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Run-off Farming in Reducing Rural Poverty in the Cholistan Desert

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I. Introduction

The Cholistan Desert is an extension of the Great Indian Desert (Figure 1), which includes the Thar Desert in Sindh province of Pakistan and the Rajasthan Desert in India, covering an area of 2,580,000 ha. It lies within southeast quadrant of the Punjab province between 27°42' and 29°45' north latitude and 69°52' and 73°05' east longitude (FAO/ADB, 1993; Arshad et al., 1995; Jowkar et al., 1996; Ahmad, 1998; Ahmad, 1999a; Ahmad et al., 2004; Ahmad, 2005; Ahmad et al., 2005; Ahmad, 2007a; 2007b; Ahmad and Farooq, 2007; Ahmad, 2008; 2012a; 2012b).

The term *run-off collection* is used to describe the process of collecting and storing water for later beneficial use from an area that has been modified or treated to increase precipitation run-off. *Run-off farming* is the integration of all aspects of collection, storage and utilization of the run-off water (Frasier, 1994; Ahmad, 2008).

In ancient history, the first run-off collecting facility was in all likelihood nothing more than a depression in a rock surface that trapped rainwater. The collected water served as a drinking water supply for man and animals (Hardan, 1975; Ahmad, 2008).

These water depression storages are still found in many parts of the world and serve as a drinking water supply (Shanan and Tadmor, 1979; Ahmad, 2008). It is probable that the first constructed water-harvesting facility was simply an excavated pit or other water storage container placed at the out fall of a rocky ledge to catch run-off water during a rainstorm (Frasier, 1994; Ahmad, 2008). The next evolutionary step may have been the construction of a rock diversion wall or gutter to provide a larger collection area. Researchers have found signs of early water-harvesting structures believed to have been constructed over 9000 years ago in the Edom Mountains in southern Jordan (Bruins et al., 1986; Ahmad, 2008). There is evidence in Iraq that simple forms of water-harvesting were practised in the Ur area in 4500 BC. Along desert roads, from the Arabian Gulf to Mecca, there still exist water-harvesting systems that were constructed to supply water for trade caravans (Hardan, 1975; Ahmad, 2008).

One of the earliest documented complete run-off farming installations is located in the Negev Desert of Israel. These installations were built about 4000 years ago (Evenari et al., 1961; Ahmad, 2008). The run-off area for these systems was upland hillsides, which were cleared of vegetation, and the soil smoothed to increase precipitation run-off. Contour ditches conveyed collected water for irrigating lower-lying fields. These systems provided an irrigated agriculture to an area that today has an average annual precipitation of approximately 100 mm. There is evidence that similar systems were used 500 years ago by the Native Americans in the southwestern region of the USA (Woodbury, 1963; Ahmad, 2008). Evidence of other ancient water-harvesting systems has been uncovered in Northern Africa. There is an uncertainty as to why most of these systems were abandoned. It is possible that the reticulation systems became clogged with silt or that the soils in the crop growing areas became infertile due to increased salinity. Others have speculated that some form of political instability or maybe a climate change in the areas forced the abandonment of the systems (Shanan and Tadmor, 1979; Kohei, 1989; Ahmad, 2008).

Figure 1 : Location map of Cholistan Desert

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II. Research Design and Methods

The work involves investigation on both constructional and depositional aspects of the archaeological record and the micro-environmental conditions (Ahmad, 2011). It is often possible to relate a soil type to a particular ecological niche in the landscape (Retallack, 1994; Buol et al., 2003; Ahmad, 2011). Soils and their properties is the product of different soil-forming factors (Jenny, 1941; Ahmad, 2011) and the parent material. As soil-forming factors also govern geomorphic processes, landscape evolution is intimately related to soil development (McFadden and Kneupfer, 1990; Kapur and Stoops, 2008; Ahmad, 2011; Kapur et al., 2011).

Traditional purposes for water resources control, storage and delivery include soil erosion prevention, rainwater harvesting, irrigation and supply of drinking water. Some of the structures associated with this have survived for many centuries. This indicates that advanced procedures had been used in their design and construction. However, it appears that indigenous knowledge has neither been well documented nor scientifically analyzed in order to utilize it for supporting the sustainable development of rain-fed run-off and spate-irrigated farming (Ahmad, 1999c).

