添付資料 - ２　　参 考 文 献

(1) 参考文献　Water Harvesting - Past and Future

(2) 参考文献　Spate Irrigation in Balochistan

(1) 参考文献　Water Harvesting - Past and Future

降雨を集めて作物や家畜に給水するウォーター・ハーベスティングを類型化して説明した資料。

Karlsruhe University（ドイツ）の Dierter Prinz 氏の著作で、1994 年 3 月 21-26 日に開催された NATO Advanced Research Workshop “Sustainability of Irrigated Agriculture”において発表されたペーパーの中のひとつ。

本件プロジェクトの Khushkaba や Highland Sailaba (報告書本文 7.1 節参照)が、Microcatchement Water Harvesting や Large Catchment Water Harvesting として紹介されている。

WATER HARVESTING - PAST AND FUTURE

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ABSTRACT. Water harvesting, defined as the collection of runoff and its use for the irrigation of crops, pastures and trees, and for livestock consumption, comprises six different forms, primarily defined by the ratio between collecting and receiving area: (1) Roof Top Water Harvesting, (2) Water Harvesting for Animal Consumption, (3) Inter-Row Water Harvesting, (4) Microcatchment Water Harvesting, (5) Medium-sized Catchment Water Harvesting and (6) Large Catchment Water Harvesting. The common goal of all forms is to secure water supply for annual crops, pastures, trees and animals in dry areas without tapping groundwater or river-water sources. In the past, water harvesting was the backbone of agriculture in arid and semi-arid areas world-wide. After a decline, it gained new interest during past decades. Its future role will be as a linking element between rainfed agriculture, soil and water conservation and irrigated agriculture, still using untapped water resources in arid lands, alleviating slightly the stress on drought-ridden farmers and communities.

Introduction

As long as mankind has inhabited semi-arid areas and cultivated agricultural crops, it has practised some kind of water harvesting. Based on "natural water harvesting" the use of the waters of ephemeral streams was already the basis of livelihood in the arid and semi-arid areas many thousands of years ago, allowing the establishment of cities in the desert (Evenari et al. 1971).

Presumably millions of hectares of land in the dry parts of the world were once used for water harvesting but a variety of causes has brought about a steady decline.

The European expansion, especially the technological development since 1850, lead to a steady increase in area under "classical" irrigation techniques with preference to large schemes. Small-scale irrigation and traditional irrigation techniques received inadequate attention. The latter include the various techniques of water harvesting and supplementary irrigation.

During recent decades the interest in water harvesting has increased and national as well as international bodies have launched programmes to investigate the potential of water harvesting and to expand its area.

The sustainability of water harvesting systems was in the past based on the 'fitting together' of the basic needs of the farmers, the local natural conditions and the prevailing economic and political conditions of the region. The preconditions for a positive future development of water harvesting will be the very same (Prinz 1994).

1 Basic Concepts and Characterization of Water Harvesting

1.1 GENERAL CONCEPT

Water harvesting is applied in arid and semi-arid regions where rainfall is either not sufficient to sustain a good crop and pasture growth or where, due to the erratic nature of precipitation, the risk of crop failure is very high. Water harvesting can significantly increase plant production in drought prone areas by concentrating the rainfall/runoff in parts of the total area.

The intermittent character of rainfall and runoff and the ephemerality of floodwater flow requires some kind of storage. There might be some kind of interim storage in tanks, cisterns or reservoirs or soil itself serves as a reservoir for a certain period of time (Finkel and Finkel 1986).

Water harvesting is based on the utilisation of surface runoff; therefore it requires runoff producing and runoff receiving areas. In most cases, with the exception of floodwater harvesting from far away catchments, water harvesting utilizes the rainfall from the same location or region. I does not include its conveyance over long distances or its use after enriching the groundwater reservoir. Water harvesting projects are generally local and small scale projects.

Germany

1.2 DEFINITION, GOALS AND PARAMETERS

There is no generally accepted definition of water harvesting (Reij et al. 1988). The definition used in this paper covers "the collection of runoff and its use for the irrigation of crops, pastures and trees, and for livestock consumption" (Finkel and Finkel 1986).

The goals of water harvesting are:

? Restoring the productivity of land which suffers from inadequate rainfall.
? Increasing yields of rainfed farming
? Minimizing the risk in drought prone areas
? Combating desertification by tree cultivation
? Supplying drinking water for animals.

In regions with an annual precipitation between 100 and 700 mm, low cost water harvesting might provide an interesting alternative if irrigation water from other sources is not readily available or too costly. (In summer rainfall areas the minimum precipitation for water harvesting is around 200 mm/year). In areas with more than 600 - 700 mm annual rainfall water harvesting techniques can prolong the cropping season. In comparison with pumping water, water harvesting saves energy and maintenance costs. These advantages are countered by the problem of unreliability of rainfall, which can partly be overcome by interim storage (cisterns, small reservoirs etc.). Modern hydrological tools (e.g. calculation of rainfall probability and water yield) allow a more precise determination of the necessary size of the catchment area.

As mentioned before, the central elements of all water harvesting techniques are:

- a runoff area (catchment) with a sufficiently high run-off coefficient (impermeability would be optimal), and
- a "run-on" area, where the accumulated water is stored and/ or utilized. In most cases the runoff is used for agricultural crops, the water then being stored in the soil profile. A high storage capacity of the soil (i.e. medium textured soils) and a sufficient soil depth (> 1 m) are prerequisites here (Huibers 1985). The water retention capacity has to be high enough to supply the crops with water until the next rainfall event.

The most important parameters to be taken into consideration in practising water harvesting are therefore: rainfall distribution, rainfall intensity, runoff characteristics of the catchment, water storage capacity of soils, cisterns or reservoirs, the agricultural crops, available technologies and socio-economic conditions (Tauer and Prinz 1992).

The tools used to identify possible runoff irrigation areas are:

- field visits;
- areal surveys and evaluation of aerial photographs;
- satellite images and their classification and evaluation (Tauer and Humborg 1992).

2. Commonly Applied Forms

As mentioned before, water harvesting has been practised for millennia and is still applied world-wide. Of the great number of forms in existence with various names, six forms are generally recognized:

a) roof top water harvesting
b) water harvesting for animal consumption
c) inter-row water harvesting
d) microcatchment water harvesting
e) medium-sized catchment water harvesting
f) large catchment water harvesting.

Table 1 gives an overview of these forms and their most prominent features. Fig. 1 shows the annual precipitation ranges for various water harvesting (WH) forms.

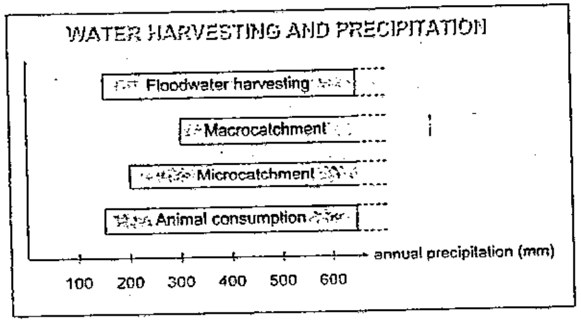


Fig. 1. Annual precipitation ranges for different forms of water harvesting in summer rainfall areas

a) Roof top water harvesting
Rain "harvested" from the roofs of buildings including greenhouses is, in many locations, a very valuable resource being used mainly for drinking and domestic purposes (UNEP 1983). However, for the purpose of this paper, roof top harvesting is excluded as its use for agricultural purposes is limited to very few locations only (Papadopoulos 1994).

b) Water harvesting for animal consumption
Ancient dwellers harvested rain water for human and animal consumption by redirecting the water running down hillslopes into cisterns.

Presently, this tradition is still practised in many regions, but where the means are available, surfaces used for rainwater collection are usually either physically compacted, chemically treated or covered to increase runoff volume:

(i) Clay soils are well suited for compaction. The surfaces are shaped, smoothened and then compacted e.g. by tractor and rubber-tired rollers.
(ii) Sodium salts, wax, latexes, asphalt, bitumen, fiberglas and silicones can be used as sealants on soils which do not swell with moisture (Frasier 1994). Plots treated with sun-melted granulated paraffin-wax yielded about 90 percent of the rainfall as runoff, compared to 30 percent from untreated plots.
(iii) Concrete, plastic sheeting, butyl rubber and metal foil can also be used to cover the soil for rainwater harvesting. Gravel may protect the underlying membrane against radiation and wind damage.

The runoff water is collected in lined or unlined pits down the slope of the catchment area (Fig. 2), (Frasier and Myers 1983, Dutt et al. 1981).

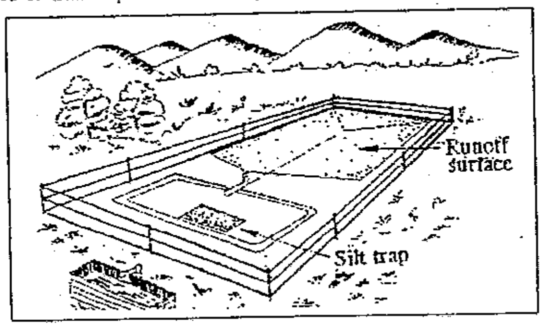


Fig. 2. Western Australia rainwater-harvesting system for animal consumption. The runoff-surface is compacted and treated.
(Source: FAO 1977, redrawn)

c). Inter-row water harvesting
Inter-row water harvesting is applied either on flat land or on gentle slopes of up to 5 % having soil at least 1 m deep. The annual rainfall should not be less than 200 mm/year.

On flat terrain (0 - 1 % inclination) bunds are constructed, compacted and, under higher-input conditions, treated with chemicals to increase runoff. The aridity of the location determines the catchment to cropping ratio (CCR), which varies from 1:1 to 5:1 (Fig. 3). Examples are given from India (Vijayalakshmi et al. 1982) and the USA (Frasier 1994).

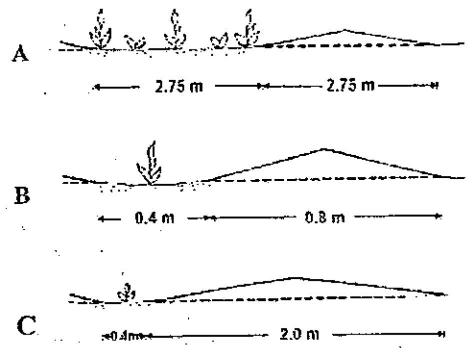


Fig. 3. Various forms of flat-land inter-row water harvesting; from A - C increasing CCR/aridity of location.
(Source: Prinz 1986)

On sloping land (1 - 20% inclination) these systems are called "contour ridges" (USA) or "Matuta" (East Africa). The ridges of about 0.40 m height are built 2 to 20 m apart, depending on slope, soil surface treatment, general CCR and type of crop to be grown. The catchment area should be weeded and compacted; the crops are either grown in the furrow, along the upper side of the bund or on top of the bund. On sloping land, this system is recommended only for areas with a known regular rainfall pattern; very high rainfall intensities may cause breakages of the bunds. Crops cultivated in row water harvesting systems are maize, beans, millet, rice or (in the USA) grapes and olives (Pacey and Cullis 1986, Finkel and Finkel 1986, Tobby 1994).

The preparation of the land for inter-row water harvesting can be fully mechanized.

d) Microcatchment systems
Microcatchment water harvesting (MC-WH) is a method of collecting surface runoff from a small catchment area and storing it in the root zone of an adjacent infiltration basin. This infiltration basin may be planted with a single tree, bush or with annual crops (Boers and Ben-Asher 1982).
Fig. 4 depicts various microcatchment systems in use.

The advantages of MC-WH systems are:
? Simple design and cheap to install, therefore easily replicable and adaptable.
? Higher runoff efficiency than medium or large scale water harvesting systems; no conveyance losses.
? Erosion control function
? Can be constructed on almost any slope, including almost level plains.

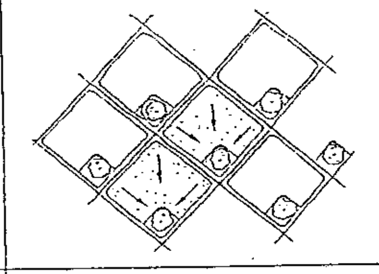
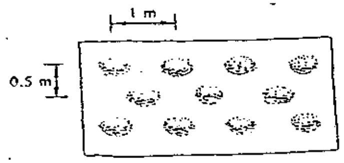
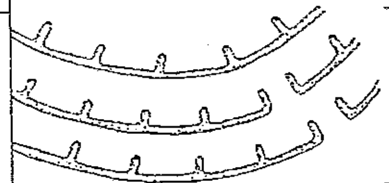
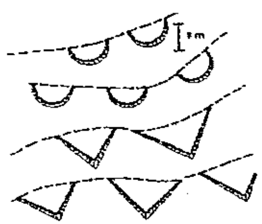
Type	Illustration	Parameters	Remarks & References
Negarin		CA= 3 - 250 CR= 1 - 10 CCR= 3 : 1 - 25:1 PREC= 150 - 600 mm/a SL = 1 - 20%	Ben-Asher 1988
Pitting		CA= 0.25 CR= 0.08 CCR= 3:1 PREC= 350 - 600 mm/a SL= 0 - 5%	"Zay system" (West Africa), "Kitui Pitting", "Katumani Pit-ting" (Kenya) Buritz et al. 1986 Gichangi et al. 1989
Contour ridges		CA= 100 CR= 20 CCR= 5:1 PREC= 300 - 600 mm/a SL= 5 - 25%	Critchley 1987
Semi-circular hoops (demi-lunes); Triangular bunds		CA= 24-226 CR= 6-57 CCR= 4:1 PREC= 300 - 600 mm/a SL= 2 - 20%	MoALD 1984

Fig. 4a. Various types of microcatchment (MC) water harvesting
CA = Catchment size (m^2) PREC = Precipitation
CR = Cropping area (m^2) SL = Slope
CCR = Catchment: Cropping Ratio

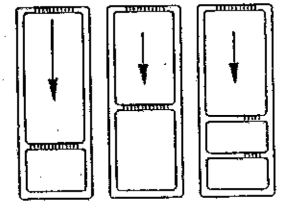
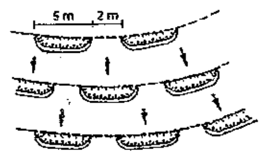
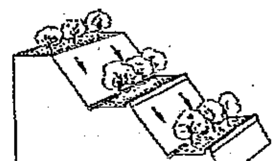
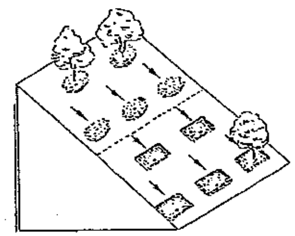
Type	Illustration	Parameters	Remarks & References
Meskat-type		CA= 500 CR= 250 CCR= 2:1 PREC= 200 - 600 mm/a SL= 2 - 15%	El Amami 1983
Vallerani-type (fully mechanized)		CA= ~ 15 CR= ~ 2.4 CCR= 6:1 PREC=100 - 600 mm/a SL= 20 - 50%	400 MC/ha = 960m² CR/ha Preparation by "wavy dolphin plough";
Contour bench terrac-es		CA= ~2-16 CR= 2-8 CCR= 1:1-8:1 PREC= 100 - 600 mm/a SL= 20 - 50%	"Conservation bench terraces"
Eye brow terraces; Hillslope micro-catchments		CA= 5 - 50 CR= 1 - 5 CCR= 3:1 - 20:1 PREC= 100 - 600 mm/a SL= 1 - 50%	100,000 trees programme in the Negev/Israel Ben-Asher 1988

Fig. 4b. Various types of microcatchment (MC) water harvesting
CA = Catchment size (m^2) CR = Cropping area (m^2 SL = Slope
CCR= Catchment: Cropping Ratio PREC = Precipitation

