International Journal of Agriculture Sciences
ISSN: 0975-3710 & E-ISSN: 0975-9107, Volume 14, Issue 4, 2022, pp.-11221-11227.
Available online at https://bioinfopublication.org/pages/jouarchive.php?id=BPJ0000217

Research Article

ACHIEVING NATURAL RESOURCE RESILIENCE THROUGH PEOPLE'S SCIENCE-A CASE STUDY OF HOT ARID ZONE OF INDIA

GAUR M.K.* AND GOYAL R.K.
ICAR-Central Arid Zone Research Institute (CAZRI), Jodhpur, 342003, Rajasthan, India
*Corresponding Author: Email - maheshjeegaur@yahoo.com

Received: April 01, 2022; Revised: April 26, 2022; Accepted: April 27, 2022; Published: April 30, 2022

Abstract: The Great Indian Desert, is a large arid region in the north-western part of the India and is named as Thar Desert. It covers around 6% of the country's total geographical area and forms a natural boundary between India and Pakistan. Scarcity of water (annual rainfall 100-500 mm yr^{-1}), extremes of temperature (highest of 47-49°C) and high population density of human as well as livestock make this region as most vulnerable deserts of the world. Droughts are very frequent to this region. However, local dwellers with centuries of experiences have evolved themselves to deal with local environments. Communities have aligned their livelihood in harmony with local resources. Very sound, time tested water harvesting structures like *tanka, khadin, Nadis, kund, Jhalaras, kui etc*. were developed to meet water requirement. The region is bestowed with several miracle plants of immense food and medicinal value to modern civilization. Nature has provided very unique, hardy and useful animals to this region to support the survival of human being here. The local people have developed art of harvesting maximum from livestock without harming the animals and nature. Traditional cultural and socio-religious values are fast dwindling under the impact of materialistic approach, industrialisation and development. This paper endeavours to illustrate the need to assist and propagate indigenous rural livelihood systems rather than mindlessly to replace or abandon them as a result of so called modernization.

Keywords: *Thar Desert, Rajasthan, Droughts, Desertification, Traditional water harvesting structures*

Citation: Gaur M.K. and Goyal R.K. (2022) Achieving Natural Resource Resilience through People's Science-A Case Study of Hot Arid Zone of India. International Journal of Agriculture Sciences, ISSN: 0975-3710 & E-ISSN: 0975-9107, Volume 14, Issue 4, pp.- 11221-11227.

