RAINWATER HARVESTING TECHNOLOGY IN INDIAN DESERT

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1.0 INTRODUCTION

Water is scarce commodity in the 11 arid districts of Rajasthan covering 1,96,150 km^2 area. Low and erratic rainfall, dominantly deep dry sandy soil terrain with dune bodies, total absence or disorganised natural drainage in major part, very deep and saline ground waters, very high evaporative conditions and frequent dust storms events makes the region most inhospitable for all in general and human in particular. Spatially, eastern margin of the desert receives more annual rainfall (500 mm) than the western international boundary (100 mm). Along with this decreasing rainfall gradient westward, there is increasing gradient of variability in rainfall as also evaporation. Thus, coefficient of variability in rainfall is 40 per cent in the east which increases to 70 per cent in western part of Jaisalmer district, while the annual evaporation is less than 1000 mm in east and it exceeds gradually 2000 mm in west. However, the rainy season is confined to a period June to September, when 90-95 per cent of the total annual rainfall is received.

Within this broad setting, there is again local spatial variability in rainfall events, even in the small areas. Under such conditions, considering the general water requirement, the availability of water resources is highly uncertain. In this backdrop of uncertainties that the rainwater management using is found to be valuable. There are some hilly, rocky, stony and gravelly surfaces interspersed in this region, that generate good runoff which may be harvested and utilized for conjunctive use. Rainwater management has, therefore, to be looked into in the context of maximising water availability in the face of increasing demand for domestic consumptive and for biomass production on sustainable basis.

2.0 RAINWATER MANAGEMENT

2.1 Management and Harvesting of Rain-runoff

Management of rain-runoff involves harvesting of excess rain falling on land surface by creating a storage facility either in field or in a constructed structure. Field surface modification also facilitate and enhance rainwater intake and diversion of runoff to recharge aquifers. Some of the common practices are briefly described here.

Khadin

In depressional area soils have developed from the silt load carried in runoff from adjoining uplands and hence are fine textured. In many situations, the base is rocky which restrict the deep percolation. This type of soil deposition with rocky catchment can be met in areas having as low as 150-350 mm rainfall. Such areas may be converted in productive table agricultural lands by constructing earthen embankments at lower periphery of field with suitable spillway arrangement. Such farms are locally called as *khadins.* This system of water harvesting and landuse is very common in Jaisalmer district of Rajasthan, where average annual rainfall ranges from 100 to 225 mm. Due to low rainfall, the ratio between catchment and command area is rather high.

Khadin cultivation has got due recognition at government level. In last three decades large number of *khadin* farms have been developed in western Rajasthan resulting significant improvement in agriculture production in the region.

Studies conducted in Jaisalmer district revealed high variation in soil salinity between cropped land (EC 0.8 to 3.6 mmhos/cm) and outside (EC 2.24 to 58.0 mmhos/cm) of the *khadin* bund (Kolarkar *et al.,* 1983). Such studies, clearly indicates that the most of the salts in runoff water are seeped out through seepage water in the downstream side of the *khadin* bund. To minimise the land degradation problem in downstream side there could be two possibilities: (1) introduction of tree component (Agrohorticulture or Agroforestry) in the *khadin* system because tree roots can utilize the water into sub-stratum, and (2) water accumulation in the farmland may be limited to the height of 60-90 cm required for good soil moisture status and evaporation losses. However, to substantiate these hypothesis, more research data are needed on various aspects of *khadin* system.

Nadis and Tanks

Besides the irrigation reservoirs and *khadins,* the inhabitants of the region harness the meagre rainfall in the form of dug out ponds locally known as *nadis* and in cisterns called *tankas.* These are age old practices of harnessing water utilised for drinking by human and livestock population. Till today, the most of the villages are depending on these structures as sources of drinking water. *Nadis* are affected by: (1) high evaporation and seepage losses of water, (2) high sedimentation rate, and (3) misuse, which are the management problems. In order to solve these problems, CAZRI, Jodhpur has developed the suitable structure of *nadi.* The main features of the development are: (1) reducing of sediment input to the *nadis* by promoting vegetation growth in the catchment areas and constructing silt traps at the inlets, (2) providing LDPE lining for minimising the seepage losses, (3) restricting the entry of animals and human beings in the *nadi* to avoid pollution problem, (4) tree plantation for shading the water surface to minimise the evaporation losses, and (5) providing wind mill or handpump for withdrawal of water (Khan, 1996).

