FOREWORD

Water is becoming a scarce resource in arid and semi-arid areas of the world. In Pakistan, water shortfall of 11% in 2004 will increase to 31% in the year 2025. Total water availability at the farm gate (both surface and groundwater) is above 134 million acre feet (MAF). Presently, about 2% water is used for domestic and 1% for industrial purposes, mostly being met from groundwater. About 97% of the available water is used for agriculture. Out of 80 million hectares (Mha) *i.e.* the total geographical area of Pakistan, 29.6 Mha is culturable whereas 13.6 Mha is canal irrigated. About 9.7 Mha of land could be made productive if water is made available. Due to increased population, urbanization and industrialization, the per capita availability has decreased from 5600 m^3 to about 1000 m^3 over the last fifty years. Water storage per capita and water productivity is also very low.

With an increase in population, the pressure on the available water resources increase in terms of increased domestic and industrial uses, increased agriculture activities required to feed the growing population. Since all these uses are interrelated, the increased use of one component may affect the other. Moreover, the quality of water may affect its uses.

The gap between the demand and supply can be met either by constructing new storage reservoirs, or by improving the efficiency of existing water use practices. In many cases, proper management of existing water resources appears to be the only alternative. An integrated and participatory approach however, is required to optimally use the available water resources. The Pakistan Council of Research in Water Resources (PCRWR) launched a project titled, "Participatory National Integrated Water Management Programme" to identify main causes of low water productivity in Pakistan and to introduce package of technologies, in different areas of the country to address theses issues. This report provides pre- project data of the selected sites, constraints and issues affecting the crop productivity and data collected will also serve as benchmark to evaluate the impact of proposed activities. I commend Dr. Ashraf and his team for the accomplishment of the report.

Dr. Muhammad Akram Kahlown
Chairman (T.I)

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List of Staff Associated with the Project

ISLAMABAD

- Dr. Muhammad Akram Kahlown, Chairman
- Dr. Muhmmad Ashraf, Chief Research (WM)
- Mr. Ahmed Zeeshan Bhatti, Assistant Director
- Mr. Hafiz Abdul Salam, Assistant Director

LAHORE

- Mr. Abdul Rauf, Regional Director
- Mr. Khuram Ejaz, Assistant Director
- Mr. Muhammad Zubair, Farm Coordinator

BAHAWALPUR

- Mr. Zamir Ahmed Soomro, Deputy Director
- Mr. Asmatullah Khawaja, Assistant Director

TANDO JAM

- Mr. Muhammad Khan Murri, Director (Incharge)
- Mr. Abdul Salam Arain, Deputy Director

PESHAWAR

- Dr. Manzoor Ahmed Malik, Director (Incharge)
- Amjad Masud, Assistant Director

QUETTA

- Mr. Abdul Jabbar, Director (Incharge)

ABSTRACT

A severe drought hit Pakistan during 1997-2002 which significantly affected the farming community in particular and the nation as a whole. It was a big blow to the economy of Pakistan, where agriculture is one of the major contributors. It was then deemed essential to develop and implement an integrated water management plan at national level through active participation of farmers in order to conserve dwindling water resources. For this purpose, "Participatory National Integrated Water Management Programme" was launched by the PCRWR in 2004, with an aim to devise a strategic plan in order to solve the mismanagement of water resources by implementing an appropriate package of available and innovative technologies and agronomic practices suited to each area of the country. Agro-climatic zoning of the country was done as per the native conditions. Thirteen pilot sites were established under the project in the irrigated, rainfed, desert, coastal and upland mountainous areas of the country. A package of appropriate technologies were identified and developed for each site in consultation with farmers and local agriculture department.

The package for irrigated areas include: watercourse improvement, improvement in farm layout, precision field leveling, improved irrigation techniques (bed and furrow irrigation method, ditch irrigation system, trickle irrigation system *etc*), adoption of low delta crops, use of low quality groundwater by skimming wells, proper irrigation scheduling and improved cultural practices (zero-tillage). For barani areas, the package consists of construction of small dams, watershed management, pressurized irrigation system, rainwater harvesting ponds and conservation structures. In deserts, rainwater harvesting ponds are being constructed and drought and salinity tolerant plants are being planted. In upland mountainous areas, lift irrigation system, artificial groundwater recharge (injection wells and leaky dams *etc*), watershed management and high efficiency irrigation are being implemented. The technologies for coastal areas include construction of rainwater harvesting ponds, installation of wind mills for the pumpage of stored water and its distribution network for livestock and human consumption.

Prior to the implementation of project activities, a detailed physical and socio-economic survey of each site was carried out in order to serve as benchmark for the assessment of the project in enhancing the water productivity and socio-economic conditions of the stakeholders and its overall impact at national level.

The sites located in the irrigated areas lie in Bhalwal, Hafizabad, Pakpattan, Kotsumbanwala, Bahawalpur, and Tando Ghulam Ali. The area of these sites ranges from 30-100 ha. The sources of irrigation include canals and groundwater which are mostly used conjunctively. Flood irrigation method is generally used. The major crops grown are wheat, cotton, rice, sugarcane, maize, potato, fodder, gram, linseed, vegetables and citrus. The average annual cropping intensity at the sites ranges from 80 to 160 percent. Average yield for wheat, sugarcane, rice, maize and cotton were 300, 55000, 3100, 6900 and 1500 kg/ha whereas the water productivity (WUE) for these crops were 0.82, 4.24, 0.09, 0.63 and 0.29 kg/m^3, respectively.

The site established in the Cholistan desert is located in the Hyderwali village where a traditional *toba* is available having 4869 m^3 storage capacity. Groundwater at shallow depths is highly brackish whereas that at 90 m depth is relatively good which may be pumped through tubewells. No conventional agriculture is practiced due to lack of irrigation water despite having highly fertile land. The main source of income for the stakeholders is livestock which rely on natural vegetation.

The selected site of northern areas is located in Malk-e-dam valley, district Swat. Agriculture is the main economic activity of the people. The sources of irrigation are rainfall, khul and tubewells whereby their contributions are 78, 15 and 6 percent, respectively. Average farm size in the area is 1.77 ha. Sixty seven percent area is cultivated, where the major crops are fruits (peach, plum, pears, apple and apricot), wheat, maize, vegetables and fodder. The average net income of farmers from fruits is Rs: 25,636/- per hectare which is the highest compared to other crops. Average net income of wheat, maize and vegetables is Rs. 3687, Rs. 3020 and Rs.15950 /ha.

The site of coastal areas is located at Murad Ali Brohi village in Thatta district. About 50% of the total area of the site is cultivated while the remaining is unavailable for cultivation due to scarcity of water and rocky soils. The sources of irrigation include rainfall and tubewells where the water table is 3 to 20 m deep. The total cultivated land of the site is 35 ha. Agriculture and livestock are the main sources of income of the people which is quite insufficient; hence the poverty rate is very high.

A site established in the upland mountainous areas *i.e.* Balochistan plateau at Chashma Achozai near Quetta. The total area of the site is 385 ha. The farm sizes vary from 1-12 ha

where mostly orchards are grown. The sources of irrigation include spring, tubewell, snow, and some scanty rainfall. The major cultivated crops are fruits (apple, apricot, peach, and plum), wheat, barley, vegetables, cumin, fodder, melon and watermelon. Conventional basin irrigation is practiced, whereby water becomes available on 14-days rotation. The fruit orchards is the highest value added product of the site contributing to 73.24% of the total farm income.

The rainfed site is located near Gujar Khan, where rainfall is the sole source of irrigation. The fields are mostly undulating and are in the form of strips. A number of perennial nullahs pass nearby lands which remain unutilized so far due to lack of pumping facilities. Average area of the sit is 7.28 ha. The major crops of the area are wheat, gram, oilseed, maize, pulses, groundnuts and fodder. The average net income for groundnut and gram is the highest. The average annual cropping intensity is 144% and the average yield per hectare of site's crops are higher than the rest of rainfed areas. The site established in Azad Jammu and Kashmir is located in Sehnsa, District Kotli. The average farm size at this site is 10 ha. The major crops grown are wheat and maize yielding 1581 and 2174 kg/ha, respectively. The contibution of non-farm income is more which indicates that farmers are less dependent on agriculture.

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Pakistan which was cited in 1995 by the World Development Report among 130 countries having the highest freshwater availability per person had faced a severe drought from 1997 to 2002. The annual rainfall showed a significant decline all over the country then, consequently reducing the rivers flows. Thereafter, an extremely serious water crisis emerged in Pakistan threatening its irrigated agriculture and domestic water supplies. The long term forecasts by experts suggest that the country has entered a dry cycle and can expect drought like conditions to return every six years. It is also predicted that a yearly increase of 4 million people to population, as per the current growth rate, would let every one out of three persons in Pakistan to face critical water shortage threatening his/her survival. The annual per capita water availability based on the current population (160 million) in Pakistan has reduced to 1000 m^3, showing a drop of 50% during the last decade. It therefore becomes very important to develop an action plan in order to conserve and utilize the dwindling water resources. Similarly, the rapidly growing trend of deteriorating water quality has also become an important issue.

Though Pakistan has the largest contiguous irrigation system of the world, yet it is a water deficit country. The Indus River and its tributaries on an average bring about 154 million acre-feet of water, annually. This includes 144.9 MAF from the three western rivers and 9.14 MAF from the eastern rivers. Most of this (about 104.7 MAF) is diverted for irrigation, 39.4 MAF flows to the sea whereas about 9.9 MAF is lost in the distribution system as evaporation, seepage and spills during floods. The peak flow months are June to August *i.e.* during monsoon; 84% of the annual flows take place solely in Kharif (summer) while during Rabi (winter) it is only 16%. Therefore, an average shortfall of 3.5 MAF occurs in Rabi season that is expected to increase to 13 MAF by the year 2017. At that stage, country would need more food and fiber to meet the needs of growing population. Therefore, the Indus River System as such would not be able to sustain self-reliance in agricultural production. Moreover, the storage capacity of existing reservoirs *i.e.* Tarbela, Mangla and Chashma would have been reduced by 25% by the end of 2010, due to sedimentation. The areas situated outside the monsoon belt (low rainfall areas) are likely to suffer the most, followed

by arid and semi-arid areas. The danger of desertification caused by more extraction and depletion of groundwater is also feared in some areas, particularly in Balochistan, where the water table is dropping at the rate of 3.5 m/annum. The aquifers would therefore run out in 15 years and will cause massive internal displacement. The state of groundwater depletion is no different even in the canal command areas as 23 out of 46 canal commands are facing decline of water table (Bhutta *et al.*, 1995). Moreover, over-exploitation of groundwater has also caused quality of groundwater to deteriorate. Out of 6,00,000 tubewells of Indus Basin, 70% are pumping sodic water (Qureshi & Bern, 1990).

Pakistan currently has 15 MAF of storage capacity and fulfils an annual demand of 105 MAF of irrigation water. No major reservoir has been built in the last 27 years making it to lag much behind its neighbouring countries like Iran, India, Nepal, Turkey and China. The drought has highlighted the lack of any definitive water policy and has exposed serious shortcomings of Pakistan's water storage and antiquated irrigation systems. Out dated irrigation techniques had caused the problems of waterlogging and salinity, whereas unequal distribution of irrigation water has resulted in social problem at community and regional level. To cope with the situation, additional storages are required at feasible sites in the Northern Areas or downstream of Tarbela alongwith harnessing the full potential of hill torrents, which are substantial. Moreover, the available water resources should be managed properly and used most efficiently and sensibly for maximum crop production per unit of applied water.

The country is facing a number of issues related to water. The most important of these are:

- Scarcity of water to meet crop requirements;
- Inadequate and untimely availability of water causing stress at critical stages of crop growth;
- Low conveyance, application and water use efficiencies;
- Water logging and salinity;
- Ground water pollution due to various kind of agriculture inputs, disposal of drainage water, reuse of saline drainage effluents and industrial wastes;
- Mixing of fresh and saline aquifers;
- Over pumping and groundwater mining; and
- Social and institutional problems.

There are several options to overcome these issues. Some of these are:

- Construction of new reservoirs;
- Improving efficiency of the irrigation systems such as canal and watercourse lining;
- Improving farm layout *i.e.* proper design of farm layout, laser leveling, proper design of irrigation system based on soil type and discharge available;
- Using high efficiency irrigation systems *e.g.*, bed and furrow methods of irrigation, zero tillage technology and sprinkler/drip irrigation system;
- Installation of skimming wells in the areas where only a thin freshwater layer exists over saline aquifer;
- Using saline groundwater, in conjunction with canal water, or independently with salt tolerant crops;
- Changing the existing cropping pattern *i.e.* by adopting less delta crops;
- Adopting proper irrigation scheduling;
- Rainwater harvesting in barani areas and deserts;
- Collection of hill torrents in uplands;
- Introduction of renewable water lifting devices in northern areas; and
- Improving the institutional set-up and management of water resources to achieve the goal of maximum production per unit of water.

There is potential for the construction of large and small dams in the country however, it involves huge investment and national consensus. The other options can easily be adopted by using appropriate technologies. However, a single approach may not be effective *e.g.* water saved by watercourse lining may be wasted in field due to undulated fields and improper size of border/basin and lack of proper knowledge of irrigation scheduling. Nevertheless, a package of these technologies could be the only way to bridge the gap between demand and supply.

1.2 NEED FOR STUDY

The water resources of Pakistan, both surface and groundwater are insufficient to meet its demands. The water productivity is far below than achievable levels, most probably due to conveyance and application losses, water consumed by high delta crops, improper irrigation scheduling, waterlogging and salinity *etc*. The gray areas of low water productivity therefore,

need to be identified and techniques to improve the efficiency and precision of water resources management need to be assessed.

Solutions to the current and impending water crises will not be found in new and extraordinary technological advances. Instead, solutions will be found through changing our patterns of water use and the way we manage water through integrated water resources management at the river basin level. However, moving forward with this integrated approach is not just a question of bringing together innovative ideas and measures from all sectors and water user communities. It also means changing the activities that are creating the problems.

Existing irrigation practices need to be changed and new roles and new accountabilities must be allowed to emerge in water sector of Pakistan. For example in most of the areas, the actual water application varies considerably from the required irrigation demand. Consequently, there is high potential for water savings by improving irrigation efficiency. Technologies will help this process, as will better water allocation practices and regulations, and better dialogue about the relationship between water for food and water for the environment.

There are many programmes and projects going on in the country aimed at efficient utilization of the water resources, however, the projects are in piecemeal and are isolated efforts. The impact of the projects has, therefore, not been felt at the national level. What the country needs is an integrated approach (both agricultural and engineering) to solve the problem of mismanagement of the water resources by adopting an appropriate package of available technologies and agronomic practices suited to the area and prevalent conditions. The proposed programme is aimed to achieve this objective and would be an important tool to bridge the gap between water demand and supply.

1.3 OBJECTIVES

- Planning and implementation of pilot projects to introduce package of technologies for optimum utilization of available water resources in irrigated, rainfed, deserts, coastal and upland areas of country with farmers' participation.
- Demonstrate and disseminate water management techniques to the farmers through field visits to pilot projects, audio-visual material, handbooks and manuals.
- Devise strategic plan to implement integrated water management programme throughout the country.

1.4 WATER MANAGEMENT TECHNOLOGIES

In Pakistan, agriculture is the major water user, consuming more than 93% of the available water resources including surface and groundwater. Despite enormous water shortage for irrigation, the users' communities in Pakistan continue to misuse water in extravagant and injudicious ways. It is well known and has been pointed out by many researchers that inefficient use of water is one of the most serious problems in Pakistan. Water management is therefore, required at every level right from the reservoirs to the farm to alter the situation. There is an urgent need to address some of the key issues at the field level by introducing latest water management technologies. The following sections describe some of the most important water management technologies identified for different areas of Pakistan. Some of the technologies are already being tried on limited scale in various parts of the country and have been proved successful. The technologies are being implemented in a much coherent way in this project, with active farmers' participation and will be appropriately disseminated through media for wide-scale adoption. This is not an exhaustive list and further technologies could be introduced if considered appropriate.

1.4.1 Technologies for Irrigated Areas

Pakistan's agriculture is classified as irrigated having about 17 million hectares (Mha) of irrigated area with 90 percent of its agriculture production from irrigated lands (Mohtadullah, 1997). Nearly, 50 percent of the total available irrigation water is lost in transit at tertiary level irrigation system, and at the farm during application to crops due to undulated fields and unnecessary field ditches. As already mentioned due to present water crises and reduced river flows, farmers are getting less water. However, the farmers are still using the obsolete methods of irrigation. The following interventions are proven helpful in saving water.

1.4.1.1 Watercourse Improvement

The annual surface water potential in the country is about 146 MAF however, the crops hardly use 31 MAF and the rest is lost as conveyance and application losses (Khan, 1997). Major losses of water (30-50%) occur at the tertiary system consisting 107,000 old, badly damaged and poorly maintained community watercourses in the Indus basin. The main causes of these operational losses are: seepage, overflow, thin distorted, silt-loaded banks, vegetation, convoluted sections rodent holes *etc*. (Kahlown *et al.*, 1998). Water losses

measured by different agencies are shown in Table 1.1. National Programme for Improvement of Watercourses (NPIW) has lined a total of 41,459 watercourses and lining of 18,700 is underway. It is estimated that about 20 MAF of water would be saved by improving the remaining watercourses in the Indus basin.

1.4.1.2 Improved Farm Layout

The layout of most of the fields is based on traditional flood basin comprising a number of unwanted dikes and ditches covering a length of over two kilometers in each square. These fields are not properly leveled and cause wastage of land hence results in low irrigation efficiencies. Removing unnecessary field dikes, ditches and trees *etc*, and designing farm layout and irrigation system based on the infiltration characteristics of the soil and stream size coupled with proper irrigation scheduling would greatly increase the land use intensity and water application/water use efficiency.



Figure 1.1: View of an Improved Watercourse

1.4.1.3 Laser Land Levelling

Precision land levelling (PLL) is a topographic modification, grading and smoothing of land to an even level, with little or no slope at an elevation difference of ± 2 cm. Precision land levelling improves the application and distribution efficiencies of irrigation with less chance of over and under irrigation. It has been reported that PLL increased the land use intensity from 8 to 63 percent and cropping intensity from 6 to 70 percent (Gill, 1994). Therefore, PLL can help reduce the amount of irrigation water required and also the labour requirements.

