RAINWATER HARVESTING: A KEY TO SURVIVAL
IN HOT ARID ZONE OF RAJASTHAN

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CAZRI – A Historical Background

• 1952: Desert Afforestation Research Station
• 1957: Desert Afforestation and Soil Conservation
• 1959: Central Arid Zone Research Institute
Distribution of Indian Arid Zone

Indian Arid Zone (38.7 m ha)

Hot Arid: 31.7 m ha
- Rajasthan: 19.60 m ha
- Gujarat: 6.22 m ha
- Haryana & Punjab: 2.75 m ha
- South Peninsula: 3.13 m ha

Cold Arid: 7.0 m ha
- Jammu & Kashmir: 7.0 m ha
Mean annual rainfall, mm (— —), stream characteristics (— —) and Eastern boundary (———) of arid zone of Rajasthan.
Environmental Constraints

- Low and Erratic Rainfall
- Intense Radiation
- Intense Radiation
- High Wind Velocity
- Problematic Soils & Water
- Sandy Soils with Poor Fertility
- Biotic Pressure
- Overgrazing
- Over-exploitation of Land and Water Resources
- Social taboos & unawareness
Natural Resources of Arid Zone

- Time Tested Water Harvesting Structures
- Pasture grasses/legumes
- Rich Mineral Endowments
- Common Property Resources
- Multi Purpose Trees/Shrubs
- Hardy and Productive Animals
- Ample Solar and Wind Energy
Problems of water resources in Indian arid zone

- Low and erratic rainfall
- Highly permeable sandy terrain
- Poor drainage network
- High evaporative demand
- Deep and generally saline groundwater
- Presence of excessive fluoride nitrate- unsafe drinking water
- Over-mining of fresh groundwater
- Dependence on Government water supply
- Water policy not implemented properly
- Absent of groundwater law
- Target oriented development of water resources
- Unwarranted local politics
- Poor socio-economic condition of local population
- Lack of education
POPULATION V/S PER CAPITA AVAILABILITY OF WATER

Expected per capita availability of water (m³)

<table>
<thead>
<tr>
<th>Year</th>
<th>National average</th>
<th>Rajasthan average</th>
<th>Arid zone of Rajasthan</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001</td>
<td>1820</td>
<td>849</td>
<td>680</td>
</tr>
<tr>
<td>2025</td>
<td>1341</td>
<td>561</td>
<td>454</td>
</tr>
<tr>
<td>2050</td>
<td>1140</td>
<td>439</td>
<td>358</td>
</tr>
</tbody>
</table>

- Water stressed level @ 1700 m³/year
- Water source level @ 1000 m³/year
- Absolute scarcity
- Population in lac numbers

Year

Options ??

Water Supply from other region - NO

- Costly, infeasible and impractical
- Other associated problems
- Dependency

Rainwater harvesting - YES

- Sustainable, cheaper, reliable
- Independency, feasible
- No associated problems

Rainwater harvesting needs - Rainfall + Catchment + Storage
Rainfall at different probability for arid districts of Rajasthan

<table>
<thead>
<tr>
<th>District</th>
<th>Probable rainfall equation</th>
<th>Correlation coefficient</th>
<th>Rainfall (mm) at probability of</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>50%</td>
</tr>
<tr>
<td>Barmer</td>
<td>$R = -172.73 \ln (P) + 892.57$</td>
<td>0.9779</td>
<td>216.8</td>
</tr>
<tr>
<td>Bikaner</td>
<td>$R = -139.88 \ln (P) + 790.98$</td>
<td>0.9552</td>
<td>243.7</td>
</tr>
<tr>
<td>Churu</td>
<td>$R = -142.53 \ln (P) + 878.18$</td>
<td>0.9570</td>
<td>320.6</td>
</tr>
<tr>
<td>Ganganagar</td>
<td>$R = -140.43 \ln (P) + 754.77$</td>
<td>0.9825</td>
<td>205.4</td>
</tr>
<tr>
<td>Jaisalmer</td>
<td>$R = -124.54 \ln (P) + 639.76$</td>
<td>0.9765</td>
<td>206.5</td>
</tr>
<tr>
<td>Jalore</td>
<td>$R = -205.26 \ln (P) + 1128.7$</td>
<td>0.9518</td>
<td>325.7</td>
</tr>
<tr>
<td>Jodhpur</td>
<td>$R = -196.29 \ln (P) + 1078.2$</td>
<td>0.9682</td>
<td>310.3</td>
</tr>
<tr>
<td>Jhunjhunu</td>
<td>$R = -148.61 \ln (P) + 937.36$</td>
<td>0.8954</td>
<td>356.0</td>
</tr>
<tr>
<td>Nagaur</td>
<td>$R = -196.88 \ln (P) + 1063.8$</td>
<td>0.9649</td>
<td>293.6</td>
</tr>
<tr>
<td>Pali</td>
<td>$R = -214.62 \ln (P) + 1201.6$</td>
<td>0.9586</td>
<td>362.0</td>
</tr>
<tr>
<td>Sikar</td>
<td>$R = -207.82 \ln (P) + 1207.2$</td>
<td>0.9602</td>
<td>394.2</td>
</tr>
</tbody>
</table>