Water collected in cisterns *(tankas)* are generally free from such problems. *Tankas* are generally owned by individual families or community as source of drinking water. The construction materials used are locally available viz. stones or bricks, cement, iron sheets etc. The entire construction is of permanent nature with top covered. The water is collected from roof tops or courtyard or natural/artificial prepared catchments. Improved designs of *tanka* for capacity ranging from 10 to 600 m^3 developed by CAZRI have been constructed in 100-400 mm rainfall zones in western Rajasthan, primarily to meet the drinking water demand on sustainable basis. The development of such structure can be one of the answers to the problems of perennial drinking water scarcity in the villages of arid zone.

In desert *tankas* may be a source for supplemental irrigation in fruit orchards, vegetable crops and for raising fruit and forest nurseries. Response of her *(Ziziphus mauritiana)* and pomegranate to supplemental irrigation from *tanka* was studied as a loamy sandy soil in the Thar desert in western Rajasthan. Compared to control (no irrigation) increase in fruit yield with 2, 4 and 6 irrigation (60 lits./irri./plant) for ber was 46.4, 80.3 and 124%, whereas, in the case of pomegranate it was 69.8, 112.5 and 191.7%, respectively (Khan, 1996).

Desert Strip Farming

Narrow strips are constructed across the land slope for farming. The intervening wider strip provides additional water. Different ratios of contributing strip to farming strip have been tried at different locations. It is reported that a ratio of 1:2 ensures significant yield of sorghum, ranging from 500 to 2600 kg/ha. Higher ratio did not increase the yield appreciably (Morin and Matlock, 1975).

Water Spreading

Water spreading is a practice where flood water is deliberately collected from a larger area or from stream sources and diverted in a small area. It improves the moisture regime in the command area for taking up crop husbandry. In the Jalore district of Rajasthan this system of water harvesting, locally called as *rela farming,* is commonly practised. It is also adopted to recharge groundwater for various future uses.

Surface runoff can be intercepted by big dykes and then led along to spread over the receiving area through a staggered system of dykes and ditches. Generally water from 4 to 12 ha can be spread over in 1 ha. Alternatively, an earth-fill is put across stream with extension diversion dyke to lead water for spreading. The method adopted are syrup pan system of spreader and spur dykes, pondage bank of spreaders only and short spreader and ditch system. In between the spreader dykes, shallow furrows could be provided to facilitate quick and uniform absorption of water. To permit out flow free spreader dykes, stone pitched rock weep holes are provided.

Anicut

An anicut is a structure constructed across a stream (nala) to intercept flash floods that sink into the soil profile and then seep down to replenish wells below for irrigating small patches. The soaked beds are cultivated during winter season. The retained water behind the structure can also be used as drinking source for human, wild animals and cattle.

In many undulating locations, earth dam is put across the *nala* with spillway that holds flood water to submerge some upstream area. Water gradually infiltrates and enriches the wells below, while the emerging upstream area is cultivated.

With the construction of anicuts at Ujalian watershed (Jodhpur district) static water level in wells located in the downstream increased from 1.8 to 2.2 m as compared to increase of only 0.5 m in wells located in adjoining areas. It has also helped in regeneration of plants of different species and grasses in the upstream area that has improved substantially the availability of fodder and fuel (CAZRI, 1989). Studies made in Pali district of Rajasthan have shown that the presence of anicut has increased aquifer recharge from 5.2% to 38.5% (Khan, 1995).

Gully Control Structure

About 4 million hectares in India are affected by gully and ravines that threaten another 4-6 million hectares of productive table lands. However with the proper management, the runoff through gullies can be harvested for ground water recharge and for human and livestock consumption.

