, one third of overall respondents did not believe it and it was the highest (46%) amongst Khuzdar region followed by Zhob (44%), Loralai (42%) and it was the lowest (11%) in Kalat region. Thirty one percent farmers said that they did not have resources for levelling or preparation of catchment area, financial constraint was reported highest (51%) in Kalat region while it was the lowest only 5% in Zhob region. Whereas 14% farmers gave other reasons for not adoption of the AZRI technology for water harvesting, due to the reasons of shortage of land, heavy rain or land near the foot of hill with large area as catchment, they have already invested heavily by constructed bunds, some farmer did not want to invest because if their would be no rain all investment will be wasted, some farmers were practicing dry sowing and during winter they migrate to low land areas, etc. Eleven percent overall farmers reported no reason, they were illiterate and believe what is going on is their faith. This type of feeling were the highest in Zhob and the lowest in Loralai regions. There were a number of respondents who reported more them one reasons for not adoption of CBWHT's and even they did not believe it. Only 5 % respondent showed labor shortage as the problem, in Loralai and Kalat region no one reported this as a cause for not adoption of CBWHT's. There were overall 6% respondents which gave combination of previous reasons for not adoption of this technology and were only found in Kalat region.

- Although the survey revealed that 50% of the respondents accepted that they would try this technology (CBWH). But it didn't indicate their belief in the technology because they also indicated that in case of sufficient moisture availability they would even cultivate the catchment area so that they could hope to increase production probabilities against low precipitation.

- It is important to relate farmers practices of water harvesting and adoption of CBWH technology developed by AZRI. Farmers are opportunistic and their practices are flexible. They do not plant their whole fields or any fixed ratio. They plant in areas where moisture has accumulated. Where as AZRI's CBWH technology trials has fixed ratio, and permanent nature of catchment area.

- A number of overall farmers who did not believe on CBWH would believe (46%) if there would be demonstration plots, 34% gave no reply, this might be they either we were not able to explain them well or they were illiterate and have no interest, and 10% if neighbor farmers adopt-it, the rest ten percent showed combination of the previous reasons. Demonstration plots were the major factor motivating the majority (56%) of Kalat region farmers, followed by Loralai (44%), Khuzdar (43%) and as the lowest (38%) in Zhob region.

6.2 Recommendation:

Catchment basin water harvesting have tremendous scope in highland Balochistan for kushkaba subsistence farmers. It not only increased the production but also reduces risks of crop failure. Although a number of farmers are using a form of CBWH technology they are not applying the improved technology developed by AZRI. For its adoption purposes following are the recommendation:

- There should be demonstration plots at farmers field where farmers should be directly involved in all steps i.e. from land preparation to crop harvesting. Provincial Agricultural Extension Department should come forward for CBWH extension.

- Kushkaba farmers are very poor and they have no money for investment, in order to promote CBWH government institutes should step front to advance credit for CBWH on easily installments or term and conditions.

- The CBWH plots at farmers field should be monitored and evaluated with and without CBWH technology. Yields both on total and cropped areas bases should be calculated.

- It is also recommended that CBWH technology be adjustable to specific farm and area conditions and should be flexible with regards to the catchment crop ratio.

- Although farmers are not specific with wheat they also grow barley, cumin, water mellon etc. But still wheat is the only staple crop of the region and farmer prefer to cultivate it. There is no spring wheat variety and the benefit of late rains can not be well harvested even with CBWH technology. There is serious need to have short season spring wheat variety for highland Balochistan.

- Barley is better crop as of low rainfall is considered. But still farmers reasons for growing less barley than wheat may have to do more with growing wheat for food security and with the present small uncertain barley market than with the production problems. It is there fore recommended that in areas where there is very low rainfall and farmers are growing wheat, efforts should be made to shift wheat to barley production. In this connection better marketing system should be established. The shift from wheat to barley also increased the efficiency of CBWH technology.

- AZRI have CBWH trials since 1986. A lot of information is gathered about wheat and barley production on these trials. It is very clear from these experiments and even with the incorporation of 50 years historical rainfall data for measuring the water runoff efficiencies and crop production, the CBWH increased moisture in the crop areas and also reduces the production risk. The following are the recommendation for new water harvesting research at AZRI:

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Attention should be diverted from CBWH trials to other water harvesting crop production techniques.

