Water Harvesting in Mountain Areas of Pakistan: Issues and Options

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Water Harvesting in Mountain Areas of Pakistan: Issues and Options [1]

Shahid M. Zia[2] and Tahir Hasnain[3]

1. Introduction

Pakistan is situated in the arid and semiarid region of the world between 24°N and 37°N latitude and between 61°E and 77°E longitude. Average annual precipitation ranges from 2000mm in the north to 100mm in the south (PCRWR, 1994). Pakistan has two mountain ranges in the Hindu Kush-Himalayas (HKH), namely the western mountains and northern mountains. Many rivers flow from these mountains to join river Indus. The Indus River and its main tributaries i.e., Kabul, Jhelum, Chenab, Ravi, Bias, and Sutlej, together form one of the largest river systems of the world. Pakistan operates the world's largest contiguous gravity flow irrigation system. About 80 percent of the arable area have been brought under irrigation through a network of barrages and canals in lowland and plain areas of Pakistan (Annex 1, 2, and 3).

Mountain agriculture is still largely rainfed. Several indigenous water harvesting methods in mountain areas, such as *rod kohi* system (water of hill torrents collected in reservoirs and used for agriculture) in southern North-West Frontier Province (NWFP); *sailaba* and *khushkaba* systems in Balochistan have been evolved over time. To supplement surface water, ground water use through tubewells is getting popular both in NWFP and Balochistan.

This study reviews Pakistan's water resources in mountain areas and their development potential for enhancing agricultural production. It attempts to examine water harvesting techniques and analyses impacts of selected policies, in this regard, on water resources and local communities.

1.1 Physical Characteristics

Pakistan has been divided into seven broad land resource regions: northern mountains, barani lands, irrigated plains, sandy deserts, sustainable rod kohi, western dry mountains and coastal areas. There exists, ecologically speaking, a great biological, physical, cultural and ethnic diversity in the mountainous areas (Fig 1). Great variation in topography, rainfall, vegetation and farming systems in the mountains, is also evident from the growth of almost all kind of crops. However, such diversity makes it difficult to generalize or to make comparisons. Further, it would require well-planned interventions in line with fragility, marginality and human adaptation mechanisms to transform mountains into agriculturally productive areas.

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1. The ICIMOD sponsored this study as part of a Regional Workshop on Local Water Harvesting for Mountain Households in the Hindu Kush-Himalayas, Katmandu.
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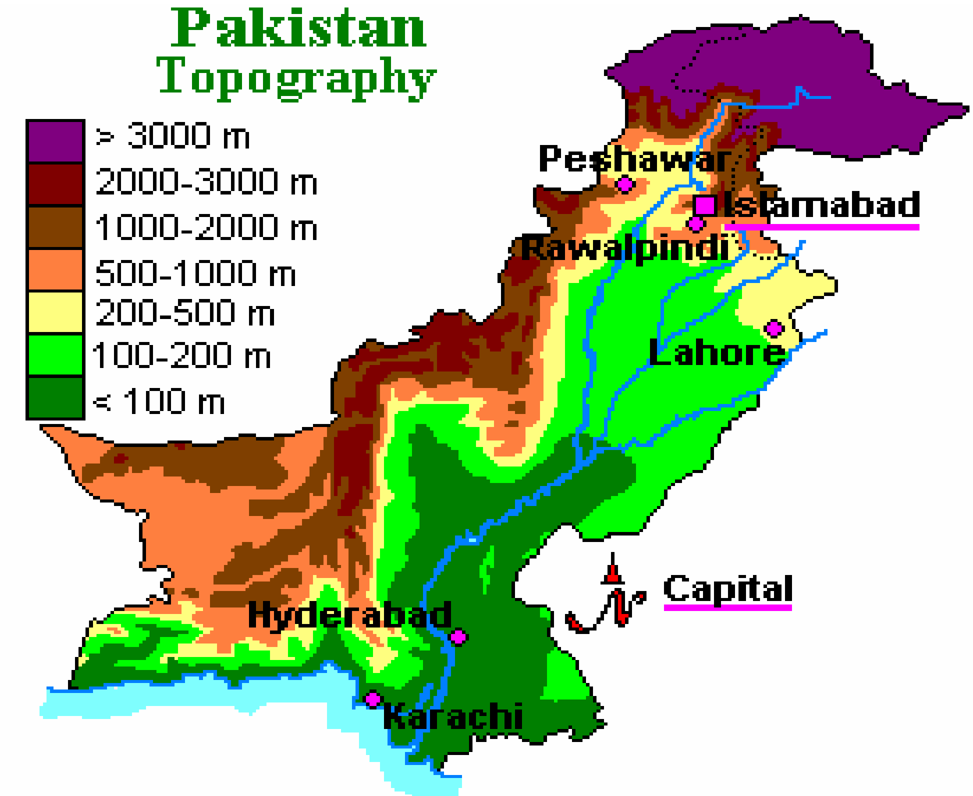
Figure 1:



In mountainous areas, arable farming, pasture or social forestry is the common use of land. It is the generally altitude, climate, physiography, soil moisture and socioeconomic conditions which determine the use of land. Over 90 per cent of the area comprises of steep slopes with shallow soils. These slopes are unstable and support patchy natural vegetation. Large tracts between 900 to 3300 meters elevation support coniferous forests. In elevations up to 1500 meters, pastures are grazed round the year. Over grazing by small ruminants cause stress on the vegetative cover. With increasing population pressures and more demand for food and fiber, mountainous lands are being put to uses that cause land degradation and thus vegetative capacity has been substantially reduced. Higher elevations between 1500 to 3000 meters are grazed only during summers, the pastoralists moving with the snowline (Fig 2).