Academic Editor / Reviewer: Rajib Das, Er Prabhat Kumar Dhara, Sabita Mishra

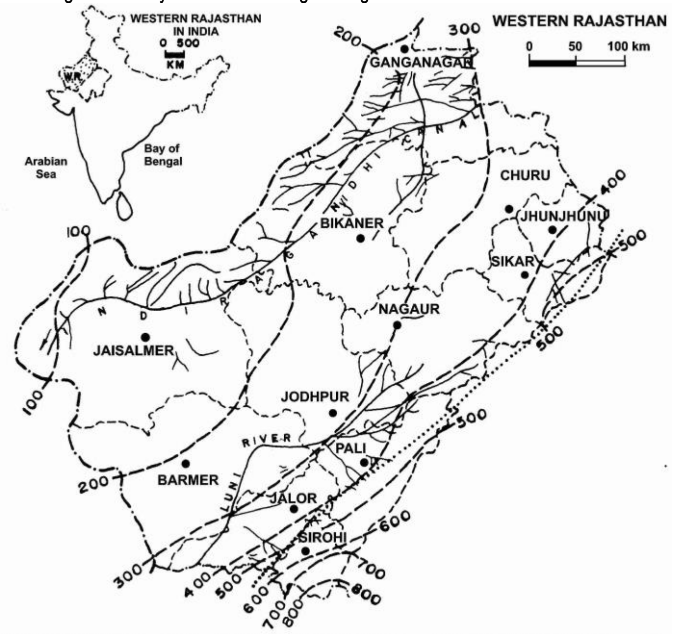
Introduction

The Thar Desert lies between 22°30'-32°12'N latitudes and 68°05'-75°45'E longitudes covering an area of 208751 km^2 in north-western part of India in the state of Rajasthan. The region comprises of 12 north-western districts of the state namely, Barmer, Bikaner, Churu, Ganganagar, Hanumangarh, Jaisalmer, Jalore, Jhunjhunu, Jodhpur, Nagaur, Pali and Sikar covering more than 60% area of the state [Fig-1]. Typical characteristics of the Thar Desert include low (100-400 mm yr^{-1}) and highly variable rainfall (CV 35-65%), high temperature regime, low humidity during summer season causing very high evapotranspiration [1,2]. Vegetation is very scanty and xerophytic thus inhabitants depend upon the animal resources, resulting in a sparse and nomadic population. Drought occurs every alternative year in different part of arid zone with probability of 47%. Rainy days in year varies from 10-15 with more than 80% rainfall occurs in July to September. Traditionally most of crops grown in monsoon (*kharif*) are rainfed. There is no perennial river system in the region and groundwater quality at most places in not good for irrigation. Under such circumstances, availability of drinking water also poses a real challenge for survival of human being. However, local people over a century of experiences have evolved themselves and developed indigenous techniques for conservation of soil and water resources, crops and biodiversity, livestock, rainwater harvesting, and vegetation. Thar Desert is unique in preserving the traditional knowledge through its cultural and religious identity that has significantly helped in the conservation and promotion of its ecosystem till date. This paper attempted to explore the diversity of traditional knowledge systems practised by the people of the Thar Desert for mitigating drought and combating desertification in The Great Indian Desert.

Droughts: A Recurring Threat

The principal source of water in arid zone is rainfall. The mean annual rainfall varies from little more than 400 mm in the south-eastern parts to less than 100 mm in the north-western part of the arid region. The rainfall is highly erratic and coefficient of variation varies from 35-65%. More than 85% of the total annual rainfall is received during the south-west monsoon season from July to September. A small quantum of about 7-10 percent of annual rainfall is received during the winter season under the influence of western disturbances. The Thar Desert of Rajasthan suffers with frequent droughts due to meagre rainfall and often delayed onset of monsoon. Extreme temperature regime during crop growing season coupled with high wind velocity quickly evaporate available soil moisture. In absence of other surface water resources, crops suffer varying degree of moisture stress leading to reduction in yield and often complete failure. The frequency of occurrence of drought in arid region is much higher compared to other climatic zones. The Analysis of the incidents of droughts and their intensity in western Rajasthan during last century indicate that 47 to 62% of the years experienced droughts of varying intensity [3]. A recent study by Das *et al*. [4] is indicative of climate change, and there is a possibility that such droughts would become more common in the future in arid region of Rajasthan. With frequent droughts and chronic water shortages in many areas, most people pay an increasingly high price for water, the poorer; especially women and children usually pay the highest price for small quantity of water [5]. The agriculture in arid areas continues to be a gamble of the vagaries of monsoon, rainfall being most critical because nearly 70% of the net sown area is still rain dependent [6]. The late onset of monsoon or no rainfall in middle of cropping season or early withdrawal of monsoon severely affects the crop productivity. A study of the impact of three drought years 1984, 1985 and 1986 on productivity of pearl millet indicates reduction in yield by 76, 31 and 39% in comparison to yield of good monsoon year of 1983 [7, 8].

Surviving the severe effects of droughts and high temperature regime is something that people located in extreme arid conditions have to deal with on a regular basis. Therefore, peoples have developed local science to predict the weather using their traditional knowledge. Traditional knowledge and local practices are adapted to the extreme conditions and have led to a historically stable agricultural system in this marginal region.



Mean annual rainfall, mm (– –), stream characteristics (—) and Eastern boundary (………) of arid zone of Rajasthan

Fig-1 Western Rajasthan rainfall and drainage

Desertification: Threat for Land Productivity

As per United Nations Convention to Combat Desertification (UNCCD) desertification has been defined as "land degradation in arid, semi-arid and dry sub-humid regions resulting from various factors, including climatic variations and human activities [9]. The non-sustainable management and land uses within the drylands often lead to over-exploitation of natural resources and a decline in productivity, the consequent desertification, followed by poverty and migration [10]. There are many drivers which leads to land degradation in hot arid zone of India. The main challenge of desertification in Thar Desert is due to recurrent droughts and increasing human and livestock pressures. The major physical manifestations of desertification in western Rajasthan are in form of wind erosion/deposition, followed by water erosion as well as water logging and salinity [11]. About 62.9% area of entire state is subjected to desertification with 44.81% area by wind erosion followed by vegetation degradation (7.62%) and 6.18% area by water erosion [12].