Table 1.1: Conveyance Losses of Watercourses as per Previous Studies

Sr. No.	*Source/Reference*	*Watercourse Conveyance Losses*	*Remarks*
1	Irrigation, Drainage and Agricultural Sectors Survey Report IBRD, May 1974	25%	-
2	Pakistan Economic Development Data USAID, August 1974	30%	Based on CSU research work
3	The Importance of Farm Water Management in Pakistan, Corey and Clyma CSU, September 1974	30 to 50%	SCARP command area
4	Watercourse Losses as related to Composition and Conditions of Banks Kempar *et al.* CSU/WAPDA, April 1975	50%	-
5	Watercourse Chak Farming, Measurements Survey WAPDA/UNDP, 1976-77	45%	-
6	Watercourse Command Survey in Pakistan's Punjab and Sindh, System Constraints and Farmers' Responses Technical Report No. 45 Early *et al.* CSU/WAPDA, 1977	47%	Measurements made on 61 watercourses
7	Losses of Water from Mogha to Field Lowdermilk, 1978	33 to 65%	Results of 40 watercourse surveys
8	Watercourse Losses in Sahiwal Tehsil, OFWM Training Institute, Punjab, December 1981	33.2%	Losses measured in 60 randomly selected watercourses
9	Report of the Expert Committee on Irrigation Problems of the Punjab October 1984	35 to 45%	-



Figure 1.2: Laser Land Levelling in Progress

1.4.1.4 Improved Irrigation Techniques

Bed and Furrow Irrigation

Basin irrigation is the most conventional method of irrigation used in Pakistan. However, application efficiency of basin irrigation is very low. Berkhout (1997) attributed the low application efficiency of basin irrigation to infiltration characteristics of soil, field undulations, intake discharge and runoff. Surface irrigation techniques however, can be improved by developing crop specific field layouts. Efficient surface irrigation methods such as bed and furrow irrigation system help save water. Kahlown *et al.* (1998) compared the results of cotton and wheat sowing on flat basin with bed and furrow. They concluded that cotton yielded maximum water use efficiency for bed and furrow method of irrigation, whereas the flat basin method of irrigation had the lowest yield and the highest water consumption. Therefore, the water saved in bed and furrow irrigation can be used to increase the cropping intensity and also for leaching the salts in salt affected soils. Based on water use efficiency, the bed and furrow method is the most efficient surface water application method.

In the bed and furrow method, water is applied only in furrows. With the passage of time, the furrows become cemented due to silt deposition. Water then moves laterally and vertical seepage of the water reduces considerably. Since water is applied in furrows, the effect of water born and water transmitted diseases on the crop health becomes minimal. The weeds,

which are transported through canal water, are trapped in the furrows from which these can be removed easily. Moreover, the same field may be used for inter-cropping *e.g.* sugarcane in furrows and wheat on beds *etc*.



Figure 1.3: A View of Bed and Furrow Irrigation System

Sprinkler Irrigation System

Sprinkler Irrigation is a method of applying irrigation water which is similar to rainfall. Water is distributed through a system of pipes usually by pumping. It is then sprayed into the air and irrigated entire soil surface through spray heads so that it breaks up into small water drops which fall to the ground. Sprinklers provide efficient coverage for small to large areas and are suitable for use on all types of properties. It is also adaptable to nearly all irrigable soils since sprinklers are available in a wide range of discharge capacity. It is Suitable for almost all field crops like Wheat, Gram, Pulses as well as Vegetables, Cotton, Soya bean, Tea, Coffee, and other fodder crops.

Ditch Irrigation System

Pakistan is famous for citrus and mango orchards. Farmers normally flood irrigate their orchards. Flood irrigation of orchards results in the wastage of water and fertilizers. The moisture and fertilizer in the fallow area encourage the germination of weeds. Farmers normally cultivate lands between the plants to control weeds. Movement of machinery in orchards damages the plants as well as the roots. Introducing ditch irrigation system can save

significant amount of water. The fallow area between the plants may be covered with mulches of crop residues. Mulches conserve moisture in the soil and discourage weed germination. Mulches also reduce evaporation and hence the salinization of the soils. Moreover, these mulches after some time decompose and add organic matter in the soil.



Figure 1.4: A View of Sprinkler Irrigation System

Drip Irrigation System

Drip/trickle irrigation is a method of efficient water supply to plants according to the requirement of plants and has a relatively low initial cost. Water trickles from the small tubes and directly feeds the roots of plants. Thus, on an average, the water required by drip irrigation is only 20 to 30% of that required by conventional methods like flooding and furrow methods. Moreover, drip irrigation avoids over-irrigation that is needed for other methods. In California, the Hawaiian Sugar Industry converted 34800 ha of sugarcane into drip irrigation out of 45000 ha (77% of total irrigated area) from 1979-1984. Drip-irrigated fields produced 22% higher yield and 26% higher production rates with less cost than fields irrigated by other methods (Anshtuz and Chaverz, 1985). Drip irrigation promotes faster establishment of young trees, aids sound germination of seeds hence increases their population per unit area, prevents thicker growth of weeds, and reduce the nutrient and moisture sharing problem of soil. Sivanappan and Kottiswaran (1985) studied a drip irrigation system for coconut fully-grown trees in a farm of 4 hectares that had been irrigated by gravity from a well. The entire area could not be irrigated regularly as the entire well dried

within a short period. The yield was about 30 to 40 nuts per tree per year. However, after adopting drip irrigation system, the entire area was irrigated daily and more area was brought under cultivation. The yield increased to 60 to 75 nuts per tree within a year of installation of the drip system.

1.4.1.5 Adoption of Low Delta Crops

High delta crops such as sugarcane and rice not only consume a major portion of the available water but also contribute to waterlogging. At present, sugarcane is sown at about 1.0 million hectares and consumes about 6.0 MAF of water in addition to huge deep percolation losses. The high delta crops can be substituted with low delta crops of high value and marketing. Strategy should be adopted to introduce low delta crops in the cropping pattern, when there is water shortage. This would help generate income rather than complete failure of high delta crops. Low delta crops with good returns therefore, should be introduced in the cropping pattern.

1.4.1.6 Enhancing Water Availability

Groundwater Quality Zonation

In the Indus Basin the native groundwater is saline due to underlying marine geological formations. However, in most irrigated areas of Pakistan, a thin layer of freshwater overlays saline water as a result of seepage from the rivers and the irrigation systems. It has been estimated that nearly 200 billion cubic meters (BCM) of freshwater lies on saline groundwater in the Indus Basin. The safe groundwater yield is estimated to be 55 MAF. Groundwater quality is highly variable in time and space. Over exploitation of groundwater however, has resulted in upconing of saline water in most of these areas. It is therefore imperative to identify thickness of freshwater so that the same is pumped by using appropriate technologies without disrupting the saline freshwater interface. Geo-physical survey/resistivity survey has widely been used to demark the interface between the saline and fresh groundwater.

Installation of Skimming Wells

Skimming well may be regarded as a technique used to pump from freshwater layer without disturbing fresh-saline water interface. The thin fresh water layers overlain by saline water

can therefore be harnessed by skimming wells. Different skimming well technologies are being used to extract from these fresh groundwater lenses. The discharge rates of these skimming wells are low as compared to deep wells.



Figure 1.5: A Multi-Strainer Skimming Well Installed in Shallow Freshwater Aquifer

Use of Low Quality Water

Groundwater is a major source of irrigation water, constituting nearly 60% of the total irrigation water available at the farm gate. Most of these groundwater supplies are however, inferior to canal water. Out of a total estimated 6,00,000 privately owned tubewells used for irrigation in Pakistan, nearly 70 percent pumped water of inferior quality either due to high residual alkalinity, sodium adsorption ratio or soluble salts. The contribution of low quality waters in irrigated agriculture is only 21% of the total irrigation water supply in Pakistan Punjab, however, in the state of Haryana and Punjab provinces of India, it is to the tune of 46 and 65%, respectively. On the country basis, the overall contribution of low quality water is about 32% (Gupta *et al.* 1994). For the analogous conditions of fertilizer use, productivity of rice and wheat crops grown on partially reclaimed alkaline soils is higher in India than in Pakistan. This clearly suggests that agricultural productivity can be significantly improved in these environments through the use of low quality waters with appropriate amendments. Low quality groundwater can significantly increase the irrigation water supplies if conjunctively used with canal water.

1.4.1.7 Proper Irrigation Scheduling

The year 1999-2000 was a drought year yet about 2.0 million tons of surplus wheat was produced. The high yield of wheat indicates that in the previous years over irrigation was practiced. Over irrigation not only wastes water but also leaches the precious soil nutrients out of the root zone. Over irrigation also contributes to water logging and groundwater pollution. Proper irrigation scheduling helps, when to irrigate and how much to apply. This issue is mostly related to awareness and education of the farmers. Table 1.2 gives crop water requirement of some major crops.

Table 1.2: Water Requirements of Major Crops

Crop	*Average Seasonal Water Requirements (mm)*
Wheat	317
Sugarcane	1451
Cotton	631
Rice	960
Maize	354

Source: Reservoir Newsletter, PCRWR, Vol. 19, No. 3, 2001.

1.4.1.8 Improved Cultural Practices

Zero-Tillage Technology

In rice-wheat rotation system, after harvesting of rice, sufficient moisture is available. If the soil is ploughed as is conventionally practised, it not only wastes the moisture present in the soil but also causes extra financial burden on farmers in term of ploughing, planking and pre-sowing water applications (*rouni*). It also unnecessary delays the wheat sowing for couple of weeks that finally affects the crop yield. Nevertheless, these fields could be sown with zero tillage technology, well in time with minimum labour and without *rouni* irrigation. In zero tillage or direct planting, seed is placed directly in the uncultivated field with the help of a seed drill. Several kinds of seed drills have been developed for the purpose. Direct planting increases the soil fertility especially the organic matter in the soil, infiltration and moisture retention. Because of less tractor wheel traffic, surface soil compaction is reduced. In contrast, ploughing of soil reduces its organic matter. Tillage and hoeing are extremely

laborious and energy consuming. Therefore, availability of labour and machinery are the deciding factor in the adoption of zero tillage technology.

In America 17.3 million hectares (Mha) are grown with zero tillage whereas in Brazil 5 Mha are sown with this technique. The technique was first developed in Brazil in early 1970s to check massive soil erosion. Moreover, 3 Mha of land is sown with zero tillage in Argentina. In Africa, zero tillage is applied mainly in South Africa and Zimbabwe and to a lesser extent in Kenya and Tanzania (Steiner *et al.*, 1998). Zero tillage technology was introduced in Pakistan during 1997 by the OFWM, Punjab and presently, more than eighty thousand hectares of wheat are sown with zero-tillage drill technology (Iqbal *et al.*, 2002).

1.4.2 Technologies for Barani Areas

The barani agriculture contributes about 10% of the total agricultural production and merely depends on the rainfall. In context of crop production, barani lands have often been underestimated. However, more than 1200 kg/acre of wheat have been produced in these areas under rainfed conditions (Ashraf and Mian, 1979) which reveals a high potential for crop production. Water is the only limiting factor for agriculture development in these areas. The occurrence of rainfall in barani areas is erratic and its spatial and temporal variation is high. Most of the rainfall occurs during monsoon (July to September). Due to uncertainty of rainfall, farmers normally use less input to reduce the risk of loss under low rainfall condition. Nevertheless, there is high potential for the development and management of water resources and therefore crop yield could be increased many folds by adopting proper water resource development and management practices.

1.4.2.1 Small Dams/Mini Dams

It has been estimated that about 9 million acre feet (MAF) of water is lost as surface runoff from Barrani regions annually (Latif, 1979). Therefore, much of the summer rain is not available for agriculture because of the surface runoff. If 50% of this runoff is retained in small/mini dams, water more than half the capacity of the Tarbela Dam could be stored. There are many potential sites for the construction of small/mini dams in northern areas of the country as well as in Pothwar region. The government of Punjab has constructed 32 small dams in the Pothowar regions. Besides supplying irrigation water, these dams have many indirect benefits. They help recharge the groundwater, provide water for domestic and municipal purposes, control soil erosion, control floods in hilly and plain tracts, help to

develop fish culture, and also provide recreational activities. There are several issues relating to these dams that need to be addressed, such as development of command area, low water conveyance and application efficiencies, reduction in reservoir capacity due to sediment deposition and vegetation growth, evaporation and seepage losses. Reports compiled by IWMI and NESPAK reveal that presently only 23% of the stored water is being utilized and cropping intensity is 60% against projected Figure of 130%. Thirty two numbers of small dams in Pothwar region have been constructed and nineteen are in process



Figure 1.6: A View of Small Dam

1.4.2.2 Watershed Management

Non-existent watershed management and natural and man induced erosion of the fragile barani soils has resulted in the depletion of the soil and water resources. Runoff in these areas causes soil erosion and sediment transport which is being deposited in the reservoirs. It has been estimated that water coming from different watersheds of Indus basin carries about 350000 acre feet of suspended sediment per year, perhaps one of the greatest sediment load in the world, and about 200000 acre feet of these sediments is deposited in reservoirs and canals (Belaud *et al.*, 1998). In addition, these sediments carry many organic and inorganic materials with them, particularly phosphorus adsorbed at the silt particles is carried into the lakes, and reservoirs and eutrophicate them. The vegetative growth in dams, streams and lakes also indicates that top fertile soils from the catchments are being brought into these reservoirs thus, converting the productive land into non-productive. Insoluble pesticides are carried to the waterways by the sediments and affect aquatic life. The world largest earth fill

dam Tarbela has lost about 35% of its reservoir capacity within twenty-four years. Similarly, Warsak and Khushdil Khan reservoirs have almost silted up. Therefore, it is imperative that immediate attention is given to watershed management.

1.4.2.3 Pressurized Irrigation Systems

Due to scarcity of water, merely 25% of total rainfed area is cultivated. Obsolete methods of irrigation result in poor application and distribution efficiencies. In most of the area, the land is highly undulated and precision land levelling is, therefore, not a feasible option. As such, gravity irrigation is not possible in these areas. Therefore, it is of utmost importance that this scarce resource is utilized most efficiently.

Small-scale sprinkler and drip irrigation techniques have been successfully introduced in Pakistan, and are particularly well suited to the water scarce barani areas. Application efficiencies can be raised to 75 to 85%, permitting almost full use of scarce water supplies. An additional advantage as compared with surface irrigation is that efficient irrigation can be carried out even where topography is undulated and soil is light textured as is the case in much of the barani areas. Raingun sprinkler and drip irrigation systems have been locally developed which are comparatively inexpensive.



Figure 1.7: Drip Irrigation System

1.4.2.4 Soil and Water Conservation Practices

Contouring

In contouring, tillage operations are carried out as nearly as practical on contours. On gentle sloping lands, contouring reduces the velocity of overland flow. If ridge cultivation is practiced, the storage capacity of furrows is increased, permitting the storage of large volume of water. It has been shown that contour cultivation at good piece of land with grass could reduce watershed runoff 75 to 80% at the beginning of the season.

Strip Cropping

Strip cropping is not a single practice; it is a combination of several good farming practices such as crop rotation, contour cultivation, proper tillage operations, stubble mulching and cover cropping. Strip cropping consists of a series of alternate strips of various type of crops laid out so that all tillage and management practices are performed across the slope or on the contours.

Terracing

The cultivated lands of Pothwar tract are undulated. The levelling of lands is not only costly but also put the soil at the risk of erosion. Terracing is a method of erosion control by constructing broad channels across the slope of rolling land. The function of terracing is to decrease the length of hillside slope, thereby reducing sheet and rill erosion, and preventing the formation of gullies. Terraces not only check erosion but also increase retention of rainwater in the soil for next crop.

Tillage Practices

Generally, the land is deeply ploughed before the outset of monsoon so that maximum moisture can be stored. On the other hand, after the on-set of rains, soil should not be disturbed. Tillage has been the most common practice adopted for improving soil physical condition for crop production. Deep tillage enhances the yield by lowering the soil strength and by increasing the evopotranspiration. Deep tillage also increases the moisture reserves in the soil by retaining rainfall. Before monsoon, the soil surface should be tilled across the slope rather than parallel to the slope. This practice retains maximum rain and conserves the

soil from erosion (Ashraf *et al.*, 1999). However, if the soil is tilled along the slope, it will increase the risk of erosion by developing gullies.

Soil and Water Conservation Structures

To control soil erosion and to conserve soil moisture, structure will be constructed at appropriate locations to dispose off the excess runoff.

1.4.2.5 Water Harvesting Techniques

Any practice that reduces the surface runoff, reduces the risk of erosion and improves the moisture reserves in the soil is regarded as water harvesting. The moisture availability can be improved by adopting conservation practices. The most important of which are: proper bundling, levelling and deep ploughing. Proper bunding and deep ploughing help hold water so that most of the water infiltrate into the soil, while leveling ensures equal distribution of moisture over the whole field. Each millimeter of saved water could increase yield of wheat by an average of about 10 kg/ha (Marshall and Holmes, 1988). The adoption of these conservation practices for a Kharif season increased the crop yield by 14% (Halcrow, 1997). However, for light-textured and sandy soils, the water harvesting technique is to increase the surface runoff and collect it at appropriate places to meet domestic, livestock and agricultural needs.



Figure 1.8: Soil and Water Conservation Practices

1.4.3 Technologies for Deserts

According to an estimate 51% of the Pakistan's land is affected by desertification, which can be brought under cultivation, if available water resources are developed and managed properly, both qualitatively and quantitatively. The main deserts of the country are Thar,

Cholistan, Thal, and Chagi-Kharan (Table 1.3). Desertification in these deserts is significantly active. More than 80% of the Pakistan is semi-arid/arid *i.e.* the areas which receive less annual rainfall. Therefore, most of the population has to derive their livelihood from these arid and semi-arid areas. These areas being potential resources have been depleted due to over exploitation of soil, plant and water resources resulting in desertification.

Table 1.3: Major Deserts of the Country

Name of Desert	*Province*	*Area (ha)*
Thar	Sindh	4,300,000
Cholistan	Punjab	2,580,000
Thal	Punjab	2,300,000
Chagi-Kharan	Balochistan	600,000
Others	-	1,220,000
Total	-	11,000,000

The groundwater in the deserts of Pakistan is generally saline. The soils in such areas are sandy in the form of sand dunes or clayey in the form of dense calcareous alkaline pans. Rainfall is the only source of freshwater in desert. Due to high infiltration rates in sandy soils and high temperatures, most of the rainwater is lost as seepage and evaporation. Moreover, a significant amount of rainfall is lost as runoff. The fresh source of rainwater could however, be collected by adopting rainwater-harvesting techniques and by using appropriate interventions to store and utilize water. Table 1.4 depicts the water harvesting potential in Cholistan. Amount of available water, besides fulfilling domestic and livestock needs, could be used for developing small-scale agriculture with pressurized irrigation systems such as sprinkler and trickle. The saline groundwater could also be used to grow salt tolerant crops with proper management practices. Moreover, drought resistant crops/trees could also be grown in these areas.