Water Harvesting Dam

On ephemeral streams, small earthen dams with the drop inlet spillways are constructed. These create a small storage to arrest silt, increase groundwater recharge promote better vegetative growth and provide water for irrigation during monsoon as well as winter season. Catchment and command area are site specific. Thus per ha unit investment is low but varies with sites.

In Chinese and lands, rainfall is much less and rains are not sharp. Nearly 4% of the and lands are stony. The interspersed high mountains give rise to streams that flow into and land. These streams have been harnessed at more locations that have increased irrigated lands from 40,000 ha to 400,000 ha (Dhir *et al.*, 1978).

Percolation Tank

In arid and semi-arid regions where rainfall is scanty, replenishment of groundwater is not in proportionate to its utilisation. Under such situation, artificial groundwater recharge through water harvesting methods may be recommended.

Percolation tanks are generally constructed on the small streams or rivulets with adequate catchment for impounding surface runoff. These tanks will have no surplus weirs as these are used entirely for recharging the aquifers through percolation. Construction of this structure takes into account the catchment area, likely runoff, designed storage at the site as well as the area of benefit of the structure. The construction of such structure is considered useful as means of conserving water and strengthening the drinking and irrigation water sources.

Studies carried out on artificial recharge through percolation in stock tank with infiltration wells carried out in village Sar, district Jodhpur revealed that average rate of percolation was as high as 48 mm/day in the month of September when the static water head in tank was maximum (4 m). However, there was progressive decrease in the rate of percolation and it reduced to 3.9 mm/day in March where the SWH was 1.2 m. This may be associated with the reduction in wetted area and deposition of fine sediment on bed and sides which reduces the permeability of soil (Khan, 1996).

Sub-Surface Barrier

In desert, groundwater recharge whether direct from rainfall or through stream flow is not regular and discontinuous reflecting variable nature of rainfall and runoff. The response of river flow on the replenishment of wells located along the banks is immediate. However, meagre recharge during runoff period does not sustain a sufficiently long period due to which scarcity of water is felt. To some extent the yield of such wells could be improved by abstracting the sub-surface flow of sandy bed streams by constructing subsurface barrier across the stream beds.

Sub-surface barrier is the most suitable structure as it is safe from flood havocs, does not need elaborate over-flow arrangement and periodic de-silting. The silt from surface area upstream of barrier is flushed away during flash floods whereas entire storage of water being underground, evaporation losses are also insignificant. The construction needs a 30 to 60 cm wide concrete or brick masonry wall extending down to the impermeable basement or compact foundation. Sub-surface barrier may also be constructed with angular rock pieces arranged in form of dry masonry 100 cm wide wall or with a 250 micron polyethylene sheeting, properly embedded in the soil. Construction of two sub-surface barriers of 10 m length each, within 300 m from the water supply well are enough to store water required for a village with population of 500 (NDWM, 1989). As the domestic wells are located in the village, there is need for constructing these structures close to the village only. One of the structure should be upstream whereas other should be downstream. If only one structure is constructed, it should be downstream of the wells. Water to intercept the basin sub-surface out flow of groundwater from around the wells. During dry season, when the pumping water level in the well is low, the hydraulic gradient is reversed and the water is drawn from the groundwater mound downstream.

Study conducted for 3 years at Kalawas, Jodhpur district revealed that with the construction of sub-surface barrier (S.S.B.) the rate of depletion of groundwater has been reduced from average 1 m to 0.3 m per year (Das Gupta and Batra, 1993).

Sand-Filled Dam

Sandy river beds underlain by hard impervious strata below and having no surface flow, except in flood seasons, are a common feature of arid and semi-arid regions. Creation of conditions where surface water could be conserved in deep sandy bed, thereby reducing evaporation, is also important. Sand-filled dam is used for stepping the flow and storing water in sand bed for domestic water supply and groundwater recharge in near vicinity. The river bed gets filled with sand and gravel deposits carried by river flood during monsoon season. Flood water is stored in the basin in voids and pore spaces of sand particles and the upper sandy mulch prevents its evaporation losses.