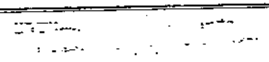
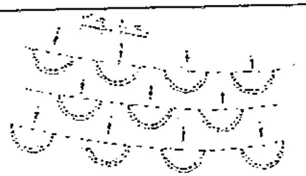
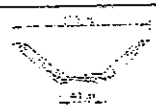
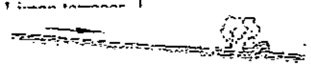
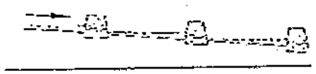
Type	Illustration	Parameters	Remarks & References
Stone dams		(extreme variations) PREC= 300 - 600 mm/a	Diguettes or Digues filtrantes: Permeable contour check dams
Large semi-circular hoops		CA= 750 - 10,000 CR= 50 - 350 CCR= 15:1 - 40:1 PREC= 200 - 400mm/a SL= 1 - 10%	Staggered position: used for crops or pasture improvement Reij et al. 1988
Trapezoidal bunds		CA= 5 - 3 x 10^5 CR= 3,500 CCR= 15:1 - 100:1 PREC= 200 - 400 mm/a SL= 1 - 10%	Staggered position; mainly for crops Reij et al. 1988
Hillside conduit systems		CA= 10 - 10^7 CR= 1 - 10^5 CCR= 10:1 - 100:1 PREC= 100 - 600 mm/a SLCA= > 10% SLCR= 0 - 10%	Examples: Avdat and Shifta Experimental Farms, Negev, Israel; For trees and annual crops Klemm 1990
Linear terraces		CA= 2x10^4 - 2x10^5 CR= 1,000 - 5,000 CCR= 20:1 - 100:1 PREC= 100 - 300 mm/a SL= 1 - 10%	In Israel mainly planted to Eucalyptus tree species; sometimes built in succession. Bruins et al. 1986
Cultivated reservoirs		CA= 1,000 - 10,000 CR= 100 - 2,000 CCR= 10:1 - 100:1 PREC= 150 - 600 mm/a SLCA = > 10% SLCR = 0 - 10%	Khadin, Rajastan (India); Ahar, Bihar (India); Tera, SE Sudan Kolarkar et al. 1983, Pacey and Cullis, 1986

Fig. 5. Types of medium-sized catchment water harvesting
CA = Catchment size (m^2) PREC= Precipitation SL = Slope
CR = Cropping area (m^2) SLCA= Slope of catchment area
CCR = Catchment: Cropping ratio SLCR= Slope of cropping area

The disadvantages of MC-WH systems are:
? The catchment uses potentially arable land (exception: steep slopes)
? The catchment area has to be maintained, i.e. kept free of vegetation which requires a relatively high labour input.
? If overtopping takes place during exceptionally heavy rainstorms, the systems may be irrevocably damaged.
? Low crop density, low yield in comparison with other irrigation methods (e.g. 40 trees per hectare for the Negarin type WH, Fig. 4a).

e) Medium-sized catchment water harvesting
Water harvesting from medium-sized catchments (1,000 m^2 - 200 ha) is referred to by some authors as "water harvesting from long slopes", as "macro-catchment water harvesting" or as "harvesting from external catchment systems" (Pacey and Cullis 1988, Reij et al. 1988) It is characterized by:
? A CCR of 10:1 to 100:1; the catchment being located outside the arable areas.
? The predominance of turbulent runoff and channel flow of the catchment water in comparison with sheet or rill flow of microcatchments.
? The partial area contribution phenomenon which is not relevant for micro catchments.
? The catchment area may have an inclination of 5 to 50 %; the cropping area is either terraced or located in flat terrain.
Fig. 5 shows the most prominent types of this system.

f) Large catchment water harvesting
Large catchment water harvesting comprises systems with catchments being many square kilometres in size, from which runoff water flows through a major wadi (bed of an ephemeral stream), necessitating more complex structures of dams and distribution networks. Two types are mainly distinguished:
? Floodwater harvesting within the stream bed, and
? Floodwater diversion.
"Floodwater harvesting within the stream bed" means blocking the water flow to inundate the valley bottom of the entire flood plain, to force the water to infiltrate and use the wetted area for crop production or pasture improvement (Fig. 6).
"Floodwater diversion" means forcing the wadi water to leave its natural course and conveying it to nearby areas suitable for arable cropping. Floodwater diversion techniques were already applied several thousand years ago (e.g. Marib, North Yemen; Brunner and Haefner 1986) and systems are known from NW Mexico, Pakistan, Tunisia ("Jessour system"), Kenya, China etc. (Reij et al. 1988), (Fig. 7). The CCR ranges from 100:1 to 10,000: 1.

3. The Past Role of Water Harvesting

3.1 GENERAL ASPECTS

As mentioned before, water harvesting played a more important role in the past for the well-being of people in dry areas than it currently does. The reasons are manyfold:
? Alternative sources of drinking water and water for irrigation were not available:
- no pumping from groundwater or other deep water sources
- very few large dams
- no long distance conveying of water through lined canals, pipes etc.

? The building of structures for water harvesting, the cleaning and smoothing of runoff surfaces, the maintenance of canals and reservoirs etc. are labour demanding: Labour was a cheap resource, or even unpaid as in the case of slaves.

Table 1. Overview of the main types of water harvesting (WH)

WH-type	Kind of flow	Kind of surface	Size of catch-ment	Catch-ment: cropping area ratio	Water storage type	Water use
Roof top water harvesting	Sheet flow	Roofs of all kinds	small		Tanks, jars, cisterns	Drinking, domestic, livestock
Water har-vesting for animal consuption		Treated ground surfaces	> 3 ha	extreme various	Tanks, cisterns	Livestock
Inter-row WH		Treated ground surfaces	1 - 5 m^2	1:1 - 7:1	Soil profile (reser-voirs, cis-terns)	Tree, bush, vegetable and field crops
Micro-catchment WH	Sheet and rill flow	Treated and un-treated ground surfaces	2-1000 m^2	1:1 - 25:1	Soil profile (reser-voirs, cis-terns)	
Medium-sized catchment WH	Turbu-lent runoff/ channel flow	Treated or un-treated ground surfaces	1000 m^2 - 200 ha	10:1 - 100:1	Soil profile (reser-voirs, cis-terns)	
Large catch-ment WH	Flood water flow	Un-treated ground surfaces	200 ha - 50 km^2	100:1 - 10,000:1	Soil profile	

Figure 6: Floodwater harvesting within the stream - bed: design of rock barrier's used to spread the water in large, shallow wadis (Nabataen system) source: Evenari and Koller 1956, from Cox and Atkins 1979

? Agriculture was the backbone of the society and very few other choices to generate income were given. Therefore, relatively more input was invested in agriculture including runoff agriculture.

Various examples shall be given to illustrate the past role of water harvesting worldwide. Unfortunately, the extreme importance of certain water harvesting techniques is often not reflected by the number or depth of publications.

Some of the techniques mentioned are still presently practised.

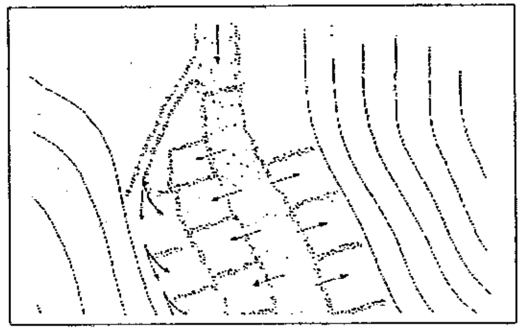


Fig. 7. Flood water diversion scheme: Design of water-spreading dams in large, deep wadis (Nabataean system).
Source: Evenari & Koller 1956, from Cox and Atkins 1979

3.2 ASIA

3.2.1 *The Middle East*

The outstanding importance of the Middle East in the development of ancient water harvesting techniques is unquestioned. Archeological evidence of water harvesting structures appears in Jordan, Syria, Iraq, the Negev and the Arabian Peninsula, especially Yemen.

In Jordan, there is indication of early water harvesting structures believed to have been constructed over 9,000 years ago. Evidence exists that simple water harvesting structures were used in Southern Mesopotamia as early as in 4,500 BC (Bruins et al. 1986).

Internationally, the most widely known runoff-irrigation systems have been found in the semi-arid to arid Negev desert region of Israel (Evenari et al. 1971). Runoff agriculture in this region can be traced back as far as the 10th century BC when it was introduced by the Israelites of that period (Adato 1987). The Negev's most productive period in history however, began with the arrival of the Nabateans late in the 3rd century B.C. (Fig. 8). Runoff farming continued throughout Roman rule and reached its peak during the Byzantine era.

Fig. 8. Reconstruction of an ancient water harvesting system ("Hillsite conduit system") in Wadi Avdat-/Negev (100 mm annual precipitation, CCR 175:1, 2 ha cropping area). Photo: Prinz

In North Yemen, a system dating back to at least 1,000 B.C. diverted enough floodwater to irrigate 20,000 hectares (50,000 acres) producing agricultural products that may have fed as many as 300,000 people (Adato 1987, Eger 1988). Farmers in this same area are still irrigating with floodwater, making the region perhaps one of the few places on earth where runoff agriculture has been continuously used since the earliest settlement (Bamatraf 1994).

3.2.2 *Saudia Arabia*

In the South Tihama of Saudi Arabia, flood irrigation is traditionally used for sorghum production. Today, approximately 35,000 ha land, supporting 8,500 to 10,000 farm holdings, are still being flood irrigated (Wildenhahn 1985).

3.2.3 *Pakistan*

In Baluchistan two water harvesting techniques were already applied in ancient times: the "Khuskaba" system and the "Sailaba" system. The first one employs bunds being built across the slope of the land to increase infiltration. The latter one utilizes floods in natural water courses which are captured by earthen bunds (Oosterbaan 1983). Fig. 9 depicts such a water spreading system in Pakistan.

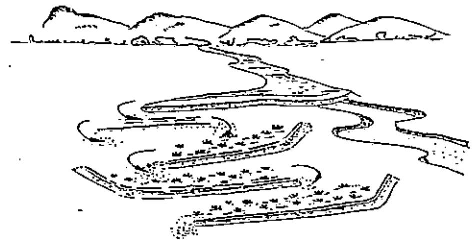


Fig. 9. Water spreading system in Pakistan to divert flood water for agricultural use. Source: Adapted from French and Hussain 1964

3.2.4 *India*

In India, the "tank" system is traditionally the backbone of agricultural production in arid and semi-arid areas. The tanks collect rainwater and are constructed either by bunding or by excavating the ground. It is estimated that 4 to 10 hectares of catchment are required to fill one hectare of tank bed. In West Rajastan, with desert-like conditions having only 167 mm annual precipitation, large bunds were constructed as early as the 15th century to accumulate runoff. These "Khadin" create a reservoir which can be emptied at the end of the monsoon season to cultivate wheat and chickpeas with the remaining moisture (Kolarkar et al. 1983). A similar system called "Ahar" developed in the state of Bihar (UNEP 1983, Pacey and Cullis 1986). Ahars are often built in series. It was observed that brackish groundwater in the neighbourhood of Ahars became potable after the Ahar was built, due to increased supply of rain water.

3.2.5 *China*

A very old flood diversion technique called "warping" is found in China's loess areas which harvests water as well as sediment.

3.3 AFRICA

3.3.1 *North Africa*

Since at least Roman times water harvesting techniques were applied extensively in North Africa. Archeological research by the UNESCO Libyan Valleys team revealed that the wealth of the "granary of the Roman empire" was largely based on runoff irrigation (Gilbertson 1986). The team excavated structures in an area several hundred kilometers from the coast in the Libyan pre-desert, where the mean annual precipitation is well below fifty millimeters. The farming system here lasted well over 400 years and it sustained a large stationary population, often wealthy, which created enough crops to generate even a surplus. It produced barley, wheat, olive oil, grapes, figs, dates, sheep, cattle and pigs. The precipitation is variable, falling in just one or two rain storms, often separated by droughts several years long. (There is no evidence of climatic change since Roman period).

Many other examples of the application of traditional techniques in North Africa can be given:

In Morocco's Anti Atlas region, Kutsch (1982) investigated the traditional and partly still practised water harvesting techniques. He found a wealth of experience and a great variety of locally well adapted systems.

In Algeria, the "lacs collinaires", the rainwater storage ponds are traditional means of water harvesting for agriculture. The open ponds are mainly used for watering animals.

In Tunesia, the "Meskat" and the "Jessour" systems have a long tradition, but are also still practised. The "Meskat" microcatchment system consists of an impluvium called "meskat", of about 500 m^2 in size, and a "manka" or cropping area of about 250 m^2 (Fig.10). Thus, the CCR is 2:1. Both are surrounded by a 20 cm high bund, equipped with spillways to let runoff flow into the "manka" plots.

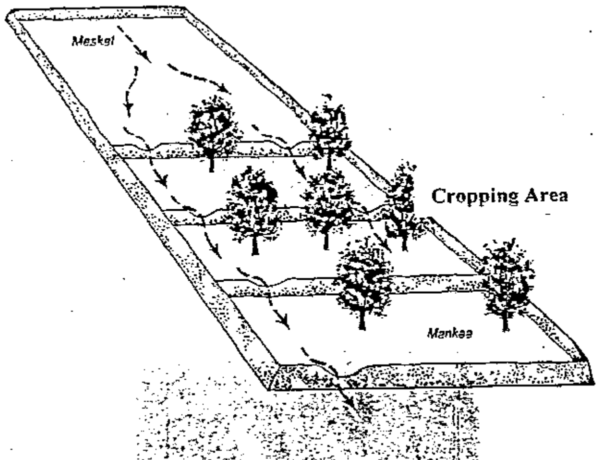


Fig. 10. The Tunesian "Meskat" microcatchment system. Source: Adapted from El Amami 1983

This system can provide the fruit tree plantation with about 2,000 m³ extra water during the rainy season.
Whereas the "Meskats" are mainly found in the Sousse region, the "Jessour" are widespread in the South (Matmata).
The "Jessour" system is a terraced wadi system with earth dikes ("tabia") which are often reinforced by dry stone walls ("sirra"). The sediments accumulating behind the dikes are used for cropping (Fig 11). Most "Jessour" have a lateral or central spillway.

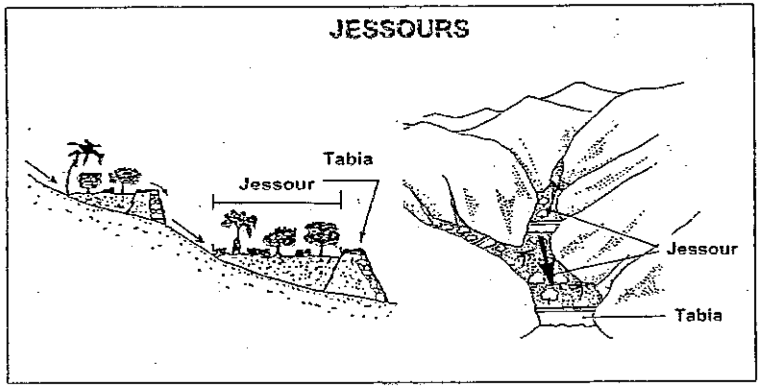


Fig. 11. A row of "Jessour" in the South of Tunesia. Source: Adapted from El Amami 1983

The "Mgouds" in Central Tunisia are channel systems used to divert flood water from the wadi to the fields (Tobbi 1994).
In Lybia, as mentioned before, archeological and historical studies have revealed the development and expansion of a highly successful dry (runoff based) farming agriculture during Roman times. On the slopes of the western and eastern mountain ranges some of these techniques continue to be practised (Al Ghariani 1994).
In Egypt, the North-West coast and the Northern Sinai areas have a long tradition in water harvesting. Remnants from Roman times are frequently found (El-Shafei 1994). Some wadi terracing structures have been in use for over centuries (Fig. 12).

3.3.2 *Sub Saharan Africa*
Traditional techniques of water harvesting have been reported from many regions of Sub Saharan Africa (Reij et al. 1988, Critchley et al. 1992a, Critchley et al. 1992b, van Dijk & Reij 1993).
A few of those systems shall be described here in more detail:

Fig. 12. Wadi Terraces from Roman times still in use in Marsa Matruh area (NW coast, Egypt). Photo: Prinz

The central rangelands of Somalia are home to two small scale water harvesting systems which have been important local components of the production system for generations:
The Caag system is a technique used to impound runoff from small water courses, gullies or even roadside drains (Fig. 13). Sometimes ditches are dug to direct water into the fields. Runoff is impounded by the use of earth bunds. The entire plot may be a hectare or more in size. The alignment of the bunds is achieved by eye and by experience. In this system, runoff is impounded to a maximum depth of 30 cm. If water stands for more than five days or so, the bund may be deliberately breached to prevent waterlogging (Reij et al. 1988).

