RUNOFF FARMING IN REDUCING RURAL POVERTY IN CHOLISTAN DESERT

Redução da pobreza rural no deserto do Cholistão através da agricultura baseada em escoamento superficial

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Abstract: *The proposed study strives to provide an overall picture for establishing a relationship of indigenous rainwater harvesting technology and its impact in poverty alleviation. The topographic form and the soil characteristics of Cholistan is the best catchment area for rainwater harvesting. Different profiles point out that the area is very poorly drained, capable of generating maximum runoff after absorbing minimum water. Water intake characteristics of fine textured soils show that infiltration rate is low to very low. Findings show that there is direct relationship between water availability and poverty reduction. Study also sheds light on both strengths and limitations of the indigenous technology on reducing rural poverty and recommends using this technology along with modern water harvesting techniques.*

Key words: Catchment, Cholistan, Environment, Hakra River, Precipitation, Runoff.

Resumo: *O estudo proposto se esforça para fornecer um quadro geral para o entendimento de uma relação do tradicional recolhimento das águas de escoamento pluviais e seu impacto na diminuição da pobreza. As formas topográficas e as características dos solos de Cholistan configuram uma excelente área para o armazenamento da chuva. As características morfológicas propiciam uma área condição de má drenagem, capaz de gerar o máximo de enxurradas após absorção mínima de água. A condição de textura fina solos mostram que a taxa de infiltração é baixa a muito baixa. Os resultados mostram que existe uma relação direta entre a disponibilidade da água e a redução da pobreza. O estudo também põe em evidência aponta os pontos fortes do ambiente local e as limitações da tecnologia tradicional sobre a redução da pobreza rural e recomenda usar esta tecnologia juntamente com modernas técnicas de recolhimento da água da chuva.*

Palavras-chave: Bacia de drenagem, Cholistão, Meio ambiente, Rio Hakra, Chuva, Escoamento.

INTRODUCTION

Cholistan 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 26,330 Km^2, it lies within Southeast quadrant of Punjab province between 27^{o}42' and 29^{o}45' North latitude and 69^{o}52' and 73^{o}05' East longitude (FAO/ADB 1993; Arshad *et al.* 1995; Jowkar *et al.* 1996; Ahmad 1999a; Ahmad and Sameera 2007).

The term *runoff 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 runoff. *Runoff farming* is the complete facility for collecting and storing the runoff water (Frasier 1994).

The first runoff 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. These water depression storages are still found in many parts of the world and serve as drinking water supply. Probably 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 runoff water during a rainstorm. The next evolutionary step might have been to construct 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). There is evidence in Iraq that simple forms of water harvesting were practiced 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).

One of the earliest documented complete runoff farming installation is located in the Negev Desert of Israel. These installations have been built about 4000 years ago (Evanari *et al.* 1961). The runoff area for these systems was upland hillsides, which were cleared of vegetation, and the soil smoothed to increase precipitation runoff. Contour ditches conveyed to collect 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). 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. Maybe the conveyance systems became clogged with silt or possibly 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).

