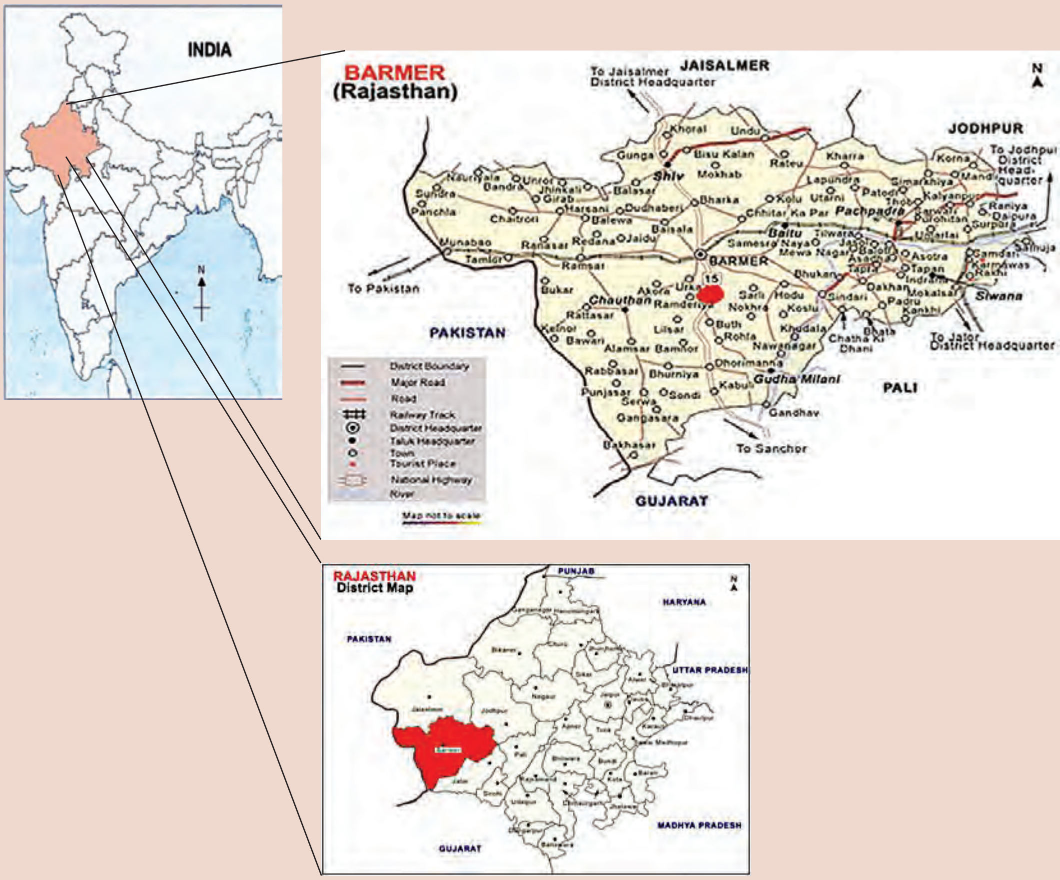
Innovative farming-system-based livelihood model for desert regions

BAIF Centre for Desert Regions

Centre for Desert Regions Programme Area



This document is an output of the "Strengthening Development Programmes And Laying Newer Directions" (SDP) project and Diversion Based Irrigation (DBI) project of BAIF Development Research Foundation (BAIF), implemented with its associate state agency, Rajasthan Rural Institute of Development Management (RRIDMA), with support from the Sir Dorabji Tata Trust (SDTT) and Jamsetji Tata Trust (JTT), Mumbai.

The SDP project seeks to develop appropriate development approaches/technology packages for areas with unique agro-climatic and social settings such as deserts/arid regions. Under the project, a Centre for Development in Desert/ Arid Regions (Centre for Desert) has been set up in Rajasthan, to coordinate activities in two pilot areas: Rapar cluster in Kachchh district of Gujarat and Barmer cluster in Rajasthan.

The DBI project aims to divert run-off water in low rainfall areas for small-scale storage and subsequent use by marginal land holders.

This document describes a farming-system based livelihood model for desert regions, which was evolved under the SDP project and fine-tuned under the DBI project.

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Preface

Human communities have adapted to very harsh and adverse physical environments. Sustainable lifestyles of a certain quality have been evolved through a deep understanding of local natural resources and their inter-relationships.

There is however scope and opportunity for enhancing livelihoods in adverse conditions, by bringing in new knowledge and ideas and systematically integrating them with traditional indigenous knowledge and skills.

With this perspective and experience, BAIF initiated work in the harsh semi-arid /desert environment of Kachchh and Barmer districts, to make innovations in the farming systems of the region.

By integrating suitable tree crops with traditional agriculture, promoting appropriate livestock, and building up on traditional water harvesting methods, a synergistic impact was produced on the livelihood situation in both areas. The approach has already been adopted by over 250 families in the pilot stage and is on the verge of wider replication.

I am grateful to Sir Dorabji Tata Trust, Mumbai for showing faith in us and allowing us to incubate innovative ideas in desert clusters.

Girish Sohani
President, BAIF

1. Introduction

Development of sustainable livelihoods in India's hot desert[1] region is a major challenge due to fundamental environmental constraints:

- Scanty and erratic rainfall, with high variability of precipitation across a season and across years
- Frequent drought
- Extreme temperatures
- Highly fragile eco-system marked by sparse vegetation
- Acute scarcity of water for drinking and irrigation

These constraints are compounded by remoteness of habitations, poor communications- network and negligible industrialisation.

In these circumstances, subsistence agriculture, supported by animal husbandry and/or traditional crafts are the only available livelihood options.

What is legally classified as agricultural land is available in plenty in desert areas, and land-holdings also tend to be large. However, yields are low because of scanty irrigation facilities, and low fertility and high alkalinity of soil.

Animal husbandry is also constrained by scanty availability of grass and native tree leaves. Permanent pastures are highly degraded and neglected. Many of these pastures do not have any basal plant cover. Increased grazing pressure has led to disappearance of many species and decline in biomass yield.

1 In this publication, 'desert' refers only to hot deserts

In the absence of any other alternatives for livelihood generation, migration is the most common coping mechanism in desert regions. Mostly men migrate and women left in villages face a difficult life due to scarcity of water, fuel and fodder.

With continuing growth in population, the desert economy is characterised by rising number of migrants and decreasing economic opportunities based on traditional practices. Climate change is likely to put additional pressure on existing ecological and socio-economic systems.

In these circumstances, there is an urgent need to develop appropriate livelihood-technology solutions for desert communities, based on a thorough understanding of their environment and existing livelihood systems.