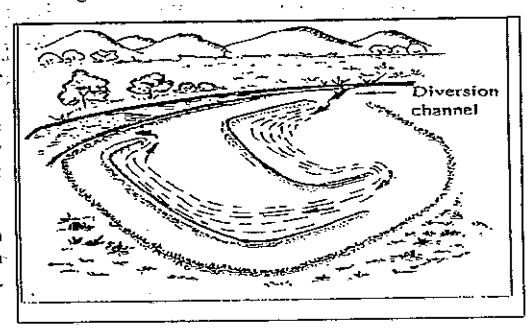


Fig. 13. The "Caag" system in Hiraan region, Central Somalia (150-300 mm annual rainfall). (Source: Critchley et al. 1992b)

The Gawan system is used where the land is almost flat and where is less runoff. Small bunds are made which divide plots into "grids" of basins. Individual basins are in the order of 500 m^2 or above in size.

In both of these systems, sorghum is the usual crop grown, although cowpeas are also common. If the rains permit, two crops are taken each year (Reij et al. 1988).

In Sudan, various types of "Haffirs" have been in use since ancient times. Their water is used for domestic and animal consumption as well as for pasture improvement and paddy cultivation (UNEP 1983).

The Haussa in Niger's Ader Doutchi Maggia have altered a considerable area with rock bunds, stalks and earth to divert water to their fields.

The Mossi in Burkina Faso also constructed rock bunds and stone terraces in the past.

Somerhalter (1987) made mention of the existance of various traditional water harvesting techniques (although on a small scale) in the Ouaddai area in Chad.

The "Zay" system in Burkina Faso is a form of pitting which consists of digging holes that have a depth of 5 - 15 cm and a diameter of 10 - 30 cm. The usual spacing is between 50 - 100 cm (Wright 1985). This results in a CCR of about 1 - 3:1. Manure and grasses are mixed with some of the soil and put into the zay (Fig. 14). The rest of the soil is used to form a small dike downslope of the pit. Zay are applied in combination with bunds to conserve runoff, which is slowed down by the bunds.

Many other traditional water harvesting systems existed or still exist, but the basic problem is that knowledge and information in this zone is extremely limited and fragmentary (Reij et al. 1988).

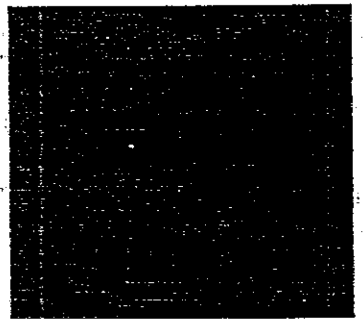


Fig. 14. The zay microcatchment water harvesting system in Burkina Faso
Source: Reijntjes et al. 1992

3.4. AMERICA: SOUTHWEST USA AND NORTH MEXICO

Traditional water harvesting was practised in the Sonoran desert by the Papago Indians and other groups. The Papago fields were located on alluvial flats, fan aprons and fan skirts of ephemeral washes, where large catchments then became concentrated. Brush weirs were used to spread the floodwaters (Nabhan 1984). Elsewhere, fields were irrigated by gravity-fed channels (arroyos) leading water from earth and stick diversion weirs (Nabhan and Sheridan 1977, Doolittle 1984). For the Eastern Sonora Region of North Mexico, an evolution in techniques took place. Brush water spreaders were gradually replaced by rock bunds as the fields' clearing was increased and the supply of brush was depleted. A highly sophisticated distribution system was demonstrated by the flood water diversion system of Chaco Canyon, New Mexico (Fig. 15).

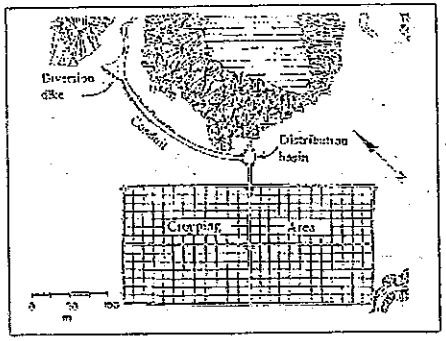


Fig. 15. Runoff farming system in Chaco Canyon, New Mexiko (175 mm annual precipitation, CCR = 470:1,9 ha horticultural area) Source: Vivian 1974

3.5 CONCLUSIONS FROM THE PAST ROLE OF WATER HARVESTING

It is evident from archeological findings and historical descriptions that water harvesting played a dominant role in many arid and semi-arid regions to sustain agricultural production.

Why did its role diminish, why did so many systems fail on the long run?

Why do we see poor land use, and even a desertified landscape, where formerly a flourishing agriculture existed?

There are no simple answers to these questions and we have to admit that the causes are in most instances not fully known or understood.

The various causes mentioned are:

? The decline of central powers (e.g. of the Byzantine empire in the Middle East) due to political shifts
? warfare incl. civil war
? economic changes, e.g. in competitiveness on local or export markets
? social changes, incl. availability of cheap labour, aspirations or attitudes of the people involved in water harvesting
? climatic change (increasing aridity, change in precipitation regime)
? increasing salinity
? decreasing soil fertility (nutrient status)
? soil erosion (wind and water erosion).

In the case of the successful floodwater farming system in the Libyen pre-desert mentioned above, the explanations for failing focus upon size and competitiveness of the markets in the coastal cities for the agricultural produce which apparently changed after the arrival of the Islamic armies in 642 AD and the conversion to Islam. But there is also some evidence that a slow salinization and some soil erosion negatively influenced the agricultural production (Gilbertson 1986).

4. The Development of Water Harvesting Since 1950

4.0. GENERAL

During this century, only very few water harvesting activities in research or implementation were undertaken before 1950. Australian farmers had already started to harvest water for domestic and animal use after World War I. During World War II, some water harvesting activities were carried out on islands with high rainfall (e.g. on the Caribbean island of Antigue). After 1950 water harvesting received renewed

interest on the research level as well as in the implementation sector, partly due to the successful reconstruction of ancient water harvesting farms in the Negev by Evenari and collegues (Evenari et al. 1971). Most of the research activities have been carried out in Israel, Australia, the USA and India, but efforts in other countries should not be neglected.
Some institutional or research activities related to water harvesting from recent decades shall be summarized here:

4.1. DEVELOPMENT IN ASIA

4.1.1 *Israel*
The Israeli experience was reviewed by Ben Asher (1988) within the World Bank Sub-Saharan Water Harvesting Study. Their research work focused on
- testing of specific water harvesting techniques, especially microcatchments (Fig. 16)
- studying soil surface characteristics, especially crust formation
- studying and modelling runoff behaviour
- analyzing the economy of water harvesting techniques.

Fig. 16. Water harvesting research on agroforestry in Wadi Mashash, Israel.
Photo: Lövenstein

The first aspect deals with the water content regime within the planted area, while the other one has to do with the availability of runoff to the planted area. On Wadi Mashash farm, a long term project with the aim of developing a model agroforestry system having medium-sized catchment water harvesting was carried out (Zohar et al. 1987, Lövenstein 1994). Developing the design criteria of microcatchments and limans is also receiving attention (Boers 1994, Fig. 17).

Fig. 17. Sheep grazing a liman at Wadi Mashash Experimental Farm, Negev, Israel. Photo: Lövenstein

4.1.2 *Jordan*
In Jordan, earth dams have been constructed since 1964 in order to force runoff to infiltrate for pasture improvement. At the final stage the total area flooded shall be about 2,500 ha. (Al-Labadi 1994). In 1972, a project known as "Jordan Highland Development Project" was initiated. Rock dams, contour stone bunds, trapezoidal bunds and earth contour bunds are used to increase soil moisture around the trees planted on steep lands (Shatanawi 1994). The total area utilized since its inception is estimated to be 6,000 hectares.
Between 1985 and 1988, Jordan's Ministry of Agriculture, in collaboration with ACSAD, used contour terraces and ridges for pasture and range improvement in the Balama district. Better growth of olive, almond and pistachio was recorded (Shatanawi 1994) on the experimental site. In 1987 the Faculty of Agriculture of the University of Jordan initiated the construction of earth dams to impound and store flood waves for irrigation purposes. The catchment area is about 70 km^2 and the annual precipitation is 150 mm. Currently there is a collaborative research project aimed at developing an integrated optimization prediction model for water harvesting, storage and utilization in dry areas in Jordan. Oweis & Taimeh (1994) report on further water harvesting reseach activities in Jordan.

4.1.3 *Other Middle East Countries*
In the Dei-Atiye community of Syria, rainwater harvesting was established in 1987 on an area of 130 ha. The project site was sub-divided into four parts for tree crops, range plants, cereals and runoff research (Ibrahim 1994). The International Centre for Agricultural Research in the Dry Areas (ICARDA) in Syria, is currently working on the improvement of various WH techniques and on the identification of water-harvesting areas suitable for various West Asian and North African (WANA) environments (Oweis and Prinz 1994).
In the North-West Arabia, a local system known as "Mahafurs" is still in use. This system is simply a shallow excavation of 20 - 100 m in diameter surrounded on three sides by earthen bunds 1 - 4 m high. The open side is pointed in the direction of water flow inside the wadi bed and used to collect water for animal consumption and moisture for plant production (Barrow 1987).
In Afghanistan, composite microcatchments have been in use for a long time. In a survey conducted in the early 1970s, over 70,000 ha of Meskat-type systems used for growing fruit trees were reported.

4.1.4 *India*
At the Centre for Arid Zone Studies in Todhpur and at the International Centre for Research in the Semi-Arid Tropics (ICRISAT) in Hyderabad, various research projects on water harvesting related programmes have been going on since 1975.
One of the findings at these research stations was that alfisols have greater runoff potential than vertisols and therefore the scope of profitable yield responses is greater on alfisols (Ryan et al. 1980).

In the eighties, ICRISAT also developed a system of broad beds and grassed drains which collect runoff in storage tanks during the rainy season to be used for supplementary irrigation during the dry season. To apply the water to the plants, bullock-drawn water casts equipped with sprinklers are used. Research results show that crop yields increased between two and fivefold (Barrow 1987, Fig. 18).

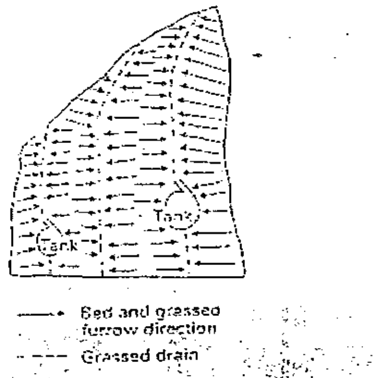


Fig. 18. The broad-bed and furrow runoff collection system of ICRISAT, Hyderabad, India. Source: Barrow 1987

ICRISAT also carried out another research work aimed at adapting a traditional tank irrigation technology to modern socio-economic conditions. The concept of this work was to improve tank management with water control and to find an alternative system of runoff and erosion controlling land management for groundwater recharge and sustained well irrigation (Von Oppen 1985). These concepts have been found to have great potential and research is still going.

4.1.5 *Other Countries*

In tropical Asia, especially southern India and Sri Lanka, earth bunds and excavated hollows have been used for runoff retention during the rainy seasons for millenia. Tank storage permits farmers to grow a second dry season irrigated crop in addition to rainfed agriculture. Tanks are sited randomly so that any overland flow from one is caught by others downslope. In case of siltation, labourers are hired to remove the silts and spread them on the cropping land during the dry season (Barrow 1987).

4.2. DEVELOPMENT IN AFRICA

4.2.1. *North Africa*

In different parts of Libya, experimental sites of contour-ridge terracing covering more than 53,000 ha have recently been established (Al-Ghariani 1994).

In 1990, the government of Tunisia started the implementation of the National Strategy of Surface Runoff Mobilization which aims, among other things, at building 21 dams, 203 small earth dams, 1,000 ponds, 2,000 works to recharge water tables and 2,000 works for irrigation through water spreading by the year 2,000 (Achouri 1994). Up to 1984, "Meskats" covered 300,000 ha where 100,000 olive trees were

planted; "Jessours" covered 400,000 ha (Tobbi 1994). Modern spate irrigation techniques have been applied in Central Tunisia since 1980, covering an area of 4,250 ha and harvesting about 20 Mm^3 of water annually.

In Wadi El-Arish region of Egypt, stone dykes were used to direct the runoff water flow for irrigation purposes. Also cisterns, which store water meant for animal and human consumption as well as for supplemental irrigation, are common in Egypt. The number of cisterns has increased from less than 3,000 in 1960 to about 15,000 in 1993 with a capacity of about 4 million m^3 (Shata and Attia 1994).

In the North-West region of Egypt a GTZ/FAO sponsored project on land use planning including water harvesting activities was carried out (El-Shafey).

In Yemen, small dams storing runoff for later use in irrigation or rural supply have been constructed since the beginning of the eighties; the total storage capacity is between 50,000 to 90,000 m^3 (Bamatraf 1994).

"Matfia" is an old technique of storing water for human and animal consumption in Morocco, which still continues (Tayaa 1994). Expensive modern technology, including the use of reinforced concrete has now been introduced in constructing the cisterns, although the local people are less interested in these large and expensive systems. Since 1984, Morocco has started constructing dams ("Barrages Collinaires") to harvest flood water. The upstream catchment area under these dams ranges from 500 to 10,000 hectares. As of 1988, thirty five of these dams had been constructed. They provide irrigation water for about 160,000 animals and 3,000 ha of cultivated plots.

4.2.2. *Sub-Saharan Africa*

An agroforestry project (PAF) aimed at improving tree planting using microcatchments was initiated by OXFAM in 1979 at the Yatenga Province of Burkina Faso. In 1982, this was modified to contour stone bunds (aligned along the contour) and used for crop production. Later, it was combined with the traditional "zai" systems which has improved its acceptability by the local farmers. It was reported that by the end of 1989, some 8,000 hectares in over 400 villages had been modified with stone bunds (Critchley et al. 1992a).

Various research projects are being carried out on the Central Plateau of Burkina Faso by many research institutes. Emphasis in the region is mainly put on improving stone bund construction, studying the effects of stone bunds on runoff, erosion and yields, rehabilitation of degraded catchment areas and combination of stone bunds with tied ridges (Buritz and Dudeck 1986).

In the Hiraan Region of Somalia the local water harvesting techniques known as "Caag" and "Gawan" still continue (Abdi 1986).

In Ethiopia, the Sudan and Botswana, small check-dams made of earth are used to catch moderate overland flow passing down slight slopes. They are called "haffirs" and support crops planted upslope (Barrow 1987).

In 1985, the Institut für Wasserbau und Kulturtechnik (Institute of Hydraulic Structures and Rural Engineering), University of Karlsruhe, Germany, started a project in Mali with the aim of testing the feasibility of runoff irrigation in the Sahel region. The total contributing area was 127 ha and the collecting area was 3.3 ha so that the CCR was 40:1. These systems have now being operated for nine years and the harvests for sorghum are three times those for comparable sites using rainfed agriculture (Klemm 1990, Fig. 19).

In 1989-91 an EC financed study was carried out by the same Institute which aimed at the development of a methodology of identifying areas suitable for runoff irrigation. Maximum use was made of data obtained from satellite systems (Landsat-TM and SPOT) on the basis of site inspections in W-Mali and N Burkina Faso. A methodology was developed which integrates meteorological, pedological, topographic and socio-economic data sets in an user-friendly GIS, distinguishing between the suitability of a site for microcatchments or macrocatchments (Tauer and Humborg 1992; Prinz et al. 1994).

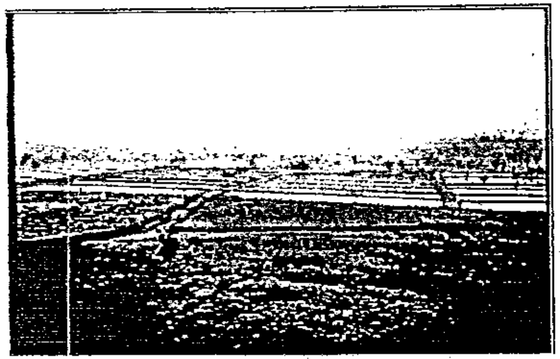


Fig. 19. A macrocatchment water harvesting system in Mali, Kayes Province. Photo: Klemm

In 1988, special ploughs developed by Italian scientists were used in Niger for the implementation of (Vallerani type) microcatchments on a large scale. Results from these plots showed excellent rates of tree establishment (Antinori and Vallerani 1994).

A set of test plots on improved trapezoidal bunds in Baringo, Kenya has been constructed. This improved version consists of earth bunds which surround the plot and diverge as collection arms upslope to increase the catchment area (MoALD 1984).

In 1984, a self-help project sponsored by Oxfam and known as Turkana Water Harvesting Project, was started in the Turkana district of Kenya. It was aimed at developing systems of water harvesting for crop production, while also introducing animal ploughing. This project has evolved into a long-term development programme involving women and is concerned mainly with pastoral production which is the main occupation of the villagers (Critchley et al. 1992a).