The purpose of this study was to review and consider the potential for using water harvesting of run-off for agricultural and domestic uses to alleviate poverty in the Cholistan Desert region of Pakistan.

a) Climate of the Study Area

The climate of the area is an arid sub-tropical, continental type, characterized by low and sporadic rainfall, high temperatures, low relative humidity, high rates of evaporation and strong summer winds (Khan, 1957; Ahmad, 2008). The study site is one of the driest and hottest areas in Pakistan. The mean annual temperature of the area is 27.5°C; the mean summer temperature is 35.5°C, and the mean winter temperature is 18°C. The mean maximum summer temperature is 46°C (Figure 2) and the mean minimum winter temperature is 7°C. The month of June is the hottest and daily maximum temperature normally exceeds 45°C and occasionally is above 50°C (Ahmad, 2002a; Ahmad, 2008). The daily maximum temperature decreases in July due to the monsoon rainy season. There is always an abrupt fall in temperature during the nights. Most of the rainfall in the area is received in the months of July, August and September during the monsoon season. The annual rainfall varies between 100 and 250 mm. About half of the total rainfall events do not result in run-off, although they usually result in a favourable environment for the growth of vegetation (Abdullah et al., 1990; Ahmad, 2008).

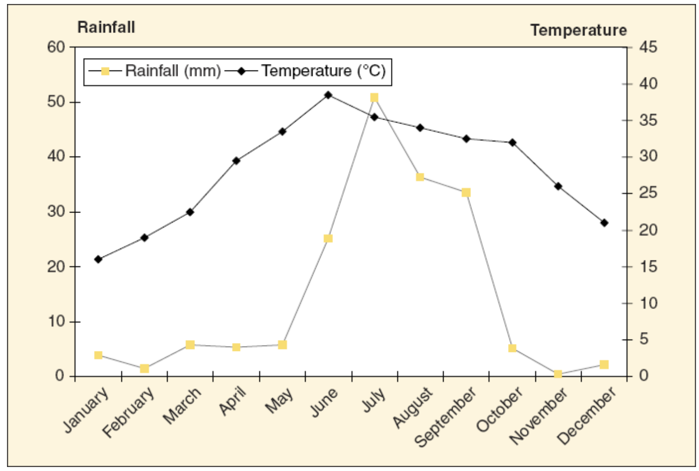
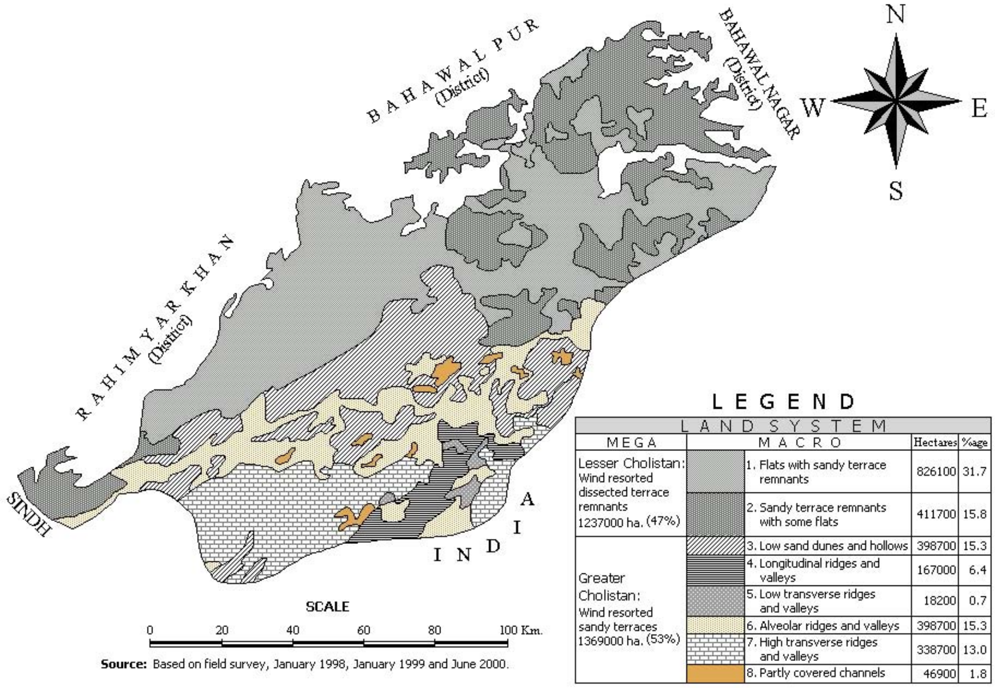