1.4.3.1 Rainwater Harvesting

The rainwater harvesting systems consist of: (i) a treated catchment area with a storage facility for storing runoff according to the shape and slope of the land; (ii) guiding the runoff to flow to the pond through a series of interconnected macro and micro channels; (iii) using

improved pond design with less surface area to reduce evaporation; and (iv) plastic lining in bed for seepage reduction. Table 1.5 shows water lost through seepage and evaporation in Cholistan Desert. The area of the catchment and the capacity of the storage pond should match so that neither is over-or under-designed. Typically, such systems are used to provide water for domestic and livestock uses.

Table 1.4: Potential Runoff of the Cholistan Desert

Year	*Total Rainfall (mm)*	*Potential Runoff for Storage (mm)*	*Total Runoff (MCM)*
1995	213.0	150.0	663
1996	152.0	96.0	424
1997	201.0	75.0	331
1998	172.0	72.6	320
1999	20.8	Nil	Nil
2000	34.52	Nil	Nil
2001	40.52	Nil	Nil
2002	52.23	10.23	20.25

1.4.3.2 Saline Agriculture

The secondary source of water in the desert is groundwater, which is mostly moderate to highly saline. This water is not useable for human drinking due to high salinity. However, the saline water has been used in many countries for agricultural purposes. Salt-tolerant plants can utilize land and water unsuitable for salt-sensitive crops for the economic production of food, fodder, fuel, and other products. Halophytes (plants that grow in soils or waters containing significant amounts of inorganic salts) can harness saline resources that are generally neglected and are usually considered impediments rather than opportunities for development. Many of these barren lands can become productive by growing selected salt-tolerant crops and employing special cultural techniques using brackish water for irrigation.

Table 1.5: Water Losses from a Pond in Cholistan Desert

Month	*Seepage losses (mm)*	*Evaporation losses (mm)*	*Total water losses (mm)*
September 1989	409.0	278.0	687.0
October 1989	153.0	205.0	358.0
November 1989	120.0	142.0	262.0
December 1989	114.0	67.0	181.0
January 1990	114.0	95.0	209.0
February 1990	113.0	68.0	181.0
March 1990	80.0	173.0	276.0
April 1990	22.0	254.0	276.0
Total	1125.0	1282.0	2430.0

Source: Akram *et al.* (1990).



Figure 1.9: Harvested Rainwater in Cholistan Desert

In Cholistan Desert, possibility of using saline groundwater with an EC 2 to 16 dS m^{-1} for different crops has been explored (Table 1.6). The results of continued use of saline water irrigation for five year showed that saline water with EC upto 8 dS m^{-1} can be successfully used for wheat without any appreciable reduction in the yield on a sandy loam soil (Akram *et al.*, 1999). The salt tolerance of some plants enables them to produce yields under saline conditions that are comparable to those obtained from salt-sensitive crops grown under non-saline conditions. The maximum amount and kind of salt that can be tolerated by halophytes and other salt-tolerant plants varies among species and even among varieties of the same species.

Table 1.6: Groundwater Quality in the Cholistan Desert

Location	*No. of Wells*	*Water Quality*				*Water-table Depth (m)*
		EC (dS m^{-1})	*pH*	*SAR*	*RSC (meq/l)*	
Dingarh	6	4.2-8.0	7.2-7.6	14-32	5.6-14.5	17-19
Bariwala	1	11.0	7.6	43	8.2	15
Kura khu	1	10.0	8.3	76.75	13.0	24
Bhambowala	1	12.4	8.0	73.30	11.8	17
Balouchni walla	1	22.0	8.3	88.5	10.5	11
Channanpir	1	29.8	8.8	207.85	54.0	11
Nagarwala	1	3.9	8.5	18.54	6.5	15
Maujgarh	4	3.0-16.5	8.2-8.9	4.45-67	12-13.4	19-22
Dakwala	1	1.35	8.5	18.54	6.5	26
Islamgarh	3	2.4-5.0	7.2-7.8	0.97-1.36	0.9-5.8	38-40
Bahikhanwala	5	4.4-6.0	7.3-7.8	2.0-2.7	5.2-22	31
Kalwarwal	2	5.7-5.9	6.5-6.7	1.61-1.73	42-4.6	35

Source: Akram *et al.* (1990).

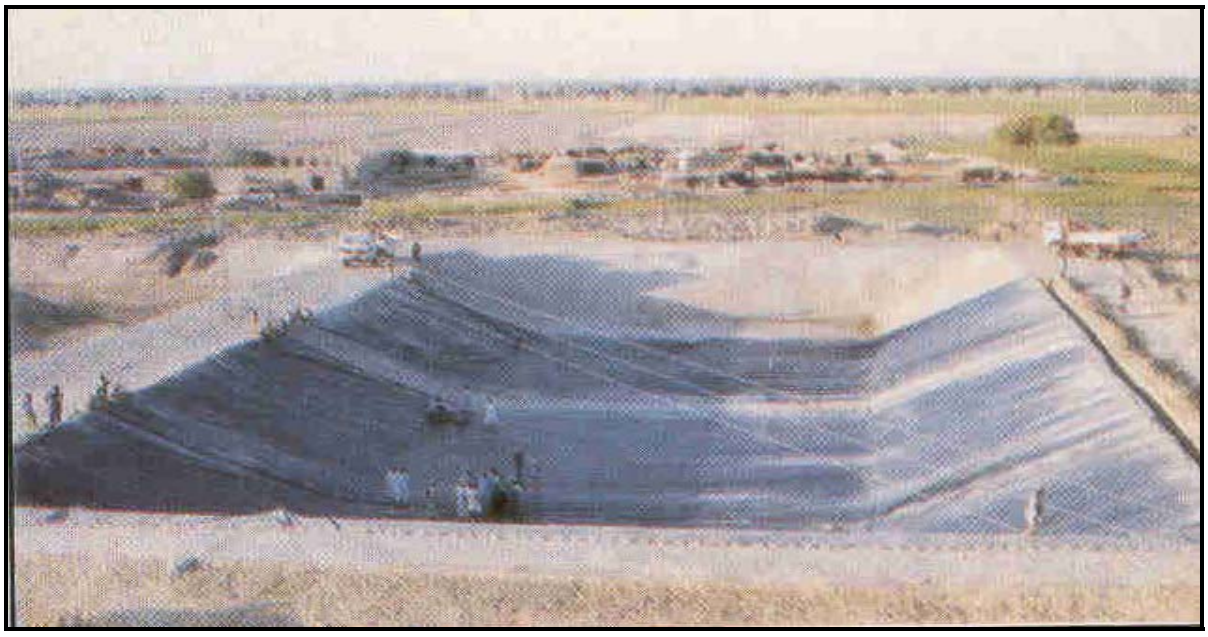


Figure 1.10: Polyethylene Lining of Pond to Control Seepage



Figure 1.11: Forest Developed with Saline Water Irrigation in Cholistan

1.4.3.3 Afforestation by Drought Resistant Plants

Overgrazing is the most important factor that increases desertification. Cattle left uncontrolled disturb the settled top layer of fields, which attracts erosive elements. Moreover, illegal tree cutting also accelerates land degradation. Sustainable soil management requires the soil be protected all round the year by mulching/crop residues. The crop residues favour

both water infiltration and soil organisms. Soil erosion increases as the percentage of soil surface cover (vegetative cover, mulches *etc*.) decreases. It is therefore imperative to have maximum surface area covered with crops, trees and shrubs *etc* and overgrazing should be controlled. Cutting of vegetation for fuel is a common feature near all habitation in Cholistan, where these natural resources are being over utilized (Table 1.7). The problem is very serious due to lack of other energy sources.

Table 1.7: Extent of Vegetative Covers in Cholistan Desert

Vegetation Cover	*Area (ha)*	*Share (%)*
Good vegetation (20-50%)	525000	20
Moderate vegetation (5-20%)	1613100	63
Poor vegetation (less than 5%)	441900	17
Total	2580000	100

Selection of crops and their varieties and adoption of suitable agronomic practices are important factors in the success of agriculture in the desert areas. Plantation of drought tolerant, short duration and long-rooted plants could be an appropriate option to mitigate soil erosion and to combat desertification.



Figure 1.12: Vegetation to Control Wind and Water Erosion in Cholistan

1.4.3.4 Livestock, Saline Fishery and Honeybee Keeping

An integrated approach is essential to develop deserts. Livestock can be developed on pasture lands irrigated by saline water. Arable land of 2.0 hectares per family can be used for fruit tree plantation and vegetable production for family consumption. At the same time these forests/pasture can be used for honeybees. Moreover saline groundwater could be used for aquaculture. The forage requirement in terms of dry matter per day for sheep, goat, cattle, and camel is given in Table 1.8.

Table 1.8: Forage Requirements of Different Animals

Animal	*Daily Requirements (kg/day)*	*Annual Requirements (kg/year)*
Sheep	2.5	900
Goat	3.0	1,100
Cattle	12.5	4,600
Camel	25.0	9, 100

Productions of fodder grass per hectare in terms of dry matter ranges from 12,000 kg to 18,000 kg per annum, depending on the variety of grass species.

1.4.4 Technologies for Upland Mountainous Areas

The upland mountainous areas are those located at very high altitudes. In such areas, a big portion of precipitation comprise of snow fall and hail. Those areas are characterized by steep slopes, high runoff and high velocities. In Pakistan, northern areas and Balochistan plateau fall in this category.

1.4.4.1 Northern Areas

In northern areas, natural streams flow downhill. However, people living on both sides of the streams are unable to use it due to steep slopes. They have to travel long distances to f*etc*h water for their household needs. Nearly all irrigation is done through Khuls and leaky channels usually constructed and maintained by the farmers, collectively.

Khuls

Khuls carry water through a crude intake structure from mountain stream. The Khul system is however restricted to higher elevations.

Lift Irrigation System

Northern areas have high potential for the execution of lift irrigation schemes. There are several locations in the area where perennial flow of water is available in the low-lying areas and there are fertile lands on either sides of the stream. Thus this water flows without benefiting the areas. Moreover, the availability and cost of fuel are major concerns for the execution of such schemes. Therefore, highly productive lands remain uncultivated due to non-accessibility of water. Renewable water lifting schemes such as hydraulic ram pump and water turbine pumps however, can easily be installed in these areas to pump water. The water thus pumped may be used for domestic, livestock and agricultural purposes.

Hydraulic Ram Pump

A hydraulic ram pump is a simple, fuel-less device used to pump water from these streams at low discharge. It uses the energy of flowing water to lift water from a stream, pond, or spring to an elevated storage tank or to a discharge point. It is suitable for use where small quantities of water are required and power supplies are limited, such as for household, garden, or livestock water supply. It may be coupled with low-pressure drip irrigation system. A hydraulic ram pump is useful where the flow is perennial and a drop of at least 1 m is available. Water flows from the source through the drive pipe and escapes through the waste valve until it builds enough pressure to suddenly close the waste valve. Water then surges through the interior discharge valve into the air chamber, compressing air trapped in the chamber. When the pressurized water reaches equilibrium with the trapped air, it rebounds, causing the discharge valve to close. Pressurized water escapes from the air chamber through the check valve guiding the delivery pipe to its destination. The closure of the discharge valve causes a slight vacuum, allowing the waste valve to open again, initiating a new cycle. The escaping water rejoins the stream. The cycle repeats 20 to 100 times per minute, depending on the flow rate. If properly installed, a hydraulic ram operates continuously without any operation and maintenance cost. Hundreds of sites are available in the northern

part of the country, where this renewable energy pump could be installed with low cost and water could be pumped a day throughout the year without any operational cost.

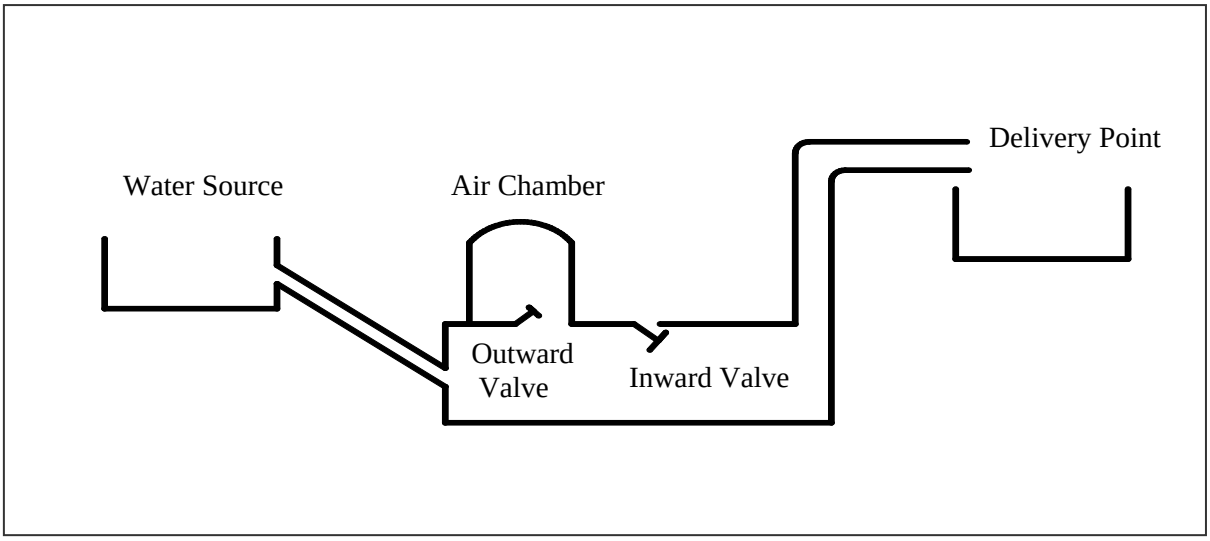


Figure 1.13: Schematic Diagram of a Hydraulic Ram Pump

1.4.4.2 Upland Mountainous Areas

Balochistan is an arid mountainous region (Figure 1.14) receiving an average annual rainfall of about 200 mm. According to the 1998 Census, the population of Balochistan is 6.511 million against 4.332 million in 1981 with an overall increase of 50.3% (Figure 1.15). Mean annual rainfall in Quetta valley is 234 mm and the total crop water requirement is 1072 mm (MINFAL, 2000). Therefore, about 5 times less rainfall is available than the total crop water requirement (if 100% rainfall is assumed as effective rainfall). This shortfall has to be met by groundwater abstractions. In Balochistan, the cultivable land and the number of tubewells have been drastically increased in the last two decades (Figure 1.16).

Due to increased and indiscriminate extractions, the groundwater has been depleted. The current level of water extraction is well beyond the sustainable level and groundwater is being mined causing a drop of more than 2 m per year in the water table in some areas. With an increase in the water-table depth, the groundwater pumping becomes uneconomical. Therefore traditional sources of groundwater are being dried. In Balochistan, rainfall is low therefore the runoff spreads over a large area and evaporates back to atmosphere without contributing to the groundwater. Therefore, it becomes imperative to let this precious resource be stored at suitable places with appropriate technologies so that maximum water

could infiltrate and contribute to recharge the aquifer for its subsequent uses at the time of need. The area irrigated in Balochistan by different sources is given in Table 1.9.