In 1990, it became known as Lokitaung Pastoral Development Project and a local management board whose members are drawn from the local traditional institutions have since been managing the project.

4.3. NORTH AND SOUTH AMERICA

In the United States of America, research emphasis is on runoff inducement from catchments and the reduction of seepage losses (Frasier 1994). Combined and supplementary systems have been tested (Fig. 20).

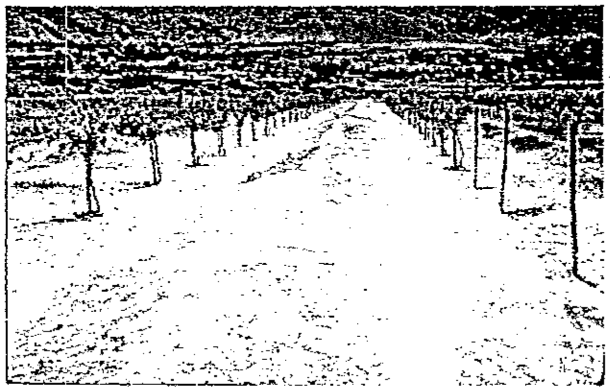


Fig. 20. Inter-row water harvesting with treated catchment in North-Central Mexico. Photo: Frasier

The traditional check-dam known as "Bolsa" is still used in the cultivation of crops in some parts of Mexico. "Bolsas" are earthen-walled basins which catch water diverted from seasonal creeks ("arroyos") (Barrow 1987). After the arroyos have wetted the bolsas, plants are cultivated on the bolsas and mulch of dry sand is spread on it to avoid evaporation.

In NE-Brazil, a modified form of the "zay" systems was introduced in 1986.

4.4. DEVELOPMENT IN AUSTRALIA

In Western Australia, topography modification in the form of catchment treatment has been practised for a long time. These are known as "roaded" catchments. They consist of parallel ridges ("roads") of steep, bare and compacted earth, surveyed at a gradient that allows runoff to occur without causing erosion of the intervening channels (Burdass 1975, Laing 1981). In 1980, it was estimated that there were more than 3,500 roaded catchment systems in Western Australia, and many of them have a top dressing or a layer of compacted clay to increase the runoff efficiency (Frasier 1994).

5.The Future Role of Water Harvesting

5.1. GENERAL CONSIDERATIONS

When analyzing agricultural production and natural resources utilization in (semi-) arid areas, some conclusions, especially regarding water harvesting, can be drawn:

(1) Government policy (within the agricultural sector) is mostly directed towards cash crop production. Cash crops, in order to be profitable, need a reliable water supply which can best be guaranteed by conventional irrigation (not water harvesting). Therefore support concerning extension services, loans, marketing support etc. are given primarily to (exportable) cash crops.

(2) Substantial amounts of rainfall in (semi-) arid areas are lost (e.g. by evaporation from soil surfaces), which could be utilized for agricultural production.

(3) In a number of countries where water harvesting played a major role in the past (e.g. North Yemen), its importance has declined (see Chapter 3.5).

(4) Despite considerable efforts undertaken in recent years (especially by international/Western donors) to promote and disseminate water harvesting techniques, the overall success is much less than expected (Siegert 1994). Figure 21 shows the relationship between some production issues and water management levels in agriculture.

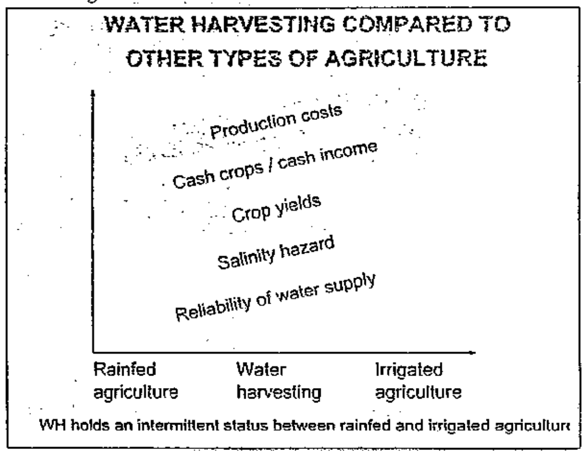


Fig. 21. Water harvesting and some production issues

5.2. CHOICE OF WATER HARVESTING TECHNIQUES

Numerous water harvesting projects have failed because the technology used proved to be unsuitable for the specific conditions of the site (Siegert 1994). Each of the water harvesting methods has its advantages and limitations which can be summarized as follows:

(1) Water harvesting for animal consumption

In developing countries, the building or reactivation of cisterns and other rainwater tanks for animal consumption can save water which othewise has to be lifted or pumped from groundwater or carried over long distances.

In "developed" countries (the USA, Australia) the search for cheap, durable soil treatment substances (e.g. sodium methyl silanolate) or ground covers continues (Arar 1993). It is expected that the costs for such treatments will be low enough in the future to treat larger areas and to obtain toxic-free runoff water.

(2) Inter-row water harvesting

In regions with not less than 200 mm (winter-rains) to 300 mm (summer-rains) annual precipitation, inter-row water harvesting will have a high potential in low-income as well as in high-income countries.

Contour ridges or bunds can be formed using hand tools, animal-drawn equipment or tractors, and therefore this technique is widely applicable for use in orchard establishment, general tree planting or for the cultivation of annual crops.

Under high-input conditions (e.g. in the USA), the space between the rows is often compacted and chemically treated to increase runoff.

(3) Microcatchment systems

Most of the research on microcatchment development has been done in Israel. A cost/benefit analysis carried out on negarin-type microcatchments in Israel in an area with less than 150 mm annual rainfall showed however, that the specific water supply was not sufficient for economic production (Oron et al. 1983). In this case, larger forms of Negarin microcatchment in higher rainfall areas seem to be more appropriate. The various other microcatchment types have their specific advantages. The quickest way to produce microcatchments is with the 'Dolphin' plough, being able to 'dig' 5000 microbasins per day, equivalent to a treated surface of 10 ha, with a water holding capacity of 600l/basin (Antinori and Vallerani 1994).

(4) Medium-sized catchment water harvesting. Medium-sized and microcatchment systems are regarded to have a high potential in the future. The desertification processes in many (semi-) arid regions have created large denuded surfaces, which are extremely difficult to revegetate.

These surfaces often yield high quantities of runoff water, which could be utilized with MSC-WH systems, especially with 'hillside conduit systems'. Many problems were experienced with trapezoidal bunds; "liman" terraces worked well in the past, if hydrologically calculated correctly, and will be a positive asset for future development (re-vegetation) in pre-desert regions.

(5) Large catchment water harvesting systems. If the development of those area systems can be combined with flood protection works for ephemeral streams, then a limited increase can be forecasted.

5.3. NEW DEVELOPMENTS

During recent years some technological developments took place in regard to water harvesting which might have some impact on the future role of WH in general:

(1) Supplemental water system

Runoff water is collected and stored offside for later application to the cropped area using some irrigation method. The water stored allows a prolongation of the cropping season or a second crop.

(2) Dual purpose systems

In a dual purpose system the runoff water flows first through the crop area, then the excess water is stored in some facility for later irrigation use.

In Arizona, USA, runoff irrigation was combined e. g. with trickle irrigation, using sealed soil surfaces to increase runoff rates.

(3) Combined systems

If the irrigation water from aquifers or from rivers/reservoirs is not sufficient for year-round irrigation, a combination with runoff-irrigation (during the rainy season) is feasible. The combination of runoff- and furrow irrigation is reported from North Central Mexico (Frasier 1994).

(4) Modelling

If more information on hydrological, soil and crop parameters is available, models can be developed and applied to water harvesting for certain environments (Boers 1994).

5.4. CONCLUSIONS

Water harvesting has proved to be a valuable tool especially in dry marginal areas

(1) to increase crop yields and reduce cropping risk
(2) to improve pasture growth
(3) to boost reafforestation
(4) to allow a higher degree of food production
(5) to fight soil erosion
(6) to make best use of available water resources
(7) to suppress soil salinity and, in a few cases,
(8) to recharge groundwater.

However, there also some problems associated with water harvesting:

(1) a higher labour input than in rainfed farming
(2) higher difficulties due to unfamiliarity with the technology and/or an unreliable water supply
(3) a negative impact on soil and vegetation resources in the catchment area due to clearing or treatment
(4) a loss of individual control in large WH schemes and
(5) the possibility of increasing number of livestock which could cause more desertification.

In comparison to former times, farmers today have to produce in a very different social and economic environment. Nevertheless, the positive elements of WH remain valid and they can be used in future for the well-being of people in the dry areas of the world. Precondition is an adequate coverage of all technical, social, economic and environmental aspects of WH in planning and implementation (Prinz 1994) - as it was apparently the case in ancient times, when sustainability was reached for many centuries.

6 CONCLUSIONS AND RECOMENDATIONS

? The present social and economic frame conditions for farmers differ strongly from those in ancient times, when water harvesting was more common, whereas the natural conditions remained similar.

? The advantages of water harvesting remain valid and farmers in dry areas have to utilize them if they want to be able to master the future.

? Farmers need scientific and institutional support to start new projects.

? The failure of water harvesting projects in the past was sometimes due to technical failures but more often the attention given to social and economic aspects was insufficient.

? There should be a global cooperation between scientists and practitioners involved in water harvesting. By learning from failures and successes, a high degree of sustainability might be reached, similar to the one which apparently existed in the past and remained for a thousand or more years.

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(2) 参考文献　Spate Irrigation in Balochistan

バロチスタン州における洪水流出水を利用した灌漑方法を整理して説明した資料。

世界銀行イスラマバード事務所の図書館にて、紹介されコピーを入手した文献でArcadis Euroconsult（オランダ）のFrank van Steenbergen氏が、バロチスタン州における洪水流出水利用について一般に紹介するために書いたペーパー。

本件プロジェクトとの関連で述べたウォーター・ハーベスティング法Khushkabaの記述があり(報告書本文7.1節参照)、本件プロジェクトで調査対象としたHighland Sailabaや Lowland Sailabaが、集水面積・河川流出・水配分の点から整理され紹介されている。

27 Oct. '03
from WB

ORGANIZED FARMERS: SPATE IRRIGATION IN BALOCHISTAN

Frank van Steenbergen[1]

1. Farmers and government in spate irrigation in Balochistan

This paper discusses the management of spate irrigation in Balochistan (Pakistan). It discusses the role of the government, particularly in financing construction, operation and maintenance of the spate systems; it discusses the role of organized farmers in these functions; and pays special attention to enabling laws, and their effectiveness, for enforcing rights to spate water and for formalizing farmer organizations. It concludes with a perspective on improved participatory management of spate irrigation systems in Balochistan.

There are a number of reasons to pay attention to spate irrigation in Balochistan. It is an arid region with occasional rainfall events. Plains border highlands, giving rise to spate systems that vary from small to very large, from very episodic to almost semi-perennial. Spate irrigation provides the economic basis (though often in combination with other sources of livelihood) for a substantial - and often poor - part of the rural population. A third of the irrigated area is under spate: of the remaining area a substantial part is dependent on groundwater exploitation, which is no longer sustainable.

The paper is organized as follows. Section 2 puts spate irrigation in Balochistan in perspective, by giving a typology and discussing the marginal nature of the farming systems. The role of government in the development and operation of the spate systems has been fairly limited in Balochistan, and by default much of the management is done by farmers. The roles of government and of the organized farmers are discussed in more detail in sections 3 and 4 respectively. On the basis of that discussion, section 5 approaches the question of improved participatory irrigation management.

2. Typology

Balochistan is the largest, but least populated (12 person per sq. km.) of four provinces in Pakistan. Its uniform aridity (nowhere exceeding 400 mm on average annually, but in many parts as low as 50 mm annually) makes unirrigated agriculture impossible. According to the Agricultural Census the area under run-off and spate irrigation fluctuates between 30,000 and 150,000 ha. The areas under canal irrigation and minor (including groundwater) irrigation each are comparable and are 140,000 ha.

Spate irrigation (called <u>sailaba</u> in Balochistan) is distinct from other rain-dependent production systems, particularly water harvesting (called <u>khuskaba</u> in Balochistan), in that the catchment of spate systems is bigger and water is diverted from river beds, instead of being collected from hill slopes or in-field. The dividing line between the smaller spate diversion systems and some of the larger run off complexes is often arbitrary, however. The farming systems and water conservation practices are similar, but the reliability in spate diversion systems is higher.

Spate diversion systems themselves differ widely. The main parameters are hydrological (catchment characteristics, rainfall pattern), geographical (location and level), hydraulic (type of diversion and size of command area) and sociological (land tenure, social structure and degree of public intervention). A useful distinction at this point is the difference between highland and lowland systems (see also table 1).

Highland systems, found in the Khurasan Range, on the eastern slopes of the Sulaiman Range, and the Central Brahui Range in Balochistan, generally have small catchments. Due to the small size of the catchments the spates are of short duration, usually lasting from one hour to one day. They are often

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difficult to control, because the slopes are relatively steep in highland areas and because only coarse material is available to build diversion structures. Similarly, the distribution of water within the system tends to follow the law of gravity more than elaborate distribution rules.

The lowland systems, on the other hand, that are common in the vast Kacchi Plains as well as in Las Bela and the Kharan basin in Balochistan, have large catchments and very shallow gradients. The flow lasts several days and can even be semi-perennial. Usually the floodwater moves slowly. It is often controlled by earthen barrages, but deflecting spurs and free intakes - similar to those in the highlands - are found as well. The low velocity flow and its long duration have resulted in extensive rules on water allocations. The flood rivers in the lowlands have often created their own plains of fine soils. Due to the soft material and due to low gradients, the sustainability of the systems is constantly threatened by excessive silt deposition and subsequently breaches of the riverbank.

The distinction between highland and lowland systems is not absolute. Lowland systems with small catchments or in the upper reaches of flood rivers on the plains share many of the characteristics of the highland systems. On the other hand, highland systems in more temperate climatic zones, where precipitation is gentle and spread over a longer period, conform in some respects to the description of the lowland systems.

TABLE.1: Typology of spate irrigation systems

	Highland systems	Lowland systems
Catchment	Limited	Large
Bed material	Stony, coarse	Sandy, fine
Gradients	Steep	Gentle
Flow	Flash floods	Semi-perennial
Diversion structures	Free intakes	Also barrages
Water distribution	Simple, 'natural'	Complex, 'manipulated'

All spate diversion systems in Balochistan, however, are marked by intrinsic uncertainty in water supplies and related to this, a marginal agricultural production system. The uncertainty in water supplies comes in two shapes. The first is the recurrent uncertainty. Water availability differs widely between the years: there are either no floods or several floods. The floods may be too violent to control and may wipe out diversion structures in one year; and in the next years the floods may be mild and controllable.

The second element of uncertainty is the dynamic character of the spate irrigation systems. In the medium-term the configuration of the spate systems changes: the bed levels of the spate rivers, the flood channels and the fields changes and the intake structures need to be adjusted. As a result of this dynamic nature some areas go out of command because the flood channel silts up or because it scours out so much that the flood can no longer be controlled and other areas become easier to irrigate. In the worst case entire systems are lost, because the river changes its course.

Spate irrigated areas in general also support a low value agriculture. The recurrent uncertainty in water supplies lies at the root. There may be either too much or too little spate flows. In the first case the spates may be beyond control, breaking the diversion structure or the flood channels, before land is irrigated.

In the alternative scenario, the season may not bring any flood or only a very small flood, that peters out before it irrigates all fields. A variation on these problems is that the downstream water users are deprived, because upstream users monopolize the flow. A further source of insecurity is the additional moisture from rains at later stages of crop growth, particularly of wheat. These rains may not come and the crop may be suitable for fodder only.

The farming systems are dominated by drought resistant, low yielding sorghum, millet, wheat, pulses, cotton and oilseeds. Most of the land is under local cultivars. Even if optimal conditions were to prevail, crop returns would have difficulty competing with alternate sources of income.

In addition to the above there is the sensitivity to crop diseases. In general, in flood-irrigated areas, especially adapted local varieties are grown. The timing of the flood determines the crop choice and there is little room to maneuver. This results in monocultures and the impact of pests can be dramatic. Yet there are very few substitutes for the varieties used and agricultural research has concentrated on perennially irrigated crops. Vulnerability is further increased as flood irrigation farmers generally lack the financial resources to apply pesticides.