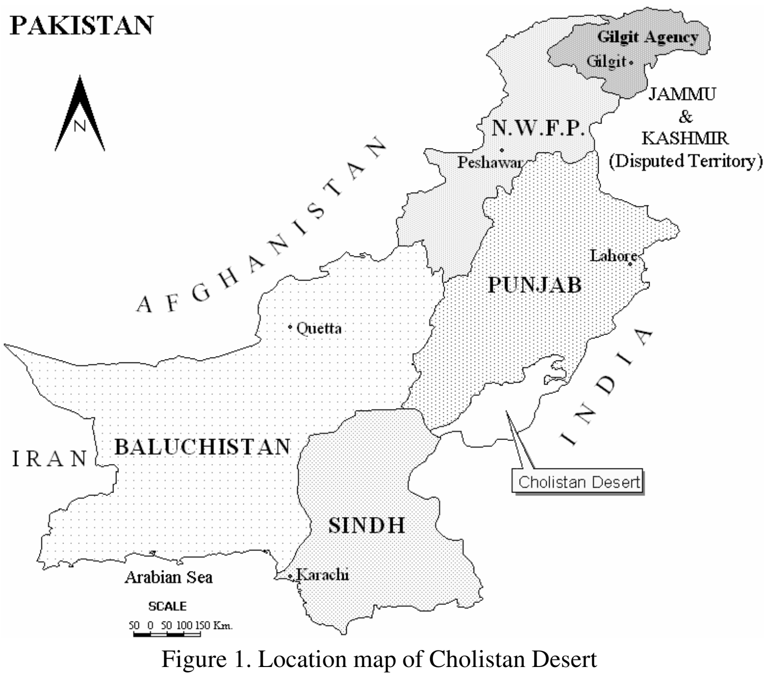

Figure 1. Location map of Cholistan Desert

Traditional methods of water resources control, storage and delivery include soil erosion prevention, rainwater harvesting, irrigation and drinking water-delivery structures, some of which have survived for many centuries. These structures, being long-lasting, indicate that advanced procedures had been followed in their design and construction. Thus, indigenous knowledge has neither been well documented nor scientifically analyzed in order to utilize it for supporting the sustainable development of rainfed, runoff and spate-irrigated farming.

Climate of the Study Area

The climate of the area is an arid subtropical, continental type, characterized by low and sporadic rainfall, high temperature, low relative humidity, high rate of evaporation and strong summer winds (Khan 1957). The site area is one of the driest and hottest areas in Pakistan. The mean annual temperature of the area is 27.5°C, whereas mean summer temperature is 35.5°C, and winter temperature is 18°C. The average maximum summer temperature goes up to 46°C (figure 2) and average minimum winter temperature falls up to 7°C. The month of June is the hottest and daily maximum temperature normally exceeds 45°C and some times crosses 50°C (Ahmad 2002a). The daily maximum temperature comes down in July due to monsoon rainy season in the country. 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 monsoon season. The annual rainfall varies between 100 and 250 mm. About half of the total rainfalls come under threshold category while, others do not create runoff however, on the whole create a favourable environment for the growth of vegetation (Abdullah *et al.* 1990).

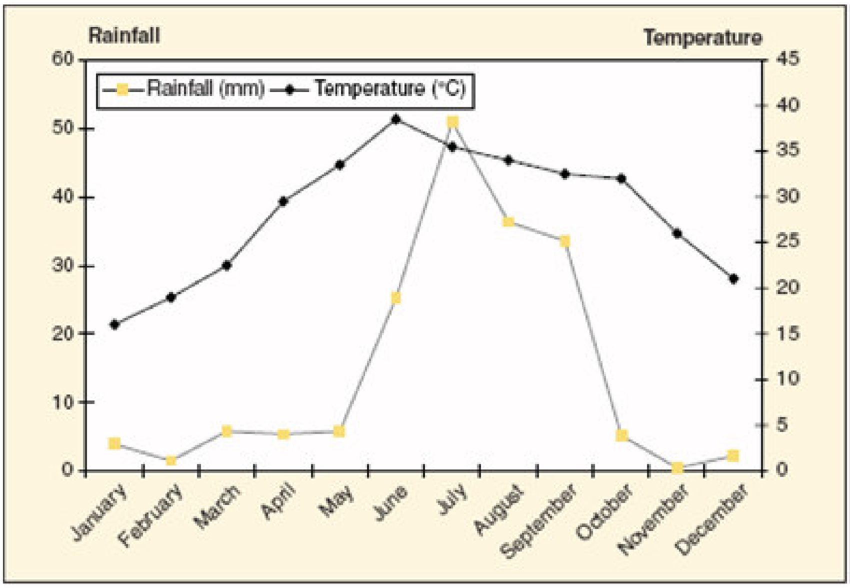

Figure 2. Ombrothermal diagram of Cholistan Desert

Geomorphology

Geomorphologically the area presents quite a complex pattern of alluvial and Aeolian deposition which was flowed by (a) wind resorting of the sediments into various forms of sand ridges (b) resorting and further deposition in spill channels (c) deposition of sediments clayey flats (d) wind resorting and dune formation. The soils of area have been developed by two type of materials *i.e.* river alluvium and Aeolian sands (Ahmad 2002a). 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 partly 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).

Based on differences in topographic form, parent material, soils and vegetation, Cholistan desert can be divided into two main geomorphic regions: Northern region, known as Lesser Cholistan, which constitutes the desert margin and consists of a series of saline alluvial flats alternating with low sand ridges/ dunes; and Southern region, known as Greater Cholistan, a wind resorted sandy desert comprising of a number of old Hakra River terraces with various forms of sand ridges and inter-ridge valleys (Tahir *et al.* 1995). 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 range ecosystem, upon which pastoralism depends.