Broadly speaking, the technology solutions have to be focused on efficient use of scarce natural resources, leading to minimisation of the risk of drought and diversification in income-sources.

As a first step, there has to be an objective assessment of a community's water, food and fodder needs, and the resources available to meet these needs. Then, there should be a thorough understanding of the community's traditional farming and water conservation technologies, and the limits or deficiencies of these technologies in the current situation.

Using these two bases of understanding as foundation pillars, appropriate technology solutions have to be designed, keeping in mind the possible environmental impact.

Based on these principles, a package of appropriate technologies has to be devised, to meet a spectrum of objectives:

Table 1.1: Centre for Development in Desert Region—package of initiatives

Focus area	Strategies	Activities
Water resources	Increasing availability of water for drinking and irrigation	• Construction of improved versions of traditional water-harvesting systems (tanka and agor) • Introduction of rooftop rainwater harvesting along with storage tanks • Recharge of open wells
	Water-use efficiency	• Promotion of integrated water-use by individual families for drinking/cooking, agriculture, animal husbandry and horticulture • Promotion of water-use efficiency in small agri-horti plots • Community mobilisation for efficient and sustainable use of water resources
Land resources	Improved agriculture	• Promotion of improved agriculture techniques, and • Crop/seed varieties suitable for arid lands
	Vegetable cultivation	• Promotion of cultivation of improved varieties of vegetables like cucurbits • Demonstration of low-cost polyhouse for nursery raising of vegetables crops
	Fodder development	• Introducing suitable fodder plant species and varieties on private lands • Establishing model plots for silvipasture development on common lands
	Tree-based farming	• Establishment of Wadi plots, after pilot-testing cultivation of suitable fruit-tree species
	Soil nutrient management	• Promotion of composting
Livestock resources	Goat development	• Providing breeding bucks of high-value 'Sindhi' breed • Healthcare and nutrition support
Human resources	Alternative income-generation	• Improving traditional method of knitting on cloths • Imparting training for making value-added items like purses, bags and dresses
	Capacity-building	• Training programmes and exposure visits
Linkages	Linkages with research institutions	• Technical guidance and inputs from institutions such as Central Arid Zone Research Institute (CAZRI) for selection and cultivation of fruit trees, grasses and field crops
	Linkages with government programmes	• Improving utility of water-harvesting structures built under MGNERGA

- Increased availability of water for domestic use and irrigation
- Enhanced economic returns from land resources
- Increase in food-crops production and fodder and forestry resources
- Improved livestock resources
- Decrease in time and labour required for collecting water, fodder, fuel wood, etc

If all the above objectives are met, there will be reduction in distress migration from desert habitations.

Desert-Livelihoods Initiatives

Under a "Strengthening Development Programmes And Laying Newer Directions" (SDP) programme, BAIF and RRIDMA set up a Centre for Development in Desert/Arid Regions (Centre for Desert) in 2007 with support from SDTT, Mumbai.

Focused on Rapar cluster in Kachchh district of Gujarat and Barmer cluster in Rajasthan, the Centre has initiated a project to:

- Create a basket of opportunities for desert communities to generate income in their own setting
- Make desert communities self-dependent through an improved natural-resource base
- Develop a model for sustainable development of resource-poor desert communities with a combination of agriculture, horticulture, livestock and traditional skills.

With support from Jamsetji Tata Trust (JTT), Mumbai, the Centre for Desert has also implemented a project for "Water resource development and water use efficiency—field pilots" under diversion-based irrigation (DBI) theme. The project was implemented in one habitation of Undkha gram panchayat of Barmer block of Barmer district.

Taking both projects into consideration, a package of initiatives was evolved as shown in Table 1.

All initiatives were undertaken through a participatory approach, with involvement of local communities at all levels, from selection of technology option, to selection of sites/ beneficiaries and implementation.

The suitability and impact of each option was carefully evaluated on technical and economic parameters, leading to modifications in design, and addition or deletion of components.

Through this evolutionary process, an innovative, economically and technologically viable, and environmentally sound farming-system-based livelihood model was developed for addressing a gamut of core needs of desert communities.

The model has been implemented in Barmer tehsil and block of Barmer district, in two desert villages, Alli ka Tala and Ranigaon Kalan, falling under Ranigaon gram panchayat, and in one habitation of Undkha gram panchayat.

2. The Context

General

Barmer is located in the western part of Rajasthan, in the Great Indian or Thar Desert. The district, located between 24,58' to 26, 32'N latitudes and 70, 05' to 72, 52' E longitudes, is surrounded by Jaisalmer district in the north, Jalore district in the south, Pali and Jodhpur districts in the east, and Pakistan in the west.

Covering a geographical area of 28,387 sq km, Barmer is the second largest district in Rajasthan. The district is divided into four sub-divisions with a total of eight blocks: Baetu, Balotra, Barmer, Chohtan, Dhorimanna, Siwana, Sheo, and Sindhari.

The 2001 Census population of the district was 1,964,835, of which 93% lived in rural areas. The district has only two towns. Population density was low, at 69 persons/sq km. Sex ratio was skewed with 896 females per 1000 males in rural areas, according to Census 2001 data. Female literacy rate was barely 44%.

According to 2004-05 data quoted in the Barmer District Human Development Report (2009), 32% of the net district domestic product (NDDP) came from agriculture, and 24% from mining and manufacturing. However, registered manufacturing units accounted for only 3% of the NDDP.

Low level of industrialisation and urbanisation is reflected in sectoral breakup of workforce: according to Census 2001 data, 75% of main workers in the district were dependent on agriculture.

Barmer is one of the country's 250 most backward districts under the Backward Regions Grant Fund Programme (BRGF).

Physiography

Apart from a small offshoot of the Aravalli hills in the east, the district is a vast sandy tract with surface elevation ranging from 70 to 457m above mean sea level. In the extreme north and west, the sandy plain is broken by hills called tibbas, which rise to a height of 91 to 122m. The highest point in the district is a hill called Chhappan-ka-Pahar in Siwana tehsil, which rises 973m above sea-level.

Only one major river, Luni, flows through the district. It has water flow only after heavy rainfall. For most part of a year, and in a year of drought, the Luni is dry. A unique characteristic of the Luni is that its water becomes brackish as the river approaches the Rann of Kutch, where it turns into concentrated brine.

The Luni has two minor tributaries, Sagi and Sukri. There are also a few nullahs or seasonal streams in the district, which flow for some distances and then disappear in the desert.

While there is no lake in the district, there are numerous small ponds, which are mostly dry by early summer.

Rainfall and Climate

The district has an arid type of climate. Normal rainfall (1901-1971) is 277.5 mm. Almost 90% of the total annual rainfall is received during the southwest monsoon, from the first week of July to the middle of September. On an average, there is rainfall of 2.5mm or more in 16.5 days a year. Most of the rainfall occurs in short and powerful bursts over a few days.