As a consequence, crop yields from spate agriculture in Balochistan are low. They typically range between 450-900 kg/hectare for wheat, 360-550 kg/hectare for sorghum, 200-500 kg/hectare for pulses, 360-620 kg/hectare for cotton and 150-350 kg/hectare for oilseeds (Mu'Allem 1987; IAN MACDONALDS 1987a; 1987b; Shah 1989). A related phenomenon, peculiar to several flood irrigation areas is that there are landowners who are 'too poor to farm'. They lack the draught animals or mechanical traction to prepare the land and repair the field bunds, and do not have the cash to buy seeds and may have lost their credibility with moneylenders. They are often forced to rent out their land to tenants, who have access to these means of production.

Outmigration is the next step. With alternative labor markets developing and standards of living rising, the movement to other areas has accelerated. This trend has sometimes been self-reinforcing, in particular in the lowland systems of Kacchi, Las Bela and Kharan, as at a certain point the number of able-bodied farmers that stayed behind was insufficient to rebuild the labor-intensive diversion works. In the absence of bunds on the river, the riverbed regresses, making the diversion of water even more difficult, causing further depopulation and ultimately the abandonment of the spate system, as the critical mass for maintenance is lost. This process of depopulation can go very fast: when in the Mirpur area water supplies were reduced because farmers upstream refused to break their bunds, the area depopulated in a matter of three years and most of the spate infrastructure became dysfunctional. In some areas the danger of depopulation is countered by tying labor to the land. The most important manifestation is the hereditary tenancy that is widespread in the Brahui Mountains. In these areas, tenants were given hereditary land rights, on the condition that they would perpetually maintain the field bunds.

3. Government involvement

Investment in irrigation in Pakistan has been dominated by perennial irrigation. Spate irrigation received relatively less attention, because of the general lower rates of returns and the difficulty of making it work technically. The motivation to invest in spate irrigation was sometimes secondary to the spate systems themselves; the public investments were justified on the basis of groundwater recharge or flood protection. Even so 74 permanent structures were constructed in the past decades in Balochistan, making up one-third of the portfolio of the Irrigation and Power Department in the Province. Most of these concerned either earthen, brick or concrete headworks. The failure rate of spate structures, however, has been high. An extensive evaluation of 47 schemes, constructed by the government of Balochistan in the last thirty years, found that only 34% still functioned satisfactorily (see table 2). The other systems have either become unusable or suffer from serious operational problems (Groundwater Consult 1991).

TABLE 2 Performance of government-constructed spate schemes in Balochistan

Date of construction	Functional	Serious operational problem	Out of order
Prior to 1973	7 (35%)	6 (30%)	7 (35%)
1974 to 1983	4 (29%)	2 (14%)	8 (57%)
After 1984	5 (38%)	7 (54%)	1 (8%)
Total	16 (34%)	15 (32%)	16 (34%)

Source: Groundwater Consult 1991

The overriding factor behind the high proportion of failures in Balochistan was the inappropriateness of the prevailing engineering concept, which was based on controlling the flow at a single point with heavy civil engineering works rather than managing the inherently varying flood rivers. The technical designs for spate systems resembled those for perennial flows, and did not accommodate the capricious nature of the spate systems. Some structures were not able to withstand the force of the violent peak floods. In other cases, headworks were by-passed by the braiding river. Moreover, the provisions for sediment transport were generally insufficient and the intakes silted up (Morton and van Hoeflaken 1994). Trying to avoid these pitfalls would have required substantial investments in large headworks, complex silt excluding devices and long marginal bunds. Though, with these investments, it would have been possible to control the rivers at a single point, the low returns to sailaba cultivation ruled against such high investments.

Besides, in a number of cases newly constructed spate irrigation systems were not utilized due to conflicts on the spate water rights[2]. To invest in a single permanent off-take compatible with the existing 'reactive' rights (further discussed in section 4) and allocation rules on a river system is extremely difficult, since existing practices do not create predictable entitlements, but at best certain probabilities of irrigation. By improving the water supply to one area, there is a fair chance that someone will be worse off somewhere else at least under some circumstances. Conflicts are hard to avoid, unless one concentrates on the tail end of the system or on small independent systems. However, even so the changes introduced by the new structures would have had to be preceded by intense consultation with the landowners in different command areas. When the spate systems in Balochistan were constructed, however, no consultation took place.

In Balochistan the role of the Irrigation and Power Department stopped very much after construction. After care was primarily limited to the posting of linemen and guards. There was no routine program for repair works, but repairs were done on an ad hoc basis. In the last five years, however, the already inadequate budgets for maintenance by the Irrigation and Power Department have further curtailed. Precise figures on maintenance requirements and actual expenditures on spate systems are not

[2] Examples of spate irrigation systems that were not fully utilized because of disputes on the water rights are Uthal Kantra (Las Bela District), Ahmadzai (Zhob District) and Safi Band (Loralai District). One system in the Anambar Plain was even blown up with the consent of the two conflict parties.

available, but the overall estimated shortfall for the operation and maintenance of irrigation and drainage structures ranges between 25-75%.

Against these budgets and budget requirements, there is no dedicated revenue. Water tax, collected in perennial canal systems by the Revenue Department, is not levied on spate systems in Balochistan. Farmers in spate irrigated areas are bound to pay land revenue and other smaller land based taxes, though. The returns are modest (in the order of US 1.5/ acre) due to the low per area rates, underassessment and decreased collection efficiency.

It is fair to say that the overall lasting impact of the public investment in new spate irrigation structures in Balochistan has not been very large. A government program that had a far larger impact however was the bulldozer subsidy program. Under these subsidy program bulldozers and frontloaders, that were provided under several aid programs, were rented out by the Agricultural Engineering Department for Rs 100-150 per hour (US $ 5-7.5). The allocation of these quotas was done by elected politicians; the political mileage that was made is testimony to the popularity of the bulldozer subsidies. The impact of the bulldozer subsidies on the rehabilitation of the flood irrigation structures has been significant and the bulldozers were used to rehabilitate and reinforce bunds and flood channels as well as construct new ones. The bulldozer subsidies also had an important impact on the social organization of the floodwater users: they removed the need to pool resources to maintain the structures. The bulldozer subsidies program however is now in decline. Several of the bulldozers are now out of order and under the subsidies no provisions were made for their replacement.

In the absence of a pervasive role of the government, the spate irrigation systems in Balochistan are by and large farmer-managed. Some of these systems in fact represent some of the world's largest farmer-management systems. The most spectacular system is the series of earthen bunds on the Nari River in the Kacchi Plains, irrigating over 50,000 ha. Management of the spate systems requires arrangements for the internal water distributions, the management of the sediment transport, the organization for maintenance, reinforced by water rights. These various management functions are discussed in the subsequent section.

4. Farmer management in spate irrigation

The three main functions in the management of spate irrigation systems are:

- the distribution of spate water
- the management of silt and scour processes in the flood channels
- the maintenance and rehabilitation of diversions structures.

This section describes how farmers manage these functions as well as the type of water rights and the type of farmer organizations in place.

Distribution of spate flows

The risks in flood irrigated agriculture are high, but the probability of being irrigated or not is not equally distributed throughout the command area of the flood irrigation systems. Within the area served by one flood river and within the command area of one off-take, there may be land with high, medium and low probability of irrigation. This probability depends on the location and level of the command area along the flood river. Often upstream land and low lying land takes precedence and in Balochistan one will typically find a flood channel with a series of small and big obstructions, forcing the water to irrigate sub command areas in stages from head to tail. Much depends, however, on the ability to control the floods: where the flood channel is deep and its bed is rocky and steep, management and control of floodwater is far more difficult. Obstructions will not stand up in high floods and a 'free distribution' will be in place, where water finds its own way through the command area, with low-lying areas having the largest probability of irrigation[3]. Yet if floods are moderate, a sequence of water deliveries from head to tail can be practiced.

The point to be made is that, unlike perennial systems, the distribution of the floodwater is not entirely in control of farmers. Nevertheless in most spate systems in Balochistan there are water allocation rules in place that modify the probabilities of irrigation. Between off-takes, there may be rules on when to close an intake or break a barrage. Within the systems, an important allocation rule is the right to a second irrigation. It is either at the discretion of an upstream landowner to divert water for a second time, or alternatively he can only avail of it after all tail-enders have been served. The latter rule clearly spreads the probability more evenly[3]. The spectrum of water allocation rules is given in box 1. These allocation rules reduce - to some extent- the antagonism and mitigate the inequity. This is important, as farmers are dependent on one another in the maintenance of the works and too much unfairness would be dysfunctional.

Box 1: Water allocation rules in spate irrigation

- the construction of diversion structures and obligations to break them;
- the rights of some land tracts against others to be irrigated, when spate flows are small;
- the sequence in which lands are irrigated and the proportions to go in the different flood channels;
- normative rules on water usage, like the entitlement to a second turn and the depth of water to be applied; and
- agreements on the disposal of the high and unusable floods.

Managing sediment transport

Scour and siltation are part and parcel of spate irrigation systems in Balochistan. Rivers in spate lift and deposit huge quantities of sediment. As a result there is constant change in bed levels, resulting in changes in bed levels and water distribution. The impact of these processes differs between the various systems. It depends on the amount and composition of the sediment load that a river carries, which depends on the rainfall pattern and the characteristics of the catchment area; its geology, morphology and vegetation cover. Farmers are usually able to identify the origin of a flood by the type of sediment that is transported by it. The degree of siltation and scour also depends on the local topography and the type of material. In spate irrigated areas with low gradients, as are found on the plains, a river is always in danger of choking itself with its own silt deposits and finding another way. Moreover, in the fine sandy deposits of the plains, the scouring of the riverbed is a larger danger than it is in the rocky and pebbly riverbeds of the highlands of the Balochistan. As a result, the lowland flood irrigation systems are particularly dynamic.

Farmers, however, are not passive actors in these scour and siltation processes. They actively manipulate land formation. They may deepen the headreach of a flood channel, in order to attract a larger flood that will further scour out the channel. If a flood river breaks its banks, farmers may close

[3] The internal differentiation of the flood irrigation systems in Balochistan has other consequences too. One consequence is that the cultivated fields receive their irrigation at different times. In particular, in an elongated flood season, the high probability lands may be supplied from the early floods, whereas others rely on later floods. Crop choice is determined by the timing of the first irrigation and the result is often a 'banding' of the command area. Typically, in systems dependent on monsoon rainfall, an early summer flood may have been devoted to an area under sorghum, with oilseeds and pulses gaining popularity later in the season. The last summer floods are often reserved for wheat. The consequence of the variation in crops is that planting and harvesting activities are spread out and as a result there is considerably exchange of labour. It also allows the farmers whose land did not receive a single watering during the season to survive.

the breaches, if it deflects water away from their land or on other occasions, they will leave the breaches intact, so that these will act as escapes, creaming off the peaks of the very high floods and maintaining the flow at their own system at a manageable level. In other cases farmers will manipulate the siltation process to force the riverbed to purposely silt up. The latter is in practice where the river has become uncontrollable, because its bed may have become too deep or too steep. The remedy is to built a strong permanent bund across the river and force the river to deposit its sediment load upstream of the bund[4].

In Balochistan these land formation processes are managed by farmers. This is unlike the spate irrigation systems on the eastern slope of the Suleman Range (DI Khan and DG Khan) in NWFP and Punjab Province, where the civil administration actively intervenes in instructing farmers to plug breaches and to connect flood channels. During the colonial times the rights to the spate flows were registered and since then disputes are resolved through a special functionary. In Balochistan there is only limited involvement by the government in supervising the timely breaking of the bunds in the main Nara system as well as in the major flood channels. This is done through the office of the so-called tehsildar gandajat, a leftover from the period when the Kacchi Plains were ruled by the Khan of Khalat. This supervision has lost much of its force now and is now often limited to conflict resolution.

Organizing the maintenance of diversion structures

Maintenance arrangements have to cope with the inequities between areas with low and high probability of irrigation. Moreover, in spate systems returns for some farmers (in areas with a very low probability) are so low that their contribution to the maintenance of the systems is hardly matched by the marginal benefit they derive from it. This is unlike perennial irrigation systems, where the value of water is almost always far in excess of the maintenance efforts.

Notwithstanding these difficulties, in many spate irrigation systems maintenance and rehabilitation is vital: without it there is simply no irrigation in a subsequent year. This is unlike perennial systems, where often more neglect is tolerable. This places a high demand on the organization of farmers, complicated by the unavoidable inequity in water supplies.

In response to these challenges, in almost all spate systems clear rules have developed on the contribution of individual farmers. There are broadly two types of systems in this regard. The first category of systems is the 'regulated' systems. In a regulated system the area that is entitled to spate irrigation is clearly demarcated. The question is how do farmers within these areas contribute, given the fact that some areas stand a far better chance of being irrigated than others. There are two extremes:

- only farmers that had their land irrigated contribute to the maintenance of the system.
- all farmers contribute in proportion to the land that is entitled to spate flows, irrespective of the probability of the spate flow:

The first option may seem fair, but does not work in practice and also does not occur in Balochistan. It does not work, because it provides too narrow and unpredictable of basis for the maintenance work. Who remembers which land was irrigated the previous year? What if the diversion structure is destroyed before anyone watered his fields?

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[4] The strategy was followed when the large Sonwa Bund was built. This bund was erected at the tail of the Nari River, the largest flood river in Balochistan. The idea was that because of the permanent bund the riverbed would silt up. With the rising riverbeds, high level inundation channels would come under command again. This would skim the peaks of high floods and would reduce the impact of a high flood on the main bund. If the riverbed were higher, it would also serve those intakes dependent on deflectors and barrages, because it would become easier to build these structures. Eventually though, the danger is that the river will silt up so much that it breaks through its banks or scours out a flood channel to create a new course for itself. This, in fact, eventually happened with the Sonwa Dam. Farmers usual reasoning in such a case, however, which is indicative of a dynamic perspective on the sustainability of the spate irrigation systems, is that even then it is easier to control the floods than it was in the old deeply eroded river course.

The second extreme on the other hand is straightforward: every one contributes to the land in the designated command area. However, it puts a disproportional burden on farmers in areas with a low probability. One often finds, therefore, in systems where maintenance is organized on this principle, that water distribution rules are in place that favor the low probability areas (such as no second irrigation and the following of strict sequence of water turns). Or, particularly in small systems, land tenure may be such that farmers have land both of high and low probability. A different route is that of dispensations in the labor or cost contributions for deprived farmers. One such dispensation is that persons who have bullocks or tractors are expected to take these along during the maintenance works, whereas other farmers only provide labor. Bullock or tractor owning farmers are often those that have a disproportional part of their land under cultivation, and in this way fairness is restored. In larger systems maintenance is often done by labor contributions, but financed out of a special water tax (gham). Often different rates are assessed on different parts of the command area. For areas with a low probability a lower tax is assessed. However, such compensation rules are not in place everywhere.

The opposite of the regulated systems described above are the voluntary systems. In these systems the area that is irrigated from spate flows is not predetermined. The rules are essentially based on a 'take it or leave it'. If one contributes to the repair of the structures, one is entitled to the flow. If one does not contribute, the field intake is closed. These voluntary systems can be very unfair on low probability landowners, as there is no dispensation. In some cases in fact, the tail enders contribute more per acre. Where deflector spurs are rebuilt a number of times, one may find tail enders contributing to several rehabilitations before they get the water.

Reactive water rights

There is a categorical difference in the water rights in spate diversion systems and perennial systems (Varisco 1983). Whereas in perennial systems in Balochistan, individual rights are often sharply defined in fixed proportions of the flow and the allowed usage time, water rights in flood systems are 'reactive'. They cope not only with the unknown proportions of the next flood[9], but also with the medium-term changes in the river morphology, due to scour, siltation and change of river course. Water distributions in the floodwater irrigation systems are based on allocation rules rather than alienable property. They describe what is 'done' and what is 'not done'. The spectrum of possible rules is given in box 1.

A second domain regulated by reactive water rights concerns the changes in the layout of the systems, as a result of natural or man-manipulated siltation or scour. Water rights may accept the changed circumstances or may try to restore prior access to the water. This also depends on the nature of the change.

In most - especially smaller - systems in Balochistan, water rights are enforced indigenously, by the farmers of the flood irrigation systems. Where conflicts occur, outside political or administrative support may be mobilized, but essentially the distribution of water and repair of irrigation infrastructure is not a government responsibility. Its involvement is limited to extend help on an incremental basis, at varying degrees of intensity, keeping in line with political principles of patronage, and divide and rule.