Wind erosion is major land degradation process in hot arid western India and affects the agricultural production system. A yield loss of 3-195 kg ha^{-1} yr^{-1} was observed due to wind erosion for pearl millet which covers a major portion of arable lands in western Rajasthan [13]. The peoples of this region are well aware of all these land degradation processes and evolved local technique to control wind erosion in western Rajasthan. The traditional people's science of controlling the speed of wind near the ground level consists of erection of micro wind-break of dead wood. The vegetation is laid down in line across the wind direction in rows 20-30 cm apart and soil is dumped on vegetation to keep them intact [14]. The traditional practice is known as *kana-bandi* in local language. Similarly, there are other practices for controlling soil and water erosion in order to maintain the productivity of crops.

Resilience for Mitigating Drought and Combating Desertification

In western Rajasthan it is a saying that during a span of 100 years 7 are famine years, 27 good years, 63 are likely to have less than normal rainfall, and 3 are destined to have such disastrous famine that people have to leave home and hearth without any possibility of returning [15]. Since climate is harsh in the region, and resource endowments are poorer than in other wetter parts of the county, recurrence of drought has compelled the local population of western Rajasthan to device through centuries of learning, ingenious ways to cope with this vagary of nature. Traditional communities of the Thar Desert have a vast knowledge, experience and capacity for developing innovative practices and products from their environment. Keeping the land fallow for a certain period (but used for grazing), livestock fanning, mixed fanning, agro-forestry, traditional water harvesting in ponds, covered tanks, *etc.*, animal husbandry is some of the mechanism through which desert dwellers used to mellow the effects of drought and at the same time ensure long-term sustainability of the resources.

Animal-Human Co-dependency

Animal-human relationships and their co-dependence in Thar Desert assumes prime importance. As per 2011 and 2012 census of human and livestock respectively, livestock to human ratio is highest (1:1.45 as per 2011 census) in arid zone of Rajasthan as against 1: 0.5 in rest of the country. Peoples of this this region are well aware of the adverse and uncertain climatic conditions of this region. Agricultural production is gamble due to droughts which occurs every alternate year (probability 47%). Agriculture is more prone to drought as compared to livestock rearing. Under drought years, agricultural production may be as low as 10% of the normal year whereas livestock production may still remain more than 50% of normal year [16]. Livestock is an important asset of the inhabitants and significantly supplements household economy [17]. As per 2012 livestock censes the total population of livestock in arid Rajasthan is 30.07 million. Goat constitute 42.53% of total livestock population followed by Sheep (22.87%), Cattle (20.55%), Buffalo (13.12%) and Camel (0.92). Goat played a very important role in survival of human being in arid zone during extreme droughts and femines that goat is known as walking ATM (Any Time Money) for its milk and meat value with least maintenance. Livestock rearing is the traditional functional specialisation of different castes and communities in the region. *Raika* is the most predominant traditional livestock rearing community [17]. *Gujjars, Rajputs, Jats, Mali, Kumhars* and *Sirvi* also rear livestock in addition to cultivation of crops. The animals are hardy in arid areas therefore productivity of arid livestock is better in comparison to other climatic conditions. Livestock farming has been recognized as an instrument of drought proofing [18].

Fallow Land System

The dominant soils in the great Indian desert are light sandy with low organic matter (0.03-0.30%), alkaline reaction (pH 8.2-8.8), poor fertility, low water-retention capacity (70-100 mm/m), and susceptible to wind and water erosion [19]. Continuous cultivation on same piece of land further degrades its texture and reduces the fertility. The traditional practice that has been followed since time immemorial is to leave land fallow for a longer period to gain fertility and protect open land from wind erosion. The crop-fallow rotation has assisted in rebuilding soil fertility and has also provided space for grazing and collection of fodder, fuel and minor forest produce [17]. The practice of crop-fallow rotation and traditional agro-forestry are two important methods used by the Thar Desert communities for improving the soil fertility and combating droughts.