Figure 2:

Northern mountains include Malakand Division, Hazara Division, Northern Areas and Murree-Kahuta Tehsil of Rawalpindi District covering 96,340 sq. km. and hosting a population of 7.82 million in 1993. Agricultural land is privately owned in small holdings with bulk of farmers engaged in subsistence farming. There are also communal and state owned lands. Income levels are relatively low and overseas remittances play an important role in the local economy.

Western dry mountains make the core of the arid land and cover, to a large extent, the major part of Kohat and Bannu districts of NWFP and tribal areas/agencies of Kurram, Northern Waziristan, South Waziristan, Bannu and Kohat (see the map). The average rural population density of 12 inhabitants per square makes the region, by far, the most thinly populated in Pakistan. The low population density is attributed to lack of water resources and economic opportunities.

The environment is impoverished by the development interventions. This area is rich in minerals and natural gas but these are exploited by the more affluent and powerful. Water is scarce and whatever resources are available, these are ill managed. Several resources still remain untapped.

The inefficient water utilization has led to wastage of tapped water resources. The water table in some areas of Balochistan is going down more than a meter every year due to over pumping for irrigation. The run off, flash flood waters are allowed to escape to the Arabian Sea leaving soils in upland areas exposed and degraded. Soil erosion, it is believed, is a major cause of desertification in upland areas.

1.2 Socio-Economic Conditions

Mountainous areas in Pakistan skim the north west of the country forming a formidable barrier. The ecology of these areas varies and their capabilities can be severely limited by the natural resources (Table 1). This is reflected in the culture and social norms of the area. The social system can be very collaborative to the extreme harshness of tribal systems. The harmonious living of the Northern areas on one extreme is countered by the tribal conflicts in the south west. The tribal system follows its own codes of conduct and justice. The tribes are very tightly organized. The tribal leadership is still intact and codes are rigidly implemented. The way of life, the compulsions in these areas are different from the plains. The social structure of some tribes has been modified in some cases by their proximity to settled areas. Efforts made previously, in this regard, by successive governments have been unsuccessful for the reason that physical power has been used as an intervention. Evidence is available that the said change can be achieved through simple economic interventions. However, these have not been followed in Pakistan. The above mentioned change may have come about by accident and not as a matter of government conscious fiat.

Table 1: Profile of Food Security and Natural Resources in Pakistan

Food production per capita 1993 1980=100	118
Food imports per capita 1993 1980=100	114
Cereal imports per capita 1994 (1,000 tons) 1980=100	201
Food aid in cereals per capita 1994 (1,000) 1980=100	19
Food aid 1992 ($ million)	190
Land area (1,000 ha) 1993	79,610
Irrigated land (as % of arable land area) 1994	80
Deforestation (1,000 ha per year) 1980-89	9
Annual rate of deforestation (%) 1981-90	2.9
Reforestation (1,000 ha per year) 1980-89	7
Production of fuel wood and charcoal (1,000m^3 per year) - 1980 - 1993	16,683 25,021
Internal renewable water resources per capita (1,000m^3 per year) 1995	3.3
Annual fresh water withdrawals 1980-89 - a % of water resources - per capita (m^3)	 33 2,053

Source: IIED. 1998.

The cultural aspects provide security and subsistence under very harsh conditions. It may be easy to condemn a given social system because it no longer coincides with an ideal model of a system. Where living conditions are harsh, where production systems are nomadic or non-existent there may be no other option but to be part of a given system. So far, modern economic opportunities have not entered the area. Conflicts between the government and the tribes are a common occurrence as a result the areas are closed to development of resources. Education, health facilities are unheard of and roads are not allowed to be constructed. Electricity is frequently vandalized. Given this scenario, development is pushed back by decades. The will and the write of the Federal government is virtually non-existent. A more participatory approach especially in the western dry mountains, is required to change the existing conditions.

2. Water Harvesting Programmes

Small isolated communities in the mountain areas use several novel techniques to store rainwater for domestic as well as agricultural uses. A few documented examples of water harvesting methods developed for agricultural purposes, in the mountain regions are; *diversion* *system* and the *dam system*. Under the diversion system, a long channel diverts the floodwater to cultivation areas adjacent to the valleys. Under the dam system, a large reservoir behind the dam is filled with floodwater. The reservoir water is then pumped through pipes to numerous sprinklers, which spread the water onto winter crops.

As far as water harvesting for domestic needs is concerned, two major approaches are applied: the community owned approach and the household approach. The communities in mountainous and arid regions collect rainwater in large reservoirs located inside or adjacent to the localities and villages. These reservoirs may be open ponds or underground, concrete, water tanks, which preserve water for varying time periods according to their size. People also practice different household techniques to harvest and store water.

The non-availability of information about the invaluable indigenous practices, is one major hurdle in the acceptance, adaptation and replication of these techniques at the broader scale. We have compiled two case studies in this document. These case studies cover the water harvesting practices developed by the indigenous people in southern NWFP called *rod kohi* system; and *sailaba* and *khushkaba* systems in western Balochistan province to address the domestic and agricultural needs of water. The agricultural and domestic watering needs of these regions are met through rainwater harvesting.