In fact, the only time when a government was directly involved in the management of spate irrigation systems in Balochistan was during the latter period of Kalat State, when the native ruler appointed the so-called tehsildar ghandajat, who was to supervise the breaking of the different barrages in the Nari River at a specified time. As discussed, the background of this practice was that otherwise the ruler's own land at the tail of the system might not be inundated. Yet this regime of regulated flood management was exogenous to the resource, and disintegrated when the political constellation changed. After Kalat State joined the newly formed republic of Pakistan in 1948, the former administration of the water rights was dismantled, and the upstream landowners refused to break their barrages after the previously specified time. In the ensuing vacuum, water rights were often determined by the relative strengths of the communities along the flood river rather than by formal regulation. In contrast, in the flood irrigated areas of Punjab Province of Pakistan, government involvement has been more persistent. In the colonial period the British administration, in order to safeguard the land revenue from the flood irrigated areas of Punjab, directly managed the use of flood water, and organized the repair of bunds and flood channels by corvee labor and posted watchmen, who were to break the barrages in time (Bolton 1908). The system has slackened somewhat, but still the District Collector supervises the water distribution and timely breaking of earthen bunds in this area (PARC/UNEP/ESCAP 1994).

Farmer organization

Who organizes the maintenance work and who supervises the water distribution in the spate system in Balochistan? In general, given the magnitude of the task, the work is organized in a surprisingly informal way. A number of influential farmers take the initiative. These are often farmers with large holdings, who stand to gain most from the reconstruction of the structures and also have most resources to mobilize fellow-farmers. The maintenance is done in a campaign mode, with a series of days planned for joint labor. In some of the large spate systems on the Kacchi Plains, a water tax (gham) is still collected through a network of local leaders. Alternatively the influential farmers try to arrange the subsidized bulldozers to their areas. In fact the arrival of the subsidized bulldozers has removed the need for structured farmer organization. In summary there are organized farmers and clear rules, as described above, but no farmer organization as such.

In some of the larger lowland systems specialist staff is deployed. They are of two types. In the Kacchi Plains designated 'engineers' supervise the construction of the large earthen bunds. During the flood season they are engaged to patrol the safety of the bund. They are paid either in kind or from the gham. This office of 'engineer', however, is not common in all the spate systems, not even in the Kacchi Plains.

A second type of dedicated staff is the 'sepoys' (literally: policemen) engaged in a limited number of spate systems in Las Bela. Their role is to mobilize, if necessary by force, farmers to contribute to the reconstruction of the diversion structures. One finds the sepoys particularly in systems based on deflector spurs, where the burden on tail-end farmers (and hence the reluctance to contribute) is relatively large. The root of this position is the pre-partition time, when the native ruler organized the construction of the diversion structures with forced labor. His interest at that time was the land revenue that he received from a well-functioning spate system. After the dissolution of the princely state, farmers valued the role of the sepoys and continued their engagement. Again, however, the position of sepoy is far from uniform in spate systems.

Remarkably in none of the spate system dedicated persons are engaged to supervise the distribution of water, unlike the perennial systems in Balochistan, where often water bailiffs (called mir-i-aab, rais or sharistra) supervised the irrigation turns of the individual farmers[5]. No such position is in place in spate systems and instead social control by individual farmers regulates the water distribution. The reason is probably that it is difficult to do it otherwise: when the spate comes, so many areas are irrigated in a very short time that it is impossible for a specialist water bailiff to patrol.

5. Participatory spate irrigation management in Balochistan: options

As most of the spate systems in Balochistan are de facto farmer-managed, the scope for irrigation management transfer in Balochistan is limited to probably 25 functional structures. The question however is whether in all these 25 cases the 'pucca' structures are what farmers would rebuild, if flood

[5] The function of water bailiff has disappeared in many perennial systems with the introduction of watches, which made it unnecessary to engage a specialist to read sundials, stars and water clocks to supervise the water distribution.

damage would require so. It is more likely that farmers would prefer a menu of earth moving interventions to restore their diversion structures: the operation of heavy tractors and bulldozers is technically less demanding and can be undertaken at lower cost. The conclusion could be that several of the spate works will last as long they will last, but once gone will not be restored in the same shape under farmer management.

Leaving aside the management of the spate systems, constructed earlier with public funds, there is however a large scope for improved participatory management of the spate systems of Balochistan. The improvements concern the type of organizations and the type of spate water management. Most of the systems are managed in a rather passive way, with campaigns to rally contribution for O&M (if already bulldozers have not been secured in sufficient quantity) and rules on what to do and what not do in water distribution, but no local planning.

Strengthening of farmer organizations and assigning them planning and active management functions should be done in the light of a river management approach. The flood management system in D.I. Khan District of Punjab in Pakistan may serve as an example (Bolton 1908). Under this approach, rather than controlling the river, one tries to manage it in its entirety. This requires a more comprehensive look at the river system and the land formation processes. Examples of interventions are: controlling breaches in the river banks by making bunds in the newly formed spillways, if necessary in stages; forcing a degrading river to silt up by blocking it with a permanent bund, even if it means that the river may eventually find a new route away from the bund; excavating new flood channels to link up braided streams. These interventions mainly involve earthmoving and resemble existing farmer techniques of manipulating siltation and scour. This 'management' approach is less capital-intensive and has a far higher chance of creating sustainable flood irrigation systems, and as such is a superior alternative to past approach of building heavy headworks at single points.

Wherever possible, farmers should continue to be the prime implementers under the river management approach. When subsidized government bulldozers continue to be made available in Balochistan, a river-level management approach allows one to use them strategically, instead of letting bulldozer allocations be solely determined by political opportunism and individual demands. Two large spate irrigation systems were completed in the Kacchi Plains (with the help of NGO's) on this formula, from which valuable lessons can be learned. The first dam is the Rehanzai Bund using water from the Bolan River and an offshoot of the Nari River. This two kilometer wide earthen dam was made by farmers organized in village organizations and has been very successful in rehabilitating an area that had not been cultivated because the river has braided. Part of the success was at the detriment of down stream water users, who, despite formal assurance, were deprived of water, as farmers on one of the flood channel of Rehanzai refused to break their bunds. This underlines the need for a river basin approach. The second example is the Sonwa dam, built at the tail of the Nari, planned and implemented by the farmers on the three main flood channels benefiting from the three kilometer wide bund. Unfortunately the bund broke after two very productive years and was not rebuilt by the farmers, who instead are using part of it. This example also shows that one should not expect miracles from farmer organizations.

While the techniques are not new, the most important crucial element in a river basin management approach is the appropriate organizational framework. Since the interventions involve changes that affect several intakes simultaneously, an institutional structure is required that supersedes the interests of the land owners on a single flood channel, and avoids decisions that are taken by a show of strength only. The challenge is to have a supra-local organization with a permanent character, since - although it may be intermittent - management never stops and the build-up of knowledge on the river's behavior is essential.

The new Balochistan Irrigation and Drainage Act, accepted in 1997 has the provisions for this. The Act was prepared as part of the institutional reform in the water sector, that is meant to create financial autonomy. One important step in this regard is the transformation of the Irrigation and Power

Department into an autonomous Irrigation and Drainage Authority with responsibilities for surface and groundwater management. The Authority can under the Act delegate its responsibilities in water management and revenue collection to Farmer Organizations. These Farmer Organizations are formed on the basis of hydraulic units and can federate. At present the hydraulic units specified are distributaries and minors of large canal systems. This should be corrected. More work needs to be done on the Act: the legal status of the farmer organizations and the procedures for registering them are not yet worked out. The first step however is to put the Act in its current shape in practice, which is not yet done.

A second legal reform that is overdue is the codification of spate water rights. Water rights are only recorded on two flood rivers, i.e. the Porali and the Nari. The competition for water will only increase and with it the risk of depriving downstream water users. The codification on the Porali has led to a conflict-free distribution of water on this river. In case of the Nari, the rules on the breaking of the bunds is not always enforced. Even so, without these rules the chaos would have far larger.

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4. Field-to-field flood irrigation, as common in Yemen, is unusual in Balochistan. In Balochistan each field typically has its own inlet channel.

9. Similarly, in perennial systems different allocation rules exist for different discharges. Often in case of high seasonal discharges, water allocation rules are not in strict accordance with water rights.

添付資料 － ３　　コンセプト・ペーパー

(1) コンセプト・ペーパー #1　USAID

(2) コンセプト・ペーパー #2 & #3　IUCN

(3) コンセプト・ペーパー#4　UNDP

(1) コンセプト・ペーパー #1　USAID

他ドナーの動向に係る調査の一環として、USAIDの今後の活動方針を確認したもの（報告書本文2.5.2節(4)項参照)。

パキスタンにおいてFAOと連携して住民参加による農村開発事業の実施を目指した基本構想が記述されている。

調査時点で未だ作成中・検討中の段階にあり、参考資料として取り扱われるものである。即ち、これは事業の実施計画ではない。

18 ... Feb ... Dr. ...

Concept Paper for USAID Assistance to Agriculture in Pakistan.

Background:

Agriculture has been defined by the Common Country Assessment of Pakistan as the potential engine for economic growth and poverty alleviation for the country. Besides its contribution of 25 percent to the GDP, agriculture is the largest single sector in the economy directly supported three quarters of the country population and employs half the labor force, contributing to the rural poverty alleviation being the sole source of income for the poor rural community. Consequently, agriculture is on the top agenda of the government, however, public expenditures on the sector is low.

In spite of the vast areas of cultivated land (22 m ha), land productivity is low due to poor resource management; inefficient use of water resources, salinity and water logging, poor access and low inputs use. Identifying these causes, FAO has demonstrated Special Programme for Food Security (SPFS) in four pilot areas based on community mobilization, On-Farm Water Management, improving access to inputs and income generation, which resulted in doubling the yield of the main food crops and more than doubling the income of the farmers. Consequently, National Programme "Enhancing Agriculture Productivity on Sustainable bases" was launched in 109 villages nationally beginning of 2003 with commitment of around Rs 500 m over three year period of government resources and technical assistance from FAO with some contribution from local CIDA office.

Over the past decades a lot of efforts have been successful in exploiting the potential irrigated areas in the countries especially in Punjab and Sindh. However, not much attention has been given to agriculture development in arid areas of Balochistan, parts of NWFP and Sindh. On the same lines, the National Food Security programme has successful packages implemented on the irrigated lands and to a good extends rainfed areas (Barani). However, it does not have development packages for implementation in arid land agriculture. It is very crucial that the National Programme will get assistance from donors like USAID, international technical organizations like FAO and ICARDA in developing and demonstrating such packages for arid lands. The successful development of such packages will help leverage more resources from other donors.

In the recent donors meeting held in Balochistan on drought mitigation, the situation there was identified as clearly alarming and non-sustainable due to intensified the aridity and expanding to larger areas, inefficient use of energy, degradation of range land due to overstocking, lowering of water table and low recharge of ground water and finally expansion of high delta crops. This perpetuates poverty in Balochistan that could lead to economic and possible political instability.

Agriculture research is, globally and nationally, the driving vehicle for agriculture development, however it is lagging behind playing its vital role in Pakistan, with almost negligible activities in the arid areas. No real developing packages have been developed over the past decades. One of the main reasons is the lack of linkages and the weak coordination between federal and provincial institutions, or even between research institutes in the same location with similar mandate. Lack of Human Resource Development and low morale especially of the young scientists is of major concern. A number of donors, including USAID have identified agriculture research especially strengthening coordination and linkages as an area, which needs more assistance/attention.

Proposed outline for USAID assistance to the agriculture sector.

Overall Objectives

To support the National Programme for Food Security especially in the arid areas of Baluchistan and possibly FATA and NWFP, which are technically backstopped by FAO. The programme will be community based, market oriented and targeting the rural poor in these sensitive area.

The proposed programme is an umbrella programme titled " **Food Security/Poverty Alleviation with emphasis on Arid Agriculture – Baluchistan as Pilot Phase**" This will enable USAID to have a quick and tangible impact on the rural poor of Balochistan. Which can be followed at a later stage by similar activities in FATA and Parts of NWFP areas that greatly affected by drought and heavy influx of Afghan Refugees.

Specific Objectives:

1. Strengthening Adaptive Research for Arid Land Agriculture with full community participation and pilot demonstration.
2. Management of scarce Water Resource through integrated and highly efficient approach
3. Efficient Range and Livestock Management with emphasis on marketing.
4. Enhance Crop Productivity on market and Sustainable basis

Proposed Activities:

1. Adaptive Research:

- Research Programme should be in support of the other three components.
- AZRC (Arid Zone Research Center) Quetta is proposed to be the focal point with linkage to Baluchistan Agriculture Research Institute, NARC, ~~Agriculture University, Faisalabad.~~

- Technical assistance from International Research Centers, ICARDA, would be sought in adaptive research component, providing suitable germ plasm and Human Resource Development.

- Plan of action should depend on community based participatory research and pilot demonstration on the farmers fields.

2. Water Resource Management

- Development of integrated policy and strategy for management of land and water resources from canal, rainfall, run off and ground water with political support.
- Promoting efficient irrigation system i.e. drip and trickle irrigation
- Assessment of ground water recharge by check and delayed actions dams and Develop plans for its construction
- Establishment of community Aquifer users organizations.
- Improving management of traditional water harvesting technique Sailaba and Khushkaba
- Community mobilization for sense of owner ship
- Human Resource development of the Line Department.

3. Range and Livestock Management

- Assessment of Natural range vegetation and stocking capacity
- Promoting the forgotten communal range management with local communities and tribes
- Improving markets for live animals and livestock products
- Promoting utilization of feedstuff other than range, i.e. crop residues with enrichments,
- Optimize the livestock and flock structure in different agro-ecological zones.

4. Enhance Crop Productivity on market and Sustainable basis

- To promote high value low delta crops;. Olive, pistachio, Almonds, Grapes, pomegranate, figs and in some areas cotton and oil seed.

- Discourage high water consumption crops, i.e. onion and paddy
- Reduce post harvest losses and improving handling/packing of vegetables/fruits.
- Promoting agro-industrial business for the target crops.

Proposed Modes Aparendi:

- An MOU to be signed between USAID/EAD/MINFAL similar to that with MOST.
- To be able to facilitate the implementation of the programme and take advantage of the global technical knowledge, FAO to be the implementing agency under the Trust Fund arrangements with the USAID and Government of Pakistan.
- High powered steering committee to be established for monitoring the programme and decision making on the activities prioritization to be chaired by the Secretary MINFAL and have members from EAD, USAID, PARC/NARC, FAOR, Planning Wing of the MINFAL, Provincial ACS and Provincial Secretaries of the Departments of Agriculture, Livestock, Irrigation, together with some resource persons in their individual capacity e.g Dr. Kausar Malik (PAEC), and Dr. Qureshi, Vice Chancellor, Agriculture University – Faisalabad
- Secretary MINFAL to act as the National Coordinator with Secretary of the concerned provincial line department as the focal point of different activities.
- Programme Manager to be hired for the duration of the programme to run the day to day work and will report to FAO and the steering committee.
- The Programme Manager will be supported by a full time National Consultants for each activity.

Proposed Framework:

- The Concept Paper to be submitted to the USAID office Islamabad for review and consideration (1st week of June 2003)
- Upon receipt writing of the agreement in principle with the concept paper from the USAID office, FAO/R office to present it to the MINFAL and FAO HQ for their review and get the go ahead for preparation of the project proposal.
  (3rd week of June 2003)
- As soon as the agreement in principle from USAID and go ahead from the Secretary MINFAL is received, project will be started. (to be ready Mid-July 2003)
- Parallel to the project formulation, MOU between the USAID and MINFAL/EAD to be negotiated.
- The project document to be submitted for technical clearance by FAO HQ
  (3rd Week of July 2003)
- As soon as the technical clearance from FAO-HQ is received, the project documents will be submitted to USAID for processing the approval.
  (End of July 2003)
- Trust Fund Agreement to be signed between USAID/MINFAL and FAO. (beginning of September 2003)

Preparatory Stage:

September to December 2003 will be considered as Preparatory stage of the project which will include;

- Notification of the Steering Committee,
- Identifying the Programme Manager.
- Identify the project sites in the three agro-ecological zones of Baluchistan
- Establishing local community organizations in the chosen sites.
- Initiate Socio-economic bench mark survey at project sites
- Identification of the research priorities based on community participation.
- The budget level foreseen for this period is limited (US$. 100,000 – 200,000).