An important feature of the rainfall is high variability. As data in Table 2.1 shows, total annual rainfall ranges from 50mm to 610mm, and variation across successive years is usually in the range of 50-70%, but can even be above 400%.

Coupled with scanty irrigation facilities, the high variation in rainfall implies that returns from cultivation are highly uncertain, and agriculture is a highly risky livelihood option. Notably, in 7 of the 15 years for which data is given in Table 2.1, rainfall was below normal.

Table 2.1: Annual rainfall in Barmer district

Year	Total rainfall (cm)	% change over previous year
1991	5	
1992	41	720
1993	39	-4.9
1994	61	56.4
1995	18	-70.5
1996	23	27.8
1997	35	52.2
1998	36	2.9
1999	21	-41.7
2000	36	23.8
2001	30	15.4
2002	9	-70
2003	48	433.3
2004	21	-56.3
2005	18	-14.3

Source: Statistical Abstract of Rajasthan, 2005

Extreme heat in summer and cold in winter is characteristic of hot deserts. In Barmer, the temperature varies from 48 degrees centigrade in summer to 2 degrees in winter. Throughout the summer, the heat is intense and scorching winds prevail.

The atmosphere is dry except during spells of rain in the monsoon. Humidity is highest in August with mean daily relative humidity of 43%. According to Central Ground Water Board (CGWB) analysis, the annual maximum potential evapotranspiration is 1850mm, with highest evapotranspiration (260 mm) in May and lowest (77mm) in December.

Soil

The soils of the district are generally sandy and very deep. In some parts, red desert soils are found. The soil texture varies from sandy loam to sandy clay loam, becoming slightly heavier with depth. Calcium carbonate is found at varying depths.

Key parameters of the soil, according to soil sample studies done in the district by National Environmental Engineering Research Institute (NEERI) in 2010, are shown in Table 2.2

Table 2.2: Key soil parameters

Parameter	Value
Sand content	70% to 88%
Silt content	4% to12 %
Clay content	7% to 19%
Porosity	23.2% to 41.8 %
Infiltration rate	6.6 to 10.2 cm/hr
Water-holding capacity	9.4% to 35.8%
pH	7.6 to 9.2
Nitrogen	3.5 to7.7 kg/ha
Phosphorus	5.2 to 17.1 kg/ha
Potassium	10.3 to 39.7 kg/ha

Overall, the soil is moderately to highly alkaline and has very low NPK content. However, the NEERI study found that the soil has moderate to highly productive microbial (rhizobium and azotobacter) population. This means that if adequate water and nutrients are provided, the soil can be productive for salt-resistant crops.

Land use

In Barmer district as a whole, 52% of the total geographical area of 2.82 million hectares is considered cultivable land; 7.2% is pasture land and 25% is fallow land. Less than 2% of the land has a forest cover, and around 13% is barren or cultivable wasteland.

Less than 7% of the net sown land (96,206ha out of 1,454,491ha) is irrigated, almost entirely through dug wells.

Water resources

Surface-water availability in the district is highly restricted by area and season. Surface-water availability is being augmented by a 74-km canal arising from the Sardar Sarovar dam, and passing through Barmer and Jalore districts. The canal is expected to meet irrigation-water needs of 233 villages and drinking-water needs of 1107 villages in the two districts.

Groundwater potential in the district is limited and generally overexploited. Groundwater availability is highest in parts with sandstone or alluvium underlays. However, the major part of the district has a hard-rock substratum with poor water-yielding capacity.

The depth of dug wells ranges from 20 to 80m. The few borewells in the district are over 200m deep.

According to CGWB data, premonsoon water levels in dug wells in Barmer tehsil ranges from 10 to 71 metres below ground level (mbgl) and 1 to 60mbgl in postmonsoon period. Groundwater is mostly brackish, with pockets of sweet water in areas (*pars*) where flowing water accumulates and seeps into the earth.

While the water does not generally have bacteriological contamination or presence of heavy metals above permissible limits, it has high total dissolved solids, high hardness, and occasionally, high flouride content. In general, groundwater in the district has limited use for drinking or agricultural purposes. Further, in all blocks of the district except Barmer, groundwater exploitation had crossed safe limits, according to CGWB data for 2004.

Traditionally, several efforts were made to harvest rainwater, through structures like:

- Tankas, or underground tanks that were connected to pipes from rooftops, or fed by paved catchment areas known as agors
- Kunds, or deep and large stepped wells
- Nadis, or ponds

However, many of the traditional structures are in a state of high disrepair. Made from mud plaster or lime mortar, the tankas were prone to breakage. Kunds require huge investments of time and labour. Water in ponds is generally used for cleaning purposes, and is unfit for drinking.

Even minors are involved in fetching water daily from long distances

Hence, the main source of drinking water currently is water tanks or handpumps installed by the government. As tanks are located in village headquarters, and settlements are spread out, people have to walk considerable distances to fetch water.

In Alli ka Tala, one of the Centre for Desert project villages, there is no handpump, and only one dug well. People depend entirely on water supplied by the government through tankers, or wells and streams at distant locations. Before the project, there were only eight tankas in the village. In Ranigaon Kalan, another project village in the same panchayat, there are only two handpumps and three private wells. Before the project, rainwater was harvested in 6 public and 14 private tanks.

Before the project, for most of the year, virtually all households (HHs) had to obtain water from a considerable distance of 5-10km to meet their daily requirements. Generally, one or two persons from each HH, including minors, had the job of obtaining water. The water was carted on camels or donkeys in 250-litre leather pouches (tanki) or 70-litre bags made of thick cloth (pakhal). Around 5 person-hours were spent each day for fetching water.

Settlement pattern

Most of the population of the district lives in rural areas, in isolated hamlets called dhanis. While several dhanis together officially form a village, the dhanis are spread over several kilometres. As a result, many dhanis lack basic facilities like water, transport, health services and primary education.

Alli ka Tala and Ranigaon Kalan, the two Centre for Desert project villages in Ranigaon gram panchayat of Barmer tehsil, comprise 8-10 dhanis located at considerable distance from each other, among sand dunes. Habitations of the two villages are 2-8km from the gram panchayat.

Demographics

A total of 152 HHs live in Alli ka Tala, with an average of 5.5 persons per HH. Of the total population of 837 persons, 57% is male. In Ranigaon Kalan, there are 186 HHs, with 5.9 persons per HH. Of the total population of 1092 persons, 59% is male. Around 15% of the population is below 6 years of age.

Social groups

In Barmer district as a whole, around 16% of the population belongs to SC groups, and 6% to ST groups. Nearly 12% of the population is Muslim.