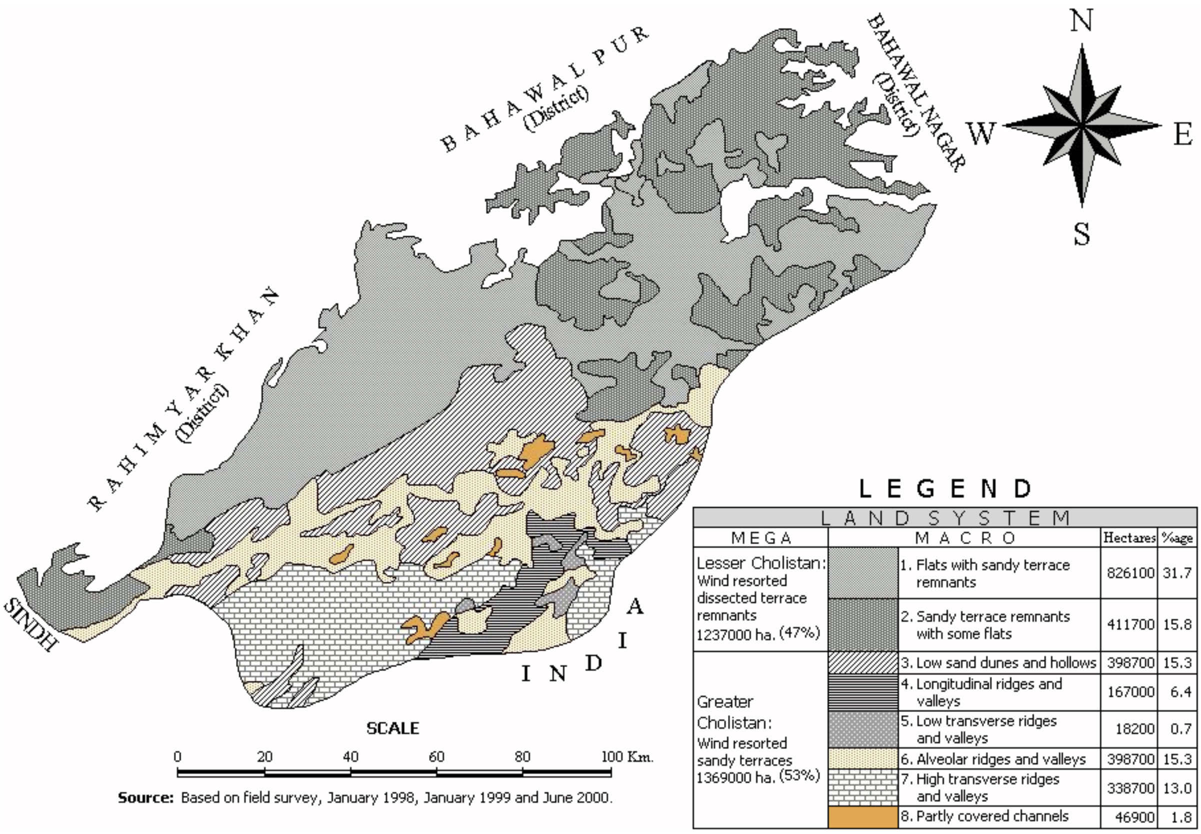

Figure 3. Land system of Cholistan Desert

Soils

The area is consisting of main four soil types *i.e.* dune land with topography ranging between undulating and steep slopes. The sand dunes lie parallel to each other connected by small streamers and are very excessively drained, coarse textured, structure less derived from Aeolian material, deposited by strong winds. Sandy soils are nearly level to gently sloping, deep to very deep, excessively drained, calcareous, coarse textured. Loamy soils are level to nearly level with hummocks of fine sand on the surface, moderately deep, somewhat excessively drained to well drained, calcareous, moderately coarse textured to medium textured (FAO/ADB 1993). Clayey soils are mostly level, moderately deep, poorly drained, calcareous, saline-sodic (table 1), moderately fine textured to fine textured, pH ranges between 8.6 and 10.0 (Baig *et al.* 1980).