Main Project Phase:

- The duration of the first phase of project is proposed to be 3 years (2004-2006)
- Based on the success of the first phase to be followed by another phase for expansion of activities to other areas in the same province and/or in FATA and NWFP
- Depending on the project formulation, the budget foreseen for the first 3 years is 4 to 5 million US$.

***Linkages with existing project and leveraging other donor suport*:**

- As mentioned above the programme is actually supporting the ongoing National Food Security Programme, which is technically supported by FAO and some financial assistance from the local CIDA office.
- The project activity will be linked with other USAID projects especially research linkage and micro-credit.
- Three FAO executed EC projects running in Baluchistan, will also be cooperating with this project. The two bi-lateral areas covering animal health and livestock production and the other one is regional project on IPM.
- FAO HQ, in support of the National Food Security Programme has carried on an effort for leveraging other resources especially from the Asian Development Bank and Italy. This effort will be strengthened with the successful implementation of the programme.

(2) コンセプト・ペーパー #2 & #3　IUCN

他ドナーの動向に係る調査の一環として、IUCNの今後の活動方針を確認したもの（報告書本文2.5.2節(4)項参照)。DADの効果測定調査、帯水層活性化パイロットプロジェクトの実施を計画している。

調査時点で未だ構想の段階にあり参考資料として取り扱われるものである。即ち、これは事業の実施計画ではない。

23 Apr 03
IUCN

Background

Balochistan is an arid, largely mountainous province of Pakistan with an area extent of 347,200 Sq. Kilometer. Its population according to the 1998 Census is 6.6 Million (Currently estimated at 7.5 Million). With history dating back to the Stone Age, Balochistan is rich in biodiversity and natural resources. The Province frequently endures spells of drought, flash floods and earthquakes. The wide variations in physical features and climate have produced diverse landscapes, ecosystems, and habitats that are not only part of important national and global heritage but also serve as source of livelihood for the poor people of the province.

Misplaced priorities, inappropriate perceptions and evaluations, and lack of integrated and holistic approach towards problem solving have made the environment a rather intricate issue in Balochistan. Whereas three million afghan refugees have intensified the effect of natural factors of environmental degradation, imperfect governance structure, insufficient stakeholders participation and defective incentive systems in-place have exacerbated the rate of degradation and its complexity. Resultantly, rangeland degradation, dichotomy of water scarcity and inefficient use, loss of forests, wildlife, habitats, and biodiversity, and increased level of pollution are some of the blatant issues to be dealt with on priority to ensure the sustainable development of the province.

Balochistan Conservation Strategy (BCS)

In order to address the environmental problems and a host of other related issues, a Conservation Strategy was prepared by the Government of Balochistan with the technical assistance of IUCN and the financial assistance of the Royal Netherlands Embassy (RNE). BCS is both a guideline and an action agenda for development. It integrates social, economic and ecological issues; proposes a way forward; sets out challenges and realistic recommendations; and identifies the actions to be taken together by the government, the private sector and civil society. Government of Balochistan approved the strategy in the year 2000.

Balochistan Programs (BP)

Following the BCS approval and adoption by the Government of Balochistan, it became important to maintain the momentum generated through the BCS process as well as continue providing the much needed neutral interface between civil society and government-run departments, and assist in capacity building and institutional strengthening for BCS implementation. The BP, a 5-year programme (March 2002 - February 2007) is aimed at the implementation of the BCS through knowledge management, capacity building, institutional strengthening and improved governance. The Programme, funded by RNE and implemented by IUCN demonstrates the long-term commitment of both partners towards sustainable development of Balochistan

Goal and Objective

The overall goal of the programme is to improve the quality of life of people of Balochistan, with the principal purpose to strengthen institutional and human capacity for sustainable and equitable use of natural resources in the Province. Specific objectives of the programme are:

- *Facilitating the implementation of the BCS*
- *Devolving BCS implementation to two selected districts of the province*
- *Promoting the conservation and sustainable use of freshwater in Pakistan with major thrust in Balochistan*

Approach

The Programme has devised a number of approaches to carry forward its work in three main sectors - Forest, Rangeland, and Water with gender and poverty alleviation as cross cutting themes. Interventions will be carried out under the following themes:

- *Policy Planning and Institutional Strengthening*
- *Awareness Raising, Advocacy and Education*
- *Good Governance*
- *Knowledge Management*
- *Demonstration projects*

Partners

IUCN, being a union, will carry forward the Balochistan Programme in collaboration and partnership with diffei government line departments, national and international agencies and civil society institutions. The District Governments and communities will be the main parners in implementing the various activities outlined under the Programme.

Districts

Based on various factors included in the criteria for selection of districts to implement key elements of the BCS, the Programme has selected Gawadar and Killa Saifullah districts for interventions.

Innovative interventions will be carried out in the districts to carry forward the knowledge management, environmental education, policy and advocacy, capacity building, institutional strengthening and good governance themes of IUCN Balochistan programme.

Following particular innovative interventions in unique context of the respective selected districts will be made for sustainable development and environmental conservation:

- Support District Government to develop a vision for development (District Sustainable Development Plan)
- Develop District Management Information System (DMIS)
- Pilot projects on ground water recharge, rainwater harvesting and water desalination and alternative livelihoods.

Water Programme

Through the Water and Nature initiative of IUCN, the IUCNP Water Programme would address key issues related with water conservation, equity in distribution and access, water harvesting, aquifer recharge, efficient and sustainable water use, watershed management, environmental flows, economic evaluation, floods and drought management, and aquatic ecosystem restoration. The approach of the Programme, which will not substantially involve itself in sanitation and clean drinking water issues, will focus on: education, awareness raising and knowledge management; institutional strengthening and capacity building; advocacy and policy advice; and, involving stakeholders.

The specific objectives of the programme are:

1. Sensitize the general public/various different water groups and decision-makers about water and nature issues.
2. Increase the capacity of government departments and civil society to tackle water issues, with integrated water resource management approach from an ecosystem perspective

Shift in policies, strategies and plans related to water resource development and management to protect and restore goods and services.

IUCN-The World Conservation Union

IUCN - The World Conservation Union was founded in 1948 and brings together 79 states, 113 government agencies, 754 NGOs, 36 affiliates, and some 10,000 scientists and experts from 181 countries in a unique worldwide partnership. Its mission is to influence, encourage and assist societies throughout the world to conserve the integrity and diversity of nature and to ensure that any use of natural resources is equitable and ecologically sustainable. Within the framework of global conventions IUCN has helped over 75 countries to prepare and implement national conservation and biodiversity strategies. IUCN has approximately 1000 staff, most of whom are located in its 42 regional and country offices while 100 work at its Headquarters in Gland, Switzerland.

In Pakistan, the Union seeks to fulfill this mission by empowering communities to participate in the implementation of the National Conservation Strategy.

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20 Aug, 03
JICA

Project Concept
Groundwater Aquifer Rejuvenation and Community-Based Water Conservation in Pishin-Lora Basin, Balochistan,

1. Background

The climate of Pakistan is predominantly arid or semi-arid with approximately half of the country receiving less than 250 mm annual rainfall on average. The province of Balochistan in the west of the country bordering Afghanistan has a mean annual rainfall of less than 100 mm in the southwest to just over 600mm in the northeast. Daytime temperatures during summer can be as high as 40° C even at higher elevations. The relative humidity is generally low throughout the year. These two issues, high aridity and low humidity cause surface water bodies to evaporate rapidly. In the absence of perennial sources of water in most parts of the province, groundwater is the only dependable source to meet the ever-increasing water demands in these areas. In particular the capital of Balochistan, Quetta, and the surrounding valleys falling in the Pishin-Lora Basin, face extreme shortage of water, as the demand is far above the available supplies. It must be mentioned that Quetta valley has good soils, good climate, and with irrigation water, deciduous fruits of the highest quality are grown and as such orchards are one of the main users of the water in Quetta valley.

In the past, groundwater was tapped through the traditional Karez system, a system of vertical wells in the alluvial fans at the foot of the mountains interconnected by a horizontal tunnel that would intercept the water table near the head of the alluvium, and provide a dependable source of water flowing under gravity to valley alluviums where agriculture is mostly practiced. The advent of electricity in the province in mid sixties, and its provision to farmers on subsidized rates to promote agriculture heralded the exponential growth of tubewells. Unregulated increase in number of tubewells over the years along with unsustainable practices has resulted in tremendous stress being placed on groundwater resources. Many areas show a drop in the groundwater table from 1 to 3 meters every year. .

Historically, the slopes of the mountains around Quetta Valley within the Pishin Lora Basin and the watersheds were covered with forests, and the natural recharge of the underground aquifer balanced well with the discharge from springs and Karezs'. With passage of time, due to human interventions and pressures imposed by an increasing population, and associated requirements of energy (fuel wood), fodder, timber for construction etc., the forest cover has all but disappeared and the soil that covered the slopes has washed down into the rivers/streams. As a result, the occasional rainstorms in this and similar vulnerable areas in Balochistan now cause flash floods. The net result has been that rate of withdrawal (or abstraction) of groundwater is no longer matched by rate of groundwater recharge. The problem is not unique to Quetta valley and is a common feature throughout Balochistan wherever there is electricity.

2. Justification

Efforts by the government to restore groundwater recharge have focussed largely on building infrastructure. . Primarily, this has meant building delay action recharge dams across some of the streams in the foot slopes of the mountains around Quetta valley. The technique, apparently, is fine. It was hoped that the deep percolation from the reservoirs created by these dams would recharge the aquifers beneath. While the Provincial Irrigation Department claims success, field observations show that the high content of fine clay in the river, brought in during storms, gets deposited and rapidly seals the beds of the reservoirs preventing percolation and recharge of groundwater. Additionally the flash floods sometimes cause the dams to be washed away at the height of the flood, causing immense damage to life and property of poor and marginalised communities. Meanwhile, more boreholes continue to be drilled, and the water table continues to drop causing the *Karez* systems to dry up and the tubewells to be deepened almost every few years. Currently water is being pumped from over 500 feet in many places raising serious questions about the sustainability of the resource. There is now an urgent need for taking remedial actions to control the situation and increase recharge to balance groundwater abstraction.

Experience has shown that building of dams alone cannot control the situation. It is of utmost importance that an integrated approach comprising engineering solutions combined with social and regulatory mechanism be applied in the affected areas to rejuvenate depleting aquifers. The IUCN Water Programme has offered to help find solutions to this critical issue and has planned to institute a series of interconnected actions over the coming years. Actions planned cover different dimensions and tiers of the problem and are aimed at policy and regulatory changes, strengthening enforcement of existing laws, empowerment of key stakeholders (government staff and water users/communities), as well as implementation of community-managed pilot demonstration projects to test new approaches and develop feasible options for replication.

The choice of Pishin Lora Basin as the project area has been influenced by the following factors:

1. This basin completely covers the districts of Quetta, Pishin, and Mastung and part districts of Killa Saifullah, Killa Abdullah and Kalat. A small part of Ziarat District also falls withjin this basin (see map 1). All these districts lie within economically the most productive zone in Balochistan due to deciduous fruit production of the highest quality.
2. The groundwater depletion phenomenon is the most severe in this basin with depletion exceeding 3 meters/year in many places due to over-exploitation of groundwater (see map 2).

3. Goal

Water conservation is promoted and practiced by all concerned stakeholders in Pishin-Lora Basin

4. Objectives

The following are the specific objectives of the Project.

1. Build knowledge base of stakeholders for improving effectiveness of recharge dams
2. Community rehabilitation and management of upper catchments in select areas
3. Demonstrate and promote integrated on-farm water management practices in a select area within Pishin Lora Basin
4. Build capacity of key partners for undertaking landscape rehabilitation and water conservation and management
5. Identify disincentives and promote adoption of economic and policy incentives for sustainable water management

4.1 Build knowledge base of stakeholders for improving effectiveness of delay action recharge dams

(A) Preamble

The success of efforts to recharge aquifers through delay action recharge dams and other techniques for achieving effective groundwater recharge needs to be reviewed in light of experiences gained thus far. The review and recommendations will supplement the knowledge base of government executing and policy-making and provide a roadmap for improved management of aquifers in the future

(B) Outputs

1. Research report on existing recharge dams and recommendations for improving their efficacy
2. Recommendations for improved design and construction of future recharge dams
3. Report on social and community issues, and coping strategies, related to groundwater management
4. Increased capacity of GoB officials at the policy making and project implementation level to manage groundwater aquifers

(C) **Main Activities**

In 2000, UNDP and GoB organized a Strategy Workshop on water resources management at Quetta. The workshop deliberated at length on various issues in water sector including depletion of aquifers in Balochistan. Based on the recommendations of the Strategy Workshop, the following activities will be carried out to achieve objective 4.1:

1. Carry out a review of existing recharge dams describing size, type, operation, and other points in a short report. This will include a map of all 162 recharge dams constructed in the Province, in relation to landscape features and river courses
2. Develop a field research project for measuring and testing extent to which dams are actually augmenting underlying aquifer. Details of the research project will include reservoir floor infiltration tests, the use of water tracers to follow infiltration water, Karez and tubewell monitoring, water sampling downstream of the dams, laboratory assessment of water samples to check for tracers, and determination of water quality fluctuations
3. Study on methods for improving recharge capability of existing recharge dams
4. Carry out participatory dialogues with water users to investigate social and community issues related to water distribution, use and management
5. Exposure visits of GoB executive technical officers to countries in the region for forging institutional links and learning from their experiences with groundwater recharge projects.

4.2 Community rehabilitation and management of upper catchments in select areas

(A) **Preamble**

Though it is not certain the full extent to which upper catchments contributes to the actual recharge of the groundwater aquifer near valley floors, yet their importance in attracting rainfalls, reducing silt load in streams, and contributing to recharge near the foothills cannot be overemphasized. It is the silt free runoff, which will ultimately help efforts to artificially recharge aquifers through infrastructure like delay action recharge dams. It is recognized that catchment restoration may be difficult on slopes that are totally denuded but the project will identify two or three sites where forest landscape restoration may be possible, and work with forest department staff to support reforestation activities using drought resistant varieties of trees, bushes, and grasses.

(B) Outputs

1. Report on forest cover in upper catchment of Pishin Lora Basin and identification of critical areas for groundwater recharge

2. Strategy and community-based management plan for promotion of forest cover as means of facilitating groundwater recharge
3. Community managed landscape restoration and improved forest cover in selected areas
4. Improved aquifer recharge
5. Improved availability of forest products for local communities and fodder for livestock

(C) **Main Activities**

1. A review of forest cover in the upper catchment through remote sensing images as a baseline for monitoring purposes and as a means to identify possible recharge areas
2. Identify and review management arrangements of those areas of natural vegetation that still exist to determine which target groups to work with in forest landscape restoration activities
3. Mobilise local communities, forest department staff and private entrepreneurs in selected areas to undertake forest and range landscape restoration activities in order to promote natural regeneration, combat soil erosion, restore ecosystem services, and improve slope infiltration capacity
4. Develop appropriate rangeland management practices, and pilot test different options for improvements in condition of select rangelands
5. Develop, test and disseminate appropriate water management practices, including construction of small recharge dams, terracing of critical slopes, and building other water retention structures

4.3 Demonstrate and promote integrated on-farm water management practices in select area of Pishin Lora basin

(A) **Preamble**

Poor irrigation efficiency and poor productivity per unit of water used for orchards and other crops is a common feature of agriculture in Balochistan. Though the recent drought in the Province has increased the affected farmers' perception of economic water use and allied benefits, yet most farmers are still using the same old practices of flood irrigation, and paying little or no attention towards achieving greater conveyance and application efficiency. The best way to raise awareness about the problem and involve user communities is by establishing demonstration projects. Hence, the project expects to establish small and medium sized field pilot projects in order to demonstrate the benefits of an integrated water management approach to all stakeholders.

(B) **Outputs**

1. Farmers in select areas adopt low-cost and high efficiency water conservation, harvesting and irrigation systems for meeting household needs and growing orchards, vegetables, and field crops
2. Increased food security as a result of greater area under crops/vegetables per unit of water used in selected sites
3. Rehabilitation of *Karez* systems in selected areas

(C) Main Activities

Together with the Irrigation Department, the Agricultural Department, and local water users, the project will carry out the following activities under this objective:

1. Demonstrate appropriate water saving irrigation techniques, including trickle irrigation, sprinkler irrigation and sub-soil irrigation for growing fruit, crops and vegetables in select areas.
2. Develop and promote options for improved source- to- farm water conveyance systems
3. Carry out a review of current borehole drilling practices, and promote enforcement of planning controls on borehole locations and restrictions on drilling depth
4. Review the operations of traditional *Karez* systems, identify and rehabilitate systems that can be salvaged, and promote these as demonstration sites

4.4 Build capacity of key partners for undertaking landscape rehabilitation and water conservation and management

(A) Preamble

In order for all stakeholders to participate fully in implementation of the project, it is critical that they are equipped with the necessary knowledge and skills for undertaking water conservation and management activities.