However, in the two villages under the Centre for Desert project, the population is entirely Hindu and belongs only to OBC or ST groups. In Alli ka Tala, 30% of HHs belong to the ST category. All the ST HHs are found in one habitation called Bhillon ki Vasti. In Ranigaon Kalan, 21% of HHs belonging to ST category, and are found mainly in one habitation called Bhakta Bhil ki Dhani.

Economic status and livelihoods

As in the rest of the district, virtually all HHs in the Centre for Desert project villages own considerable agricultural land. Among HHs participating in the project, it is seen that 50% HHs own over 5 hectares (ha) and only a fifth of HHs have small or marginal landholdings (less than 2ha). No HH is landless. However, the landholding is in all cases largely nominal, as only around a third of an HH's holding is cultivated, due to scarce rainfall and lack of irrigation facilities.

All HHs participating in the project own goats, with an average of 8 goats per HH. Around a fourth of HHs own sheep, with average 12 sheep per HH. One-fifth of HHs own camels or donkeys, with one such weight-carrying animal per HH. No HH owns cows, buffaloes or poultry.

In general, the population of small ruminants and camels owned by HHs is declining. Due to paucity of water, fodder and capital, HHs have not invested in milch animals, unlike HHs in some other parts of the district, who have increasingly turned to buffalo-rearing.

All HHs make ends meet through a combination of agriculture, livestock-rearing and labour-work done in and around the village, or by migrating to distant locations. Migration is also done for grazing animals.

Destinations for labour-migration include Sanchor town in neighbouring Jalore district, Jodhpur, Baroda and Ahmedabad in Gujarat, and some cities of MP. Migration is done in two cycles: from November to February, and in April-May.

A few HHs are engaged in production of traditional craft-items and in around 5% of HHs participating in the project, one member of the family has wage-employment in government or private sector.

Officially 22% of HHs in Alli ka Tala and 27% HHs in Ranigaon Kalan are in the BPL category. However, with known deficiencies in BPL categorisation, a more useful indicator of economic status is status of housing. Among HHs participating in the project, it is seen that nearly 70% live in fully kaccha (mud) houses and only 13% HHs have fully pukka houses made from brick/stone and cement. None of the houses have toilets.

Crop cultivation

Mixed cropping in the Kharif (monsoon) season is the predominant mode of cultivation in the project area, with no cultivation done in Rabi or summer. Crops grown in Kharif are:

- Bajra (pearl millet)
- Guar (*Cyamopsis tetragonoloba*)
- Moth bean (*Vigna aconitifolia*)
- Til (sesame) and
- Mung bean (*Vigna radiata*).

Till the project intervention, only desi (local) varieties of seeds were used. Nutrients were supplied only through composted dung. No crop protection methods were followed.

Mainly due to scanty and erratic rainfall, yields are low and highly variable. Table 2.3 shows how rainfall impacts yield of bajra, the main crop. It can be seen that even in normal-rainfall years, yield is only around 175kg/ha. When rainfall is below normal, yield reduces by 30%-90%. Yield is also determined by timing of rainfall and number of days of precipitation. Highly erratic precipitation accounted for low yield in 2005, while floods devastated crops in 2006.

Natural vegetation

The natural vegetation of the area comprises small shrubs, salt-tolerant trees and hard grass varieties.

Table 2.3: Annual rainfall and bajra yield in Barmer district

Year	Rainfall (cm)	Yield (kg/ha)
2000	36	197
2001	30	260
2002	9	7.5
2003	48	552
2004	21	225
2005	18	75
2006	60	151
2007	25	173
2008	21	130

Data source: Statistical Abstracts, Directorate of Economics and Statistics, Jaipur, Rajasthan.

Grasses found in the project area include bhurat (*Cenchrus bidlorus*), gokharu or kanti (*Tribulus terrestris*), sewan (*Lasiurus sindicus*) and bekar (*Indigofera* species).

Shrubs include ker (*Capparis decidua*), jhar ber (*Zizyphus nummularia*), bhoo bavali (*Acacia jacmontii*), murali (*Lycium barbarum*), irna (*Clerodendrum phlomoides*), sinia (*Crotalaria burhia*) and aak (*Calotropis procera*).

Trees found in the area include khejari (*Prosopis cinerara*), kumath (*Acacia senegal*), rohida (*Tecomella unduleta*), neem (*Azadirachta indica*), babul (*Acacia nilotica*) and mitha jal (*Salvadora oleoides*)

The tree population in common lands is dominated by *Salvadora oleoides*, Acacia varieties, neem and *Calotropis procera*, found singly or in groups.

In farmers' land, the most common trees are *Prosopis cinerara* and *Tecomella unduleta*. *Crotolaria burhia* is a common weed.

Facilities

Both the project villages are connected by tar road public transport facilities (by bus or jeep). Neither village is electrified. There is a bank and a post office in Ranigaon gram panchayat. There are two schools and one anganwadi (ICDS centre) at Alli ka Tala. In

Ranigaon Kalan, there are three schools and one anganwadi.

The nearest hospital is a primary health centre at Ranigaon, at a distance of around 8km from the villages. The nearest market is 25km away at Barmer town, which also has the block, tehsil and district headquarters.

Most of the population lives in isolated settlements

The Core Challenge

The profile of the project villages and HHs, which is representative of communities across the desert region of western India, shows that the core livelihood challenge is ensuring adequate availability of water through the year, to meet needs of families, their animals and their crops.

While scope for tapping groundwater is limited, harvesting and distribution of surface water in a large scale, through canals or underground channels, involves huge capital outlays and long project-execution periods. Further, the environmental impact of such structures has to be considered. Mention must be made here of flash floods that struck Barmer in 2006 and caused extensive damage and submergence. The floods, a bizarre phenomenon in a chronically drought-prone area, are partly attributed to damage caused to the natural drainage system, due to construction of canals and railway lines.

Hence, the traditional technology of localised rainwater harvesting is the best option. If upgraded in a cost-effective and sustainable manner, and coupled with promotion of water-economisation, the technology will help solve a host of problems faced by communities in desert regions:

Families will save on time and effort spent in fetching water daily. More manpower will be available for productive purposes. Women will be freed from drudgery. Minors will not be compelled to be out of school.

Some high-value crops can be grown, to increase family incomes, and thereby ensure food security.

Supplemented with breed-improvement and fodder-development efforts, there will be an increase in income from livestock.

Better water-availability status combined with higher income will improve the health and education status of families.

Sustained and sustainable increases in income will lead to drop in distress migration.

Keeping these possibilities in mind, the Centre for Desert team piloted a variety of initiatives over a period of around four years, starting 2007. From these efforts, a farming-system model, combining water-resource development with agri-horti-forestry and fodder and livestock development, emerged as a cost-effective and sustainable option, with replication potential.