Water resources of Cholistan

Primary source of water is rainfall, which is the only source of sweet water in Cholistan. Rainwater is collected in natural depression or man-made ponds locally called *"tobas"* (figure 4, 5). There are 598 *tobas* in Cholistan (CDA 1996) where desert dwellers collect and store rainwater from natural catchment. *Dhars* act as good catchment for rainwater harvesting. Water loss through evaporation from such ponded water was estimated as the highest as compared to seepage losses (Khan *et al.* 1990; Ahmad 2002a). The average rainfall in Cholistan is 100-200 mm. Most of the rainfall is received during monsoon season from July to September; however, some of it may fall during winter as well. A huge amount of water if harvested and stored properly, not only enough for drinking of human beings and livestock but also much portion of water could be used for raising nurseries and forage (Baig *et al.* 1980).

Table 1. Types of soil and wind erosion

Soil Types	Extent(Hec.)	Percentage	Wind Erosion	Extent(Hec.)	Percentage
Saline sodic clayey soils (*Dhars*)	441,900	17.0	Non or slight	441,900	17.0
Loamy soils	58,700	2.0	Moderate	58,700	2.0
Sand dunes	1,133,900	44.0	Severe	2,079,400	81.0
Sandy soils	945,500	37.0			
Total	2,580,000	100.0	Total	2,580,000	100.0

Source: After Pakistan Desertification Monitoring Unit, 1986.

Secondary source of water is groundwater, which is saline and not fit for drinking and agriculture purposes. Even brackish water is being used for livestock and other domestic purposes. The aquifer in Cholistan is deep due to absence of canal system and rainwater recharge is negligible. Changes in water quality of wells take place according to 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 water (Abdullah *et al.* 1990). Groundwater, located at depths ranging from 30 to 90 meters is mostly saline, with salinity ranges from 368 to 35,000 mg/l (Baig *et al.* 1980) of total dissolved solids (TDS). Two major aquifers in Cholistan have sweet water but are surrounded by saline water (FAO/ADB 1993).

The first aquifer extents for 80 Km. from Fort Abbas towards Moujgarh, and is from 10-15 Km. wide. The aquifer lies between 40 to 100 meters below the surface and has an estimation volume of 10,000 million liters.

The second aquifer has its centre about 20 Km. northwest of Derawer Fort. It occupies an area of 50 Km^2, has a maximal thickness of 100 meters, and lies about 25 meters below the surface. This sweet aquifer is surrounded and underlain by bodies of brackish to saline waters (FAO/ADB 1993). Sweet water in Cholistan is also present in isolated lenses like Phulra, Moujgarh, Dingarh, and Derawer Fort along the abandoned Hakra River bed and Bhai Khan, Ghunnianwala, Islamgarh, Lakhewala and Renhal near Pak.-India border. Salinities of less than 1,900 total dissolved solids at the latter three are more than suitable for human drinking, whereas livestock can tolerate levels as high as 15,000 TDS, or more in the case of camels (Baig *et al.* 1980).

Figure 4. Adaptive approach for local *toba*

Figure 5. Indigenous approach for local *toba*

Because of low and spatially erratic rainfall, water scarcity in Cholistan is endemic. Low rainfall, high infiltration in sandy soil 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 soils bottom, often of a saline or saline-sodic nature. The *dhar* is surrounded by sand dunes so that drainage ends blindly within the *dhar*.

Traditional methods of water resources control, storage and delivery include soil erosion prevention, rainwater harvesting, irrigation and drinking water-delivery structures, some of which have survived for many centuries. These structures, being long-lasting, indicate that advanced procedures had been followed in their design and construction. Thus, indigenous knowledge has neither been well documented nor scientifically analyzed in order to utilize it for supporting the sustainable development of rainfed, runoff and spate-irrigated farming (Ahmad 1999c).

Surface water development for irrigation

Runoff-farming/water harvesting in Cholistan desert can play important role for supply to local people and their livestock for drinking and minor irrigation. It is estimated that if we harvest about 60% of the rainfall, 120 mm per annum from 17% catchment area, 441,900 ha then 0.3 MAF (million acre feet) water can be supplied for drinking and growing vegetables per year. It is observed that at Dingarh, where the soil is clayey, runoff starts after receiving 11 mm rainfall and on sandy soils the runoff starts after receiving about 33 mm rainfall continuously. Pakistan Council of Research in Water Resources (PCRWR) is collecting runoff at Dingarh by making ditches of different sizes. The harvested water is collected in the pond of size 32.11m´ 32.11m´ 3.67m = 3783.96m^3 (PADMU 1986).