Studies carried out for 4 years at Jodhpur revealed that evaporation reduction in sand filled reservoir was about 92%, although reduction in storage capacity was nearly half. In comparison to other treatments the quality of stored water in sand-filled reservoir was superior (Khan, 1996).

2.2 Water Harvesting from Roof Surfaces

Roof water harvesting is an old practice in many parts of the world. In India this method is largely practised in north-eastern region and western Rajasthan. In the ancient times, houses in western Rajasthan constructed with stone and lime were so structured that they had a self-contained roof water harvesting system. Rainwater from roof tops was regulated through in-built drainage network in an underground tank (cistern) constructed in the premises of houses. This was so in all the old buildings, forts and palaces in the region. However, with the modernisation, like many traditional practices, roof water harvesting technique also has been neglected.

In the last few decades, expansion of cities and for that matter villages have taken place at a very fast rate. Construction stone masonry structures on large scale has created many ill effects in the society; for example, impervious roof tops of buildings generate high percentage of water yield during monsoon period, which is beyond the capacity of the existing drainage network. This results in frequent choking of drainage system and water stagnation is found everywhere. If this precious water is harvested, channelised and stored by adopting roof water harvesting technique in individual houses and public buildings, the problem of water scarcity can be minimised to a great extent on one hand and reducing the load on drainage lines on the other. It will also help in improving the surroundings and overall environment.

The maximum possible water yield from a roof catchment system is directly proportional to the catchment surface area, its runoff efficiencies and the amount of rainfall. Field measurements indicates that a portion is evaporated and a portion is splashed out from the catchment.

Runoff efficiency of uncovered catchments ranged from 18-37% for different slopes. Among the covered catchments the highest runoff efficiency of 94% was achieved from surface covered with plastic sheet, followed by roof made of corrugated GI sheet (85%), stone slab roof (81%), paved surface (68%), clay tile roof (56%) and metal road (52%). The lowest runoff efficiency of 39% was achieved from thatched straw roof, possibly due to water absorption by straw (Table 1) (Khan, 1994).

2.3 Water Harvesting through Constructed Catchments

Under this system, catchment are constructed to induce runoff. The principle involved is that rainwater falling over catchment slopes is induced to flow either to planning area to supplement the soil moisture profile recharge or to a reservoir constructed for storage and subsequent utilization. Employing this principle, several techniques of water harvesting have been developed for conjunctive use in the and zone.

Table 1 : Runoff efficiency of different types of catchments (1993-94)

Type of catchment	Runoff efficiency (%)
Uncovered catchment	
Sloping 0.2%	18
Sloping 0.5%	22
Sloping 2.0%	34
Sloping 5.0%	37
Covered catchment	
Straw roof (thatched)	39
Clay tile roof	56
Corrugated G.I. sheet	85
Stone slab and lime concrete roof	81
Plastic sheet cover	94
Paved surface	68
Metal road	52

Inter-plot water harvesting

Studies on *in-situ* water harvesting conducted at CAZRI, Jodhpur revealed microcatchments constructed with a 5% slope in the field in a ratio of 0.5 with crop area, resulted in 120% higher yield over control (Singh *et al.,* 1973). In further studies, it was found that such catchments resulted in upgrading the soil moisture regime on an average by 20% throughout the season (Singh, 1976). The system can ensure a reasonably good yield even in drought years when many crops would normally fail due to prolonged moisture stress (Singh, 1985). The approach, thus, can meet the sustainability requirements.

In an other study it was observed that 6 m wide inter-row space as catchment with 3% slope on both sides is optimum for improving the moisture regime of ber orchards in arid sandy soil conditions of Jodhpur (Singh, 1985).

Inter-row water harvesting

Under this technique, 50-60 cm wide ridges alternated with 30-40 cm inside furrows (15 cm deep) are constructed using a ridger equipment. Crops are planted in furrows adopting a paired row design. Ridges yield runoff to the furrows, thus enhancing the moisture regime in the root zone. Singh et al. (1973) reported 210% increase in the yield of pearl millet with this system.

They concluded that ridge-furrow technique has better adaptability for small holders, as no area of the field is lost to catchment construction.