One telling indicator of the viability of the model is the fact that a large number of HHs have voluntarily invested their time, labour as well as money, in adopting the model.

3. The Model

The BAIF Centre for Desert livelihood-model is designed to sustainably meet the requirements of water, food, fodder and income of nuclear families living in desert areas.

Under the design of the model evolved till March 2012, the basic asset generated for participating families is a combination of:

- An improved version of the traditional tanka with an agor (catchment area), to store 60,000 litres of water
- A 0.2-ha Wadi plot with around 100 improved varieties of fruit and fodder-yielding shrubs/trees, which will provide income in 3-5 years, and several multi-purpose trees
- 5 goats of high-value breed (mostly replacements through genetic upgradation).

The above parameters are not frozen. The Centre for Desert, or any other agency implementing the model, may modify the specifications according to local conditions, family's needs and investment capacity, and funding options.

The core principle of the design is linking family-based water harvesting to survival as well as livelihood needs.

While the tanka meets the annual water needs of families for domestic use, feeding goats and irrigating young fruit trees/shrubs, the Wadi plot provides regular annual income to meet food needs. It also meets fodder requirement of goats. Family income is augmented by selling goats.

To cater the fuel wood and fodder requirement of families, grafted and improved varieties of indigenous species like khejri, guggal, kumath, neem and pilu are planted in blocks or along field borders. High yielding varieties of perennial forage grass like sewan (Lasiurus Sindicus) and dhaman (Cenchrus setigerus) are planted in denuded pastures, and around Wadi plots.

Local goat breeds are crossed with bucks of Desi Sindhi buck, to get higher milk production from female progeny and male progeny with higher body weight. Desi Sindh bucks are placed with selected goat keepers with feed support and insurance for breeding in the dhanis. Goat keepers are trained in first aid and use of herbal and modern medicines to keep the animals healthy.

Innovative approach

Construction of improved versions of tankas has been promoted in desert areas by government and non-government agencies, through subsidies or grant support. However, it is seen that these initiatives have not largely led to HHs taking to tanka construction on their own. Further, many of the newly constructed tankas are poorly maintained by beneficiary HHs.

Discussions with HHs in the project area revealed that poor interest in tankas was mainly because these structures did not provide any direct livelihood benefits. The structures met only water needs, and that too partly.

Hence, after several initial efforts, including construction of tankas of various sizes, the Centre for Desert team hit upon the idea of linking tankas to Wadis with income-yielding trees/shrubs requiring little water.

Initially, tankas of around 20,000-litre capacity were constructed with cash and labour contributions from participating families. Similarly, Wadi plots were established for each family.

Considering desert conditions and scarcity of water, the size of Wadi plots was deliberately restricted to 0.5-acres, compared to the standard size of 1-acre used in other Wadi locations. (For detailed information on BAIF's Wadi model, please visit www.baifwadi.org). Around 100 shrubs/trees yielding fruits with established commercial value, such as ber (*Ziziphus mauritiana*) and pomegranate were planted in each of the plots. Hardy and multipurpose trees were planted along the plot boundaries.

The community's interest in the tankas and Wadi linkage was immediately evident. While 20,000-litre tankas were constructed primarily for meeting domestic-water needs, a majority of families started using the tanka-water for irrigating Wadi plots. In one sample of 34 families, it was seen that 30 of them were using tanka-water for Wadi plots.

Naturally, the rainwater harvested in the tanka was not then adequate to meet the family's water needs through the year. Families therefore resorted to purchase of water, supplied through tankers, and filled it in tankas. In the sample of 34 families, it was found that 30 families had purchased water and refilled tankas, for an average of 2.5 times a year, incurring average expenditure of Rs 2000. At the same time, around a third of families reported that they did not use water stored in tankas to feed animals, as it was "costly water".

From this pattern of usage, it was determined that a tanka with capacity to store 60,000 litres of rainwater was optimally required for economic sustainability of the model.

Based on realistic and conservative estimations, discussed in the next section, the model is cost-effective and feasible in desert conditions.

The community response to the model, reflected in voluntary labour and cash contributions, is highly encouraging, and initial results indicate that the assumptions made in the design of the model are valid.

Minimum water needs of HHs in desert conditions

The Centre for Desert's farming-system based livelihood model is based on estimation of minimum water required per year in desert conditions, to meet the basic survival needs of family-members, family-owned goats and Wadi saplings that will yield regular and sufficient income after 3 years. Water-needs vary according to size of HH and season. Nevertheless, as shown in Table 3.2, total requirement of 60,000 litres a year can be grossly assumed.

Excavation for tanka

Completed tanka and agor

Table 3.2: Minimum water needs

Consumption head	Consumption rate	Total quantity (litres)
Drinking, cooking	20-30 litres per day	10,000
Feeding water to 5 goats	20-30 litres per day	10,000
Irrigation of 100 saplings in Wadi plot*	5 litres per sapling per week	40,000**

** Saplings of multipurpose tree species grown along plot boundaries are not watered.*

***It is assumed that 15% of water requirement will be met by rainfall and dew.*

The main consumption head is the saplings in the Wadi plot. Around 3-5 years after plantation of the saplings, the irrigation requirement will reduce drastically. The surplus water can be then used to:

- Expand the Wadi plot, or
- Cultivate vegetables, especially in summer

The water-requirement estimate does not include water required for bathing, washing and cleaning. It is assumed that water for these purposes will be met from other sources like bore wells, government water supply, etc. It is however seen that many families, who have constructed tankas under the Centre for Desert initiatives in Barmer, use some tanka-water for bathing also.

Tanka and agor specifications

The size and specifications of any rainwater harvesting structure are determined by the following criteria:

- Average rainfall and magnitude of minimum assured rainfall
- Estimated water requirement for different purposes
- Availability and cost of suitable construction materials, and skilled labour, for building different kinds of materials and structures

On the basis of the above parameters, the optimum specifications for the tanka and agor under the Centre for Desert model are as follows:

- Circular underground tanka of 4.23m diameter, constructed with stone masonry, with cement plaster and cement concrete, and covered with stone-slab roof
- Circular agor, or catchment area around tanka, of 19.54m diameter, including diameter of tanka, constructed with cement concrete in saucer shape, with gentle slope towards the centre[1].

The above structure can harvest 60,000 litres of rainwater if there is 250mm of annual rainfall.

Annual rainfall in Barmer is often lower and sometimes higher than 250mm. Nevertheless, the above specifications are considered optimal because of the Wadi-plot requirements. It is assumed that:

- Apart from tanka-water and rainfall, there is no source of water for the Wadi saplings.
- If rainfall in a particular year is below 250mm, or a family uses more water for domestic purposes or feeding animals, the family will purchase water in tankers and store it in the tanka, to meet the shortfall. Expected returns from Wadi justify the expenditure on water.