Figure 2 : Ombrothermal diagram of Cholistan Desert
Source: After Akhter, R. and Arshad, M. (2006).

b) Geomorphology

Geomorphologically the area presents a relatively complex pattern of alluvial and aeolian deposition which has developed from: (a) wind re-sorting of the sediments into various forms of sand ridges, (b) re-sorting and further deposition in spill channels, (c) deposition of sediments into clayey flats and (d) wind re-sorting and dune formation (FAO/ADB, 1993; Ahmad, 2008). The soils of the area have been developed by two types of materials, *viz.* river alluvium and aeolian sands (Ahmad, 2002a; Ahmad, 2008). The alluvium consists of mixed calcareous material, which was derived from the igneous and metamorphic rocks of the Himalayas and was deposited by the Sutlej and abandoned Hakra Rivers most probably during different stages in the sub-recent periods. The aeolian sands have been derived mainly from the Rann of Kutch and the sea coast and also from the lower Indus Basin. Weathered debris of the Aravalli has also contributed. The material was carried from these sources by the strong south-western coastal winds (FAO/ADB, 1993; Ahmad, 2008).

Based on differences in landform, parent material, soils and vegetation, the Cholistan Desert can be divided into two main geomorphic regions: the Northern region, known as the Lesser Cholistan, which constitutes the desert margin and consists of a series of saline alluvial flats alternating with low sand ridges/ dunes; and the Southern region, known as the Greater Cholistan, a wind re-sorted sandy desert, which is comprised of a number of old Hakra River terraces with various forms of sand ridges and inter-ridge valleys (Baig et al., 1975; Tahir et al., 1995; Ahmad, 2008). The Mega Land Systems (Lesser and Greater Cholistan) are split into eight Macro Land Systems (Figure 3), based on geomorphology which controls soils, moisture and eventually vegetation – an important component of the range ecosystems on which pastoralism depends (Figure 4, 5).



LAND SYSTEM			
MEGA	MACRO	Hectares	%age
Lesser Cholistan: Wind resorted dissected terrace remnants 1237000 ha. (47%)	1. Flats with sandy terrace remnants	826100	31.7
	2. Sandy terrace remnants with some flats	411700	15.8
Greater Cholistan: Wind resorted sandy terraces 1369000 ha. (53%)	3. Low sand dunes and hollows	398700	15.3
	4. Longitudinal ridges and valleys	167000	6.4
	5. Low transverse ridges and valleys	18200	0.7
	6. Alveolar ridges and valleys	398700	15.3
	7. High transverse ridges and valleys	338700	13.0
	8. Partly covered channels	46900	1.8

Processed by the author

Figure 3 : Land system of Cholistan Desert

Figure 4 : Habitation condition on sandy desert at Cholistan Desert. Ahmad, Farooq 2008

Figure 5 : Lizard looking for food at Cholistan Desert. Ahmad, Farooq 2008

c) Soils

The sand dunes have undulating to steep topography, with the dunes lying parallel to each other and connected by small streamers. They are very well drained and have coarse textured, structure-less soils derived from aeolian material. The near level to gently sloping areas have deep to very deep sandy soils which are very well drained, calcareous and coarse textured (Baig et al., 1975; Ahmad, 2008). Loamy soils occur on the level to near level areas with hummocks of fine sand on the surface. These soils are moderately deep, relatively well drained, calcareous and with a moderately coarse to medium texture (Baig et al., 1975; FAO/ADB, 1993; Ahmad, 2008). Clayey soils occur on level areas and are moderately deep, poorly drained, calcareous, saline-sodic (Table 1), moderately fine textured to fine textured with a pH range from 8.6 to 10.0 (Baig et al., 1980; Ahmad, 2008).