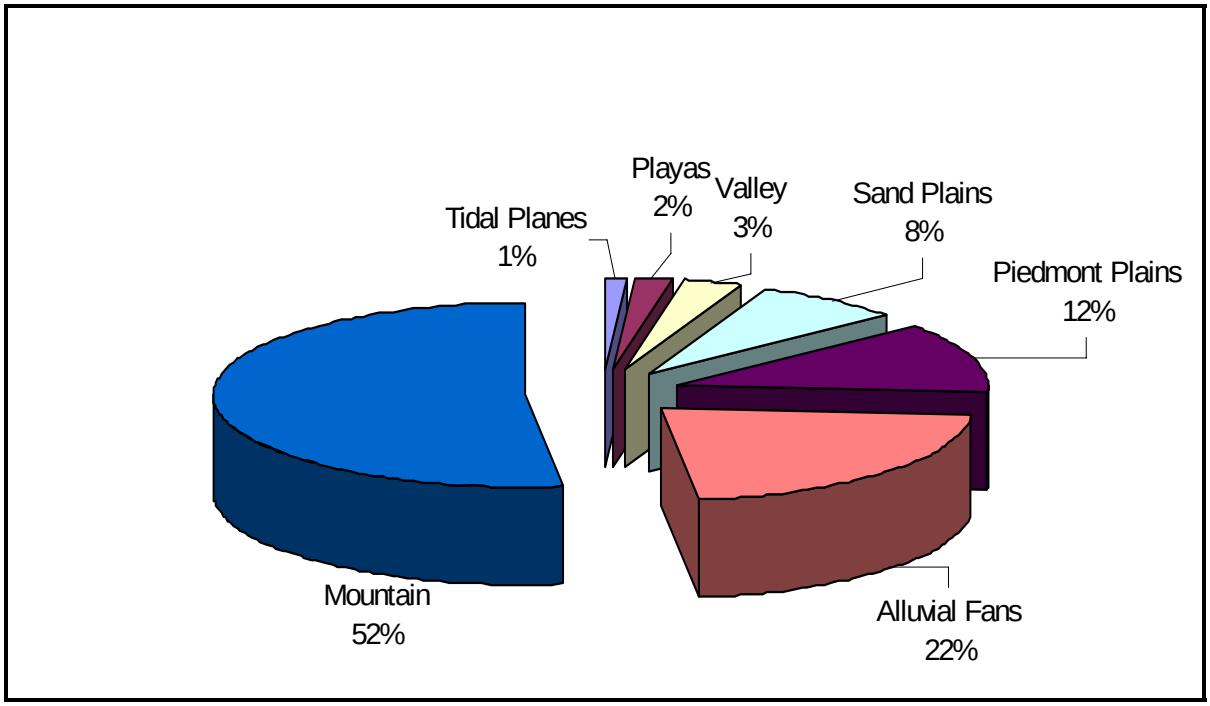


Figure 1.14: Distribution of Landforms in Balochistan

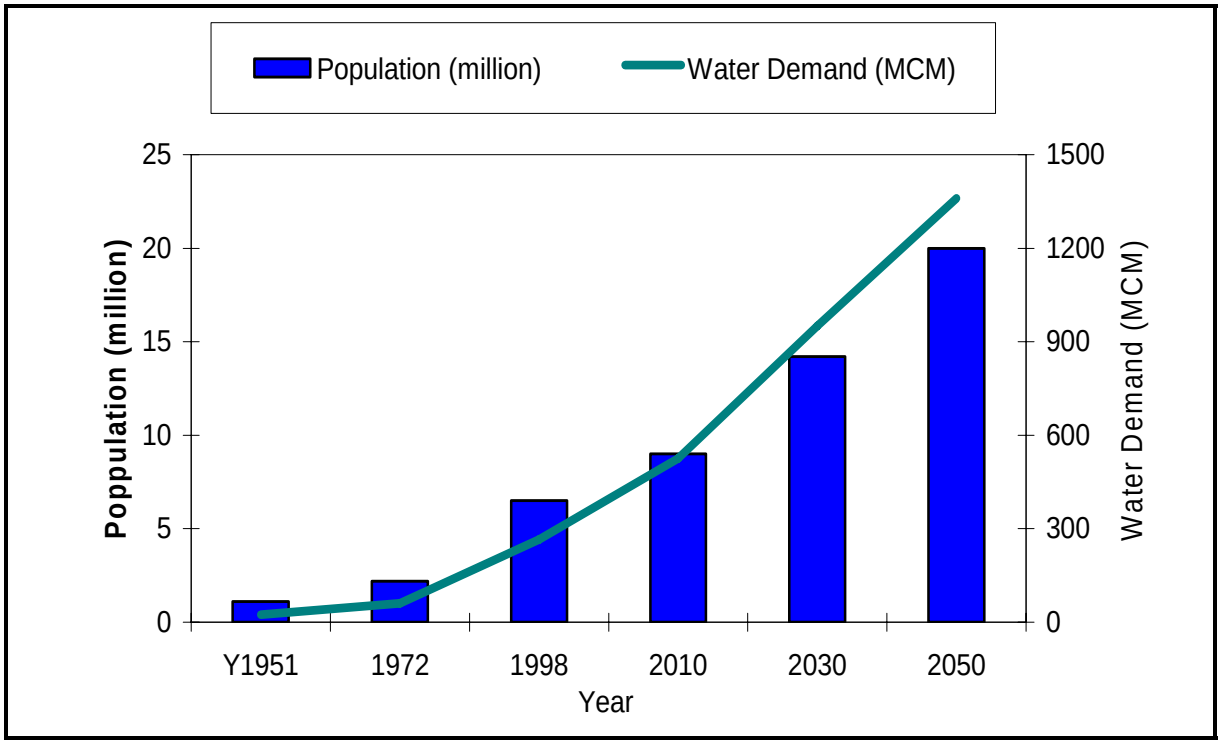


Figure 1.15: Projected Water Demand and Population Rise in Balochistan

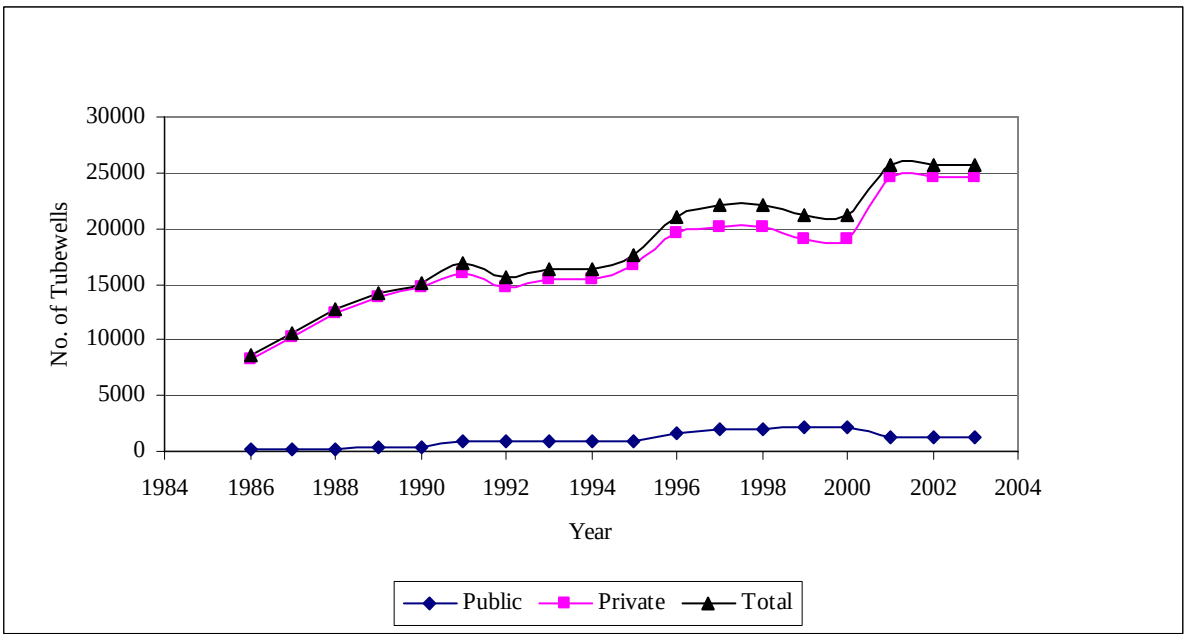


Figure 1.16: Increase in the number of Tubewells in Baluchistan

Table 1.9: Area Irrigated by Various Sources in Balochistan

Sr. No	*Sources*	*Area Irrigated (000 ha)*	*Percentage of Total*
1	Canal Irrigated	494	29.30
2	Sailaba (Flood and Khushkaba WaterHarvesting)	843	50.00
3	Karezes and Springs	100	5.93
4	Tubewell	235	13.94
5	Wells	14	0.83
Total		1686	100

Source: Agriculture Statistic of Balochistan 1995-96

Artificial Recharge

In order to increase the annual safe yield of an aquifer, artificial recharge measures can be undertaken. Artificial recharge is the deliberate process of replenishing water into the groundwater storage through works. A number of methods have been developed to recharge groundwater artificially. The most widely used are delay action dams, percolation basins, modified streambeds, diversion structures, ditches, furrows, and injection wells. Delay action

dams delay the passage of flood flow by retaining it behind an impoundment structure. Recharge thereby takes place by infiltration behind the structure through the bed and sides of the reservoir. It also causes more recharge in the downstream of structure due to reduced velocity of flow through controlled release. In either case the reservoir acts as a sediment trap. Regular maintenance is therefore required in the form of sediment removal, either by hand or by flushing through gates or spillways. Failure to control the sediment deposition can seriously affect the life of dam. Delay action dams typically have high initial recharge rates, which fall dramatically with time. Table 1.10 presents some rivers of Balochistan and their runoff

Table 1.10: Average Annual Runoff of the Rivers of Balochistan

Sr. No.	*River*	*Catchment Area (Mha)*	*Average Annual Runoff (MCM)*
1	Bolan	0.40	63
2	Chattar	0.22	109
3	Dasht	2.52	279
4	Hingol	3.44	1990
5	Hub	0.93	247
6	Kaha	0.57	476
7	Lahri	0.39	190
8	Nari	2.15	560
9	Porali	1.29	569
10	Sanghar	0.49	416
11	Shadi	0.43	132
12	Sori Janubi	1.71	204
13	Vehowa	0.26	159
Total		*14.80*	*5394*

Artificial recharge is also done by leaky dams with the concept to accelerate recharge by releasing water into downstream channels of rivers and streams. This is done as soon as the silt settles in the reservoir. The design and construction of leaky dam are on principles of leaky embankments and release of the silt free water to downstream areas for infiltration,

because the river and stream beds usually remain porous as have variable deep layers of mixed, boulders, cobbles, gravel, sand, silt and clay. Once, the runoff water is made part of shallow to deep aquifer, it becomes immune to evaporation losses and conserved for future.

Watershed Management

Watershed management is defined as the process of formulating and carrying out a specific course of action involving manipulation of the natural system or watershed to achieve specified objectives, without adversely affecting land, water and vegetation resources. Watershed management also helps recharge the aquifer. Watershed management measures have been introduced in a number of catchments in Balochistan to control surface runoff, reduce soil erosion, and encourage re-vegetation of watersheds confounded by overgrazing.

A major feature of watershed management is the construction of contour bunds/trenches and the replanting of appropriate plant species within the bunded areas. This reduces the rate of runoff by trapping and delaying the water, some of which is taken up by the plants. There is an associated reduction in the level of silt carried in the overland flow and ultimately in the flood flow. The watershed management practices such as trenching and replanting the catchment may enhance recharge to the groundwater aquifer by increasing infiltration. The potential to increase groundwater recharge through watershed management may result in a significant positive impact upon regional water resources of Balochistan.

High Efficiency Irrigation Systems

The water available in Balochistan would be very costly due to: (i) cost involve in recharging the aquifer; and (ii) pumping the same water to the surface. Such water could not be used to grow conventional crops with conventional irrigation methods. Therefore, growing high cash crops/orchards and the adoption of high efficiency irrigation systems such as bubbler and drip become imperative.

1.4.5 Technologies for Coastal Area

The coastal areas of Pakistan are prone to seawater intrusion which greatly affects its groundwater and agriculture. Water management programme in the coastal areas will therefore be limited to monitoring seawater intrusion in the coastal areas. The technologies include rainwater harvesting ponds, installation of wind mills and installation of water distribution system.

Installation of Wind Mills

A wind mill is a machine designed to convert the energy of the wind into more useful forms using rotating blades. In much of the cases, wind mills served to grind grain, later applications include pumping water. Due to high velocity wind available in the coastal areas, wind mills are the cheapest water lifting devices which can be feasibly adopted to regulate water supplies from the rainwater harvesting ponds to the end consumer.

Water Distribution System

The transportation of harvested water from the ponds to the livestock and humans is also very important as the ponds are located at a substantial distance. Therefore, the harvested water would be channelized through distribution system for its efficient usage.

CHAPTER 2

MATERIALS AND METHODS

2.1 SITE SELECTION

Thirteen pilot sites have been selected in all agro-climatic zones of Pakistan in order to implement site-specific package of water management technologies as detailed in Table 2.1 and shown in Figure 2.1:

Table 2.1: List of Sites Established under PNIWMP

Sr. No	*Zone*	*Province (No of Sites)*	*Location*
1	Irrigated Areas	Punjab (5) Sindh (2)	Bhalwal, Hafizabad, Pakpatan, Kotsumblawala, Bahawalpur, Tando Ghulam Ali and Matli & Tilhar
2	Deserts	Punjab (1)	Hyderwali, District Bahawalpur
3	Northern Areas	NWFP (1)	Makedam valley, District Swat
4	Coastal Areas	Sindh (1)	Murad Ali Brohi, District Thatta
5	Upland Mountainous Areas	Balochistan (1)	Chashma Achozai, District Quetta
6	Rainfed Areas	Punjab (1)	Gujar Khan, District Rawalpindi
7	Azad Jammu and Kashmir	AJ&K (1)	Sehnsa, District Kotli

2.1.1 Site Selection Criteria

The sites have been selected considering the agro-climactic zone, water availability, groundwater quality, farm size, farmers' motivation, cropping pattern *etc*. The local agriculture departments were consulted before finalization of appropriate sites. Small and medium farmers with less than 10 hectares of landholdings were the main target of the project. Pilot projects have been initiated in irrigated, rainfed, deserts, upland mountainous, coastal and AJK areas of the country. In irrigated areas, 7 sites were selected each having an area of about 80 hectares, whereas the farm size of each pilot site in the rainfed, coastal and AJK areas were 40 hectares. In Balochistan and NWFP, the farm size is 20-40 hectares. It

was intended to maximize the number of beneficiaries at each pilot site with the aim to develop community level organization and participation of stakeholders in the agricultural developmental activities. This would help in wide-scale adoption of successful technologies amongst the community, which is one of the main objectives of the project.

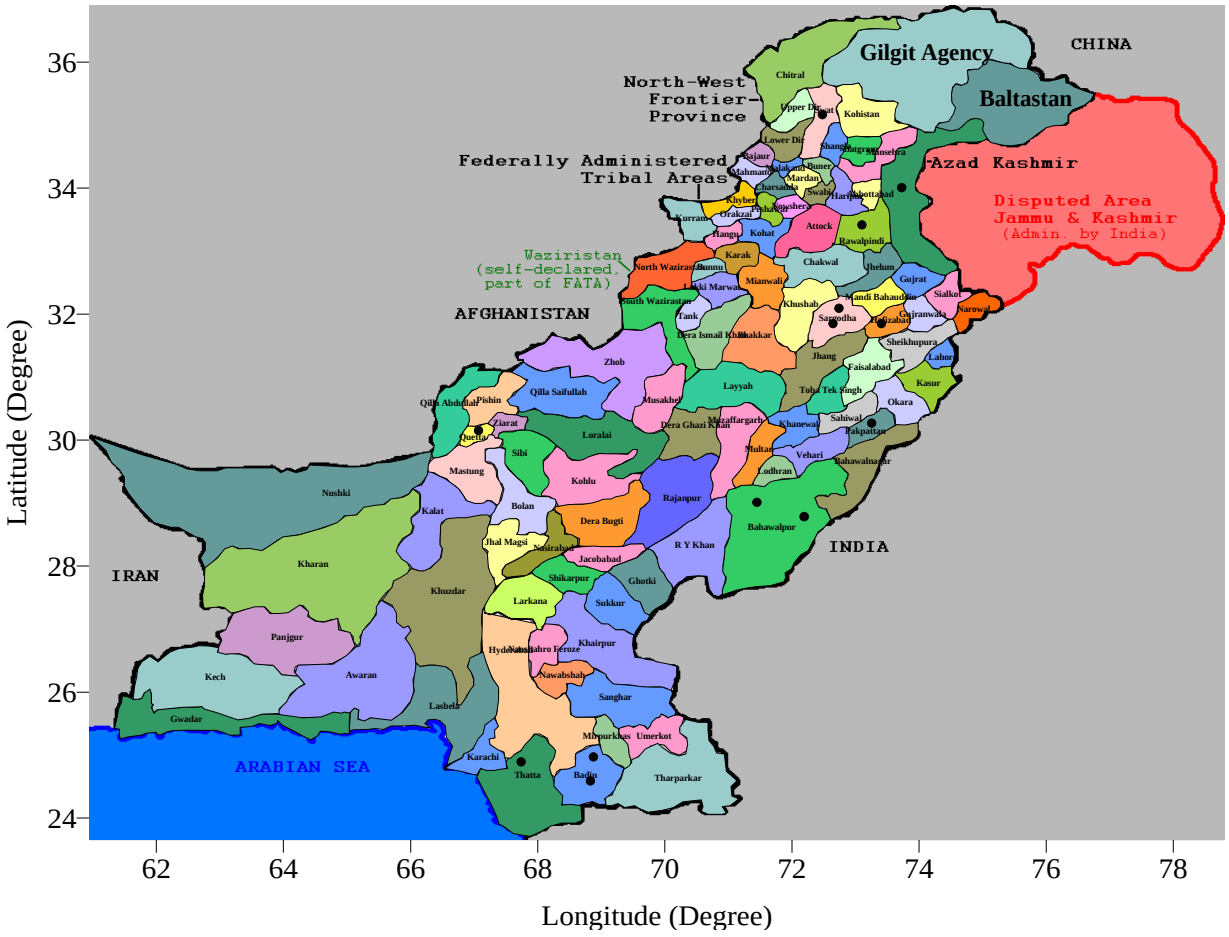


Figure 2.1: Location of Pilot Sites Established under the Project (●)

2.2 BASELINE SURVEY

Baseline surveys of the selected sites were conducted to determine general topographic features, existing and prospective water management technologies, number of stakeholders, their motivation level and degree of organization, *etc*. All these technical and social aspects were compared to determine the degree of suitability of each site for the project. Thereafter, topographic survey of the finally selected sites was conducted to develop maps in order to plan and implement different water management technologies. A detailed socio-economic survey of all pilot sites was carried out to assess pre-project status of the sites in order to establish benchmarks to be used later as indicators for the post project evaluation.

2.3 SOCIO-ECONOMIC SURVEY

The pre-project socio-economic status of each site was assessed by site-specific questionnaires, developed and pre-tested in the field. The survey included information like cultural practices, cropping pattern, cropping intensity, land use intensity, area irrigated by each farmer, cost of sowing *etc*. Moreover, data on soil type, infiltration rate, field size, stream size, conveyance and application efficiencies, water quality, crop variety, sowing time, cropping intensity, crop yield *etc*. were also recorded.

The collected information helped refine package of appropriate technologies identified for each site. However, the package was further refined and finalized in consultation with the local collaborating organizations. The package of technologies has been described in Chapter 1.

For maximum stakeholder participation in the developmental activities, the farmers of each pilot site were organized in the form of Water Users' Association (WUA). An agreement was signed with the WUAs are involved in all day to day activities of the project and has been made responsible for the operation and maintenance of the systems after completion of the project in order to ensure its sustainability.

2.4 DATA COLLECTION

The data regarding all technical and socio-economic aspects of the pilot sites prior to any developmental activity have been collected; the post-project data will be collected after implementation of project activities. This will help assess the impact of the project and provide guideline to develop plan for country-wide implementation of appropriate water management technologies.

CHAPTER 3

PRE-DEVELOPMENT SOCIO-ECONOMIC STATUS OF PILOT SITES

3.1 IRRIGATED AREAS

Seven sites were selected in canal irrigated areas, out of which five exist in Punjab and 2 in Sindh. The detailed pre-development status of each site is given in the following sections:

3.1.1 Site 1

The site 1 is located at Chak No. 10 ML Bhalwal, District Sargodha in the command of watercourse No. 62394-L having a gross commanded area of 32 ha, out of which 31 ha is cultivated. Most of the fields are unleveled. The site is owned by 5 farmers, two possessing more than 6 ha, two with 2-6 ha and one with 2 ha of lands. Twenty percent farmers are illiterate.

3.1.1.1 Sources of Irrigation

Tubewells and canal water, both are available at the farm but canal supplies are insufficient. There is an annual closure of one month in the peak demand period *i.e.* December/January. As the canal water supplies are insufficient to fulfill the irrigation requirements, therefore groundwater is used to supplement irrigation. All farmers use both canal and tubewell water, conjunctively.

Watercourse

A watercourse No. 62394-L, off taking from Ratto Klan minor irrigates a gross command area of 32 ha. An open flume type outlet exists on the canal with a sanctioned discharge of 115 lps whereas the measured discharge of the outlet was 90 lps. The watercourse is unlined with a total length of 915 m. There is a lot of vegetation and trees on the watercourse banks (Figure 3.1). It follows a zigzag path, along which its flow-section varies from place to place. The slope of watercourse is also uneven, consequently giving rise to dead storages at a number of points. As there is no paved way for the passage of animals therefore, ponds have been developed in the watercourse.



Figure 3.1: Existing Condition of Watercourse No. 62394-L

In addition, sewerage water of the village is disposed off in the watercourse, causing blockage of the watercourse and contamination of water. Due to degree of unevenness of fields and flow availability at different reaches of the watercourse, time taken to irrigate one acre of land varies along the length of the watercourse. Therefore, reach-wise irrigation time and conveyance losses were measured with a cutthroat flume (Figure 3.2).