2.1 Rod kohi Water Harvesting System in Southern NWFP

The southern regions of the NWFP province, comprising D.I. Khan and Tank districts, are bounded by *Suleiman* range on the west, *Bhittani* range on the north and *Marwat* range on the east. The area between *Suleiman* range and the Indus River, interalia, constitutes a huge wasteland locally known as '*Damani* Area'. This area is frequently subjected to hill torrent flooding. Five major hill torrents called zams, along with a number of small ones, traverse *Damani* area. Flash floods of shorter duration and higher magnitude hit the area generally during monsoon, part of which is utilized by the locals in a traditional manner of irrigation called *Rod Kohi* System. The *zams* bring large quantity of water laden with high silt charge when they come eroding soils from the *darahs* (passage between the hills). The water is used by the landowners through a network of *gandis/sads* (earthen temporary dams constructed across the bed of the torrents), in the piedmont area, enroute to the Indus River. There water is led into the embanked fields, through "*khulas*" (shallow channels) and '*palas'* (trail-dikes). The high embankments used to divert water into terraced fields are generally filled with water from about 1 to 1.5 meters deep, after which the water is released to the next field and so on. This system of diversion continues till either the flood flows are completely exhausted or all the fields are filled. The major *zams* have some perennial flows aggregating to about six cubic meters per second, which are used for cultivation of about 28,340 ha. The monsoon flows are utilized for *Rabi* cultivation in September and October.

The *Rod Kohi* (hill torrent) Irrigation System of the area is more than a century old and is the vital component of the local economy, social set up and the environment. The under construction Chashma Right Bank Canal (CRBC) is planned to command the area located on the right bank of river Indus would continue to depend on the traditional *Rod Kohi* System. Total *Damni* area under *Rod Kohi* Irrigation System is 263, 730 ha. This is inclusive of 23,500ha area being irrigated by CRBC under gravity flow conditions. The area irrigated through perennial supply available at different *zams* is bout 24,300 ha. The remaining 239,430 hectares are irrigated by flood irrigation. The *Rod Kohi* System comprises of 11 flood channels, which originate from *Kohe-Suleiman* range through different gorges (*darrahs*). Out of these five are major hill torrents (*zams*) and six are small hill torrents (rods). Major *zams* Tank, Gomal, Sheikh Haider, Daraban and Chodwan further fan out into 17 rods. The rods are further divided into minor distributors (*wahs*) to take the water into the fields. This network aggregates to 1,168 km into length. In addition to this a number of diversion weirs/distribution structures have been constructed on different rods to divert flow in different channels. A *zam* can be broadly divided into mountainous area, sub-mountainous and plain area. The five major *zams* are rain-fed and perennial. These *zams* possess considerable discharge, in which sediment concentrations are enormous and the damming of flood flows in some cases is not economically feasible. Thus, these *zams* warrant a systematic planning for effective management.

Rod Kohi System is governed by rules and regulations called '*Kulyat and Riwajat-i-Abpashi*' (rules and regulations for irrigation) established more than a century ago by the local people. These rules and regulations provide detailed information regarding distribution of flows to the riparian. However, the settlement officers have made minor changes, modifications and adjustments, from time to time without violating the basic governing principles or the established rights of different villages and their people.

2.1.1: The Rod Kohi System: Critical Issues

The farmers have some problems with the *Rod Kohi* System. The '*sad/gandis*' built improperly, usually breach under the flow of floodwater before the required irrigation is accomplished. Quite often these are not completely constructed, and thus, create problems in irrigation. The floodwater continually cut out new channels and ravines. Consequently, the whole area is affected by flood flows. Sometimes the floods of different torrents accumulate in certain ravines, rendering the flow unmanageable and cause huge damage to lands, and property. The embankments surrounding the fields, which play a vital role in the irrigation system of the area, are generally weak and get washed away, releasing most of the impounded water. The fields, therefore, sometimes do not retain sufficient moisture, to make any cultivation possible.

The other main problems that farmers face in the Rod Kohi System are the non-availability of the earth moving machinery at appropriate time and inadequate man power for constructing temporary diversion dykes during the hot months of June and July, when sufficient water, shelter and fodder are unavailable. This leads to higher irrigation costs every year (table 2). The evidence shows that every year the cost of irrigation and the area irrigated fluctuates. And as expected, the area irrigated and the associated costs do not go hand in hand. That means the cost of irrigation is not linearly associated with the area irrigated. The costs have risen from less than a Rupee to more than 60 Rupees per acre from 1979 to 1989 (Fig 3).

The short-lived flows of floodwater do not conform to the crop water requirements of the area. The flood flows are generally impregnated with a high silt charge, which preclude the possibility of economical management through reservoirs. The banks of channel are irregular in height and width, which create over-ban flooding phenomenon in various reaches of a channel. Generally the major *zams* have a number of tributaries and offshoots which run into each other and complicate the entire management system. Furthermore, on account of the bilateral slope and highly variable flows loaded with silt, the channels frequently change their course to make the locations of cross drainage structures on canals and roads unpredictable.