On the other hand, if there is a source of water for Wadi-plots, the tanka and agor can be of smaller size. Assuming 250mm rainfall, the tanka and agor diameters for tankas of different storage capacity are given in the Appendix.

If the family house has a cement-slab roof, the roof can be used as catchment area, and an agor would not be required. The tanka

1 For detailed specifications and technical drawings of tankas of different dimensions, please refer to CAZRI's 2009 publication, *Rainwater Harvesting Through Tanka in Hot Arid Zone of India*.

Drip irrigation system fed by rooftop rainwater harvesting

Wadi plot with fencing

can be fed from a pipe leading down from the roof. A few such rainwater harvesting systems have been constructed in Barmer by the Centre for Desert. It is however seen that the number of houses with large and flat rooftops is low. Rooftop rainwater harvesting is hence suitable only in a few cases, to meet the water requirements of the family, a few small animals and a small vegetable plot.

A tanka surrounded by an agor has one or two inlets with silt traps at the upper end. The roof of the tanka has an opening with a lockable metal hatch, for drawing water, and entering the tanka for maintenance work.

The Centre for Desert encourages families to invest in handpumps to extract water from the tanka. However, many families have not installed handpumps over the tanka, as they fear theft of stored water.

Water stored in a tanka can be manually transferred to a 500-litre plastic tank placed at a height of 3 feet above a horticulture plot of around 100sqm, which is fed by drip lines from the tank's tap. The Centre for Desert has piloted such a drip extension, which provides water through gravity to around 100 small plants at the rate of 4 litres per hour. The total cost of the drip system is Rs 6000.

Tanka: general considerations

If fed by water collected in rooftops, tankas have to be located near houses. If a tanka is constructed with an agor catchment area, the structure has to located in the lower side of the Wadi plot. Considering excavation costs, rocky sites are not suitable.

Special care has to be taken in sites with murrum (gravelly) sub-surface. Murrum has a tendency to swell when moist, and can cause cracks in tanka walls. Hence, at such sites, the tanka should be surrounded by a thick layer of sand.

In Barmer and other desert areas of Rajasthan, masons with experience of constructing tankas are available. These specialist masons, who command higher labour rates, usually know all the techniques and precautions to be followed while constructing circular tankas. Nevertheless, families investing in a tanka, and the facilitating agency, should ensure that:

- All materials (sand, cement, water, curing agents, etc) and tools required are on site before work is commenced.
- Uninterrupted availability of mason, especially the specialist tanka-mason, is assured during the construction period. While services of the specialist tanka-mason are required for around 12 days, a mason is required for construction of an agor for around 9 days (for a 60,000-litre tanka with agor).
- The place where mortar is mixed is clean, flat and smooth.
- Tools are clean and free of old mortar.
- Only clean and sieved sand is used.
- Only potable water, free from chemicals and other impurities, is used for mixing mortar and while curing.

- Bags of cement are stacked in a closely packed pile, and preferably covered with a plastic sheet, to avoid damage due to moisture.
- While minimal water should be used for mixing mortar, water should be used generously for curing. Curing should be done during and after construction. Proper curing is essential for obtaining long-term benefits from the structure.

In the Centre for Desert's experience, a tanka+agor with storage capacity of 60,000 litres can be constructed in 3-4 weeks, excluding the time required for curing.

It is expected that tanka constructed in the above manner will last for at least 30 years, if routine maintenance is done regularly.

Quality of harvested rainwater

Rainwater is the cleanest form of water, without harmful bacteria, dissolved salts, minerals and heavy metals often found in groundwater. If rainwater is collected in a properly constructed tanka with a clean agor, it would be normally free from soil particles as well. Nevertheless, for use as drinking water, the water can be made absolutely safe by addition of potassium permanganate in the tanka, and by filtering extracted water.

Participant family in a ber Wadi

Tanka maintenance

Regular activities to be done to maintain quantity and quality of water stored in a tanka are:

- Keeping catchment area clean and clear of moss, dirt and leaves
- Trimming trees and shrubs that overhang the catchment area
- Cleaning tanka inlets and silt traps
- Inspecting inside of tanka annually before rains, for cracks, and to remove any sediments.

Wadi-plot requirements

Wadis have to be established on level plots of agricultural land near the family's home. The tanka+agor has to be built in or close to the Wadi plot. To save time in obtaining water for domestic use, and take good care of the Wadi saplings, the family's house has to be close to the Wadi plot.

(BAIF's Wadi experience in other areas shows that even when families have homes at some distance from their Wadi plots, they eventually build a home within the plot, using the income generated from the plot).

As open grazing is common in desert areas, the Wadi plot has to be fenced. Stone-fencing is generally not viable in desert areas. Making fencing from dried thorny bushes requires a lot of time and effort. The fencing is also prone to termite attacks. Hence, the Centre for Desert has successfully promoted wire-mesh fencing for Wadi plots in desert areas.

For ensuring economies of scale in marketing, only a few fruit varieties should be planted. At the Barmer project site, promising results have been achieved by planting 50 plants of two hybrid ber varieties (Gola and Seb) promoted by CAZRI, along with 50 other fruit-yielding plants like pomegranate, gunda/lashota and bael. Main returns are expected from ber (see box *Ber: A Boon in Deserts*).

Ber: A Boon in Deserts

Hybrid ber varieties promoted for Wadi plots yield plum-sized fruits in two years

Ber, also known as Indian jujube or desert apple, is a boon in arid or semi-arid regions.

The tree can survive temperatures as high as 50° C, grows naturally even in areas with average annual rainfall of only 125mm, and flourishes in alkaline soils with pH as high as 9.2.

Thus ideally suited for deserts, ber provides the three vital "f's" that desert-dwellers require: fruit, fodder, and fuel.

Ber fruit is a rich source of vitamin C, second only to guava and ranked much higher than oranges. While the fruit is usually eaten fresh, it is also consumed in other forms: dried, candied, pickled, or as juice. Dried ber-powder is valued for its medicinal properties and has an export market.

The leaves of ber are nutritious fodder for sheep and goats. Analysis of the chemicals constituents on a dry weight basis indicate that the leaves contain 15.4% crude protein, 15.8% crude fiber, 6.7% total minerals, and 16.8% starch.

Ber timber is hard, strong, fine-grained and reddish in color. It is often used to make agricultural implements. Ber wood is used as firewood, or to make charcoal.

While wild ber trees can be 10-12m tall, the hybrid varieties promoted by the Centre for Desert acquire a maximum height of around 1.5m. Hence, 80 ber shrubs can be planted with distance of 5x5m in an area of 0.2ha. This degree of planting density is possible because the shrub has to be pruned every year, initially to build a strong stem, and later for production of fruits: fruits are grown on a current season's growth.