Table 1 : Types of soil and wind erosion

Soil Types	Total Area (ha)	Total Area (%)	Wind Erosion (degree)	Wind Erosion Area (ha)	Wind Erosion Area (%)
Loamy soils	58,700	2	Moderate	58,700	2
Saline sodic clayey soils (*Dhars*)	441,900	17	Non or slight	441,900	17
Sandy soils	945,500	37	Severe	2,079,400	81
Sand dunes	1,133,900	44			
Total	2,580,000	100	Total	2,580,000	100

Source : After Pakistan Desertification Monitoring Unit (1986).

d) Water resources of Cholistan Desert

The primary source of water is rainfall and this is the only source of potable ("sweet") water in Cholistan. Rainwater is collected in natural depression or man-made ponds called locally *"tobas"* (Figure 6, 7). There are 598 *tobas* in Cholistan (CDA, 1996; Ahmad, 2008) where desert dwellers collect and store rainwater from natural catchments. *Dhars* provide an efficient catchment for rainwater-harvesting. Water loss through evaporation from these ponded water storages was estimated to be higher than for seepage losses (Khan et al., 1990; Ahmad, 2002a; Ahmad, 2008). The average rainfall in Cholistan is 100-250 mm. Most of the rainfall is received during the monsoon season from July to September however; some of it may fall during winter. If harvested and stored appropriately, a large quantity of water would be available for humans and livestock as well as for plant nurseries and growing forage (Baig et al., 1980; Ahmad, 2008).

The secondary source of water in the Cholistan is groundwater, which is saline and not suitable for drinking or agricultural purposes. However, in this region, even brackish water is being used for livestock and other domestic purposes. The aquifers in the Cholistan are deep as a result of the absence of stream flow and only neglible recharge from rainwater. Changes in water quality of wells relates to the type and amount of salts present in the parent material. Most of the groundwater resources are alkaline in reaction causing precipitation of Ca^{2+}, SO_4^{2-} and CO_3^{2-} ions and increasing the ionic balance of Na^+ and Cl^- in the water (Abdullah et al., 1990; Ahmad, 2008). The groundwater, located at depths ranging from 30 to 90 metres, has salinity levels ranging from 368 to 35,000 mg/l of total dissolved solids (Baig et al., 1980; Ahmad, 2008).

Two major aquifers in the Cholistan have "sweet" water but these are surrounded by saline water. The main aquifer extends for 80 km from Fort Abbas towards Moujgarh, and is 10-15 km wide. The aquifer lies between 40 to 100 metres below the surface and has an estimated volume of 10 gigalitres (FAO/ADB, 1993; Ahmad, 2008).

The second aquifer has its centre approximately 20 km north-west of Derawer Fort. It occupies an area of 50 km^2, has a maximal thickness of 100 metres, and lies about 25 metres below the surface. This "sweet" aquifer is surrounded and underlain by bodies of brackish to saline waters (FAO/ADB, 1993; Ahmad, 2008). "Sweet" water in Cholistan is also present as isolated lenses at Phulra, Moujgarh, Dingarh and Derawer Fort along the abandoned Hakra River bed and Bhai Khan, Ghunnianwala, Islamgarh, Lakhewala and Renhal near the Pakistan-India border. Salinities of less than 1,900 mg/l TDS at the last three locations indicate they are more than suitable for human drinking. Livestock can tolerate levels as high as 15,000 mg/l TDS, or more in the case of camels (Baig et al., 1975; Baig et al., 1980; Ahmad, 2008).

Figure 6 : Adaptive approach for local *toba* at Cholistan Desert. Ahmad, Farooq 2008

Figure 7 : Indigenous approach for local *toba* at Cholistan Desert. Ahmad, Farooq 2008

Because of low and spatially erratic rainfall, water scarcity in Cholistan is endemic. Low rainfall, high infiltration in the sandy soils and rapid evaporation preclude the establishment of permanent sources of surface water in the desert. However, shallow ephemeral lakes are formed in *dhars,* which have highly impervious loam or clay soil bases, often of a saline or saline-sodic nature (Abdullah et al., 1990; Ahmad, 2008). The *dhars* are surrounded by sand dunes so that they form a terminal drainage system.

e) Surface water development for irrigation

Water harvesting/runoff-farming in the Cholistan Desert can play an important role in supplying local people and their livestock with drinking and minor irrigation. It is estimated that if approximately 60% of the average annual rainfall of 120 mm was harvested from 17% of the total catchment area (*i.e.* the saline-sodic component - Table 1) then 318 Ml of water could be stored and used for drinking and growing vegetables per year. This volume would cover approximately 106000 ha to a depth of 30 cm. It is observed that at Dingarh, where the soil is clayey, run-off is initiated after 11 mm of rainfall and on sandy soils the run-off starts after receiving approximately 33 mm of continuous rainfall. The Pakistan Council of Research in Water Resources (PCRWR) is collecting run-off at Dingarh in earthen excavations which are 32.11 m sq and 3.67 m deep (volume = 3784 m^3) (PADMU, 1986; Ahmad, 2008).