Table 2: Yearly irrigation of area by flood water and the cost in D.I.Khan

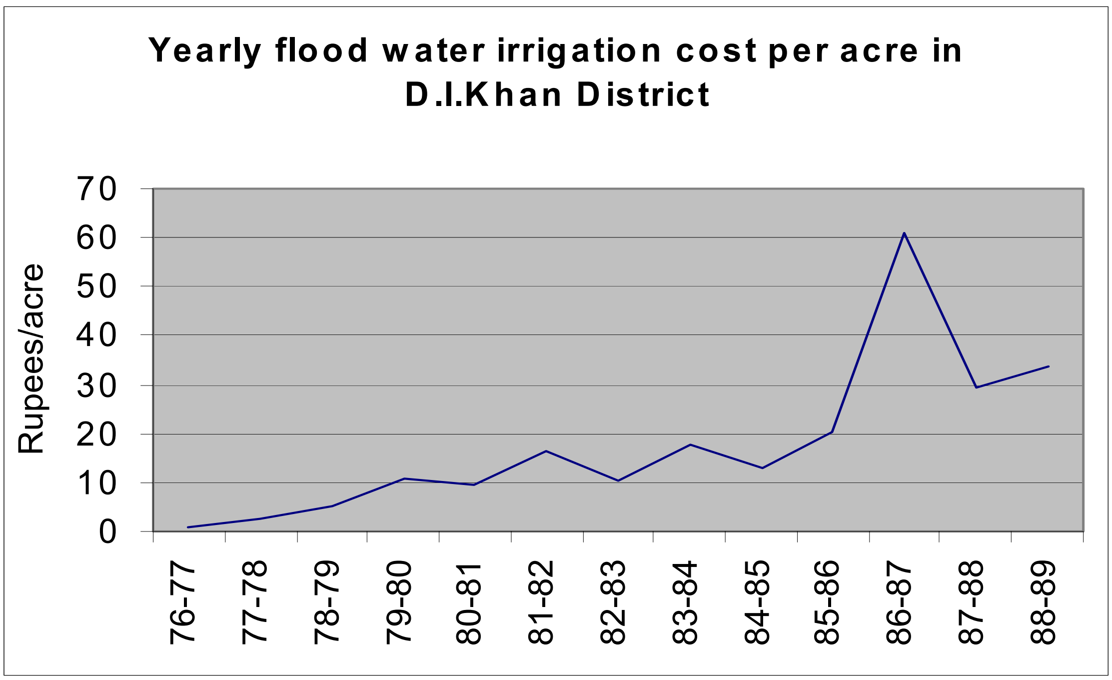
Year	Area irrigated (000 acres)	Amount spent (000 rupees)
1976-77	202	185
1977-78	280	665
1978-79	350	1,825
1979-80	245	2,675

Continued.....

Year	Area irrigated (000 acres)	Amount spent (000 rupees)
1980-81	284	2,675
1981-82	188	3,075
1982-83	406	4,250
1983-84	280	4,960
1984-85	346	4,414
1985-86	324	6,601
1986-87	125	7,628
1987-88	250	7,341
1988-89	250	8,391

Source: PARC, 1990.

Figure 3



Source: PARC, 1990.

The *Rod Kohi* channels have got silted up at different places due to continuous neglect and improper maintenance. Quite often it is unable to accommodate the full water discharge and results in unpredictable floods. These ravines ultimately join the ones scoured out by neighboring torrents to further aggravate the flood situation. The water, thus, does not flow in its proper course; on which *gandis* (dams) are erected. The floodwater continues to flow unchecked and goes waste instead of being put to good use. In addition it causes damage to the lands and property. The time, location and mode of construction and the quality of the *gandies* are important factors that determine their efficacy in diverting the floodwaters for a meaningful purpose. Sometimes when the dam is not constructed before the onset of a flood, or it is imperfectly built and the shallow channels are not prepared and maintained to withdraw water from the dams, they are washed away under the pressure of impounded water.

The hill torrents keep on changing their course due to varying capacity of discharges and sediments. The diversion of flow in one channel above its carrying capacity cause flood problems, crop damages in the area, infrastructure wreckage, land erosion and ravine formation; ultimately the result is social problems. Cross drainage structures are constructed to control the situation but due to unpredicted channel behaviour and quantum of flow, there is every possibility of damage to the irrigation system. At present, the *Rod Kohi* System is working under the supervision of the Deputy Commissioners both in D.I. Khan and Tank districts. The existing administrative setup is facing some major constraints, like paucity of maintenance funds, non-availability of jeeps for supervising staff, inadequate office buildings and engineering staff, scarcity of earth moving machinery and mobile workshops and inadequate extension services by the agriculture department for training and awareness of farmers.

2.2 Water Harvesting in Northern Balochistan

The Pishin district lies in northern Balochistan. The general character of the district is mountainous. The northern half of Pishin district is covered by the Topa Plateau. The hill ranges are fairly uniform in character, which consist of long central ridges from which frequent spurs descend. The spurs vary in elevation from about 1,500 to 3,300 meters. The major occupation is agriculture joined with others like forestry, hunting and fishing. The major agricultural crops of the district are wheat, tobacco, potato, apple, grape and barley. Sheep and goat breading is also common in the district because of vast pasturelands, and is a major source of livelihood of the people. The local people manufacture blankets and *Namdas* and embroidery work is carried out as cottage industry.

In Pishin rainfed farming is widely practiced. Two major water harvesting techniques applied by the people include building embankments and bunds to divert the stream and floodwater in the rainy season. It is called *Sailaba* system in Balochistan. The other one, *Khushkaba* system depends upon direct rains. The farmers sometimes develop a small catchment area on upper side of the field and the rainwater is harvested for farming on the lower side. Sometimes no catchment area exists and the water is directly harvested in the cultivation fields.