Traditional Agroforestry System

The sole cultivation of crops is very risky and even uneconomical in arid areas due to extreme and adverse climatic conditions. Therefore, most desert farmers raise livestock as a subsidiary occupation and allow trees and shrubs to grow on cultivated tracts in order to cover risk and uncertainty of crop production. Agroforestry although integrated with agriculture, is an age old, well defined land use system of western Rajasthan. The traditional agroforestry system in the villages of the Thar Desert includes the number of trees, especially *Khejri* (*Prosopis cineraria*) and *Ber* (*Z. nummilaria*) are the most important multipurpose woody components of traditional agroforestry system [20, 21]. Trees provide fodder, fuel and other minor forest produce, besides keeping part of the cropland under natural vegetation. *Ber* (*Z. nummilaria*), Hingona (*Balanites aegyptiaca*) and *Aak* (*Calotropis procera*) bushes have deep roots, which are cut before planting the next crop and provide various kind of products to local communities.

The tree based agricultural systems are considered more efficient in nutrient cycling than many herbaceous systems because of the extensive and deeper root system of trees than the herbaceous species [22]. Trees provide an assurance to the farmers towards sustainable crop production in normal rainfall year, while in drought and famine years, they provide top feed for livestock [23].

Management of Pasture lands: A traditional approach

Religious practices have played a very important role in management of pasture lands in arid zone since time immemorial. Grazing of livestock is common practice in arid zone of Rajasthan. The traditional systems of grazing in western Rajasthan are in form of *orans* and *gauchars*. The village green woodlands are called as *orans* and grazing lands are called as *gauchars*. The native people of the Thar Desert have a healthy tradition of preserving *orans* and *gauchars* in the name of a local deities. These are land attached to deities and were considered sacred forest and were excellent source of biodiversity conservation. In '*Orans* & *Gauchars*' nobody is allowed to cut trees or shrubs. Only animals can graze over the vast areas which are full of biomass. Statute/symbol of local Gods/Goddess (*i.e*., *Thans, Majisa Jamboji, Jog Maya, Bhomiaji, Pabuji, Harbuji, Ramdeoji, Mamaji* and others.) are established under the shade of trees and nobody is allowed to cut trees, twigs or leaves due to the fear of the gods/goddesses. Traditions of planting trees around temples, religious places, farms, wells and community places have been practiced since old days to check the spreading of desertification around villages. These practices maintained a proper ecosystem and reduce the expansion of the process of desertification.

Orans and *Gauchars* occupy about 62000 ha area in western Rajasthan. In the recent past over population of livestock has put a tremendous pressure on the grazing lands. Due to heavy grazing pressure, poor management and poor rainfall conditions the carrying capacity of these ranges and grasslands reduced to 0.68 ACU ha^{-1} [24]. There is need to restore these grazing lands by reseeding and introduction of perennial grasses, shrubs and bushes for increasing the productivity. The highly nutritive fodder grasses such as *Lasiurus sindicus, Cenchrus ciliaris, C. setigerus* and *Cymbopogon jwarancusa* are well adapted to the Thar Desert environment [25].