$R =$ rainfall (mm) for probability (P) and $\ln$ is natural logarithm
Techniques for Enhancing Runoff from Catchments

- Simple earth smoothing and compaction helps increasing runoff from catchment areas. Success is generally greater on loam or clay loam soils. Care must be taken to reduce the slope and/or the length of slope to lessen runoff velocity and thereby reducing runoff.

- Small amounts of sodium salts - particularly NaCl, NaHCO$_3$ applied to desert soils where vegetation has been removed- causes dispersion of the surface soil, reducing infiltration and increases runoff. However, this type of treatment requires a minimum amount of expanding clays in the soil.

- Removal of stones and boulder and unproductive vegetation from catchment helps in uninterrupted flow, enhances runoff to collection site.

- Land shaping into roads and collection of water in channels.

- Sandy soils have low water holding capacity. Spreading of clay blanket to the soil surface reduces the infiltration and consequently accelerates runoff.

- Chemical treatments like wax, asphalt, bitumen and bentonite prevent downward movement of water, which augments runoff.
Catchment area (m²) required for 1 m³ of runoff at different rainfall probability for three catchment conditions

<table>
<thead>
<tr>
<th>District</th>
<th>Catchment area required for 1 m³ of runoff (m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Rainfall at 50% P</td>
</tr>
<tr>
<td></td>
<td>C- 0.2</td>
</tr>
<tr>
<td>Barmer</td>
<td>23.10</td>
</tr>
<tr>
<td>Bikaner</td>
<td>20.50</td>
</tr>
<tr>
<td>Churu</td>
<td>15.60</td>
</tr>
<tr>
<td>Ganganagar</td>
<td>24.30</td>
</tr>
<tr>
<td>Jaisalmer</td>
<td>24.20</td>
</tr>
<tr>
<td>Jalore</td>
<td>15.40</td>
</tr>
<tr>
<td>Jodhpur</td>
<td>16.10</td>
</tr>
<tr>
<td>Jhunjhunu</td>
<td>14.00</td>
</tr>
<tr>
<td>Nagaur</td>
<td>17.00</td>
</tr>
<tr>
<td>Pali</td>
<td>13.80</td>
</tr>
<tr>
<td>Sikar</td>
<td>12.70</td>
</tr>
</tbody>
</table>

C= 0.2 for untreated natural catchment; C= 0.3 Compacted natural catchment
C=0.4 Compacted artificially treated catchment
Rainwater Characteristics

- The cleanest water is always that which falls freely from the sky. The natural water cycle is very efficient in screening out contaminants that are normally found in ground water and other sources.
- Rainwater does not come in contact with the soil, and so it does not contain contaminants such as harmful bacteria, dissolved salts, minerals or heavy metals.
- Rainwater is healthy and is soft water so, among other things, you will use less soap.
- Roof-collected rainwater can be made safe and potable by adopting some simple measures such as cleaning of rainwater storage structure and catchment, diversion of first flush and coarse rainwater filters.
- The quality of rainwater further improves with time after the rain, mainly due to sedimentation and bacteria die-off.
- It takes an average of 3.5 to 4 days to achieve a 90% reduction in *E.Coli* numbers.
- It has been proved that people drinking tank rainwater are at lower risk of many diseases than those drinking public mains water.
Mode of water transportation
Dependency on drinking water sources