Application of organic and inorganic fertilizers is recommended to maximise production. In Barmer, good results have been obtained by application of vermicompost and micronutrient formulations.

While full fruit-production of 80-130kg/tree/year begins after 10 years in wild varieties, the improved ber varieties like Gola and Seb start yielding in the second year, and are expected to give full production of 100kg/year from the 4th year.

The most serious problems faced by ber are attack by fruit flies and powdery mildew. Both problems can be easily tackled with controlled spraying of chemicals.

One year after plantation, survival rate of ber saplings in Barmer Wadi plots is close to 80%. Comparatively, survival rate of pomegranate and date palms is 50% and 22% respectively. With good value in local and distant markets, ber is thus highly suited for commercial cultivation in desert areas.

4. Benefits

The BAIF Centre for Desert livelihood-model provides important direct and indirect benefits.

Estimation of direct benefits, presented below, is based on actual costs incurred and income obtained at the Barmer project sites in 2011-12. Apart from differences due to inflation, there would be locational variations in costs and net returns according to:

- Cost and availability of skilled and unskilled labour required for construction
- Transportation costs incurred to procure cement, stone and other materials that may not be available on-site
- Local market rates for fruit and other produce of selected Wadi trees/shrubs.

Despite these riders, the discussion below can be taken as a basis for estimating the viability of the model.

Costs

The Centre for Desert's total cost of establishing one tanka+Wadi unit in Barmer project site in 2011-12 was around Rs 143,320. The breakup of capital investment costs is given in Table 4.1.

Apart from delivering direct economic benefits, the BAIF model greatly reduces hardship involved in fetching water

Table 4.1: Capital investment costs*

Asset	Cost head	Cost (Rs)	HH contribution (Rs)	Project support (Rs)
0.2-ha Wadi with 80 fruit trees /shrubs and multipurpose trees along boundary	Iron net fencing	20,000	13,000	7000
	Pit digging, filling, basin preparation	2500	Labour	2500
	Nutrients (vermicompost, micronutrient formulation and forate)	3000	Labour	3000
	Fruit tree/shrub saplings	2000	Labour	2000
	Insecticides/pesticides	3000	Labour	3000
	Plantation of multipurpose trees on boundaries	1000	Labour	1000
	Sub total	31,500	13,000	18,500
60,000 litre Tanka	Material cost (cement, stone slab, crushed gravel, sand and stones)	46,800	0	46800
	Unskilled labour (36 person-days)	12,600	12,600	0
	Skilled labour (12 person-days)	6000	6000	0
	Water (from tanker)	1800	1800	0
	Sheaves and gate	1000	1000	0
	Handpump	1500	0	1500
	Miscellaneous	1000	0	1000
	Sub total	70,700	21,400	49,300
Agor	Material cost (cement, stone slab, crushed gravel, sand and stones)	25,220	0	25,220
	Unskilled labour (26 person-days)	9100	9100	0
	Skilled labour (9 person-days)	4500	4500	0
	Water	1800	1800	0
	Miscellaneous	500	0	500
	Sub total	41,120	15,400	25,720
GRAND TOTAL		143,320	49,800	93,520
%		100	35	65

** Based on actual expenses incurred in 2011-12*

The costs incurred on construction of tanka and agor were substantially lower than costs incurred by other agencies, at other locations in Rajasthan, for the following reasons:

- No contractors were used. The beneficiary family arranges for skilled and unskilled labour and supervises the work, along with project staff.

- Some materials like gravel and small stones were locally procured.
- Labour and time required for excavation in sandy soil is relatively low.

If a rooftop is used as a catchment area, the cost of agor construction would be saved. Minor additional cost would have to be incurred for laying a pipe from the rooftop to the tanka.

The income-generation potential of the assets created can be supplemented by:

- Cultivation of vegetables like cucurbits, using improved-variety seeds
- Breeding high-value goats

The cost incurred by the Centre for Desert for promoting vegetable cultivation over an area of 0.05ha is Rs 2500. For breeding high-value goats, one 'Sindh' variety buck costing Rs 10,000 was distributed among 10 HHs. Hence the cost per HH was Rs 1000.

These two incremental investments, aggregating to Rs 3500 per HH, greatly increase returns.

Recurring Costs

No costs are involved in maintaining a well-constructed tanka. Recurring expenditure will have to be incurred on a Wadi plot for:

- Providing nutrients to plants
- Spraying insecticides/pesticides
- Buying water if there is a shortfall, due to below-normal rainfall or some other reason
- Replacing dead or severely diseased plants
- Repairing the fence, if required

Direct Income Benefits

Direct income benefits are obtained from this model in at least two ways:

Income obtained from sale of fruits: Income from this source is partly realisable from year 2 and fully realisable from year 4.

Table 4.2: Direct income benefits at 2012 prices

Source of income	Avg. unit per HH	Production	Selling rate	Gross income (Rs)	Input cost (Rs)#	Net income (Rs)	Remarks
Fruit trees	80 plants	2720kg	Rs 12/kg	32,640*	2000*	30,640	Average fruit yield per plant at Barmer project sites is 34kg.
Goat	6 goats	3 kids	Rs 2000/ kid	6000	1500	4500	One Sindhi buck provided for 10 HHs.
Total				38640	3500	35140	

** Figures obtained from 55 project HHs surveyed in Feb/March 2012. HHs' total ber production was 58,455kg from 1733 trees. The plants had been planted in 2008 and 2009. The leaves of the plants, which are lopped off every year, are good fodder, which sells at Rs 5/kg. As the fodder is used by HHs to feed goats, its value has not been included in net income.*

 # Input cost covers only paid-out costs for compost, fertilizers, pesticides, veterinary services, etc. All labour work related to Wadi and goat rearing is done by family members; there is no paid-out labour cost.

Improved varieties of ber like Gola and Seb planted at Barmer project sites have yielded fruit at an average rate of 34 kg/plant in year 3 itself. The fruit commanded a market value of Rs. 12-15/kg.

Goat rearing: On an average, one HH participating in the project at Barmer rears six goats. The project provided one Sindhi breed buck per 10 HHs, so that they can increase their income from goat rearing. One-year-old goats, with body weight of 60-80 kg, fetch at least Rs 2000. In a year, a family can reasonably expect to sell at least 3 kids.

It can be seen that at 2012 prices, HHs can get total net income of at least Rs 35,000 through a Wadi with a 60,000-litre tanka. The income would be obtainable for 15-20 years as ber plants and goats are highly drought-resilient.