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 places 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, despite proper material and design, because of social and economic factors that were not adequately integrated into the systems (Frasier 1983; FAO 1994). These systems failed because of personnel changes, water was not needed, lack of maintenance and/or because of communication failures. A successful system must be:

- 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 topographic form and the soil characteristics indicate that Cholistan is the best catchment area for rainwater harvesting. Different profiles point out that the area is very poorly drained, capable of generating maximum runoff after absorbing minimum water. Water intake characteristics of fine textured soils show that infiltration rate is low to very low. It seems due to the absence of pores or due to very poor porosity. However, intake characteristics of soils also prove that the area is suitable for rainwater harvesting and collection (Figure 6).

Use of ground saline water for irrigation in Cholistan

Although the groundwater is saline but it can be used for saline agriculture to grow salt tolerant trees, vegetables, crops and fodder grasses in non-saline-non-sodic coarse textured soils with minimum adverse effects due to rapid leaching of salts beyond the root zone and flushing of salts from root zone by rains. Furthermore, dense saline-sodic soils can also be used for growing such palatable grasses, which are very salt tolerant and capable of surviving in soils having poor properties. The sandy and loamy soil that is about 1 million hectares can be brought under agriculture by using underground saline water and harvested rainwater (Ahmad 1999b).

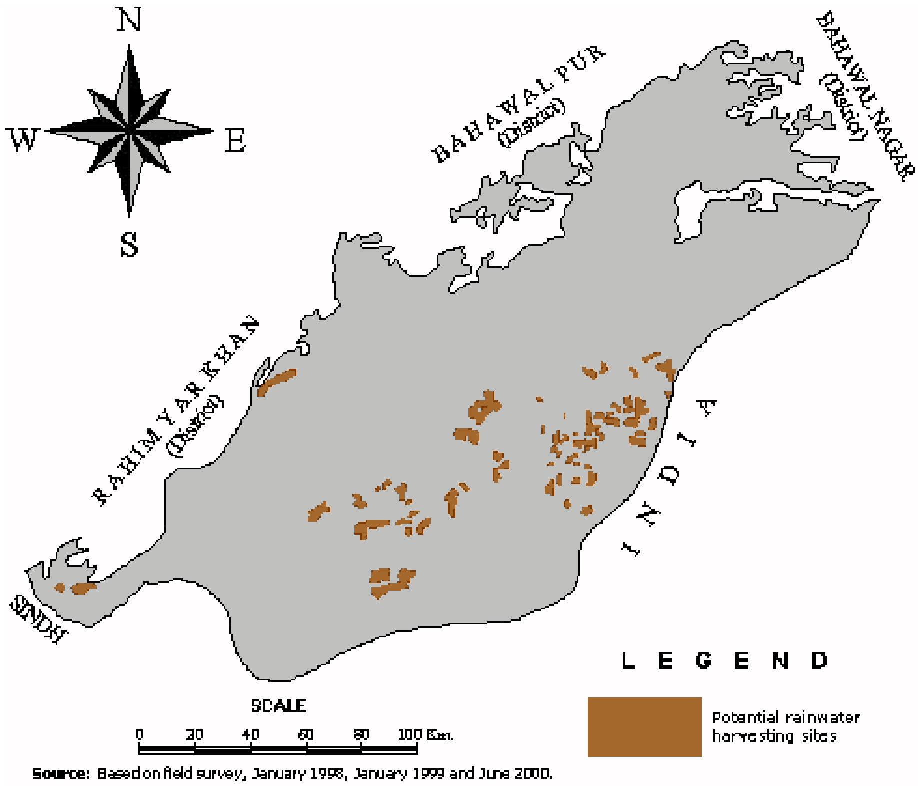

Figure 6. Potential rainwater harvesting sites of Cholistan

Experiments showed that under certain conditions plant could not only survive but also even vast area of land could be irrigated with water of such high concentration. The soil is either sandy gravel or dune sand. 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).