2.4 Water Harvesting Through Treated Catchments

The least expensive method of catchment is the natural or untreated catchment Natural basement complex rock outcroppings, exposed clay areas or iron oxide cemented sands make excellent natural catchments. In urban areas, roof tops and graded and paved streets are generally available for use at little or no cost. In areas, where good natural catchments are not available, runoff can be induced by treating the catchment surface.

The practice of watersheds to increase water yield for crop production is an old one as evidenced by ancient systems in the Negev desert in Israel (Evenari *et al.,* 1971; NAS, 1974). Sheet metal, butyl rubber, asphalt roofing, bentonite paraffin, fibre glass, reinforced asphalt, plastic sheeting with gravel cover, etc. have been used to cover the contributing area and thus induce large volume of runoff. Compacted earth and smoothening of surface are two simplest methods for increasing runoff. Treating the catchment area with chemicals help in reducing infiltration and inducing large volume of runoff.

Studies on various water proofing materials, conducted in small catchments at CAZRI farm at Jodhpur have given encouraging results (Table 2) (Murthy and Issac, 1980).

The result shows that *janta* emulsion, followed by sodium carbonate spray were most effective sealants and generated runoff 68% and 66%, respectively. Cost wise sodium carbonate was cheaper than *janta* emulsion. Catchment treated with lime concretion and bentonite mixed with soil also generated runoff more than 50% of rainfall.

2.5 Management of Stored Water by Reducing Evaporation Losses

Evaporation accounts over two third of water losses from surface water bodies in hot and regions. This component of water loss may be minimised by adopting suitable technology viz. by reducing wind velocity through developing shelter-belts of suitable tree species around water bodies or by artificially shading of water surfaces. However, shelter-belts have not been found very effective in evaporation control due to its limitations of partially shading of surface water.

Studies on artificial shading of water surface have shown encouraging results in controlling evaporation losses. Shading of water surface with polyethylene sheet successfully reduced evaporation by 91 per cent and cost of water saved was Rs. 2.54 per 1000 litres. Evaporation reduction with floating materials ranged from 37 per cent for *Saccharum munja* to 82 per cent for polystyrene sheet. Foamed rubber sheet, polyethylene sheet and bamboo reduced evaporation by 74 per cent, 66 per cent and 53 per cent, respectively. The floating polystyrene sheet and polyethylene covers were the most economical, saving water for Rs. 3.07 and Rs. 4.44 per 1000 litres, respectively (Table 3) (Khan *et al.* 1990).

Table 2 : Average runoff (1972-75) and cost of lining of various treatments

Treatments	Average runoff %	Cost of lining Per m^2 (Rs.)
Control	29	-
Bentonite 20% mixed with soil 1.25 cm thick	54	1.25
Cement 8% mixed with soil, 1.25 cm thick	25	0.90
Mud plaster-tank silt with wheat straw, 1.25 cm thick	42	0.45
Lime concretion, 5 cm thick	56	0.45
Janta emulsion (JE) premixed 1.25 cm thick (8% solution of JE and K. oil @ 4 litres)	68	3.10
Mechanical stabilization	37	0.30
Sodium carbonate spray 1 kg per 1 0 m over 1.25 m thick tank silt compacted	66	0.60
Mud plaster (95% mud, 3% straw and 2% JE)	54	1.20
Grass cover *(Lasiurus sindicus)*	27	0.50

Table 3 : Evaporation reduction efficiency of treated tanks and cost of water saved under different methods (December 1987 to June 1989)

Treatment	Area of covered water surface (%)	Evaporation reduction efficiency (%)	Cost per 1000 lit. water (Rs.)
Shading			
Polyethylene sheet	100	91	2.54
Floating Covers			
Polyethylene sheet	75	66	4.44
Foamed rubber sheet	90	74	8.50
Polystyrene sheet	98	82	3.07
Bamboo	83	53	9.90
Sacchrum munja	90	37	11.36

Control - Average annual evaporation was 2382 mm (open tank)

3.0 CONCLUSION

In hot and regions such as Indian Thar desert, where water availability is meagre, rainwater management technology may be an answer to improve water availability for sustenance.

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