The climate of the district is generally dry and cold, because it lies outside the range of monsoon currents. The rainfall is irregular and scanty and the precipitation varies from year to year. Spring and summer see very little rain fall. The rainfall and snowfall usually occur in January and February. Sometimes snow falls even in March, and the winter rains continue throughout April. The mean annual rainfall in the district varies from 200mm to 300mm. Pishin's elevation from sea level ranges between 1200 to 2000 meter (Anees at el, 1980). Its climate is mild in summer. The maximum temperature rarely goes beyond 35c. The winters in Pishin are severely cold with snowfall and sub-zero-temperature.

2.2.1: Water Sources and Need for Rainwater Harvesting

Major sources of drinking water in the district are wells, spring, river, stream, and ponds. Three fourth of the population use these sources to meet different water needs. The piped water is available to 15 percent households. Piped water is mainly available in the urban areas. Rural population depends upon spring, stream and pond water (Census 1981). Farming in the district is mostly rainfed (*Barani*). In some of the areas, agriculture is carried out with the help of *karezes*. *Karez* is a centuries old system developed by the local people (Pithawalla, Meneck B. 1952). These are underground waterways linking water of various wells and then bringing the water to elevated places, from the downsides. The use of tube-wells has become common in recent years, but both the tube-wells and *karez* are unable to

meet the agricultural and domestic water needs, which can be met through rainwater harvesting.

Pishin like other upland areas of Balochistan is a water scarce district. In spite of being a major source of water for downstream plains, mountain region it self is short of water for irrigation and needs water harvesting for sustainable crops and plants production. There are many important factors responsible for shortage of water in the district, like temporal distribution of water flows, incompatibility between mountain terrain and conventional approach of irrigation systems and failure to develop irrigation designs suited to mountain situations. The scarcity of water in the district calls for adopting comprehensive water harvesting and management strategies in order to meet the demands (Ashraf, M.M. & M. Anwar, 1995).

2.2.2 Water Harvesting System for Rrainfed Farming in Pishin

In the centre and north-east of Balochistan province seven districts are defined as highland rainfed areas. These districts, namely Quetta, Kalat, Pishin, Loralai, Zhob, Kachi and Khuzdar have a total geographical area of 14.9 million hectares, a little less than 43 percent of the total geographical area of the province. The area under crops in the rainfed highlands of Balochistan in 1985-86 constituted 37 percent of the total cropped area of the province (Buzdar, N. et al, 1989). The main characteristic of rainfed farming systems is that it is dependent on erratic and uncertain rainfall causing frequent crop failures. The farmers try to diversify crops and enterprises to minimize risk and ensure continuous subsistence. The farming community's cooperative mechanism also works as insurance against personal economic disasters.

Most of the cultivable lands in Pishin district lie in valleys surrounded by mountain ranges or hills. The most predominant soil types are clay loam, loam and sandy loam. Generally the soils are deeper towards valley centres. Fertility is adequate in areas where rainwater deposits new layers of silt each year. These characteristics of soils in Pishin are quite favourable for rainfed farming. Both type of major farming systems *Sailaba* (Flood) and *Khushkaba* (rainfed) farming systems are in use. These systems are different from each other due to the nature of moisture supply system practiced under each of them.

3. Policies that Influence Water Harvesting at Local Level

The network of irrigation in Pakistan comprises dams, canal, tubewells and rains. The federal government has developed national water policy in consultation with the provinces. In general, water policy in Pakistan is synonymous with irrigation policy with its main objective to enhance irrigation water supplies and irrigated areas through increased investments in irrigation systems.

According to the constitution of Pakistan, water is a concurrent or shared resource between the centre and its four provinces. The federal government has published five year plans ever since the late Fifties. Eight plans have been published so far and the latest one (1993-98) completed in 1998. Both federal and provincial ministries and their allied institutions prepare their annual public sector development plans. Major national projects are managed at the federal level, however, the provinces are also encouraged to plan and undertake projects. Most of these five-year plans include irrigation related projects and programmes but non of these projects deals with water harvesting.

In 1998, the federal government has announced agricultural package. The package for the policy guidelines for the agricultural development in Pakistan announced by the government, provides relief to boost irrigation facilities in the mountain/rainfed areas (GOP, 1998).

Firstly, the water of hill torrents will be harvested through diversions and will be utilised for Rabi (winter cropping season) crops on a sizeable area throughout the Solaiman Range in the Northern Areas, North West Frontier Province (NWFP), part of Punjab and Balochistan. Secondly, for barani (rainfed) areas, schemes of small dams, sprinkler and drip irrigation projects will be initiated to enhance water availability through using water saving new irrigation techniques.

There are some other policies that may have some indirect impact on water harvest and thus water supplies at the farm level. These are discussed in the following section.

3.1 Subsidies and Water Resources

Substantial subsidies on machinery and fuel have encouraged digging of more wells. More wells quite often result into inadequate or careless maintenance of other water resources. For instance, in Baluchistan, availability of subsidized tubewell water has resulted in poor management of traditional *karez* system (Jassra et al, 1998). As a result, many *karez* are no more operational.