Water harvesting and conservation as a strategic tool

Strategies for combating drought include the components of 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 and feed and fodder resources and socio-economic aspects. All these components are essential and important and help in alleviating the impacts of drought but the most strategic tool for combating and mitigating the drought shall be through enhanced water supplies at the local level (Sharma 2003). This may be achieved partially through importing water from other less affected regions but more sustainable through water harvesting and conservation in the drought prone region itself. Water harvesting, though an age-old practice, is emerging as a new paradigm in water resources development and management due to recent efforts of both government and non-government organizations and several innovative communities (Sharma 2001). Several 'bright spots' of successful water harvesting measures for drought proofing can be easily seen in operation in Pakistan, India, Iran, China and some other countries. The water resources generated locally help in meeting domestic and livestock needs, provide water for supplementary/ deficit irrigation, enhance groundwater recharge; reduce storm water discharges, urban flood and seawater intrusion in coastal areas. Participatory management of water resources ensures effective utilization, maintenance and sustainable operation of these systems.

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

Poverty issues

- 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. This is not to say that poor land users are land degraders, while the rich are conservers. Soil conservation is always viewed as being a cost to land users in terms of additional efforts and more trouble. The traditional knowledge of the local inhabitants enables them to detect soil moisture and water-holding capacity using very simple methods. They examine the soil subsurface consistency for moisture, and the soil suitability of this moisture for agriculture, by rolling up a handful of soil and testing its compactness and stability. This traditional methodology allows the proper testing of soil moisture before cultivation, a procedure that enhances soil conservation. The problems of soil erosion can be halted, and certain practices can lead to soil enhancement and rebuilding.

These options include:

- Stopping the overuses that lead to the destruction of vegetation.
- Controlling overgrazing of animals, since their trampling and eating diminishes the vegetative cover.
- Enhancing rehabilitation techniques by propagation of native species.
- Implementing agro-diversity with care that is, avoiding the planting of a monoculture.
- Shelter-belts planted perpendicular to the prevailing wind direction is effective in reducing the wind speed at the soil surface (wind breaks).
- Strip farming: this involves planting crops in widely spaced rows but filling in the spaces with another crop to ensure complete ground cover. The ground is completely covered so it retards water flow, and the water soaks into the soil, consequently reducing erosion problems.

CONSTRAINTS

The major constraint in livestock production in Cholistan Desert is the shortage of sweet water. This is compounded by the prolonged droughts of many years when *toba* water dried out completely.

In Greater Cholistan, feed for livestock is still available, 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. The wells are unlined and must be re-dug each season. On the other hand in the western part (Lesser Cholistan) the quantities of both water and feed are inadequate.

Landless pastoralists suffer due to the scarcity of rangelands for grazing in the irrigated fringes where they work as poorly-paid labour or as tenant farmers on farmlands generally used for agricultural crops. The combination of long distances travelled by the livestock in search of forage, harsh temperature rising above 50°C, inadequacy of feed, undernourishment and highly saline drinking water from wells, all contribute to high mortality rates.

CONCLUSIONS

Potential of 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 rain water 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 household economy. Indications are that rainwater-harvesting measures when adopted on a large scale may minimize the risk of water scarcity even during severe drought years but such studies are few and scattered. Further research is needed to ascertain to what extent these interventions help to withstand droughts and to what extent shall cover the deficit.

Potential of water harvesting as a strategic tool for drought mitigation can be realized through a policy framework to develop institutional mechanism to 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, NGOs and concerned government departments.

Small and micro-water harvesting systems should be made integral part of basin-wise planning and water resource development at the regional and national levels.

REFERENCES

Abdullah, M., Akram, M., Khan, A.D., and Qureshi, R.H. (1990). "Internal water resources management by plants under various root environment stresses with special reference to kallar grass Leptochloa Fusca", Proceedings of the National Seminar on Water Resources Development and its Management in Arid Areas, 6-8 October 1990, Quetta, Pakistan.

Ahmad, Farooq (1999a). "Ecological restoration in Cholistan", Journal Geographic, Vol. 2(1), pp.34-38.

Ahmad, Farooq (1999b). "Eco-regeneration and runoff collection in Cholistan", UNEP: Desertification Control Bulletin 35, pp.50-54.

Ahmad, Farooq (1999c). "Rainwater utilization and ecological restoration in Cholistan", Proceedings of VI International Rangeland Congress, 19-23 July 1999, Townsville, Australia, pp.709-711.

Ahmad, Farooq (2002a). "Socio-economic dimensions and ecological destruction in Cholistan", Ph.D. dissertation, Department of Geography, University of Karachi, Pakistan.