Other Benefits

The model provides several other key benefits:

Increased availability of water: The model has led to increased availability of water for drinking, goat-rearing and as protective irrigation for horticulture and vegetables cultivation. It has helped HHs save cost and time expended to procure water, saving hours of hard labour mostly put in by women. In Barmer, the 2011-12 market value of 60,000 litres of water saved in the tanka was around Rs. 12,000.

Increased availability of fodder: In desert conditions, fodder is scarce and has, like water, considerable market value. From the year 4 onwards, each ber plant will yield around 4kg fodder. Availability of 320kg fodder per HH per year (from 80 Wadi plants) makes goat rearing a very viable and remunerative livelihood option for poor HHs in desert conditions.

Scope for vegetable production: The tanka water enables vegetable cultivation on small plots. Used for household consumption, the produce improves nutritional status of HHs. Surplus produce, which is sold, fetches some additional income.

Benefits from forestry trees and other plantation: The fuel wood and fodder requirement of families is met through plantation of grafted and improved varieties of trees like khejri, kumath, neem, shisam, ardu, subabul and pilu. The trees act as wind breaks, control soil erosion and help improve the micro-climate. Lashota fruits will be used to make pickles, for home consumption or sale.

Improved health and hygiene: The availability of water has led to improved health and hygiene status of participating families. The quality of drinking water has improved, reducing incidence of waterborne diseases.

Table 4.3: Grant and family contribution for different types of water harvesting structures constructed till March 31, 2012 at Barmer project site under BAIF programmes

Details	Tanka+Agor	Tanka with rooftop harvesting	Only agor construction*	Total
Total units	142	25	40	207
20,000-litre units	60	25	40	125
60,000-litre units	82	0	0	82
Total cost (Rs)	8,743,650	1,100,000	875,000	10,718,650
Project grant (Rs)	5,90,3650	600,000	555,000	2,058,655
Cash contribution by families (Rs)	2,840,000	500,000	320,000	3,660,000

**Agors were constructed around tankas built earlier under MGNREGA.*

Breeding high value goats

Income from the tanka+Wadi model increases significantly when complemented by breeding of high value Sindhi goats. The breed is found in Barmer district, close to the border with Pakistan. The breed lives on open grazing and has good potential for milk and meat production. Kidding rate is high (2-3 kids/year).

Goat rearing is traditionally undertaken by the majority of the families in remote desert locations. However, due to paucity of fodder, families generally rear only female goats to meet milk requirements. On an average, one household rears 4-5 female goats. As male goats are not reared, there is a problem of breeding and breed multiplication.

In view of this constraint, the Centre for Desert took the initiative of providing Sindhi breed bucks to selected farmers, called Bakri Mitras. Bucks are insured and Bakri Mitras are trained to undertake proper feeding and management. Feed support is given at the rate of 250gm per buck per day. Technical inputs are provided for health care. One buck is to be shared by 10 goat-owning households, for breeding purposes.

The progeny is sold on weight basis to local middlemen, who sell the animals in Ahmedabad's meat market. A 5-8 months old kid, weighing 25-35kg, can fetch sellers Rs 2500-3000. Weight gain is about 50-60kg/year. Households can thus earn good revenue from goat rearing.

Grant Support

As investment in a Wadi-linked tanka is a viable alternative to large irrigation programmes, which are extremely costly and have long-gestation periods, there is a strong case for providing grant support to families opting for the model, depending on their income status.

The support need not cover all costs. The Centre for Desert initiative in Barmer has shown that families are willing to contribute substantially in terms of labour as well as cash.

The quantum of contribution made by participating families for construction of different types of water harvesting structures at the Barmer site till March 31, 2012 is shown in Table 4.3. It can be seen that families bore 34% of the total cost.

Likewise, families contributed for establishment of Wadi plots in roughly the same proportion.

Details of the nature and quantum of a family's contribution for implementation of the Centre for Desert's model in the Barmer project are are shown in Table 4.1. As can

With harvested rainwater, a Wadi becomes a viable source of income in harsh desert conditions

be seen, families are expected to contribute around 35% of the total cost, apart from making significant contributions in terms of casual labour. Support can be given for this 35% component through soft loans.

Replication potential

The Tanka-Wadi model is replicable in any Indian desert location where rural communities are struggling to meet their basic water, food, fodder and income needs.

Apart from general parameters like average rainfall, estimated water-requirement of families, size of land-holdings, and families' willingness to make cash/labour contributions, the following points are to be considered during replication:

Skilled and experienced masons are required for constructing circular tankas. If such skills are not locally available, additional costs will have to be incurred for procuring masons from other locations, or training local masons.

Excavation cost and time for constructing underground tanks is relatively low in sandy soil. In soils with clay content, or soils with rock sub-stratum, the excavation costs will be high.

Overall costs and returns will be significantly different in locations that are at a distance from large markets.

Timely scheduling and execution of activities is the key to successful implementation of this model. If availability of funds and manpower does not match planned schedules, costs will rise and quality will suffer. If a Wadi plot is not established, or a tanka is not built, before the monsoons, one whole year is lost.

5. Appendix

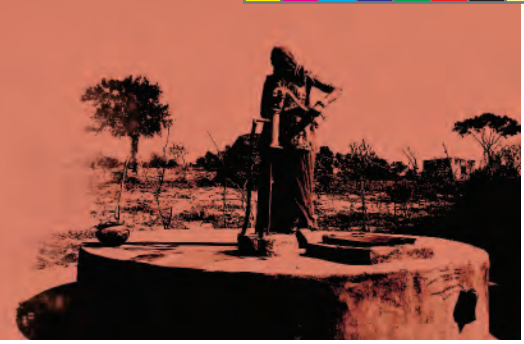

Table 5.1: Tanka and agor dimensions for different water storage capacities (assuming 250mm rainfall)

Storage capacity (litres)	Tanka diameter (m)	Agor diameter (m) including tanka diameter
20,000	2.94	11.28
30,000	3.37	13.70
40,000	3.71	15.96
50,000	3.99	17.84
60,000	4.23	19.54
70,000	4.46	21.10
80,000	4.66	22.56
90,000	4.85	23.94
100,000	5.03	25.22

Note:

- Depth and diameter of circular tanka are equal, and calculated by the equation D=(1.27*V)/ 0.33, where D=diameter as well as depth in meters and V= capacity in cubic meters
- On the basis of capacity of the tanka, the catchment area for collection of runoff (R) is determined, considering the average rainfall (P) and run-off coefficient (C), using the formula R=P*C*V
- In order to collect maximum runoff, the catchment area is sloping (saucer-shaped) and paved with cement. Hence, coefficient of runoff is considered as 0.80.

An indicative visual representation of the livelihood model, showing its components: a tanka+agor in a Wadi, with (optional) drip-irrigation system, and vegetable cultivation and goat rearing as supplementary income-sources

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