Water harvesting/runoff-farming techniques are technically sound methods of water supply. There have been many water-harvesting/runoff-farming systems constructed and evaluated at many different locations in the world. Some of the systems have been outstanding successes, while others were complete failures. Some of the systems failed, despite extensive effort, because of material and/or design deficiencies. Other systems failed, in spite of appropriate material and design, because of social and economic factors that were not adequately integrated into the systems (Frasier, 1983; FAO, 1994; Ahmad, 2008). Other factors contributing to the failures were personnel changes, the water were not needed, lack of maintenance and/or communication failures. A successful system must be (Cluff, 1975; Hutchinson et al., 1981; Pacey and Cullis, 1986; Ahmad, 2008):

- Technically sound, properly designed and maintained
- Socially acceptable to the water user, and
- Economically feasible in both initial cost and maintenance at the user level.

The landforms and soil characteristics of the Cholistan Desert indicate that it is a very suitable area for rainwater harvesting. Some sites, partly because of their very poor drainage, are capable of generating maximum run-off (Shanan and Tadmor, 1979; Ahmad, 2008). Water infiltration is low to very low in the fine textured soils of the Cholistan desert. This may be related to the absence of soil pores or very poor porosity. Figure 8 illustrates the areas in the Cholistan Desert which are considered suitable for rainwater harvesting.

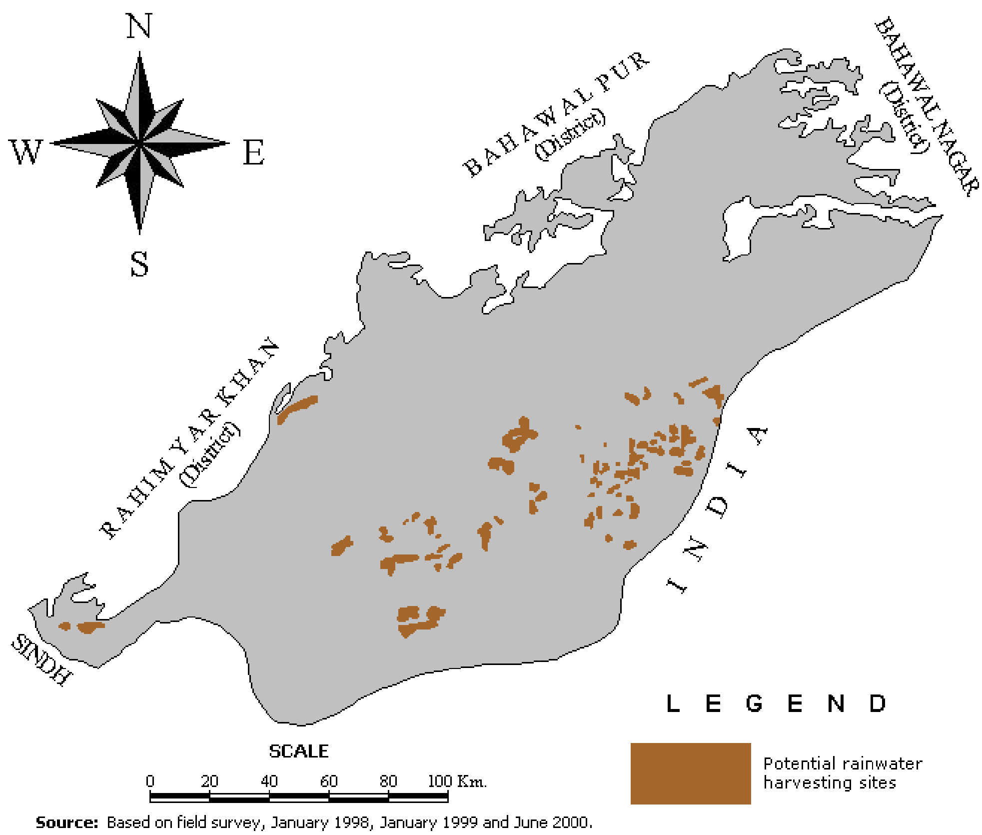


Figure 8 : Potential rainwater harvesting sites in the Cholistan Desert *Processed by the author*

f) Use of ground saline water for irrigation in Cholistan Desert

Although the groundwater is saline, it can be used for irrigation to grow salt tolerant trees, vegetables, crops and fodder grasses in non-saline, non-sodic coarse textured soils (Baig et al., 1975; Ahmad, 2008). This can occur with minimum adverse effects due to the rapid leaching of salts beyond the root zone (Abdullah et al., 1990; Ahmad, 2008).