Ahmad, Farooq (2002b). "Sustainable management of groundwater in the drylands of Pakistan", Proceedings of 2nd South Asia Water Forum, 14-16 December 2002, Islamabad – Pakistan, pp.93-101.

Ahmad, Farooq; Farooq Sameera (2007). "Role of rainwater harvesting in reducing rural poverty in Cholistan desert", Abstract in 12th All Pakistan Geographical Conference, 19-21 March 2007, Lahore, Pakistan, pp.24.

Arshad, M., Altaf-ur-Rehman Rao, and Akbar, G. (1995). "Cholistan desert in a state of flux", UNEP: Desertification Control Bulletin 26, pp.55-58.

Baig, M. Shabbir, Akram, M., Hassan, M. Amjad (1980). "Possibilities for range development in Cholistan desert as reflected by its physiography and soils", The Pakistan Journal of Forestry, pp.61-71.

Bruins, H.J., Evenari, M., Nessler, U. (1986). "Rainwater-harvesting agriculture for food production in arid zones: the challenge of the African famine", Applied Geography, Vol. 6, pp.13-32.

CDA (1996). "Master plan for the development in Cholistan", Cholistan Development Authority (CDA), Bahawalpur, Pakistan.

Evenari, M.L., Shanan, L., Tadmor, N., Aharoni, Y. (1961). "Ancient agriculture in the Negev", Science, Vol. 133, pp.979-996.

FAO (1994). "Water harvesting for improved agricultural production", Food and Agriculture Organization (FAO), Rome, Italy.

FAO/ADB (1993). "Cholistan area development project", Report No. 59/53 ADB-PAK 58 (Final version), Food and Agriculture Organization (FAO), Rome, Italy.

Frasier, G.W. (1983). "Water quality from water harvesting systems", Journal of Environmental Quality, Vol. 12(2), pp.225-231.

Frasier, G.W. (1994). "Water harvesting/runoff farming systems for agricultural production", Proceedings of FAO Expert Consultation, 21-25 November 1993, Cairo, Egypt.

Hardan, A. (1975). Discussion: session I. In: Proceedings of the water harvesting symposium, 26-28 March 1974, Phoenix, Arizona, G.W. Frasier (Ed), ARS-W-22, US Department of Agriculture, Agricultural Research Service, pp.60.

Jowkar, F., Khan, M. Ajmal, and Khan M. (1996). "Socio-economic dimensions of resource management in Cholistan", Institute for Development Anthropology (IDA), Binghamton, New York.

Khan, A.D., Akram, M., Abdullah, M. (1990). "Rainwater harvesting in Cholistan desert", Proceedings of the National Seminar on Water Resources Development and its Management in the Arid Areas, 6-8 October 1990, Quetta, Pakistan, pp.59-80.

Khan, Mubashir Lall (1957). "Water balance and magnitude of water deficiency in the arid zone of West Pakistan", Pakistan Geographical Review, Vol. XII (2), pp.65-69.

PADMU (1986). "Desertification process in Cholistan desert", PCRWR Publication No. Pakistan Desertification Monitoring Unit 7/86, pp.155.

Shanan, L. and Tadmor, N.H. (1979). "Micro-catchment systems for arid zone development", A Handbook for Design and Construction, Ministry of Agriculture, Israel.

Sharma, B.R. (2001). "Availability status, development and opportunities for augmentation of groundwater resources in India", Proceeding of the ICAR-IWMI Policy Dialogue on Ground Water Management, November 6-7, 2001, CSSRI, Karnal, India, pp.1-18.

Sharma, B.R. (2003). "Development of water resources and their efficient utilization in water scarce regions", Proceedings of the International Workshop on "Drought Management Strategies", Iranian National Committee on Irrigations and Drainage, Tehran, Iran, pp.3-12.

Tahir, M.A; Naim, M.A; Ahmad, M. (1995). "Landforms and soils of Bahawalpur division", Proceedings of the 6th All Pakistan Geographical Conference, 26-29 December 1993, Islamia University Bahawalpur, Pakistan, pp.311-325.

Woodbury, R.B. (1963). "Indian adoptions to arid environments", In: Aridity and Man, Publication No. 74, American Association for the Advancement of Science, Washington D.C., pp.55-85.