- Contour strip and wide row cropping seems to hold promising in many countries with semi-arid climates and required sloping land. This could also be suitable for highland Balochistan. AZRI is already started working on these directions during 1992. Efforts should be continued with maximum involvement of farmers and better management practices.

- Twenty two percent of Kalat region farmer are practicing dry sowing. There was no water harvesting research activity with regard to dry sowing. Needs some research activities to boost the production possibilities and reduced the risk of crop failures under dry sowing practices.

- Run off water efficiencies should be calculated from the experimental plots. Exertion for modeling work to calculate runoff efficiencies and yields based on historical rainfall data should be continued and all time series data on rainfall should be updated.

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APPENDIX I

Table 1. Labor hours and cost for control and each treatment for the production of wheat (total area basis).

	Treatments		
	control	1:1	2:1
		hr/ha	
Tillage (tractor)	1.5	0.8	0.5
(man)	1.5	0.8	0.5
Planting (animal)	18.0	9.0	6.0
(man)	18.0	9.0	6.0
Catchment maintenance	-	10.0	15.0
		Rs/ha	
Tillage[1] (tractor & man)	142.3	71.2	47.4
Planting[2] (animal & man)	252.2	126.1	84.1
Harvesting[3]	122.4	98.9	96.5
Threshing[4]	82.1	71.4	53.4
Catchment maintenance	-	56.0	84.0
Set-up cost for catchment[5]	-	64.0	96.0
Seed cost[6]	375.0	187.5	125.0
Total costs	974.0	675.1	566.4
Grain yield (kg/ha)	146.0	127.0	95.0
Straw yield (kg/ha)	541.0	410.0	327.0
Gross benefits (Rs/ha)[7]	1223.8	988.6	765.0
Net benefits (Rs/ha)[8]	249.8	313.5	198.6

Control=crop in entire area; 1:1=crop in half area; 2:1=crop in 1/3 area.

[1] labor cost=5.6 Rs/hr (45 Rs/day) and tractor cost=90.0 Rs/hr.

[2] Camel cost=6.25 Rs/hr (50 Rs/day)

[3] Harvesting cost @ 10% of grain and straw yields.

[4] Threshing cost @ 15% of grain yield.

[5] Using 3.0 hr/ha for tractor and 12.0 hr/ha for man for catchment set-up and amortized over 10 years at 12% annual interest rate.

[6] Seed rate (100/ha) * seed price (3.75 Rs/kg).

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

[8] Gross benefit - total costs.

Table 2. Labor hours and cost for control and each treatment for the productio[n] of wheat (cropped area basis).

	Treatments		
	control	1:1	2:1
		hr/ha	
Tillage (tractor)	1.5	0.8	0.5
(man)	1.5	0.8	0.5
Planting (animal)	18.0	9.0	6.0
(man)	18.0	9.0	6.0
Catchment maintenance	-	10.0	15.0
		Rs/ha	
Tillage[1] (tractor & man)	142.3	71.2	47.4
Planting[2] (animal & man)	252.2	126.1	84.1
Harvesting[3]	122.4	197.4	229.5
Threshing[4]	82.1	142.3	160.3
Catchment maintenance	-	56.0	84.0
Set-up cost for catchment[5]	-	64.0	96.0
Seed cost[6]	375.0	187.5	125.0
Total costs	974.0	844.5	826.3
Grain yield (kg/ha)	146.0	253.0	285.0
Straw yield (kg/ha)	541.0	820.0	981.0
Gross benefits (Rs/ha)[7]	1223.8	1973.8	2295.0
Net benefits (rs/ha)[8]	249.8	1129.3	1468.7

Control=crop in entire area; 1:1=crop in half area; 2:1=crop in 1/3 area.

[1] Labor cost=5.6 Rs/hr (45 Rs/day) and tractor cost=90.0 Rs/hr.

[2] Camel cost=6.25 Rs/hr (50 Rs/day)

[3] Harvesting cost @ 10% of grain and straw yields.

[4] Threshing cost @ 15% of grain yield.

[5] Using 3.0 hr/ha for tractor and 12.0 hr/ha for man for catchment set-up an[d] amortized over 10 years at 12% annual interest rate.

[6] Seed rate (100/ha) * seed price (3.75 Rs/kg).

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

[8] Gross benefit - total costs.

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