Figure 3.2: Measurement of Conveyance Losses

It is evident from Table 3.1 that irrigation time increases along the length of the watercourse. The average conveyance losses of the watercourse were found to be 3.43 lps/100 m *i.e.* 35%. The previously measured conveyance losses of watercourses by different agencies vary from 25 to 50% (Table 1.1). The application efficiency of the farm fields were also measured by

moisture contents measurements through composite sampling of fields at 3 locations. The overall irrigation efficiency was 44 percent (Table 3.1).

Table 3.1: Irrigation Time, Conveyance Losses and Efficiencies

Parameter	*Head*	*Middle*	*Tail*	*Average*
Irrigation Time (hours/ha)	4.32	5.14	5.97	5.14
Conveyance Losses (lps/100 m)	3.27	3.42	3.60	3.43
Conveyance Efficiency (%)	62	65	68	65
Application Efficiency (%)	69	66	63	66
Irrigation Efficiency (%)	43	43	43	43

Tubewells

Three out of 5 farmers have installed diesel operated tubewells at their farms to meet shortage of canal supplies. The depth of well varies from 30 to 48 m. Table 3.2 shows that overall groundwater quality was unfit for irrigation.

Table 3.2: Chemical Quality of Groundwater

T/W No.	*EC (dS/m)*	*pH*	*TDS (ppm)*	*SAR*	*RSC (meq/l)*	*Remarks*
1	2.8	8.5	1988	15	8.0	Unfit
2	2.7	8.1	1945	18	11	Unfit
3	1.4	8.3	987	5.5	3.6	Unfit

3.1.1.2 Irrigation Practices and Soil Classification

Flood irrigation method is mostly adopted at the site (Figure 3.3). The fields usually form half or quarter of an acre. Soil infiltration rate was measured by double ring infiltrometer. The average infiltration rate at the site was found to be *8 mm/hr*. The texture and chemical properties of the soils were determined by mechanical and chemical analysis of soil samples, respectively. Samples were collected from different horizons of the soil profile *i.e.* 0-15, 15-30, 30-45, 45-60, 60-90 and 90-120 cm, from head, middle and tail of the watercourse. The

overall texture of soil at the site is clay-loam where most of the chemical properties of the soil were within permissible range (Table 3.3).

Table 3.3: Chemical and Physical Properties of Soil

Sr. No.	*Depth (cm)*	*EC (dS/m)*	*pH*	*SAR*	*ESP*	*Textural Class*
1	0-15	1.1	7.2	1.3	2.0	Clay Loam
2	15-30	1.1	7.8	1.1	1.9	Clay Loam
3	30-45	4.2	7.7	1.7	2.7	Clay Loam
4	45-60	2.1	7.0	2.1	3.1	Clay Loam
5	60-90	1.7	7.2	2.3	3.4	Clay Loam
Average		*2.04*	*7.4*	*1.7*	*2.6*	*Clay Loam*



Figure 3.3: Conventional Irrigation Practice at the Site

3.1.1.3 Cropping Pattern and Intensities

The cropping pattern of the area is mixed, where citrus orchards occupies a large part of the command area with wheat, fodder and sugarcane as the other major crops. The good quality citrus produced here is not only sold in local markets but is also exported. The cropping intensities of the area during Kharif and Rabi were recorded to be 82% and 84%, respectively with annual cropping intensity of 166% (Table 3.4)

Table 3.4: Cropping Pattern and Intensities (2005-06)

Kharif Crops	*Cropping Intensity (%)*	*Rabi Crops*	*Cropping Intensity (%)*
Orchard	36	Wheat	10
Orchard & Fodder	14	Orchard	28
Sugarcane	15	Orchard, Wheat	14
Fodder	17	Orchard, Fodder	9
Kharif Season	*82*	Sugarcane	12
		Fodder	11
		Rabi Season	*84*

3.1.1.4 Crops Input, Yield and Water Use Efficiency

The mean seed rate in respect of principal crops is summarized in Table 3.5. Generally, farmers use seeds @ 136 and 5310 kg/ha for wheat and sugarcane, respectively. The maximum seed rate for wheat is 200 kg/ha, whereas the recommended is 100 kg/ha. Similarly, for sugarcane the recommended seed rate is 8900 kg/ha. The usage of chemical fertilizers is common in the area due to increased cropping intensities and short supply of natural manures. The recommended fertilizer rate in terms of urea and DAP for wheat is 185 kg/ha and those for sugarcane is 355 kg/ha. Therefore, the fertilizer application was below the recommended level in the area.

The yield of crops depend on many factors including sowing time, quality and quantity of seeds, availability of water, degree of fertility, adequate irrigation at right time, farm management practices and efficient supply of supporting services *etc*. However, land and water management play the most important role as all other inputs depend on it. On average, the recorded crop yields were 3060 and 59,300 (kg/ha) for wheat and sugarcane, respectively (Table 3.5). The water productivity (WUE) of wheat and sugarcane is 1.02 and 4.94 kg/m^3, respectively.

Table 3.5: Inputs, Yield and Water Use Efficiency of Major Crops

Crop	*Seed Rate (kg/ha)*	*Fertilizer*		*Irrigation (No)*	*Yield (kg/ha)*	*Water Use Efficiency (kg/m^3)*
		Urea	*DAP**			
Wheat	136	124	124	3	3,060	1.02
Sugarcane	5310	247	185	12	59,300	4.94

*Di-ammonium Phosphate.

3.1.1.5 Constraints to Crop Productivity

The views of farmers were recorded during the survey to determine the constraints hindering crop productivity. Hundred percent respondents complained of inadequate supply of irrigation water, 80% were having problems with selling their products, 60% were facing lack of storage facilities and 60% complained delayed payments of their sold commodities.

3.1.1.6 Beneficiaries' Participation

The overall irrigation efficiency and crop productivity of the site is low. One of the main reasons is lack of farmers' participation in farm management. In order to have more involvement of stakeholders for improving farm productivity, the farmers of the site were organized in the form of a Water Users' Association (Table 3.6). The WUA is involved in the implementation as well as operation and maintenance of all project activities.

Table 3.6: Water Users' Association (WUA)

Name	*Landholding (ac)*	*Designation*
Malik Sanaullah	10	Chairman
Haji Rehmant	5	Vice Chairman
Malik Mukhtar Ahmed	3.5	Secretary
Hussain Sabir	10	Cashier
Malik Nisar Ahmed	2	Member

3.1.2 Site 2

The site is located in village Jahanian, Tehsil and District Hafizabad. The gross commanded area of the site is 46 ha, out of which 44.5 ha is cultivated. It falls in rice-wheat cropping pattern. The average farm size is 4 ha. There are 11 farmers at the site, five own 2 ha, three 2-6 ha and three more than 6 ha. Only nine percent farmers are illiterate.

3.1.2.1 Sources of Irrigation

Both tubewell and canal water supplies are available at the site. Out of 11 farmers, only 2 exclusively rely on canal water as their fields are close to the outlet, whereas most of others farmers irrigate their fields with canal and tubewell water, conjunctively.

Watercourse

A watercourse No 12300-L off takes from Prem Kot Minor, Kot Nakka distributary. The total length of watercourse is 1443 m and all is unlined. This watercourse has an open flume type outlet with a discharge of 45 lps. Figure 3.4 shows that there was a lot of vegetation and trees on watercourse banks. The discharge varies along the flow resulting in dead storages at a number of locations.



Figure 3.4: Existing Condition of Watercourse No.12300-L

Table 3.7 shows that the time to irrigate a hectare at head is less than at middle and tail reaches. The average conveyance losses of the watercourse were found to be 1.52 lps/100 m. The application efficiency of the field was also measured and the overall irrigation efficiency of the site is around 39% (Table 3.7).

Table 3.7: Irrigation Time, Conveyance Losses and Efficiencies

Parameter	*Head*	*Middle*	*Tail*	*Average*
Irrigation Time (hours/ha)	5.75	8.63	9.88	8.12
Conveyance Losses (lps/100 m)	1.36	1.49	1.71	1.52
Conveyance Efficiency (%)	46	51	58	52
Application Efficiency (%)	79	74	72	75
Irrigation Efficiency (%)	36	38	42	39

Tubewell

Seven farmers have installed their own tubewells, all are electric powered. The depth of well varies from 30 to 82 m. The tubewell water was found fit for irrigation (Table 3.8).

Table 3.8: Chemical Properties of Groundwater

T/W No.	*EC (dS/m)*	*pH*	*TDS (ppm)*	*SAR*	*RSC (meq/l)*	*Remarks*
1	0.75	8.03	533	1.9	1.3	Fit
2	0.9	7.94	639	0.7	1.7	Fit
3	0.79	8.41	561	1	1.9	Fit
4	0.81	8.63	592	1.6	1.5	Fit

3.1.2.2 Irrigation Practices and Soil Classification

Flood irrigation method is commonly practiced at the site. The measured soil infiltration rate was *22 mm/hr*. The infiltration rate at such kind of soils normally ranges from 10-20 mm/hr (FAO, 2006). Soil samples were collected from head, middle and tail of the watercourse up to 90 cm depth. The soil is sandy clay loam in texture (Table 3.9)

Table 3.9: Chemical and Mechanical Properties of Soil

Sr. No	*Depth (cm)*	*EC (dS/m)*	*pH*	*SAR*	*ESP*	*Textural Class*
1	0-15	1.4	7.7	1.8	2.7	Sandy Loam
2	15-30	1.1	7.6	1.2	2.1	Sandy Loam
3	30-45	0.8	7.6	0.7	1.5	Sandy Clay Loam
4	45-60	0.8	7.4	0.7	1.5	Sandy Clay Loam
5	60-75	0.8	7.3	0.9	1.7	Sandy Clay Loam
6	75-90	1.0	7.7	1.6	2.5	Clay Loam
Average		*1.0*	*7.6*	*1.2*	*2.0*	*Sandy Clay Loam*

3.1.2.3 Cropping Pattern and Intensities

Table 3.10 shows the cropping intensities for Kharif 2005 and Rabi 2005-06 were 73 and 76%, respectively and the annual cropping intensity was 149%. The major crops grown were rice (40%) and wheat (52%).

Table 3.10: Cropping Pattern and Intensities (2005-06)

Kharif Crops	*Cropping Intensity (%)*	*Rabi Crops*	*Cropping Intensity (%)*
Rice	40	Wheat	52
Linseed	5	Gram	5
Vegetable	3	Vegetable	2
Fodder	25	Fodder	17
Kharif Season	*73*	*Rabi Season*	*76*

3.1.2.4 Crops Inputs, Yields and Water Use Efficiency

General seed rate for wheat crop was 136 kg/ha and seedlings @ 47000/ha for rice crop. Almost all farmers use chemical fertilizers for their crops (Table 3.11). The average yields of wheat and rice crops are 3360 and 2075 (kg/ha), respectively. The water productivity (WUE) of wheat and rice is 0.67 and 0.03 kg/m^3.

Table 3.11: Input, Yield and Water Use Efficiency of Major Crops

Crop	*Seed Rate (kg/ha)*	*Fertilizer*		*Irrigation (No)*	*Yield (kg/ha)*	*Water Use Efficiency (kg/m^3)*
		Urea	*DAP**			
Wheat	136	370	75	5	3360	0.67
Rice	47000 (seedling)	370	50	75	2075	0.03

*Di-ammonium Phosphate.

3.1.2.5 Constraints to Crop Productivity

The responses of farmers regarding constraints of crop productivity during both Kharif and Rabi seasons were recorded in the PRA. Hundred percent respondents complained

inadequate supply of canal water. About 82% farmers attributed it to unlevelled fields, 55% to lack of storage facilities and 27% to adulterated pesticides.

3.1.2.6 Beneficiaries' Participation

Farmers of pilot site were consulted and WUA has been formed (Table 3.12). Water User Association is involved in the implementation as well as operation and maintenance of all project activities.

Table 3.12: Water Users' Association (WUA)

Name	*Landholding (ha)*	*Designation*
Abdul Aleem Khan	23	Chairman
Muhammad Afzal	3	Vice Chairman
Ray Fiaz Ahmed	5	Secretary
Ray Walayat	7	Cashier
Walayat Hussain	1.5	Member

3.1.3 Site 3

The site is selected in village Hotta, Tehsil and district Pakpattan. It falls in the cotton-wheat cropping system. The gross command area of the site is 49 ha, whereas the culturable commanded area is 48 ha. Most of the command area is unlevelled. The average farm size is 5 ha and the site is owned by 10 farmers. Four farmers own 4 ha, three 4-8 ha, and three more than 8 ha. Only thirty percent farmers are illiterate.

3.1.3.1 Sources of Irrigation

Both, canal and tubewell water supplies are available but canal supplies are non-perennial as there is annual closure of about six month from October to April. All the farmers use both canal and tubewell water for irrigation.

Watercourse

The watercourse No 7995-R, off takes from Khadir branch, it is 1224 m long and is unlined (Figure 3.5). It has an AOSM type outlet with a discharge of 89 lps at Hotta minor outlet.



Figure 3.5: Existing Condition of Watercourse No. 7995-R

Table 3.13 shows that per hectare irrigation time increases along the length of watercourse. The average conveyance losses of the watercourse were found to be 2.94 lps/100 m. The overall irrigation efficiency of the command therefore is 41 percent.

Table 3.13: Irrigation Time, Conveyance Losses and Efficiencies

Parameter	*Head*	*Middle*	*Tail*	*Average*
Irrigation Time (hours/ha)	4.12	5.14	6.17	5.14
Conveyance Losses (lps/100 m)	2.70	2.89	3.23	2.94
Conveyance Efficiency (%)	54	58	65	59
Application Efficiency (%)	74	68	65	69
Irrigation Efficiency (%)	40	39	42	40

Tubewell

Six farmers have installed electric powered tubewells at their farms. The depth of well varies from 50 to 55 m. The groundwater quality is fit for irrigation (Table 3.14).

Table 3.14: Chemical Properties of Groundwater

T/W No.	*EC (dS/m)*	*pH*	*TDS (ppm)*	*SAR*	*RSC (meq/l)*	*Remarks*
1	0.5	7.4	341	0.1	0.1	Fit
2	0.2	7.8	149	0.4	Nil	Fit
3	0.5	7.3	355	0.3	0.3	Fit
4	0.2	7.9	156	0.1	Nil	Fit
5	0.4	7.5	270	0.2	0.1	Fit

3.1.3.2 Irrigation Practices and Soil Classification

Farmers mostly use flood irrigation method but 30 percent farmers were found using bed and furrow irrigation for cotton crop. Soil infiltration rate was found to be 23 *mm/hr.* The textural and chemical properties of soil were determined up to 90 cm depth (Table 3.15).

Table 3.15: Chemical and Mechanical Properties of Soil

Sr. No.	*Depth (cm)*	*EC (dS/m)*	*pH*	*SAR*	*ESP*	*Textural Class*
1	0-15	1.1	7.3	1.7	2.6	Sandy Clay Loam
2	15-30	0.6	7.5	0.9	1.6	Sandy Clay Loam
3	30-60	0.5	7.6	1.4	3.0	Sandy Clay Loam
4	60-90	0.4	7.6	0.9	1.6	Sandy Clay Loam
Average		*0.6*	*7.5*	*1.2*	*2.2*	*Sandy Clay Loam*

3.1.3.3 Cropping Pattern and Intensities

The pilot site is located in cotton-wheat zone and the same cropping pattern is practiced mostly in the area. The cropping intensities were 79% and 78% during Kharif 2005 and Rabi respectively and the annual cropping intensity was 157% (Table 3.16). The major crops grown are cotton (30%) and wheat (32%) at the site. Sugarcane and maize are the other major crops.

Table 3.16: Cropping Pattern and Intensities (2005-06)

Kharif Crops	*Cropping Intensities (%)*	*Rabi Crops*	*Cropping Intensity (%)*
Cotton	30	Wheat	32
Maize	18	Maize	22
Rice	23	Potato	7
Fodder	8	Fodder	17
Kharif Season	*79*	*Rabi Season*	*78*

3.1.3.4 Crops Input, Yield and Water Use Efficiency

Generally, a seed rate of 136, 15, 10 and 25 kg/ha were used by the farmers for wheat, cotton, rice and maize crops, respectively. Almost all farmers use chemical fertilizers and the application rate of fertilizers on the fields is given in Table 3.17. Average yields of 3450, 2760, 3450 and 6916 kg/ha were recorded for wheat, cotton, rice and maize, respectively (Table 3.17). The water productivity of wheat, cotton, rice and maize is 0.86, 0.39, 0.15 and 0.63 kg/m^3, respectively.

Table 3.17: Inputs, Yield and Water Use Efficiency of Major Crops

Crop	*Seed Rate (kg/ha)*	*Fertilizer*		*Irrigation (No)*	*Yield*	*Water Use Efficiency (kg/m^3)*
		Urea	*DAP**			
Wheat	136	250	185	4	3450	0.86
Cotton	15	250	250	7	2760	0.39
Rice	10	250	185	23	3450	0.15
Maize	25	500	123	11	6916	0.63

*Di-ammonium Phosphate.

3.1.3.5 Constraints to Crop Productivity

About 60% of the respondents reported inadequate supply of irrigation water as the major constraint, about 60% poor quality seeds and 30% lack of storage facilities.

3.1.3.6 Beneficiaries' Participation

Farmers of site were organized into a Water Users' Association (Table 3.18). The WUA is involved in the implementation and will be responsible for operation and maintenance also.

Table 3.18: Water Users' Association (WUA)

Name	*Landholding (ha)*	*Designation*
Muhammad Riaz	8	Chairman
Nasir Jamal	12	Vice Chairman
Parwaiz Manzoor	8	Secretary
Muzaffar Qadir	10	Cashier
Asif Mehmood	5	Member

3.1.4 Site 4

The site is located in the village of Kotsumblawala Bhera, Tehsil Bhalwal, District Sargodha. The gross commanded area of the site is 38 ha, out of which 37 ha is cultivated. The average size of the farm is 7 ha. The site is owned by 10 farmers, three farmers with 2-6 ha, six farmers more than 6 ha and one with 2 ha of land.

3.1.4.1 Sources of Irrigation

Both, canal and tubewell water supplies are available at the site, but canal supplies are non-perennial as there is annual closure of about six month from November to April. All farmers use groundwater during the closer of canal supplies.

Watercourse

A watercourse No 14000-R, off taking from Shahpur branch irrigates a command area of 38 ha. The watercourse is unlined having a total length of 792 m. This watercourse has pipe outlet with a sanctioned discharge of 90 lps. There was a big dead storage at the start of watercourse and lot of vegetation and trees on watercourse banks (Figure 3.6). The reach-wise irrigation time, conveyance losses and irrigation efficiencies are given in Table 3.19. The irrigation time to irrigate one hectare increases along the length of the watercourse. The average conveyance losses of the watercourse were 3.13 lps/100 m. The overall irrigation efficiency of the site was 42 percent (Table 3.19).