Flushing of salts from the root zone also occurs after rain. Furthermore, fine textured saline-sodic soils can be used for growing palatable grasses which are very salt tolerant and capable of surviving in soils with otherwise poor agricultural potential. The sandy and loamy textured soils that cover 1 million ha can be brought under agriculture by using underground saline water and harvested rainwater (Ahmad, 1999b; Ahmad, 2008).

Experiments have shown that where sandy gravel or dune sands occur, plants can survive very well under the use of harvested rainwater and vast areas of land could be irrigated. Moderately saline irrigation water stimulates vegetation, assists the benevolent bacteria of the soil and improves yield and quality. Further, use of brackish water reduces soil evaporation, transpiration of plants and increases resistance to drought (Abdullah et al., 1990; Ahmad, 2002b; Ahmad, 2008).

g) Water harvesting and conservation as a strategic tool

Current strategies for combating drought include early warning and drought monitoring, contingency crop planning for drought-proofing, integrated watershed management, improved agronomic practices, alternative land use systems, management of livestock, animal health, feed and fodder resources and socio-economic aspects (Khan, 1992; Ahmad, 2008). All these components are essential and important and contribute to the alleviation of the impacts of drought. However, it has been noted that the most strategic tool for combating and mitigating droughts is enhanced water supplies at the local level (Sharma, 2003; Ahmad, 2008). This may be achieved partially through importing water from other less affected regions, but more sustainably through water harvesting and conservation in the drought prone region itself. Water harvesting, although an age-old practice is emerging as a new paradigm in water resource development and management due to recent efforts of both government and non-government organizations and several innovative communities (Sharma, 2001; Ahmad, 2008). Several 'bright spots' of successful water harvesting measures for drought-proofing are readily evident in operation in Pakistan, India, Iran, China and several other countries (Michael and Jowkar, 1992; Jowkar and Michael, 1995; Ahmad, 2008). The water resources generated locally help in meeting domestic and livestock needs, provide water for supplementary irrigation, enhance groundwater recharge, reduce storm water discharges, urban flooding and sea water intrusion in coastal areas. Participatory management of water resources ensures effective utilization, maintenance and sustainable operation of these systems (Ahmad, 1997a; Ahmad, 2008).

The Government of Pakistan is committed to international action in dealing with issues of sustainable development and poverty-eradication and is taking the necessary steps, given its resource and capacity constraints, to honour its pledge to contribute to the targets agreed to by the member states of the UN in the Millennium Development Goals (Farooq et al., 2007; Ahmad, 2008). It is the firm resolve of the Government to work with the various stakeholders in the public and private-sector in meeting those commitments (Ahmad, 1997a; Ahmad, 2008).

h) Poverty Issues

The main issues of poverty (GOP and IUCN, 1992; Ahmad, 2008) in areas such as the Cholistan Desert relate to:

- Drinking water scarcity for human and livestock population.
- Fodder shortage for livestock.
- Forced migration of human and livestock toward irrigated lands due to shortage of water and fodder.
- Absence of a proper livestock marketing system.
- Absence of industry relevant to livestock products – milk, wool and hides.
- Lack of medical facilities for humans and livestock.
- Lack of education because of the non-availability of schools and teaching staff.
- Lack of communication facilities.

It has been observed that poverty and lack of water, even for drinking, tend to encourage people to focus on immediate needs rather than on those benefits that may materialize only in the long term (GOP and IUCN, 1992; Kharin et al., 1999; Ahmad, 2008). This is not to say that poor land users are land degraders (Thomas, 1997; Ahmad, 2008), while the rich are conservers. Soil conservation is often viewed by many land users as being a cost and inconvenient (Farooq et al., 2007; Ahmad, 2008).