Likewise, in Baluchistan, farmers do not virtually pay electricity bills on the basis of electricity consumed. In fact, it is highly subsidised. As a result, they run tube-wells round the clock. The over-pumping of water has two implications. First, over-mining of ground water results into lower water table with almost no recharge, ground water-table falls more than a meter every year. Second, due to availability of almost free irrigation water, farmers generally do not apply indigenous in-situ water harvesting techniques. Thus, rain-water, a very scarce resource, is used inefficiently. The evidence shows that with proper in-situ water harvesting techniques cultivated area can receive substantially more (upto 300 percent) rain fall than that of actual rainfall (Khan, undated).

3.2 Research Policy and Water Harvesting

It has frequently been argued that arid lands in Pakistan though do not receive enough rain fall, proper water harvesting of rain water can be a cheaper source of moisture for crop production where other sources are costly (Khan, undated). Some of the simplest indigenous water harvesting systems can collect 20 to 40 percent of the precipitation for later use. In the early Eighties, Pakistan Agricultural Research Council (PARC) initiated research, in collaboration with ICARDA, to generate viable technologies for water harvesting in rainfed areas. As a result, Arid Zone Research Institute (AZRI), Quetta, developed on-farm water harvesting technology that could increase water storage in the cropped area. Yields in the cropped area were also considerably high (Rees, et al, 1989a). In another study, Rees (1989b) found that cleaning and compacting of upper parts of gently sloping valley-bottom fields, to form a catchment area, could result in considerable increases in water availability and, thus, crop yields can be doubled.

These technologies are in use at various levels and are being refined. The World Bank assisted on-farm water harvesting project-III and IV of Ministry of Agriculture & Livestock aims at maximizing infiltration and storage of water from rainfall in the cultivated areas. Water harvesting strategies for the catchment and sub-catchment areas have been developed (Table 3).

3.3 Watershed Management

Increased demand for forest products and rapidly growing population put further pressure on natural resources in upland areas resulting in degraded watersheds. Though watershed management continued to receive attention, the need for large-scale watershed management projects was felt only after the construction of large dams. Since 1962, watershed management recommendations have emerged as major components of forest policies. Strategies proposed to improve watersheds include large-scale a forestation, soil and water conservation through check dams, gully plugging, and terracing of fields. These steps help increase in-situ water harvesting.

Table 3: Summary of Alternative Water Harvesting Development Strategies

1. **Steeply Sloping Land**
   - 1.1 Erosion Protection
   - 1.2 Forestry Plantations on hedge rows and reverse terraces
   - 1.3 Range Development
2. **Gently Sloping Land**
   - 2.1 Contour Terracing
   - 2.2 Grassed Waterways to control flow
   - 2.3 Pasture Development
3. **Terraced Land**
   - 3.1 Field Levelling (level or graded)
   - 3.2 Improvements to Field Bunds
   - 3.3 Field Spillways and Waterways
   - 3.4 Ridge and Furrow or Contour Furrows
   - 3.5 Improved tillage practices
   - 3.6 Development of Micro Catchments (where annual rainfall is less than 750 mm)
   - 3.7 Improved Farming Systems including development of rotations, improved drought resistant crop varieties etc.
4. **Rainfall Regimes**

   Annual Rainfalls:

< 250 mm]	Developed Micro catchments
250-500 mm]	in Field-Field-Hill Runoff-
500-750 mm]	Alternate
> 750 mm	No additional catchment required.
5. **Eroded Land-Gullied**
   - 5.1 Check structures and other erosion protection structures
6. **Small Streams**
   - 6.1 Diversion Weirs and Channels
   - 6.2 Check Dams for Storage
7. **Depressions**
   - 7.1 Storage Ponds
   - 7.2 Reservoirs
   - 7.3 Check Dams

Source: GOP, 1996.

3.4 Deforestation and Water Supply

In general, deforestation affects water supplies in two major ways. One, it alters the microenvironment of the area and can have negative impact on the annual rainfall. Second, deforestation can accelerate soil erosion, resulting in silting of dams, streams and water channels downstream and, thus, lower water supplies at the farm level. The deforestation in Pakistan is estimated to be somewhere between 7000 to 9000 hectares per annum that equals an annual decline of 0.2 percent in forest vegetation (National Conservation Strategy, 1993). Several projects and programmes, both public, NGOs and private, are underway to minimise deforestation in the country.

3.5 New Farming Systems and Demand for Water

New technological developments, coupled with strenuous public and private sector efforts, have virtually made it possible to shift from traditional crops to high value crops in mountain areas. Large areas have been shifted from traditional crops to vegetables like potatoes, turnips, carrots and radish. Vegetable crops require more and regular irrigation water than other crops (maize). These new developments can lead to new investments for in-situ water harvesting as the returns from the additional water supplies would be very high. Moreover, more and regular water supplies can have positive effect on crop yields and cropping patterns.

3.6 Demand Management Policies

Additional demand for water has to be met either through additional supplies or through demand management. On-farm water management techniques, developed through several development projects like PATA, help increase water use efficiency on the one hand and to develop or improve water-harvesting techniques on the other. Vegetable crops, particularly off-season vegetables, generate more income allowing farmers to accumulate capital for future investments to improve in-situ water harvesting. There are no policies to guide or influence in the development of certain crop rotations that are in line with water availability in that particular region.

4. Institutions involved in water harvesting

Institutions are quite often defined as simply government agencies and private organisations. But more broadly speaking, it is in fact the institutions that set the ''rules of the game'' within which economic system would operate. For instance, property rights system is considered a water institution because it determines access to land and water, and thus, influences the decision to make investments in the farm. The property rights help define the structure of incentives and disincentives, rules, rights and duties that guide human activities and encourage conformist behaviour (Bromley, 1989). Farmers with secure property rights tend to invest more in improving in-situ water harvesting and in ex-situ harvesting.