Figure 3.6: Existing Condition of Watercourse No. 14000-R

Table 3.19: Irrigation Time, Conveyance Losses and Efficiencies

Parameters	*Head*	*Middle*	*Tail*	*Average*
Irrigation Time (hours/ha)	2.47	6.17-7.41	8.64	5.97
Conveyance Losses (lps/100 m)	2.87	3.10	3.42	3.13
Conveyance Efficiency (%)	62	67	74	68
Application Efficiency (%)	64	61	60	62
Irrigation Efficiency (%)	40	41	44	42

Tubewell

Three of the farmers have their own diesel powered tubewells. The depth of well varies from 30 to 40 m. The groundwater was found fit for irrigation (Table 3.20).

Table 3.20: Chemical Properties of Groundwater

T/W No.	*EC (dS/m)*	*pH*	*TDS (ppm)*	*SAR*	*RSC (meq/l)*	*Remarks*
1	0.5	7.4	341	0.1	0.1	Fit
2	0.2	7.8	149	0.4	Nil	Fit
3	0.5	7.3	355	0.3	0.3	Fit
4	0.2	7.9	156	0.1	Nil	Fit
5	0.4	7.5	270	0.2	0.1	Fit

3.1.4.2 Irrigation Practices and Soil Classification

Flood irrigation method is used at the site. The average infiltration rate at the site was found to be 23 mm/h. The textural and chemical properties of soils were explored from fields adjacent to head, middle and tail of the watercourse up to 90 cm, depth (Table 3.21). The soil is predominantly sandy clay loam.

Table 3.21: Chemical and Mechanical Properties of Soil

Sr. No.	*Depth (cm)*	*EC (dS/m)*	*pH*	*SAR*	*ESP*	*Textural Class*
1	0-15	1.1	7.3	1.7	2.6	Sandy Clay Loam
2	15-30	0.6	7.5	0.9	1.6	Sandy Clay Loam
3	30-60	0.5	7.6	1.4	3.0	Sandy Clay Loam
4	60-90	0.4	7.6	0.9	1.6	Sandy Clay Loam
Average		*0.6*	*7.5*	*1.2*	*2.2*	*Sandy Clay Loam*

3.1.4.3 Cropping Pattern and Intensities

The site has a mixed cropping pattern. Citrus is grown over large part of the command area. The cropping intensities during Kharif 2005 and Rabi 2005-06 were 73% and 85%, respectively and the annual cropping intensity was 158 % for the year 2005-06 (Table 3.22).

Table 3.22: Cropping Pattern and Intensities (2005-06)

Kharif Crops	*Cropping intensity (%)*	*Rabi Crops*	*Cropping Intensity (%)*
Orchard	32	Wheat	35
Orchard & Fodder	8	Orchard	28
Sugarcane	4	Orchard & wheat	8
Fodder	20	Orchard & Fodder	4
Vegetable	9	Fodder	10
Kharif Season	*73*	*Rabi Season*	*85*

3.1.4.4 Crops Input, Yield and Water Use Efficiency

Average seed rate for wheat and sugarcane were 124 and 5,560 kg/ha, respectively (Table 3.23). The rate of fertilizer application by the farmers on their fields is given in Table 3.23. Averagely, 3,460 and 53,350 kg/ha yields were recorded for wheat and sugarcane, respectively. The water productivity of wheat and cotton is 1.15 and 3.55 kg/m^3, respectively.

Table 3.23: Inputs, Yield and Water Use Efficiency of Major Crops (kg/ha)

Crop	*Seed Rate (kg/ha)*	*Fertilizer*		*Irrigation (No)*	*Yield (kg/ha)*	*Water Use Efficiency (kg/m^3)*
		Urea	*DAP**			
Wheat	124	185	124	3	3,460	1.15
Sugarcane	5560	370	250	15	53,350	3.55

*Di-ammonium Phosphate.

3.1.4.5 Constraints to Crop Productivity

Hundred percent respondents attributed low yield to unlevelled fields. About 60% faced problems in selling products, about 80% had lack of storage facilities and 50% farmers complained the delayed payment of their sold crops. About 40% reported outputs damage due to pests and disease attack. Eighty percent farmers reported expensive farm inputs as the major constraint to crop productivity.

3.1.4.6 Beneficiaries' Participation

The beneficiaries' participation at the farm level had been minimal prior to the project activities which resulted in low output. Farmers of the site were arranged into a WUA (Table 3.24). The Water Users' Association is involved in the implementation as well as operation and maintenance of the project activities.

Table 3.24: Water Users' Associations (WUA)

Name	*Landholding (ha)*	*Designation*
Ghulam Abas Khan	1	Chairman
Muhammad Afzal Khan	10	Vice Chairman
Asif Khan	15	Secretary
Ahmed Sher	4	Cashier
Amjad Khan	7	Member

3.1.5 Site 5

The site is located in Chak No. 82-A/DB, Tehsil Yazman, District Bahawalpur. It is about 48 km from Bahawalpur and 14 km South-west of Yazman Mandi. The total area of the site is 202 ha. There is an equal landholding of 5 ha of each farmer. The area is under command of Desert Branch Canal. A perennial distributary 3-L, off takes from Desert Branch at Kudwala regulator and feeds the area. The project area is bounded by the Cholistan desert.

3.1.5.1 Topography

Topography of the area is predominately plain with a few sand dunes at scattered places. First farm gate is at about 2 m below the bed level of the distributary. Farmers did not bother for proper land leveLing. However, for irrigation, they search possible ways for preparation of branch watercourses. Consequently, long length meandering branch watercourses have been constructed, which cause too much water losses.

3.1.5.2 Irrigation Source (Watercourse)

Total length of main watercourse from distributary to first farm gate is 2400 m, out of which 1500 m is already lined with bricks in rectangular section. Unlined portion is more than 2 m wide. The actual sanctioned path of watercourse is hindered by sand dune of 3 m height due to which farmers have changed its sanctioned path, resulting in huge water losses. Moreover, the curvatures made in lined portion of watercourse causes deposition of silt in bed. The profile map of watercourse is presented in Figure 3.7.

Discharge of watercourse measured at canal outlet was 186 lps, it reduced to 164 lps at the end of lined section and was 133 lps at the start of the command area. Discharge of watercourse further reduced to 115 lps at the last farm gate (Table 3.25). The reason for such low conveyance efficiency of the watercourse was poor physical condition of both lined and unlined portions (Figure 3.8).

Table 3.25: Watercourse Discharge and Conveyance Losses at Different Sections

Section	*Measured Discharge (lps)*	*Parameter*	*Quantity*
Canal outlet	186	Losses in the lined portion (lps/100 m)	1.46
End of lined portion	164	Loss percentage (lined portion)	12
At farm gate	133	Losses in the unlined portion (lps/100 m)	3.44
Middle of command area	125	Loss percentage (unlined portion)	19
Tail of command area	115	Conveyance efficiency (%)	38

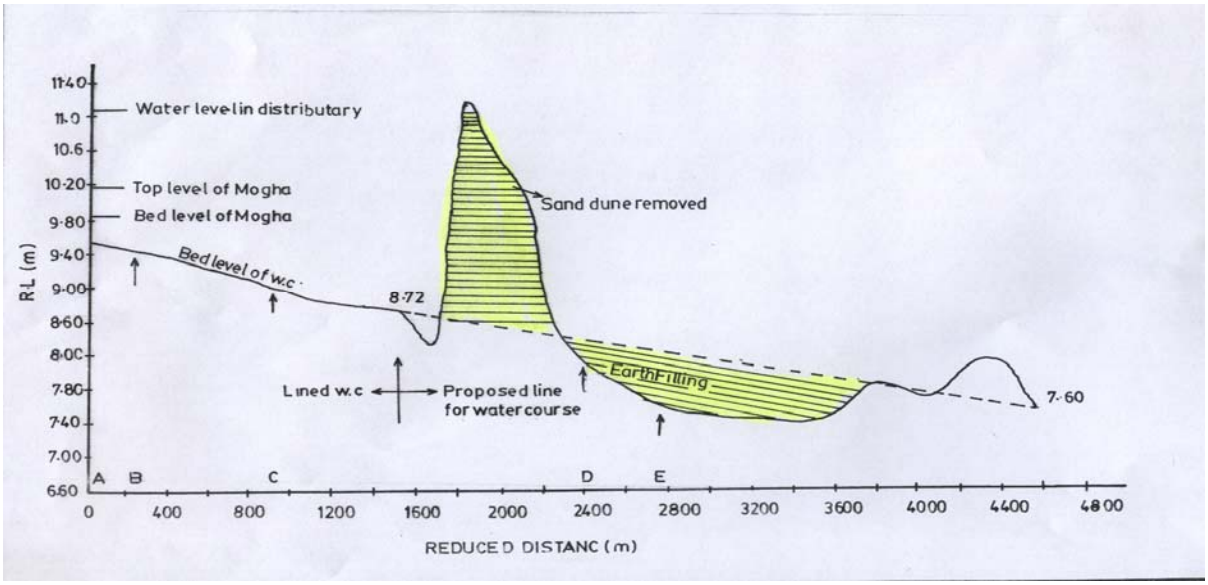


Figure 3.7: Profile of Sanctioned Path of Watercourse No. 48400-L



Figure 3.8: Existing Condition of Watercourse No. 48400-L

3.1.5.3 Crops Yield and Water Use Efficiency

During PRA, average yield and water use efficiency for wheat and cotton crops were recorded. Table 3.26 shows that yield and WUE of both the crops are very low.

Table 3.26: Yield and Water Use Efficiency (2005-06)

Crop	*Water used (m^3/ha)*	*Yield (kg/ha)*	*Water use efficiency (kg/m^3)*
Wheat	4695	2000	0.42
Cotton	6355	1300	0.2

3.1.5.4 Cropping Pattern and Intensities

Wheat followed by cotton is the general cropping pattern of the area however; mustard crop is also grown in Rabi season on some areas. Cropping intensity for the year 2005-06 (Pre-Project) was calculated to be 148% (Table 3.27).

Table 3.27: Cropping Pattern and Intensities (2005-06)

Crop	*Cultivated Area (ha)*		*Fallow*		*Average Yield (kg/ha)*	*Cropping Intensity (%)*
	Rabi	*Kharif*	*Rabi*	*Kharif*		
Wheat	120	-	43	-	1976	148
Mustard	37	-	-	-	1235	
Cotton	-	140	-	60	1284	

3.1.5.5 Constraints to Crop Productivity

The major constraints found to affect the crop productivity were soil salinity, shortage of water, uneven fields, financial problems and hard soils.

3.1.5.6 Beneficiaries' Participation

Implementation of project has been made conditional to the farmers' participation and a WUA has been formed (Table 3.28):

Table 3.28: Water Users' Association (WUA)

S. No	*Name*	*Designation*
1	Mr. Abdul Malik s/o Khuda Bux langah	President
2	Mr. Shabbir Ahmed s/o Naseer Khan	General Secretary
3	Mr. Haq Nawaz s/o Rasool Bux	Member
4	Mr. Aollah Jiwaya	Member
5	Mr. Ibrahim s/o Jamal Khan	Member

3.1.6 Site 6

The site is located in the Tando Ghulam Ali, District Badin. Watercourse 1-R is the source of irrigation for the area originating from Wagherji minor that is fed by Naseer Wah branch of Rohri canal. The water course is 1740 m long and provides irrigation facilities to about 37 families commanding 144 ha of land. The 1-R watercourse has been selected because it faces serious types of deteriorations due to repeated de-silting processes from decades which has created over sized, wider haphazard running channel on unlevelled land. Consequently huge loss of water was occurring through leakage, seepage and rodent holes. The lining of watercourse will save water and would bring more area under cultivation.

3.1.6.1 Watercourse 1-R

The command area of the watercourse comprises 6 villages. The educational level in the area is very poor and most of the farming community is illiterate and reluctant to adopt the modern technologies. The main source of their income and livelihood is agriculture, livestock and labour in nearby towns and cities. Due to poor economic conditions and lack of marketing facilities, the yields are very low.

The survey and soil sampling of the area was conducted to determine its fertility. The soils were found fertile and well drained due to silty loam texture. The overall salinity was severe enough to hamper the normal growth of field crops. However, the availability of canal water is not regular and depends upon the schedule of Rohri canal by the Irrigation Department. During the canal closure periods, there is acute shortage of water for irrigation and drinking. The water-table depth measured in the area ranges from 12-15 m which remained unutilized for irrigation due to non availability of pumping facilities. Improvement of watercourses can facilitate to increase overall crop yields, saving of water for other purposes and economic status of the farmers.

The existing condition of watercourse is poor (Figure 3.9) which results in heavy water losses. The measured losses are 25, 30 and 30% at the head, middle and tail, respectively. The data collected prior to the project is given in Table 3.29, which shows that average cropping intensity is very low *i.e.* 82% and the main reason is the shortage of irrigation water.

3.1.6.2 Watercourse 1-AR

The watercourse 1-AR is also located in the Tando Ghulam Ali village of District Badin. It originates from Wagherji minor that is fed by the Naseer Wah branch of Rohri canal. The watercourse is 2190 m long and provides irrigation facilities to about 40 families over 160 ha of land. The lining of watercourse would save water and more land cultivation will be possible. The soils were found fertile and well drained due to silty-loam texture. The overall salinity was not so severe that it could hamper the normal growth of crops. However, the availability of canal water is erratic and depends on the schedule of Rohri canal. During the canal closure periods, there is an acute shortage of water for irrigation and drinking. The water-table depth in the area ranges from 6-7 m, where the groundwater is mostly non-saline



Figure 3.9: Existing Condition of Watercourse No. 1-R

to marginal and remained unutilized for irrigation due to non-availability of pumping facilities. The watercourse is unlined and suffers from huge water losses due to a number of reasons (Figure 3.10). The improvement of watercourses in the area, installation of skimming wells can facilitate to increase the overall crop yields, saving of water for other purposes and uplift the economic conditions of the farmers. The pre project data are given at Table 3.30.

Table 3.29: Cropping Pattern and Intensities in the Command of W/C No. 1-R

Crop	*Cultivated Area (ha)*		*Average Yield (kg/ha)*	*Cropping intensity (%)*	
	Rabi	*Kharif*		*Rabi*	*Kharif*
Cotton	-	30	1155	44	38
Chilies	-	13	1000		
Sugarcane	12	12	58000		
Dhancha	-	-	-		
Banana	-	-	-		
Vegetables	-	-	-		
Wheat	43	-	2400		
Berseem	9	-	2450		
Fallow	80	89	-		
Annual				*82*	



Figure 3.10: Existing Condition of Watercourse No. 1-AR

Table 3.30: Cropping Pattern and Intensities in the Command of W/C No. 1-AR

Crop	*Cultivated Area (ha)*		*Average Yield (kg/ha)*	*Cropping intensity (%)*	
	Rabi	*Kharif*		*Rabi*	*Kharif*
Cotton	-	22	1050	41	29
Chillies	-	11	7000		
Sugarcane	13	13	55000		
Dhancha	-	-	-		
Banana	-	-	-		
Vegetables	-	-	-		
Wheat	47	-	2400		
Berseem	6	-	2100		
Fallow	94	114	-		
Annual				*70*	

3.1.7 Site 7

The site is located in the Matli and Tilhar towns of District Badin which fall in the rice-wheat zone. The irrigation sources for the sites are watercourses 35-R and 9-R, which originate from Imamwah Janubi and Dando minors of the Phulali canal, respectively.

3.1.7.1 Watercourse 35-R

The watercourse feeds an area of 115 ha of land owned by 27 families in Matli. The major sources of income of the inhabitants are agriculture, livestock and labour. However, the crops yield is low due to water deficit and unlevelled fields. The availability of canal water is insufficient and irregular as Phulali canal is non-perennial. It is operated most of the year to provide drinking water to the population of Badin and Thatta districts. Therefore, acute shortage of irrigation water is confronted during canal closure periods. The water table is within 2-3 m, where the groundwater is marginal to saline. Moderately saline groundwater with shallow water table has also salinized the soils. Repeated de-silting has deformed the watercourse at a number of places (Figure 3.11) due to which, its conveyance efficiency is very low *i.e.* 40%. Also, the application efficiency is low due to lack of levelling and proper irrigation scheduling. Hence, the improvement of watercourses and use of groundwater can facilitate to increase the area of cultivation, overall crop yield and saving of water. The pre-project data are given in Table 3.31.

Table 3.31: Cropping Pattern and Intensities in the Command of W/C No. 35-R

Crop	*Cultivated Area (ha)*		*Average Yield (kg/ha)*	*Cropping intensity (%)*	
	Rabi	*Kharif*		*Rabi*	*Kharif*
Sugarcane	7	17	55000	70	91
Sunflower	25	-	1300		
Jantar	-	8	15000		
Wheat	50	-	1500		
Rice	-	80	4000		
Fallow	33	10	-		
Annual				*154*	

3.1.7.2 Watercourse 9-R

The watercourse is located in the Tilhar town of District Badin. It off takes from Dando minor of the Phulali Canal and feeds an area of 120 ha. It is 2735 m long and provides irrigation facilities to about 29 families. The people have moderate to good education level

and mostly earn their livelihood through agriculture, livestock and labour. The soils in the area are fertile with silty loam texture. However, moderately saline groundwater (water-table depth 1-2 m) and soils, shortage of irrigation water and lack of modern technologies have limited the crop productivity. The watercourse has serious types of deteriorations mostly because of repeated de-silting processes (Figure 3.12) due to which it has conveyance efficiency of about 38%. The lining of watercourse would therefore save water, increase cultivated area and crop productivity. The data in respect of cultivated area, cropping pattern, cropping intensity and yields of different Kharif and Rabi crops are given in Table 3.32.