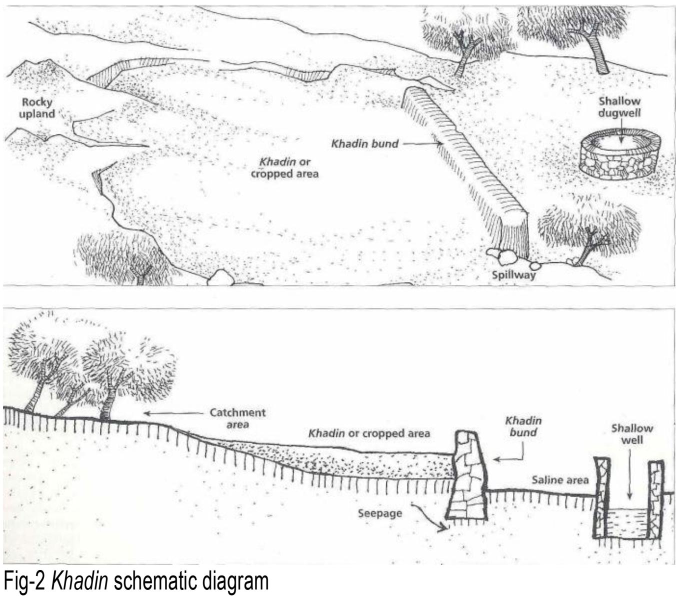


Fig-2 *Khadin* schematic diagram

***Khadin*- Runoff farming for crop production in hyper arid areas**

Traditionally, *Khadin* system was designed and developed by the Paliwal Brahmins of Jaisalmer (Rajasthan) in 15th century [26]. This system has a great similarity with the irrigation methods found some time back in 4500 BC in Iraq, and in Nabateans of the Middle East. *Khadin* is a low-lying area surrounded by rocky catchment and is therefore site-specific technique of runoff farming in hyper arid zone (rainfall < 250 mm) of India. Meagre runoff generated by low rainfall from a larger catchment (usually rocky) is concentrated in a low-lying smaller area (known as *Khadin*) to the height of 60-90 cm during monsoon season and crops (*i.e*., wheat, mustard and gram) are grown in *rabi* season on conserve moisture [Fig-2]. Since runoff from a very large catchment belonging to many farmers is get collected in a smaller area, therefore production from *Khadin* is shared on the basis of size of catchment of the contributing farmer.

Research on *Khadin* soils indicated that they are more fertile compared to other desert soils. The organic carbon contents in surface and sub-surface soils varies from 0.39 to 0.76% and from 0.12 to 0.40%, respectively [27]. As crops are grown on conserved moisture in *Khadin*s, application of fertilizer is generally not practised. The available P_2O_5 and K in the soil varied from 26-120 and 300-1000 kg ha^{-1}, respectively. The total nitrogen content in different *Khadin* ranges 0.018-0.035%, and pH of the surface is usually below 8.5 [28]. The *Khadin* has great promise for enhancing crop production in hyper arid region like Jaisalmer [29].

Tanka- A traditional source of drinking water and lifesaving irrigation

Collection and storage of excess rainwater in tankas (underground cisterns) is an age-old tradition for meeting domestic water requirements. Till today, the most of the villages are depending on these structures as source of drinking water. Tankas were usually constructed near religious centres and in villages for community usage due to the belief in the sanctity of water. Beside this, every household used to have underground tanka of varying capacity from 5-15 thousand litres to meet drinking water requirement of the family. Big families used to have more than one tanka in their homes. Community tanka of 3-5 lakhs capacity were found the arid region. Smaller tankas are generally connected with rooftop for rainwater harvesting. However, artificial catchment was constructed for rainwater harvesting for larger/community tanka.

Vangani [30] have observed that an individual family tanka is better managed than a community tanka. The water collected in small tankas is generally used for drinking purposes. Since, complete drought or long dry spells within a season are very common in this region, the harvested rainwater from bigger tankas can be used to provide supplemental/lifesaving irrigation particularly to trees and crops. It was observed that with supplemental irrigation the fruit yield of *ber* (*Ziziphus mauritiana*) and pomegranate increased substantially in comparison to no irrigation [31, 32]. The system of rainwater harvesting by tankas and subsequently its recycling for life saving irrigation can provide an effective check against dry spells and drought for economic yields [33, 34]. Construction of tanka on individual family basis has psychological impact of pride of ownership to the beneficiaries. Planation of suitable species of trees around tanka at many places has helped in environment improvement.

***Nadis*-A community pond**

Nadis are village ponds used to store runoff water from adjoining natural catchments during the rainy season. In arid Rajasthan *nadi* system of water harvesting is the oldest practice and still the principal source of water supplies for human and livestock consumption [35]. Across Rajasthan, most *Nadis* have a capacity of between 1,200 to 15,000 m^3. Water availability in *nadi* ranged from 2-12 months after the rains. In the old days, *Nadis* were constructed with the active help of community participation. Grazing cattle, defecating or urinating, and felling trees or plants in the catchment of the *nadi* were strictly prohibited. The village folk used to clean up the *Nadis* regularly. Since *Nadis* received runoff from sandy and eroded rocky basins, large amounts of sediments used to deposit regularly in them, resulting in quick siltation.