The traditional knowledge of the local inhabitants enables them to detect soil moisture and water-holding capacity using very simple methods (UNEP, 1991; Ahmad, 2008). They examine the soil subsurface for moisture, and the suitability of the soil agriculture, by rolling up a handful of soil and testing its compactness and stability. This traditional methodology allows the testing for soil moisture before cultivation, a procedure that enhances soil conservation (GOP and IUCN, 1992; Ahmad, 2008). The problems of soil erosion can be addressed, and certain practices can lead to soil enhancement and rebuilding. These options include (Ittelson, 1973; Hanan et al., 1991; Ahmad, 2008):

- Stopping the overuse that leads to the destruction of vegetation.
- Controlling overgrazing of animals (their trampling and grazing diminishes the vegetative cover).
- Enhancing rehabilitation techniques by propagation of native species.
- Careful implementation of agro-diversity (*i.e.* avoiding the planting of a monoculture).
- Shelter-belts (wind breaks) planted perpendicular to the prevailing wind direction (effective in reducing the wind speed at the soil surface).
- Strip farming: This involves planting crops in widely spaced rows but using the inter-row spaces for another crop to ensure complete ground cover (FAO/UNEP, 1983; Megateli et al., 1997; Ahmad, 2008). This retards overland flow of water, enhances infiltration and reduces soil erosion.

i) Constraints

The major constraint for livestock production in Cholistan Desert is the shortage of "sweet" water (Ahmad, 1997b; Ahmad, 2008). This is compounded by the prolonged droughts (often several years) when *toba* water dries out completely (Ahmad, 2002a; Ahmad, 2008).

In the Greater Cholistan, feed for livestock may still be available during a drought, but the *toba* water is depleted and the thirsty herds are forced to migrate towards semi-permanent settlements where well water is adequate but of poor and saline quality, not fit for drinking (Baig, 1982; Ahmad, 2008). The wells are unlined and must be re-dug each season. However, in the western part (Lesser Cholistan) the quantities of both water and feed are inadequate during drought periods (Khan, 1992; Ahmad, 2008).

Landless pastoralists suffer due to the scarcity of rangelands for grazing in the irrigated fringes (Squires, 1998; IFAD, 1998; Ahmad, 2008) where they work as poorly-paid labour or as tenant farmers on farmlands generally used for agricultural crops (Khan, 1992; Farooq et al., 2007; Ahmad, 2008). The combination of long distances travelled by the livestock in search of forage, very high temperatures (above 50ºC), inadequacy of feed, under-nourishment and highly saline drinking water from wells, all contribute to high mortality rates.

III. Conclusions

The potential for water harvesting in different countries and regions is not yet fully understood, quantified and implemented. Indigenous and innovative technologies in the form of micro-catchments, storage cisterns, run-off water harvesting based farming, embankment ponds, check dams on natural streams, percolation tanks, recharge tube wells, sub-surface barriers, integrated watershed development and rainwater-harvesting in urban areas offer a large potential even under water scarce regions.

Several village-level success stories have demonstrated that water harvesting based development paradigms were able to mitigate drought and positively impact on household economies. Limited studies indicate that rainwater-harvesting measures, when adopted on a large scale, may minimize the risk of water scarcity even during severe drought years. Further research is needed to ascertain more accurately to what extent these interventions would assist communities to withstand droughts.

Water harvesting as a strategic tool for drought mitigation can be realized through a policy framework to develop institutional mechanisms for water harvesting at different levels such as user, watershed, urban locality, district, state and federal level by having representatives from local level people's institutions, non-government organizations and concerned government departments. It is recommended that small and micro-water harvesting systems should be made an integral part of catchment wide planning and water resource development at the regional and national levels.

Biographical Sketch

Farooq Ahmad is an Assistant Professor at the Department of Geography, University of the Punjab, Lahore, Pakistan. He holds a Ph.D. in Geography (2002) and Post Doctoral Fellow (2009), the Department of Geography, The University of Sheffield, United Kingdom. His expertise is archaeo-historical environmental surveys and multi-disciplinary studies on ancient settlements in the Cholistan desert. He has contributed more than 50 research papers to international conferences around the globe. His current research involves Rainwater harvesting, Geomorphology, Geoinformatics, Remote Sensing, Satellite Image Processing, Hyperspectral Image Analysis, GPS and Land Surveying.

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