Figure 3.11: Existing Condition of Watercourse 35-R



Figure 3.12: Existing Condition of Watercourse 9-R

Table 3.32: Cropping Pattern and Intensities in the Command of W/C No. 9-R

Crop	*Cultivated Area (ha)*		*Average Yield (kg/ha)*	*Cropping intensity (%)*	
	Rabi	*Kharif*		*Rabi*	*Kharif*
Sugarcane	5	5	50000	65	77
Sunflower	40	-	1200		
Vegetables	-	2	-		
Wheat	28	-	1400		
Rice	-	80	4000		
Fodder	5	5	12000		
Fallow	42	28	-		
Total				*142*	

Summary

At irrigated sites canal and groundwater are mostly used conjunctively. Most of the watercourses are entirely unlined while some are partially lined with discharge of 40-120 lps. The average conveyance losses and conveyance efficiency varies from 1.5-3.5 lps/100 m and 40-60%, respectively. The quality of groundwater varies from site to site, it was better in Hafizabad, Pakpattan, Kotsumbanwala, as compare to Bhalwal, Bahawalpur and Tando Ghulam Ali. The fields were not precisely levelled due to which the application efficiency of site ranges from 40-70%. The overall irrigation efficiency of sites was as low as 40 to 50%. The major constraints to crop productivity as recorded by the respondents were: (i) inadequate supply of canal water, (ii) adulterated pesticides, (iii) low quality fertilizers, (iv) selling and storing problems; and (v) delayed return of sold commodities. The sites established in Bahawalpur and Sindh were particularly deficient in irrigation water due to unavailability of good quality groundwater, consequently having low cropping intensity (80%) and yield. The socio-economic conditions of these stakeholders were between poor and lower middle category. However, the sites located in upper Punjab belong to middle and upper middle classes.

3.2 DESERTS

The deserts in Pakistan spread over an expanse of 11 Mha. The availability of freshwater is so scarce in these areas that people have to f*etc*h drinking water from miles. This is also the

only constraint which has impeded the development of very basic economic activities like agriculture and livestock, therefore population density and living standards in these areas is very low. The major deserts of Pakistan are: Thar (4.3 Mha), Cholistan (2.58 Mha), Kharan (1.82 Mha) and Thal (2.3 Mha).

Cholistan is a vast sandy desert in the south-east of the Punjab province. It is one of the driest and hottest area of the country. Low and sporadic rainfall, high temperature, low relative humidity, high rate of evaporation, and strong summer winds characterize its climate. The main soil types in the area are sandy, loamy and clayey. The sandy soils are gently sloping, extending very deep, excessively drained, coarse textured, and calcareous in nature. Despite lack of freshwater resources, utility of the deserts as vast rangeland has never been doubted. The vegetation is typical of arid regions and consists of xerophytic species. People of the area are entirely dependent on livestock, whereby most of the soils serve as graze lands. That's why the area has always played an important role in the national economy through livestock. It supports to meet the protein and dairy requirements of substantial segment of the country's population. The site is located at Hyder wali village (District Bahawalpur) in the Cholistan desert (Figure 3.13).

3.2.1 Socio-Economic Status

The socio-economic benchmarks of the site at Hyder wali have been documented by PRA.

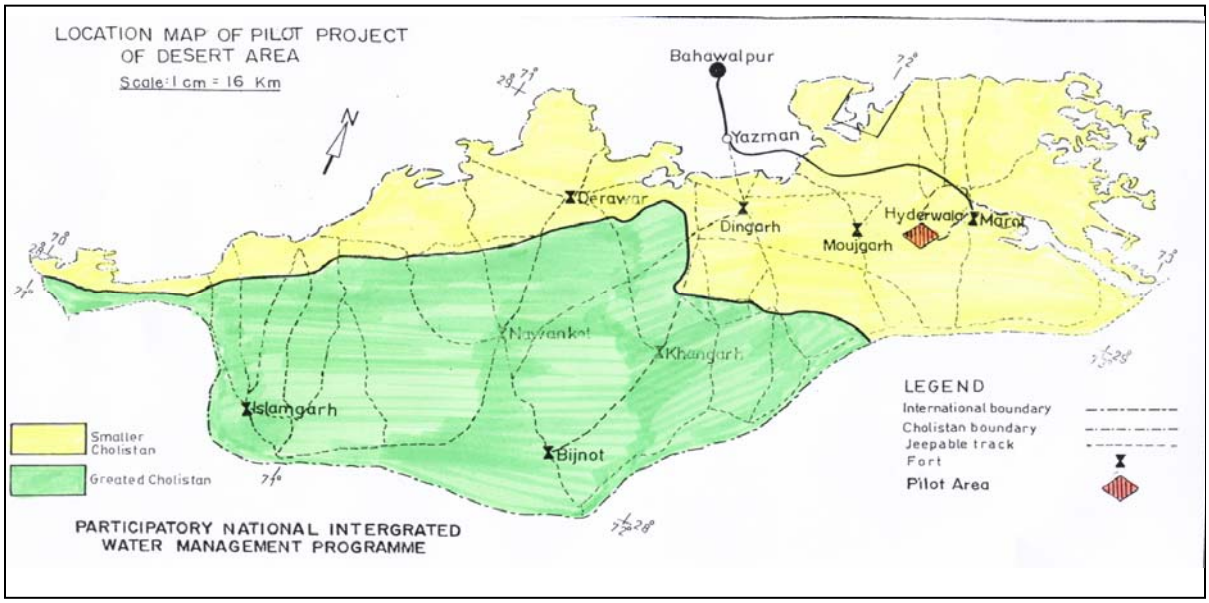


Figure 3.13: Location Map of the Site Established in the Cholistan Desert

3.2.1.1 Water Availability

Surface Water

A traditional pond (*Toba)* is available in settlement of the village, having a storage capacity of about 4869 m^3. The quality of harvested rainwater is good in terms of TDS (300 ppm), however because of turbidity and long stay in ponds, the aesthetic and bacteriological quality of this water becomes questionable.

Groundwater

The groundwater extracted from shallow wells (open wells) is highly brackish. The water-table depth is only 18 m, whereas the wells are dug up to 21 m depth from where water is lifted by the Persian wheels. The groundwater quality of deep tubewells which tap water from 90 m depth is good. Table 3.33 gives the status of groundwater quality of dug wells and tubewells. It can be seen from the table that, dug well water is not of good quality, it is used for domestic purposes only when the *Tobas* dry up.

Table 3.33: Groundwater Quality Status at the Site

Source	*Discharge (lps)*	*Water table Depth (m)*	*Depth of Well (m)*	*Water Quality TDS (ppm)*
Dug well	-	18	21	1900
Tubewell	1	18	91	495

3.2.1.2 Agriculture

Due to shortage of water and lack of land ownership, conventional agricultural activity is not undertaken. It was found during the survey that all of the stakeholders were using state owned lands for livestock grazing. But the lands around the village offer very good potential for agricultural activity on large scale if freshwater could become available to meet crop water requirements and land ownership is transferred to local peoples.

3.2.1.3 Livestock

There is no fodder grown in the area due to unavailability of water. The needs of the livestock are met from natural vegetation, which is in abundance during and after the rainy season (Table 3.34). However, when the vegetation either dries up after prolonged dry season or is over grazed, the inhabitants of the area are left with no option but to move to more productive/irrigated areas in order to feed themselves and their livestock.

Table 3.34: Livestock Owned by the Interviewed Persons

Name of Farmer Interviewed	*Livestock*					*Total*
	Cattle	*Sheep*	*Goat*	*Camel*	*Donkey*	
Khadim Hussain	15	-	-	-	-	15
Muhammad Sidique	40	-	-	-	-	40
Rahim Bux	5	-	-	1	-	6
Muhammad Panah	2	17	7	3	1	30
Muhammad Bux.	20	150	-	1	2	173
Muhammad Azeem	10	50	5	-	-	65
Khuda Bux	2	50	5	-	-	57
Allah Yar	3	50	-	1	2	56
Ghulam Nabi	31	-	-	-	-	31
Allah Wadhaya	1	2	10	-	-	13
Average per family	13	32	3	1	1	50
Livestock percentage	26	64	6	2	2	100

Under sufficient rainfall conditions, the livestock population exceeds 5000. In addition to permanent settlers, a number of animals are brought by gypsies. At the time of survey, people were migrating due to non-availability of fodder. The survey comprised of ten families each was having 50 heads of livestock. Among different kind of livestock owned by the people, sheep was dominant (64%) followed by cows (26%), goats (6%), camel (2%) and donkey (2%). There is no veterinary care centre in this settlement, therefore people use local expertise to treat their livestock. This works well for minor maladies but in serious cases, mostly the animals die.

3.2.1.4 Education and Living Standard

The family size ranges from 3 to 17 persons, however the average family size in the area is 9. The living standards fall mostly in the poor and middle class. Mostly the people reside in katcha huts with no electricity or other facility. As no exact parameter is available to bifurcate the living standards, therefore bifurcation has been made on the basis of livestock belongings and general conditions. As per the criterion, fifty percent of the interviewed persons are poor while the remaining 50 percent fall in the middle class. Education level of the area is very low as 83% of the people are uneducated. Only 14 percent have completed their primary education, whereas 3 percent attended middle classes.

3.2.1.5 Income Levels

Major source of income for the people is livestock. However, some of them own lands in irrigated area. Table 3.35 shows that the family income ranges from Rs.47, 000/- to Rs.175,000/- per annum whereas the per capita average annual income becomes 10,000/-

Table 3.35: Annual Income from Different Sources

Name of Farmer Interviewed	*Annual income (Rs.) and source*			*Total*
	Livestock	*Agriculture*	*Labour/Service*	
Khadim Hussain	12000/-	75000/-	20000/-	107000/-
Muhammad Sidique	75000/-	100000/-	-	175000/-
Rahim Bux	12000/-	-	35000/-	47000/-
Muhammad Panah	20000/-	-	40000/-	60000/-
Muhammad Bux.	40000/-	70000/-	15000/-	125000/-
Muhammad Azeem	30000/-	-	40000/-	70000/-
Khuda Bux	9000/-	-	40000/-	49000/-
Allah Yar	8000/-	-	35000/-	43000/-
Ghulam Nabi	50000/-	60000/-	10000/-	120000/-
Allah Wadhaya	8000/-	-	40000/-	48000/-
Average per family	*26400/-*	*30500/-*	*27500/-*	*84400/-*

3.2.1.6 Drought and Frequency

There is no scientific data available to indicate the drought occurrence and its frequency. However, the normal cycle of drought was estimated to be ten years. Length of normal droughts ranges from one to three years but prevailing drought has prolonged up to 10 years. In the survey respondents stated that drought affects the local people very adversely by increasing human, livestock and wildlife mortality, increases the risk of getting sick, causes loss in income levels due to which the migration of human and wildlife towards settled area increases. It also causes shifting of sand dunes, increases wind erosion, and loss of vegetation cover over the landscape. Up-till the time of survey, the impacts of the last drought were not subsided.

3.2.1.7 Constraints and Problems

The constraints and problems as identified by the local population are: scarcity of water and fodder; migration; lack of marketing; health; and communication facilities. The top priority of the community is the water availability and the last is the provision of health and communications facilities. Moreover, the land is state owned and the peoples are not allowed to use the land for agriculture or any other purpose. The area possesses very good potential for rangeland development. Before the drought, the grass lands were very rich. Inspite of the extensive grazing by big herds of livestock, the grasslands were not exhausted. However, the grassland has been vanished by the drought. If, mechanical method of sprinkler is adapted, the deserted lands can be converted to green grasslands.

Summary

The quality of harvested rainwater in Hyderwali is good. The quality of groundwater is good in shallow wells as compare to deep wells. Due to unavailability of water and lack of landownership, conventional agricultural practices are not undertaken. The major source of income of people is livestock. Due to scarcity of rainfall, fodder grown in the area were insufficient to fulfill the needs of livestock, people were migrating. At the time of adequate rainfall period, livestock population increase. The people are mostly illiterate, where the average annual per capita income is Rs. 10,000/- only. A cyclic drought hits the area every 10 years which further worsen the conditions. The other major problems are lack of health, communication and marketing facilities.

3.3 NORTHERN AREAS

The site is located in Malk-e-Dam valley Swat at longitude of $72^0\ 21'\ 16''$ E and latitude of $34^0\ 38'\ 20''$ N. Most of the population of the valley has an average family size of 14 persons in the Abuha village, Malk-e-Dam valley, Tehsil Barrikoat District Swat. A view of the pilot site is given in Figure 3.14.

The valley falls on the south of Peshawar-Mangora road, some 20 km short of Mangora. Extending north south, the valley starts from a gorge at the bottom of uphill with torrent streams flowing in the main stream (maximum discharge 48 cumecs) running across the valley till it opens some 8 km down near its confluence with the river Swat. Soils of the valley are stratified comprising of various textures originated from glacio-fluvial deposits,

consisting of boulders of various dimensions mixed with silt, sand, clay, stone and gravels. Top layer is of clay loam texture and allows good agriculture.



Figure 3.14: A View of the Pilot Site Established in Northern Areas

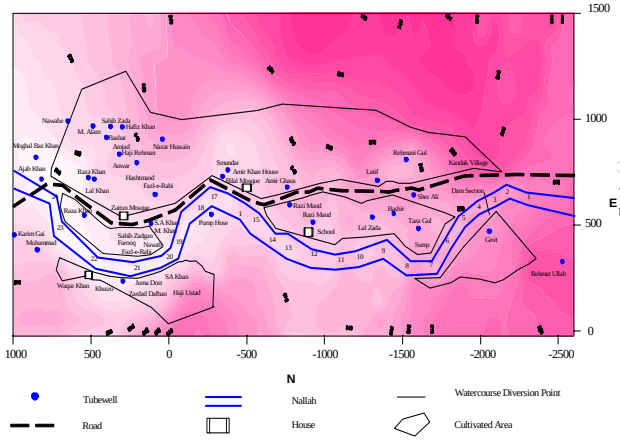
About 64% of the population is under-matric while 37% are uneducated. However, higher education trend is encouraging making the community more receptive towards improved practices and technologies if made available. As per survey, 64% of the farmers depend merely on farming without any supplemental source of income, that limits their investment capability and as such their farming remains underdeveloped.

3.3.1 Topography

Detailed topographic survey was carried out and the maps are given in the Figure 3.15 and 3.16. Topographic map of the pilot site exhibits that the channel originates at reduced level of 852 m and has an elevation of 832 m after running through a distance of 1600 m. Average slope of the channel is 1.37% and the reduced level of the cultivated land along the right bank of the channel varies from 829 to 849 m and along left bank from 833 to 865 m. Therefore, gravity irrigation is not possible for the entire cultivated land along the channel reach even if adequate flow is available. Sprinkler irrigation is proposed as the best option for irrigation of high fields along the channel. Similarly, slope of 1.5% comes out from profile map of nullah. That slope is proposed to be utilized for pumping by installing hydra-ram pumps and storing it in small storage tanks constructed at appropriate heights on hill slopes. The stored water can be used for growing orchards on hill slopes through trickle irrigation.

3.3.2 Climate, Water Availability and Irrigation Practices

Average annual precipitation in the valley is about 800 mm, out of which 54% falls in summer (April-September) and the remaining 46% in winter (October-March). Average daily maximum and average daily minimum temperatures during summer and winter are 28 ^{o}C and 2 ^{o}C, respectively. Peak potential evopotranspiration (June) is 7.4 mm/day and the average is 3 mm/day. Although rainfall at the pilot site is sufficient but not uniformly distributed. In NWFP, 46% of the cultivated area is irrigated, of which 83% is canal and the rest with tubewell and lift pumps irrigated. At the pilot site, no canal water is available, but good quality groundwater is available having TDS below 500 ppm and pH from 7 to 7.8. Irrigation is therefore, normally practiced, tapping groundwater through deep tubewells. Water is pumped into storage tanks on high terraces from where it is released in gravity flow channels, or GI pipe network, to irrigate the adjacent fields. Survey revealed that 85 tubewells have so far been installed and their number is rapidly increasing.



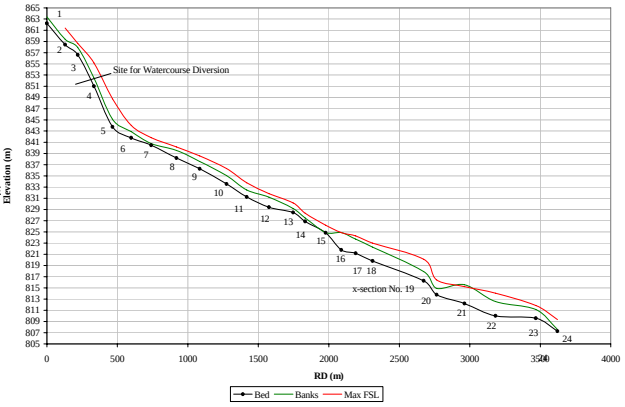


Figure 3.15: Topographic Map of the Pilot Site *Figure 3.16: Profile Map of Nullah*

The tubewells irrigate 78% of the irrigated area against 15% through diversion channels and 6% by lift pumps. Discharge range of these tubewells is from 6 to 14 lps. Average water table depth is 25 to 30 m and survey revealed that the water table is declining at an alarming rate of almost 1 m per year. Resultantly, groundwater pumping is rapidly becoming

expensive. Due to terraced farms, close conduit pressurized conveyance is sometimes practiced, which is very often not practical for scattered high fields. Even the fields considered leveled have slopes beyond admissible limits thereby highly reducing the application efficiency. Intercropping is commonly practiced in the orchards. In most cases, basin irrigation is adopted for orchards and intercrops are left to rainfed only, because of poor application efficiency and costly pumping. Irrigation of many fields is hampered due to peculiar mountainous topography. A self help based contour channel diverted from the upper reaches of the stream carrying 14 to 21 lps discharge was used to command about hundred acres of land. A portion of the channel was eroded due to 2006 flood desertifying the command area. Such incidents are common and many fields are prone to erosion due to steep slopes and inundation. Soil conservation and protection measures are required, but poverty level of the community does not warrant those practices. The desertified land can again be made productive if the eroded portion of the channel is rehabilitated through protection measures.

The farmers operate their tubewells to irrigate their fields without due consideration of water management or groundwater behaviour. The lack of regulated water use practices, excessive pumping and reduced recharge due to recent drought coupled with increased water demand owing to intensive cultivation has lowered water table to 30 metre which otherwise was 15-20 metre a decade before. It will further decline if the present trend of growing more and more orchards and vegetables on tubewell irrigation continue under the traditional irrigation practices.

3.3.3 Land Use and Farm Size

The detail of land use and farm size is given in Table 3.36

Table 3.36: Land Use and Farm Size

Description	*Quantity*
Average farm size	1.77 ha
Cultivated area	67%
Uncultivated area	33%
Fallow area in Rabi	3%
Fallow area in Kharif	13%

Common reasons of non-cultivation were undulated fields, high levels and water shortage. Water shortage is the main reason for more fallow area in Kharif than in Rabi. Survey revealed that land holding is not only small but also in terraced patches. Such small farmers cannot afford the required irrigation infrastructure. Purchasing water is not only expensive but also too difficult and inefficient to carry to the terraced and scattered fields. Limited and uncertain irrigation facilities keep the soils less productive and consequently discourage the farmers for adequate use of non water inputs. Resultantly yield remain very low.