Institutional structures are also important for allocating available water to different users or to define rights for harvesting rain water. Communities in Balochistan, over-time, have evolved an institutional structure within themselves to allocate the water they harvest through *karez* system. This is similar to that of water users association, a concept that is popular with water policy specialists and practitioners.

Research Institutions are involved in finding ways to improved water-use efficiency through institutional performance. For instance, Arid Zone Research Institute (AZRI) has developed water-harvesting techniques capable of water-use efficiency at the field level. The On-Farm Water Management Programme of Ministry of Agriculture is now testing and adapting these technologies on more than 40 sites in hilly areas of Pakistan. There is a host of institutions involved directly or indirectly in influencing water-harvesting techniques in Pakistan.

WAPDA is the principal federal institution dealing water sector operations throughout the country vigorously. However, the Federal Planning Commission is the supreme body for overall planning of economic development of Pakistan (also see Annex 5).

It has frequently been argued that the major constraint on efficient water management during the past two decades has been the weaknesses of institutions involved in water management. These institutions need to be strengthened and re-organised, where necessary, in order to cope with emerging water management problems brought about by new agricultural crops, water uncertainties and changed social and cultural environments. The policy making process that

currently involve many institutions, mostly in fragmented fashion, do not develop policies to manage water in its totality in a rational way. Without institutional strengthening and rationalisation, water management cannot become optimal.

5. Options

5.1 Incentives and Disincentives to Conserve Water

There are number of factors that provide or influence economic incentives for conserving water. The first, and perhaps the most important, amongst these is right prices. Quite often, under-pricing and under-valuation of resources lead to over exploitation of resources and tremendous loss. The standard policy instrument to correct the situation is to set the market prices right by internalizing social costs. For instance, a subsidy on the use of goods that improve the sustainable use of natural resources and a tax on the use of goods with undesirable consequences can be a useful tool to correct the market and set the prices right.

Secure property rights is another powerful economic instrument that can effectively be utilized to promote sustainable use of natural resources and to conserve water. Right water prices and secure property rights may lead to more intensive water conservation efforts. Participation of people in the management of watersheds and in sharing the benefits is one form of improving the property rights. The evidence shows that substantial improvement in natural resource management can be realized by just enhancing peoples participation in a systematic way. Examples to support this argument abound. For instance, Agha Khan Rural Support Programme (AKRSP) has successfully managed to reduce natural resource degradation in AKRSP areas through better participation of communities. Efforts are being made to provide property rights of state owned lands (mostly marginal lands) to the *haris* (tenants) in Sind and Baluchistan. It is expected that it will encourage the tenants (now owners) to invest more to enhance water availability at their lands.

Other factors that can alter economic incentives include, poverty, inequality, and uncertainty. With uncertain future and inequitable access to resources, poverty can lead to unsustainable resource utilization. Tobacco growing areas of District Mansehra provide a very good example where small farmers have virtually cleared the neighboring hills to meet their fuel requirements for processing tobacco. The development strategies that aim at improving social life and promoting equitable access to resources have better chance of success. Most of the water development projects in Pakistan (which are considered as success stories) have based their strategies on providing equal access to resources and improving peoples participation.

5.2 Replicating Experiences

Both systems, the *Rod Kohi* Irrigation System of D.I. Khan and the *Sailaba* System can easily be replicated in other areas with similar kind of geophysical conditions. The *Rod Kohi* System is typical of hilly areas that face flash floods/hill torrents. The development of this System on artificial basis is possible with high costs to create catchment area. The technology applied for rainfed farming is very simple and cheap, which can be adopted easily. National Engineering Services Pakistan (NESPAK), Irrigation Department, NWFP, and Agriculture Department have the potential and skills to provide institutional support for replicating this system in other areas.

The *Sailaba* farming system is like the *Rod Kohi* System in NWFP province, but here the size of streams/torrents is smaller than hill torrents in NWFP. The *Sailaba* harvesting is dependent upon the collective efforts of the community.

5.3 Public and Private Partnership

The *Khuskaba* farming is practiced by individual farmers, but with the mutual support of community members. The *Khushkaba* farming system is very important for those areas where no irrigation system, streams or hill torrents are existent. Institutional support to replicate and strengthen the rainfed agricultural technology in Balochistan is available in the form of Arid Zone Research Institute (AZRI) in the public sector. Many non-governmental organizations like Baluchistan Rural Support Program (BRSP), Strengthening Participatory Organization (SPO) are actively involved in agricultural development and can play a very effective role particularly to promote *Sailaba* harvesting system where community participation is important. So, the public and private partnership in this regard can be very effective for technology development and dissemination.

5.4 Other Options

More reliable water supply is certainly the most favourable option for development interventions. However, neglecting development of highly irregular rain water of arid zone, would be to neglect a significant potential for domestic use and agricultural production. Therefore this water resource potential should not be dismissed in any development strategy for arid zones.

The development of low cost water reservoirs can play an important role in sustainable mountain agriculture. Topography in mountains provides ample sites for construction of medium and small size reservoirs by blocking ephemeral streams. The stored water can be used for supplemental irrigation of crops and plants.

Introduction of some Distribution Management System (DMS) could be beneficial to ensure the longevity of the resources available. This would need in-depth study of the socio-economic aspects of the respective communities. The study through facilitating the understanding of social dynamics can help in developing community-based institutional arrangements to introduce water allocation practices essential to ensure proper water use.