- Tanka: 35%
- Nadi: 42%
- Wells: 15%
- Other sources: 8%
Traditional storages & improvements

Traditional Tanka

Improved family tanka (21m³ capacity)

Community tanka (300m³ capacity)
Design details of improved tanka of 100,000 liters capacity

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Yield of Ber</th>
<th>% Increase over control</th>
<th>Yield of Pomegranate</th>
<th>% Increase over control</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Kg/plant</td>
<td></td>
<td>Kg/plant</td>
<td></td>
</tr>
<tr>
<td>No irrigation</td>
<td>12.2</td>
<td>-</td>
<td>10.6</td>
<td>-</td>
</tr>
<tr>
<td>2 irrigation</td>
<td>17.9</td>
<td>45</td>
<td>18.0</td>
<td>70</td>
</tr>
<tr>
<td>4 irrigation</td>
<td>22.8</td>
<td>80</td>
<td>22.5</td>
<td>113</td>
</tr>
<tr>
<td>6 irrigation</td>
<td>27.3</td>
<td>124</td>
<td>30.9</td>
<td>199</td>
</tr>
</tbody>
</table>

**Diagram:**
- Tanka (Capacity 1,000,000 litres)
- Plan of Tanka
- Section at AA'
  - Openable lid 60 x 60 cm (Iron sheet & angle iron frame)
  - RSJ 150 x 150 mm
  - C.C. (1:4:8)
  - Cement plaster (1:4)
  - 15 mm thick C.C. (1:3:6)
  - 20 mm thick
  - Cement concrete 25 mm thick
  - Stone slab roofing (100 mm thick)
  - Scale 1 cm = 1 m
CAZRI EXPERIENCE

- Construction of tankas for raising orchard at few location have significantly improved the economic condition of farmers. The Benefit cost ratio of tanka ranged from 1.25 to 1.40 under different uses (Goyal et al. 1995, Goyal & Sharma, 2000).

- The improved tanka designs developed and demonstrated by CAZRI have got wide acceptability in the region. The designs have been replicates in large numbers by different developmental agencies.

- The number of improved tanka in different capacity ranges constructed in the region are 11,469 with a total storage capacity of 4,75,200 cubic meters and are sufficient to meet the drinking and cooking water requirements for a population of 1,32,000 throughout the year (Khan & Venkateswarlu, 1993).

- Tanka is highly economical compared to hauling of water from long distances. Hauling water in the villages cost 75 paisa per liter which is very high compared to only 2 to 5 paisa per liter of water available from a tanka located near the settlement.
Roof water harvesting
Traditional Nadi

- High evaporation
- More seepage
- Low capacity
- Unhygienic

Improved nadi with LDPE lining
IMPROVED DESIGN OF NADI-LDPE LINING
JASDER NADI, BARMER AGAUR, BARMER DISTT.
BENIFICIARIES—500 PERSONS AND THEIR LIVE-
STOCK THROUGHOUT THE YEAR
CAPACITY—18,100 cu. m.

PLAN

SECTION ON SS
SCALE 1 cm = 80 cm

CROSS SECTION ON AA
SCALE 1 cm = 4 m
50 x 50 x 6 mm ANGLE IRON POSTS
FOR FENCING
1:4:8 CEMENT CONCRETE
W.L.

DETAILS OF A
SCALE 2 cm = 1 m
5 cm THICK SAND
CUSHION

SECTION ON BB
SCALE 1 cm = 40 cm
20 cm THICK SOIL
OVER BURDEN ON
LDPE LINING
1000 GAUGE
LDPE LINING
5 cm THICK SAND CUSHION
BELOW LDPE SHEET

STONE MASONRY WALL
IN 1:6 CEMENT MORTAR

W.L.