(B) Outputs

1. Organised and trained community members implementing integrated water management schemes in select areas
2. Increased capacity of select local communities in restoration and management of degraded forests and rangelands
3. Sharing of experiences and lessons learned nationally and regionally

(C) Main Activities

1. Raise awareness amongst water users about the risk of unsustainable water management practices and the need for water conservation measures
2. Training and capacity building of water users for effective implementation and management of scare water resources.
3. Awareness raising of decision-makers and training of technical staff in water conservation
4. Training of communities in forest landscape restoration and catchment management
5. Dissemination of lessons learned through IUCN Pakistan Water Portal, IUCN global website, written text, lectures and other communication means.

4.5 Identify disincentives and promote adoption of economic and policy incentives for sustainable water management

(A) Preamble

The problem of over-exploitation of groundwater resources in Balochistan is directly related to perverse economic incentives (e.g., electricity subsidies, and low water prices) and absence of disincentives for overexploitation of groundwater. The project will investigate economic aspects of water management in Balochistan and advocate adoption of appropriate incentives, and elimination of disincentives for water conservation.

(B) Outputs

1. Report on realistic pricing policies which create incentives for water conservation practices
2. Research report on economic incentives/disincentives for regulating use of groundwater
3. Appropriate policy incentives for promoting community involvement in water conservation initiatives/schemes

(C) **Main Activities**

The activities for achieving the above mentioned objective will include:

1. Review impact of current flat electricity charging system on groundwater use and conservation, determine opportunity costs and provide recommendations for a fair and equitable realistic charging system, including necessary steps that need to be taken to enforce the system
2. Review impact of current water charging system and provide recommendations for a fair and equitable water pricing system
3. Develop incentive schemes to promote catchment management and water conservation, and recommend steps that need to be taken to implement these schemes
4. Review policies that have an impact on water management, and make recommendations for policy adjustments to promote pro-poor incentives for IWRM

6. Administrative arrangements and stakeholders

The project will be managed by IUCNP through the IUCN Water Programme. Project staff will consist of existing staff of IUCNP, GoB line department technical staff, and professionals hired specifically for the project. The project will be executed by establishing partnerships with different stakeholders in the project area. Partnerships will be formed with GoB line departments (Irrigation, Agriculture, and Forest), local communities and water users (in upper catchment areas and in pilot project areas), and local NGOs and CBOs working in the area. It is recognized that without the active participation of users, chances of the project succeeding will be minimal. The user/beneficiary communities in areas where project activities will be undertaken will, therefore, be mobilized and made partners in project activities. The project will build the capacity of communities and water users to undertake maintenance and operation of implemented schemes beyond the life of the project.

Full use will be made of existing to make use of human resources available with the local CBOs and NGOs. This will be achieved by building partnerships with the local NGOs through negotiated MOUs setting forth clear areas of responsibility for each.

7. Project Duration

5 Years

8. Indicative Budget

Indicative Budget in US Dollars for a period of four years is annexed. The support and oversight from the IUCN Water Programme will contribute USD 200,000 as co-finance to this project, in the field of policy advice, awareness about IWRM, information exchange and technical oversight.

The budget includes the cost of a project coordinator and means of transport, running costs of transport and office, and a management overhead of 15%. Technical assistance in included in individual budget lines

Annexure

Indicative Budget

Activity	Budget	Total Budget
Effective management of the upper catchment of Pishin Lora basin		
Forest cover assessment	50,000	50,000
Management review	15,000	15,000
Forest cover expansion	200,000	200,000
Forest landscape restoration	200,000	200,000
Training and awareness	50,000	50,000
Sub-total	515,000	515,000
Sustainable on-farm water management technology		
Demonstrate irrigation techniques	150,000	150,000
Source to farm water conveyance systems	25,000	25,000
Training and capacity building	70,000	70,000
Raising awareness	40,000	40,000
Borehole drilling review	15,000	15,000
Karez assessment	25,000	25,000
Sub-total	325,000	325,000
Effective groundwater recharge through ecosystem restoration		
Review of DAD	20,000	20,000
Field project design.	10,000	10,000
Field research	250,000	250,000
Laboratory assessment	80,000	80,000
Participatory social assessments	100,000	100,000
Visits to India and Nepal	40,000	40,000
Groundwater recharge options	15,000	15,000
Sub-total	515,000	515,000
Integrated management of a sub-catchment within the Pishin-Lora basin		
Social mobilization	60,000	60,000
Rangeland management practices	30,000	30,000
Water management practices	50,000	50,000
Forest landscape restoration	200,000	200,000
Rainwater harvesting	100,000	100,000
On-farm water management	50,000	50,000
Training	50,000	50,000
Awareness campaign	70,000	70,000
Lessons learned	25,000	25,000
Sub-total	635,000	635,000
Economic incentives for sustainable water management are adopted		
Electricity charging study	25,000	25,000
Water charging study	25,000	25,000
IWRM incentive schemes	30,000	30,000
Policy reform recommendations	40,000	40,000
Sub-total	120,000	120,000
Total activity budget		2,110,000
Project Coordinator (4 X 30,000)		120,000
Project Vehicles (2)		80,000
Project Running cost (4 X 20,000)		80,000
IUCN Management overhead (15% of activity budget)		316,500
Project M&E (4 X 10,000)		40,000
Grand Total		2,746,500

Say $ 2.75 Million

(3) コンセプト・ペーパー#4　UNDP

他ドナーの動向に係る調査の一環として、UNDP の今後の活動方針を確認したもの（報告書本文 2.5.2 節(4)項参照)。2003 年に終了した Area Development Program Balochistan (ADPB) が、貧困削減を中心課題とした Millennium Development Goals (MDGs) of UNDP に与える効果を説明している。

MDGs は、UNDP が 2015 年を目標年として世界に公約した今後の活動に係る基本構想である。バロチスタン州においても同構想に沿った活動を検討することになる。

22 Oct '03
from UNDP Quetta

LINKAGE OF ADPB WITH MILLENNIUM DEVELOPMENT GOALS (MDGs) OF UNDP

The goal of Area Development Program Balochistan is 'Poverty Alleviation'. For achieving this complex and multi-facetted aim, all the program objectives, targets and interventions carried out so far, have close co-relation to the Millennium Development Goals (MDGs) of UNDP generally. The linkage of each MDG to ADPB interventions are as follows:

1. **ERADICATE EXTREME POVERTY:** The basic core of the program is to organize, build capacities and facilitate the communities to harness their own potential and generate local resources in order to come out of poverty. Nearly 509 COs comprise of 8,832 members, who have raised an amount of Rs. 38,09,748/- as cumulative saving in all regions. Capacity building of members in leadership, different sector related techniques and business/credit management has developed the human resource. Various micro-enterprises have developed through credit and due recovery rate is about 42%. **Agriculture and Integrated Pest Management (IPM):** In order to increase productivity, improve quality of agricultural output in the project area, a number of activities are being carried out. To promote good quality improved varieties of crops and fruits, 478 plots were established. To support women and to generate income at household level, ample quantity of vegetable seeds for kitchen gardening were provided to the members of WCOs. Since water scarcity is becoming a serious threat for agriculture in Balochistan attempts have been made to introduce short duration cash crops with minimum water requirement for instant pulses. To provide technical assistance and guidance to farmers, two soil and water testing laboratories and one biological laboratory have been established. To cope with pests problems 9 power spray machines were provided to community organizations on 50% cost sharing basis (and 30 knap sack sprayers free of cost) and 362 community members were given training in IPM approaches, orchard management and efficient use of irrigation water. About 1500 farmers have received training in different aspects of agriculture. Mechanized farming resulted in higher yield and income. Adoption of IPM techniques led to a reduction of production losses. Adoption of pruning practices resulted in an improvement in quality and yield of fruits. **Livestock & Fodder:** Animal health care was maximized through vaccination, parasitic control and treatment of 5,40,199 animals. Farmers' know how was upgraded on scientific lines in livestock health care, management, feeding, nutrition and marketing through training of 3,872 male and female farmers. Livestock health care services and veterinary of input delivery system at valley level was strengthened through training of 32 village livestock activists and opening of five veterinary centres through micro-credit. For drought mitigation improved cost effective feeding techniques was disseminated through fabrication and feeding of 3,63,000 Urea Molasses Blocks. Livestock fodder production base was strengthened by demonstrating improved multi-cut fodder production on 1051 acres. Breeding efficiency in ewes through flushing techniques in 4,359 ewes was improved. For income generation in female COs introduced high producing 216 teddy goats and 7,881 rural poultry chicken were introduced. Early withdrawal of male young stock from range through demonstrating commercial lamb and calf fattening of 5296 animals was encouraged. For long term dairy cattle development introduced cross breeding of local non descript cows with H/F germ plasm covering 265 cows was introduced.

2. **ACHIEVE UNIVERSAL PRIMARY EDUCATION:** Lack of educational facilities in most of the project areas compelled ADPB to choose innovative and informal mechanisms of increasing amenities for primary education for children and basic literacy for adults. These included 'home' schools teacher training for girls from WCOs, establishment of home schools independently as well as through linkages with NGOs and provision of basic school material for improvement of existing schools. This has resulted in enrollment of about 1000 children, most of whom are girls. In some villages, literacy/tuition centers are established, where

women from communities are receiving non-formal education. Support is also provided to two institutions for improving their delivery for education of 'special children'.

3. **PROMOTE GENDER EQUALITY AND EMPOWER WOMEN:** For the purpose of gender mainstreaming, ADPB involves women in the process of development as WCOs, right from need identification, planning, implementation to monitoring. Some strategic actions in this regard include gender sensitization of stakeholders, liaison with all important GAD forums, gender review of new provincial policies and write-ups on women rights & development. Moreover in the communities, along with men, women's economic empowerment is supported by capacity building of WCOs for decision making, income generation, business management, vocational skills and other sectoral interventions. Women's access to credit, micro-enterprise and service delivery is facilitated. As an impact of these activities, there is involvement of almost equal number of women & men in development process, all components of ADPB are gender balanced, GAD & human rights have become a regular part of public sector training courses in Balochistan, women's work load for fetching water and fire wood has reduced, they have emerged as bread winners in villages and have collectively earned around Rs. 5,50,000/- in the last two years period.

4, 5, 6. **REDUCE CHILD MORTALITY, IMPROVE MATERNAL HEALTH & COMBAT HIV/AIDS, MALARIA AND OTHER DISEASES:** For better health and hygiene of communities, the activities performed in ADPB field areas include 'Traditional Birth Attendant Training' (TBA) training to women from communities, due to which the TBAs/ health activists can handle maternal & child health cases correctly and more hygienically, with better information on nutrition, vaccination, family planning, first aid and minor general ailments. Hygiene orientation is also provided to men and women, which includes general diseases, including STDs and HIV/AIDS. Health relief camps providing medical advice and treatment to nearly 200 - 400 patients in each camp are conducted throughout the length of project. These camps also serve the purpose of a quick survey of prevalent diseases. For clean drinking water and diarrhea control, hand pumps are installed in all regions and sanitation habits promoted by demonstrating PIT latrines in villages either at communal places, such as school or in the homes of the poorest community members. Smokeless stove making was demonstrated to women in different field areas. Malaria control program and EPI program of Health Department is facilitated in field areas.

7. **ENSURE ENVIRONMENTAL SUSTAINABILITY:** **Range Management & Watershed Management:** Activities of the sector have mainly focused on creating awareness among communities about natural resources, rehabilitation of depleted rangelands, improvement of range areas and introduction of grazing management. The activities included: training of 608 livestock farmers in grazing management plus 96 farmers in range plant species plantation and management; establishment of 12 community range reserves; planting of palatable trees and shrubs over 3,044 acres; and production of 3,33,000 range plants in nurseries. The watershed management sector on the other hand aims at improving the recharge rate of aquifers, increasing production of agriculture and fodder crops through water harvesting, and protection of valuable farmlands from erosion. Activities conducted for achievements of these objectives include: training of 127 farmers in nursery raising; planting of catchments area over 2,366 acres by planting shrubs and trees of suitable species; construction of 15 water recharge ponds; 37 small water ponds; 2 fish ponds; 1.160 million cft. valley dikes; and 44,623 cft check dams; planting of 42,000 trees on farmlands; construction of water harvesting and spreading structures over 1,275 acres; 72,670 cft. flood protection gabion structures; and production of 1.400 million plants in watershed management nurseries. **Irrigation & Water:** The main activities include; demonstration of nine high efficiency irrigation systems (HEIS) comprising five trickle, two Bubbler and two sprinkler guns at Quetta, Mastung, Muslim Bagh and Sanjavi. Three training sessions were imparted in O&M of high efficiency irrigation systems, irrigation scheduling and fertigation techniques; 140 farmers and agriculture staff took part in the orientation training of community farmers to the

high efficiency irrigation was arranged which was attended by 20 farmers. Three brochures were prepared for farmers' training, which covered fertigation, irrigation scheduling through high efficiency irrigation systems for surface irrigation methods. Also 24 demonstration plots of improved irrigation practices were established and field training was imparted to the farmers. 190 farmers from various communities participated. Rehabilitation of 20 karezes at Pishin, Muslim Bagh, Loralai, Kalat and Khuzdar was completed. seven lined water reservoirs for irrigation were constructed, while construction of two inverted siphons was undertaken. Additionally two lined irrigation channels were constructed, and 15 community drinking water supply schemes were completed. A green house was constructed for tissue culture laboratory at Agriculture Research Institute Sariab. Technical support provided to trickle irrigation project of agriculture department. Also water quality testing equipments was provided for laboratory of Irrigation and Power department. **Productive and Social Infrastructure:** Rehabilitation of eight karezes and six water supply schemes were completed. Channel construction of one siphon / conduit was completed. Constructions of four water storage reservoir for irrigation were completed. Also a 'date packaging factory' and a cutting /training stitching unit were established at Burshore/Pishin and one at Loralai.

8. DEVELOP A GLOBAL PARTNERSHIP FOR DEVELOPMENT:

Linkage has been developed with Export Promotion Bureau, for exploring avenues of international marketing of local products, such as agricultural products and handicraft.

All goals are measured against baseline year, 1990

Millennium Development Goals

By 2015 all 189 United Nations Member States have pledged to:

1. Eradicate extreme poverty and hunger

- Reduce by half the proportion of people living on less than a dollar a day
- Reduce by half the proportion of people who suffer from hunger

2. Achieve universal primary education

- Ensure that all boys and girls complete a full course of primary schooling

3. Promote gender equality and empower women

- Eliminate gender disparity in primary and secondary education preferably by 2005, and at all levels by 2015

4. Reduce child mortality

- Reduce by two thirds the mortality rate among children under five

5. Improve maternal health

- Reduce by three quarters the maternal mortality ratio

6. Combat HIV/AIDS, malaria and other diseases

- Halt and begin to reverse the spread of HIV/AIDS
- Halt and begin to reverse the incidence of malaria and other major diseases

7. Ensure environmental sustainability

- Integrate the principles of sustainable development into country policies and programmes; reverse loss of environmental resources
- Reduce by half the proportion of people without sustainable access to safe drinking water

- Achieve significant improvement in lives of at least 100 million slum-dwellers by 2020

8. Develop a global partnership for development

- Develop further an open trading and financial system that is rule-based, predictable and non-discriminatory. Includes a commitment to good governance, development and poverty reduction—nationally and internationally
- Address the least developed countries' special needs. This includes tariff- and quota-free access for their exports; enhanced debt relief for heavily indebted poor countries; cancellation of official bilateral debt; and more generous official development assistance for countries committed to poverty reduction
- Address the special needs of landlocked and small island developing States
- Deal comprehensively with developing countries' debt problems through national and international measures to make debt sustainable in the long term
- In cooperation with the developing countries, develop decent and productive work for youth
- In cooperation with pharmaceutical companies, provide access to affordable essential drugs in developing countries
- In cooperation with the private sector, make available the benefits of new technologies—especially information and communications technologies

For more information on the Millennium Development Goals, see the following Web sites:

www.un.org/millenniumgoals
www.undg.org/login.cfm
www.undp.org/mdg

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