3.3.4 Agriculture

Almost 80% of the population is engaged in subsistence agriculture. Farming is dominated by production of fruit orchards, cereal crops, vegetables and fodders. Rabi crops include wheat, vegetables and Rabi fodder. Maize and vegetables are sown in Kharif. Fruit orchards remain the most attractive farming commodity, sown on almost 47 percent of the cultivated area and f*etc*hing more income per unit of land as compared to the other commodities. Most common prevailing orchards include, peach, pears, plums, apple and apricot. The fruits are largely dispatched to market, most commonly at Peshawar and Rawalpindi (150 to 250 km) and less commonly at Mangora (20 km). Because of the poor road infrastructure and inadequate packing facilities, most of the fruit is perished and wasted during transportation. Even then the farmers are getting net income of Rs 25,636/ha which is highest of the other prevailing commodities grown. Net income from orchards can be increased if irrigation facilities are improved and packing and transportation infrastructure is strengthened.

Rabi cropping intensities are given in Figure 3.17. Wheat is the most dominant Rabi crop having the dual purpose of staple food and dry fodder for livestock. In Rabi, almost every farmer devotes a substantial portion of its land for wheat. Traditional varieties of wheat such as Bhakkar 200, 2002, Inqilab 91, 97 and Fakhar-Sarhad are sown. Variety matching the agro-climatic potential of the area has been introduced and resultantly yield remains below average. Low yield discourages the farmers from adequate use of inputs and fertilizers. Net income from wheat, therefore is Rs 3,687/ha which although is low but still better than the other cereal crops.

Kharif cropping intensities are shown in Figure 3.18. Maize is the major Kharif crop of the area. Most commonly sown varieties are hybrid-Punjab, Azam, Jalal and Pahari. Farmers do

not consider it an attractive crop and its consumption is more or less domestic and for fodder purposes. Net income from maize comes Rs. 3020/ha.

Different vegetables are grown in the area including cabbage, cauliflower, tomatoes, peas, beans, onion, capsicum, spinach and potatoes. The area has a good potential for production of vegetables. Despite the area having good potential for vegetables, yield of vegetables is 12150 kg/ha, generating net income of Rs. 15950/ha. Mechanized farming and laser land levelling are least practiced in the area. Bed and furrow method of irrigation prevails for vegetables. The vegetables normally require frequent shallow irrigation, which is not practical owing to mountain topography and limited water resources. High pressure irrigation system can mitigate that problem and can increase the yield of vegetables in the area having good yield potential.

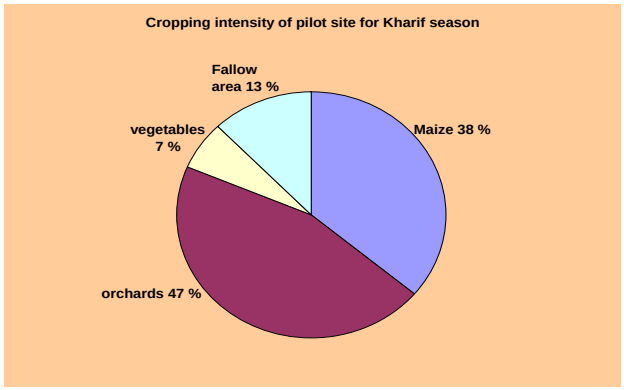


Figure 3.17: Rabi Cropping Intensity

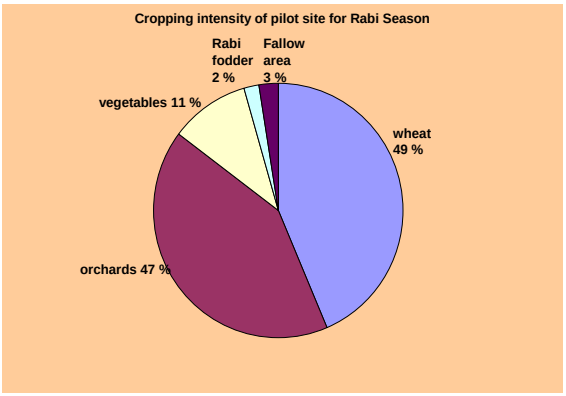


Figure 3.18: Kharif Cropping Intensity

Agricultural production is constrained by many factors, including: lack of cultivated land; irregular, small, and high fields, inadequate surface water and high cost of pumping; undulated field requiring costly piped conveyance system; poor income level; low literacy rate and limited access to micro-credit; lack of awareness about improved farming practices; technologies; extension services; and quality seeds.

Summary

The soil of Malk-e-dam valley is of clay loam texture. Sixty four percent farmers depend upon agriculture. Irrigation is mostly done with groundwater and rainfall as no canal water is available. Average water-table depth is 25-30 m. Extensive pumpage is however causing an annual decline of 1 m in the water table. The constraints to crop productivity are: irregular, small and undulating field; low literacy rate; seed quality; lack of awareness about improved

agricultural practices. However, improved cultural practices and irrigation facilities, packing and transportation facilities could further improve water productivity and net income.

3.4 COASTAL AREAS

The site is located in the coastal belt, 47 km away from Karachi in Murad Ali Barohi village, Gharo town, District Thatta. The area is hilly and is covered by small hills from all around. The national highway is situated in south of the project area. The stratum is predominantly rocky with shallow soils of a maximum depth of 1 to 1.5 m. About 50% areas is cultivated, where sowing of flowers, vegetables as well as poultry farming is common, 25% is culturable waste due to unavailability of water, whereas the remaining 25% is unavailable for cultivation due to rocks. The upper layers of cultivable soils are sandy and have steep slopes. The hilly catchments of area generate runoff in the tributaries and streams in the form of flash floods to ultimately dispose in the Arabian Sea. The average annual rainfall in the area is 300 mm and mostly occurs in summer.

3.4.1 Socio-Economic Status

The area is devoid of basic social needs like school, dispensary, electricity, water supply and communication network. Therefore, mostly people are uneducated and belong to poor and below medium class. The main sources of income are agriculture, livestock and labour. Drinking water and electricity facilities are available only in two villages *i.e.*, Jakhio and Khaskhaily but there is no proper sewerage system in the whole area. The irrigation sources for the area include rainfall and two seasonal streams and limited groundwater because of saline groundwater. There are six diesel operated tube wells of 14 lps discharge capacity which are used for irrigation and drinking needs. Mostly submersible pumps are used in the area, where water-table depth varies from 3 to 20 m.

Table 3.37: Socio-Economic Features of the Site

Sr. No.	*Description*	*Quantity*
1	Population (No)	2240
2	Literacy Rate (percent)	40
3	Total Landholding (ha)	66
4	Cultivated Land (ha)	35
3	Landholding (ha/family)	0.23
5	Average Annual Income from Agriculture (Rs/capita)	38
7	Tubewells (diesel operated)	6

Summary

The depth of soils at Murad Ali Brohi village is 1-1.5 m. Around 50% of the area is cultivated and 50% is unavailable for cultivation due to rocks and unavailability of water. The average annual income from agriculture becomes only Rs. 38/capita. The area suffers from flash floods during rainy season which rapidly disposes into the Arabian Sea causing damage to crops and soils. The area is extremely devoid of the basic social needs like dispensary, electricity, sewerage, water supply and communication.

3.5 UPLAND MOUNTAINOUS AREAS

The site is located in the Chashma Achozai near Quetta city and is situated at 30^0 17.8/ latitudes, 66^0 57.8/ longitudes at an altitude of 1646 m above sea level. The selected site is surrounded by a series of Koh-e-Takatoo mountains on the north, Killi Almas & Killi Sara Ghurgai on the east and Baleli on the west. Quetta-Chaman road also runs parallel to selected site at a distance of 0.5 km.

The climate of the project area is generally dry and cold. The rainfall is erratic and scanty as the area does not fall in the monsoon belt. There are slight chances of snowfall during the winter (October to March), whereas the summer season is moderate and hot.

According to 1998 census, the population of Chashma Achozai village is 1750, with an average annual growth rate of 5.83%. The literacy rate is 40.3%, which is much better than other parts of Balochistan. Four major pashtoon tribes *i.e. Kasi*, *Dummar*, *Kakar* and *Breach* live in the area. The farm size varies from 1-12 ha. Mostly orchards are grown in the area. The total area of the site is about 385 ha.

3.5.1 Sources of Irrigation

There are two main sources of irrigation *i.e.* spring and Tubewell. The spring water is distributed among farmers through traditional warabandi system on 14 days rotation. There are 34 shareholders who avail spring water according to their extent of landholding and participation in the construction work of spring water channel. The total length of the main channel is about 3,416 m. The discharge of spring measured at daylight point with current meter on the 27th January, 2007 was 30 lps. As the spring water does not fulfill the irrigation requirement of the command area, the farmers have installed their own tubewells. Twenty-five tubewells have been installed in the command area; out of which 8 have been dried. The water table in area is from 61 to 94 m.

3.5.2 Cropping Pattern and Intensity

There are two cropping seasons in the area (Quetta District) *i.e.* Kharif and Rabi. The important Rabi crops are wheat, barley, vegetable, cumin and fodder, whereas Kharif are vegetables, potatoes, melon, watermelon, fodder, onion *etc*. There is a series of orchard of different species where good quality apple, apricot, peach and plum are produced. The total orchard area is about 80 ha, with 19 ha of vegetable, 45 ha of wheat and 2.43 ha of fodder.

In the area 52% farmers have a farm size up to 4 ha, 24% have up to 6 ha and 24% have above 6 ha. The peak consumptive period of water for orchards starts from April till end of October. The farmers irrigate their fields mostly by the conventional irrigation system *i.e.* large basin, causing extensive water losses. In the project area, 62% of shareholders get spring water up to 10 hours on 14 days rotation, 26% up to 15 hours and 12% more than 15 hours.

3.5.3 Beneficiaries' Participation

In order to have maximum stakeholder participation, WUA of Chashma Achozai was formed. It consists of all the farmers owning land in the command of Chashma Achozai. A list of members is given in Table 3.38:

Table 3.38: Water Users' Association (WUA)

President	Haji Abdul Rashid Kakar
Vice President	Khudai Rahim
General Secretary	Zain-ul-Abdin
Joint Secretary	Abdul Rashid Kasi
Press Secretary	Zubair Ahmed
Cashier	Haji Dawood

Summary

The total area of the site is 385 ha with a total population of 1750. The literacy rate is 40%, where mostly people belong to lower middle and middle class. Spring and Tubewell are the main sources of irrigation. Spring water is not enough to fulfill the crop water requirement of the area, therefore, farmers have installed their own tubewells. The crops grown in the area are wheat, barely, fodder, melon, watermelon, vegetables and fruits *etc*. Eighty percent area comprises of orchards which is the major capital generating activity.

3.6 RAINFED AREAS

The site is located in Tehsil Gujar Khan, District Rawalpindi, 55 km south-east of Islamabad. Geographically, it lies at latitudes 33°-15'-35" N and longitudes 73°-17'-59" E. It comprises of four villages *i.e.* Bhagpur, Dhok Mal Khokharan, Bouchial and Chiari Baghial. The cropping intensity and yield of the area is low due to sole dependence on rainfall. Mini dams, lift irrigation schemes, dug wells, sprinkler and drip irrigation sytsem have been identified as the appropriate water development and management technologies.

3.6.1 Socio-Economic Status

The distance of the site from farm market (Gujar Khan) is about 10 km. The water sources include rainfall and perrenial nullahs which remains unutilized so far. The agricultural features of the area are given in Table 3.39.

Table 3.39: Socio-Economic Features of the Site

Average farm size (ha)	7.28
Cultivated land (%)	69
Uncultivated land (%)	31
Reasons for non-cultivation of land	Water shortage, un-developed/uneven land
Method of irrigation	Rainfed
Education level	Matriculate



Figure 3.19: A Veiw of Agricltural Field



Figure 3.20: A View of Perennial Nullah at the Site

3.6.1.1 Cropping Pattern, Yield and Income

The important Rabi crops are wheat, gram and oilseed, whereas the Kharif crops include maize, pulses, groundnut and fodder. In Rabi, mostly wheat is grown, whereas maize and groundnut are dominant in Kharif season. The cropping pattern, intensity, yield and net income of the crop are given in Table 3.40. The average annual cropping intensity was about 144 percent during 2005-06. The yields of wheat and maize are higher *i.e.* 2471 and 2965 kg/ha, respectively than other crops. The average net income was found the highest for groundnut (Rs. 24710/ha) in Kharif and gram (Rs. 12355/ha) in Rabi, respectively. The annual farm income that includes crops, by products of crops, livestock, by products of livestock and farm machinery comes out to be 70 percent, whereas non-farm income (salary, pension, rent *etc*) was 30 percent.

Table 3.40: Cropping Pattern, Intensity, Yield and Net Income

Crop	*Average Yield (kg/ha)*		*Average Net Income (Rs/ha)*		*Cropping Intensity (%)*	
	Kharif	*Rabi*	*Kharif*	*Rabi*	*Kharif*	*Rabi*
Wheat	-	2471	-	4942	72	82
Gram	-	1779	-	12355		
Oilseed	-	1581	-	7413		
Maize	2965	-	3336	-		
Pulses	988	-	8648	-		
Groundnut	1828	-	24710	-		
Fodder	1977	-	2965	-		
Annual					*144*	

3.6.1.2 Constraints to Crop Productivity

The constraints to crop productivity as identified by farmers during PRA includes water shortage, no access to agricultural machinery (rotavator, harvester *etc*), high prices of diesel, undulated lands, costly inputs, soil erosion, scanty rainfall *etc*. Most of farmers were unaware of the utilities of modern technologies like laser levelling, bed planting and improved verities of seed. The yields of crops at the site are lower than that of irrigated areas. However, these yields are higher than average of rainfed areas, since the site receives comparatively more rainfall than the other rainfed areas (Table 3.41).

Table 3.41: Comparison of Yields (kg/ha) with Irrigated and Rainfed Areas

Crop	*Site*	*Irrigated*	*Rainfed*
Wheat	2471	2628	1321
Gram	1779	-	711
Oilseed (Kanola, Sarsoon)	1581	797	-
Maize	2965	2385	-
Pulses	988	-	520
Groundnut	1828	-	1051
Fodder	1977	574	-

3.6.1.3 Beneficiaries' Participation

To have maximum stakeholder participation, WUA was formed which is involved in the implementation as well as operation and maintenance of the project activities (Table 3.42).

Table 3.42: Water Users' Association (WUA)

Name	*Area (ha)*	*Designation*
Mrza Muhammad Mukhtar	5.06	President, WUA
Altaf Hussain	3.74	Secretary, WUA
Raja Gulfaraz	2.02	Member
Haji Zafar	8.85	Member

Summary

Water source at this site include rainfall and unutilized perennial nullahs. Average farm size of the site is 7.28 ha, where 69% area is cultivable. The yields of wheat in Rabi and maize in

Kharif are higher than other crops. The average net income for groundnut in Kharif and gram in Rabi are the highest *i.e.* Rs. 24710 and Rs. 12355/ha, respectively. Farmers normally rely more on non-farm income. The constraints to crop productivity include: shortage of irrigation water, inaccessible latest cultural practices, and high diesel prices, which do not let pumping from nullahs feasible and loss of soil.

3.7 AZAD JAMMU AND KASHMIR

The site is located in the Sehnsa valley district Kotli (Azad Kashmir). The site comprises four villages *i.e.* Plate, Plate Bala, Kharawat and Chak Sardar. The valley is surrounded by mountains and forests full of medicinal plants and wild life. The sources of water include rainfall and an unutilized perennial, nallahs which ultimately dispose into the river Jhelum *i.e.* the boundary point between Azad Kashmir and Pakistan. Sehnsa is a sub-divisional headquarters of Kotli district at a distance of 35 km from district headquarters.

3.7.1 Socio-Economic Status

The site is located at a distance of 95 km from the agricultural market *i.e.* Rawalpindi. Mostly the education level in the area is middle. The people are relatively less dependent on agriculture. The salient socio-economic features of the site are given in Table 3.43.



Figure 3.21: A View of Perennial Nullah in the Valley



Figure 3.22: A View of Agricultural Field

Table 3.43: Socio-Economic Features of the Site

Description	*Quantity*
Average farm size	10 hectares
Cultivated land	75 percent
Uncultivated land	25 percent
Reason for non-cultivation	Undeveloped, uneven, soil erosion, water shortage, fallow land, rocky
Method of irrigation	Rainfed
Rabi Crop	Wheat
Kharif Crop	Maize

3.7.1.1 Cropping Pattern, Yield and Income

The major crops grown in rabi and kharif are wheat and maize, respectively. The cropping pattern, intensity, yield and net income of the crops are given in Table 3.44. The cropping intensity of wheat and maize is 100 percent whearas the average cropping intensity was about 200 percent during 2005-06.

Average yield of wheat and maize is 1581 kg/ha and 2174 kg/ha, respectively. The yield of wheat in the area was higher than that for average in the rainfed Punjab. In contrast, yield of maize was less than that of rainfed Punjab. The average net income of the wheat and maize at the farm is Rs. 4448 and Rs. 2916/ha, respectively (Table 3.44). The annual non-farm income

(54%) is more than that earned from agriculture which indicates that farmers are less dependent on agriculture, due to lack of availability of irrigation water.

Table 3.44: Cropping Pattern, Intensities,Yields and Net Income

Crop	*Yield (kg/ha)*		*Average net income (Rs/ha)*		*Cropping intensity (%)*	
	Kharif	*Rabi*	*Kharif*	*Rabi*	*Kharif*	*Rabi*
Wheat	-	1581	-	4448	100	-
Maize	2174	-	2916	-	-	100
Annual					*200*	

3.7.1.2 Constraints to Crop Productivity

The major constraints that hamper crop productivity include shortage of irrigation water, expensive agricultural machinery, soil erosion, undulated lands, lack of awareness, poor quality of fertilizers and seeds.

3.7.1.3 Beneficiaries' Participation

The WUA has been formed (Table 3.45) to have maximum stakeholder participation. The farmers are involved and made responsible for operation and maintenance of project activities.

Table 3.45: Water Users' Association (WUA)

Name	*Landholding (ha)*	*Designation*
Shah Nawaz Khan	1.82	President, WUA
Zafar Iqbal	1.52	Secretary, WUA
Raja Abdul Karim	2.27	Member
Raja Kamal	3.54	Member

Summary

The average farm size at this site is 10 ha, out of which 75% is cultivable. Twenty five percent of the total area is unavailable for agriculture due to uneven lands, rocky soils, soil erosion and water shortage. The people are less dependent on farm income (46%) as the agriculture solely depends on scanty and undependable rainfall. The average net income for the wheat and maize at this site found Rs. 4448 and Rs. 2916/ha, respectively. The constraints to crop productivity include: shortage of irrigation water, expensive agricultural machinery, soil erosion, undulated lands and adulterated fertilizers.

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