0 250 cm

EARTH
Criteria for construction of Nadi

(a) Catchment

The catchment is an integral part of nadi. Selection of site for the construction of a nadi is primarily made on the basis of an available natural catchment and its water yield potential. Rocky hills are excellent natural rainwater catchments. Catchment area of rock outcropped or stony/gravelly pediments with steep slope also have high water yielding efficiency.

\[ AC = \frac{Y}{(P \times C_f)} \]

where
\( AC = \) Catchment area, m\(^2\)
\( Y = \) Storage capacity of nadi, m\(^3\)
\( P = \) Dependable annual rainfall, m
\( C_f = \) Coefficient of runoff

The runoff coefficient depends upon physiographic setting, type of soil and rainfall pattern.
(b) Storage Capacity

A nadi is designed on the basis of daily per capita water consumption, number of persons to be served and lean period days. The basic water requirement ($V_r$) for dry period is worked out as

$$ V_r = \frac{C \times N \times D}{1000} $$

where

- $V_r$ = Basic water requirement for lean period days, M$^3$
- $C$ = Daily per capita water consumption, litres
- $N$ = Number of persons to be served
- $D$ = Lean period days

Per capita water consumption with livestock recommended for western Rajasthan is 70 litres per day and for the rest of the country 40 litres per day. The lean period considered for western Rajasthan is 300 days.

The actual nadi capacity is worked out to be as

$$ VC = V_r + WL $$

where

- $VC$ = Actual capacity of nadi
- $WL$ = Annual expected water losses from nadi
Khadin system of water harvesting for crop production

Traditional Khadin

- No outlet structure
- Uneven water distribution
- Wastage of excess water
- Improper catchment to cultivated area ratio

Improved Khadin
Khadin system of water harvesting for crop production
Design package and guidelines for *khadin construction*

Central Arid Zone Research Institute, Jodhpur has prepared the design package and guidelines for construction of *khadin* by users agencies;

- *Khadin* may be defined as a water harvesting system used for runoff farming on stored soil profile moisture.

- The catchment may be classified on the basis of infiltration rate. In the areas where infiltration rate is less than 5 cm hr\(^{-1}\) may be considered as good catchment, 5-12 cm hr\(^{-1}\) as bad catchment. The delineation of catchment should be done on the cadestal/village map or G.T sheet through reconnaissance survey.

- The average rainfall of over 30 years available at the nearest rain gauging stations should be considered for working out the catchment yield. Log Pearson III method or strange table should be used.

- For calculation of flood discharge upto 480 ha area Rational Formula and above 480 ha Dicken's Formula may be used.
• *Khadin* may be constructed in a area where soil is fine textured, medium to deep with high soil moisture retention capacity. Soil should be free from salinity.

• In order to have economic design the ponding depth over sill level at the *khadin* bund may vary from 0.65 to 1.10 m with overall average of 0.60 m.

• The flood lift may be adopted as 0.3 m.

• During the ponding period from July-October there will be wave action therefore, a free board of 0.5 m may be considered.

• The side slopes of the bunds may be generally kept 2.5:1 (D/S) and 2:1 (U/S). However, these would be governed by the type of soil, angle of repose, bund cross section and its safety factor.

• The top width of *khadin* bund may be calculated by appropriate formula and not for constructing inspection road.

• A murrum capping of 7.5 cm thick layer be provided over the bund section for protection against wind and rain erosion.

• The head outlet sluice of appropriate size may be provided in the *khadin* bund for the release of the standing water if any before the rabi sowing.
Some issues:

1. Encroachment on catchments
2. Contamination of harvested water
3. Utilization of harvested rainwater by stakeholders
4. Sharing of harvested water
5. Maintenance/desilting of water bodies
6. Technology for reduction in evaporation and seepage losses
7. Direct use vs. Recharge of groundwater
8. Misuse of water for non-productive/commercial purposes
9. Misconception about quality of water
10. Easy access to alternative sources of water
Thousands have lived without love, not one without water

EVERY DROP COUNTS...WE ARE COUNTING ON YOU...I BE WATER WISE...ITS WORTH IT...
JHALARA & BAWARI

- Unique design, water input through sub-surface recharge
- Approach to water through steps
- Used for drinking and other domestic purpose
- Most of them neglected and require renovation
Beri

A small dug well of 0.5-0.75 m dia depth 10 m
Used in extreme emergency for drinking purposes only
Presently out of use
A smaller well is called Kui

Constructed in downstream side of channel or pounded water

Provide sweet water in saline groundwater area for shorter duration