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Annex 1

Area irrigated by Different Sources

(Million hectares)

Year	Canals	Wells	Canal & Wells	Tubewells	Canal & Tubewells	Others	Total
1990-91	7.89	0.13	0.08	2.56	5.87	0.22	16.75
1991-92	7.85	0.16	0.11	2.59	5.93	0.21	16.85
1992-93	7.91	0.18	0.10	2.67	6.23	0.24	17.33
1993-94	7.73	0.14	0.09	2.78	6.22	0.17	17.13
1994-95	7.51	0.17	0.10	2.83	6.41	0.18	17.20
1995-96	7.60	0.18	0.11	2.89	6.58	0.22	17.58
1996-97	7.81	0.18	0.11	2.88	6.61	0.26	17.85

Source: Economic Survey, 1997-98 (pp 62).

Annex 2

Monthly Average Rainfall at Mountain Areas of Pakistan in 1996

(Millimetres)

Area	Jan	Feb	Mar	App	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rawalpindi	82	122	130	47	32	145	299	328	72	60	3	6
Peshawar	29	74	76	38	15	12	18	110	51	203	42	0
Abbottabad	74	112	256	144	0	162	164	160	89	120	19	14
Kohat	35	43	60	17	31	50	34	107	9	55	1	0
D.I. Khan	15	15	50	0	15	37	19	45	21	10	0	4
Quetta	34	34	30	1	8	2	0	0	0	3	0	9
Zhob	15	19	27	27	28	15	81	114	90	0	0	5

Source: Agri. Statistics of Pakistan, 1996-97 (pp 143).

Annex 3

Overall Water Availability in Pakistan

(Million Acres feet)

Year	Surface Water	Ground Water	Total Water Availability
1989-90	176.26	42.98	117.14
1990-91	185.24	43.98	119.62
1991-92	186.85	44.90	122.05
1992-93	176.60	46.00	124.70
1993-94	180.56	47.45	128.01
1994-95	181.23	48.42	129.65
1995-96	192.59	38.26	130.85
1996-97	192.82	39.23	132.05

Source: Agricultural Statistics of Pakistan, 1996-97 (pp 142).

Annex. 4

Glossary of Local Terms

Rod Kohi	Traditional irrigation through hill torrents
Danani Area	Wasteland between river Indus and mountains of *Suleiman* range
Zam	Hill torrent
Darah	Passage between hills
Sad/Gandis	Earthen dams
Pala	Trail-dike
Khula	Shallow channels
Wah	Minor water channels
Kuliat and iwajat-e-Abpashi	Rules and Regulations for Irrigation

Annex 5

Institutions involved in water harvesting
Government Agencies

1. Ministry of Water and Power (MWP).
2. Federal Water Management Cell (FWMC).
3. Central Engineering Authority (CEA).
4. Water and Power Development Authority (WAPDA).
5. Provincial Irrigation Departments (PIDs) of each province.
6. Irrigation & Power Deptt. of each province.
7. Pakistan Council of Research in Water Resources (PCRWR).
8. Small Dams Organisation, Irrigation & Power Deptt. of each province.
9. Ministry of Food & Agriculture.
10. Pakistan Agricultural Research Council (PARC).
    - National Agricultural Research Centre (NARC).
    - Arid Zone Research Institute (AZRI).
11. Department of Public Health Engineering and Irrigation, in each Province.
12. Agriculture & Engineering Universities.
13. Irrigation Research Institute, Lahore.
14. Agency for Barani Agriculture Development (ABAD).
15. Soil Survey of Pakistan.
16. Geological Survey of Pakistan (GSP).

International Agencies

1. International Irrigation Management Institute (IIMI).
2. United Nations (Tech. Assistance Programme).
3. United Nations Development Programme (UNDP).
4. Food and Agriculture Organisation (FAO).
5. World Bank.
6. USAID
7. Japan International Cooperative Agency (JICA).
8. Asian Development Bank (ADB).
9. The World Conservation Union (IUCN)-Pakistan.

Private Sector

1. National Engineering Services Pakistan (NESPAK), Islamabad.
2. Halcrow Rural Management (HALCROW), Islamabad.
3. Hazara Engineering Consultants, Lahore.
4. National Engineering Services, Lahore.
5. Enterprise Development Consultants (EDC), Islamabad.

Non-Government Organizations (NGOs)

1. Pakistan Institute of Environment Development Action Resource (PIEDAR)
2. Agha Khan Rural Support Programme (AKRSP)
3. Actionaid-Pakistan.
4. Strengthening Participatory Organisation (SPO)
5. National Rural Support Programme

Annex 6

Comparative Efficiencies of Farms With and Without Supplemental Private Tube-well Water Supply.

	Non-user of Tube-well Water	Tube-well Water User	Increase in Yield
Cropping intensity	113	157	
Percent of gardens in cropping pattern	2	11	
Crop yields	(tonnes per hectare)	(tonnes per hectare)	(percent)
Sugarcane			88.6
Wheat	29.0	54.7	41.1
Rice Irri	1.7	2.4	52.6
Rice Basmati	1.9	2.9	29.4
	1.7	2.2	
Net value per hectare	(Rupees)	(Rupees)	27.0
	2,470	3,137	

Source: Pakistan National Conservation Strategy (Table 2.9).