High evaporation and seepage losses through porous sides and bottom, heavy sedimentation due to biotic interference in the catchment and contamination are major bottlenecks. Evaporation losses ranged from 55 to 80 per cent of the total losses in various environments [36]. Seepage losses are greatest during the rainy season (July-September) when *nadi* is completely filled. To overcome these problems, LDPE lining on sides and bottom keeping surface to volume ratio 0.28 and provision of silt trap at inlet was found to be effective [37]. The site selection of *nadi* is based on availability of natural catchment and its runoff potential. The location of the *nadi* had a strong bearing on its storage capacity due to catchment and runoff characteristics. *Nadis* are 1.5 to 4.0 m deep in dune areas and those in sandy plains vary from 3 to 12 m. In addition, planting suitable tree species around the *nadi* creates an oasis in the desert and improves the local environment [38].

Fig-3 Improved *Nadi* with LDPE lining

***Baori* /Bawdi**

Baoli/Bawdi are essentially step wells usually found in Rajasthan, Gujarat and some parts of northern India. The main purpose for construction of these stepwells is primarily to provide domestic water with safety and ease to the local people without use of bucket and rope. *Baori* are normally rectangle in shape with steps on three sides. The main source of water in the *Baori* is essentially groundwater, therefore *Baori* are usually more than 50 feet deep. The people's science has played a marvellous role in design and development of *Baori* in this region. *Baori* is a bigger structure and require lot of labour and material, therefore, these *Baori*'s are constructed with community participation and most of time with help of local ruler. One is two *Baori* are very common under one local community or kingdom. *Baori* also serves the purpose of common place of gathering for social function and resting place for outside travellers. Sculptures and inscriptions in stepwells demonstrate their importance to the traditional social and cultural lives of people [39]. Some of the famous *Baori*'s of Rajasthan include Chand *Baori* (800-900 AD)-Abhaneri near Bandikui [Fig-4], Neemrana *Baori* (1760 AD)-Neemrana, *Panna-Meena-Ka-Kund* (16th Century)- Amer, Dhabhai-Ji-ka-Kund (1658 AD)-Bundi, and most recently added Birkha *Baori* (2005-2008 AD) in Jodhpur. If the city of Bundi, is referred as the "City of Stepwells" then Rajasthan is "The State of Stepwells" as the highest number of Indian Stepwells are in Rajasthan [40]. Due to indiscriminate exploitation of groundwater for various purposes, the water table is declining at faster rate and most of the stepwells are now dried up except few with tourism attraction. There is need to encourage groundwater recharge in these areas.

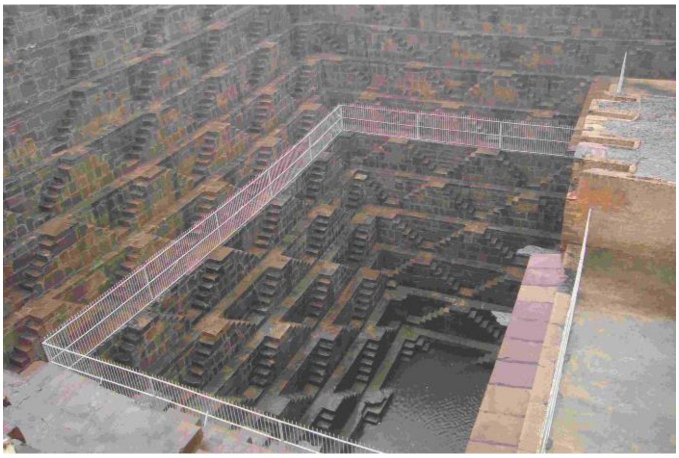


Fig-4 *Chand Baori* Abhaneri (Distt. Bandikui)-Rajasthan

Jhalaras

Jhalaras are human-made water harvesting structure similar to *Baori* found in Rajasthan and Gujarat. *Jhalaras* water is primarily meant for community use and for religious rites. The main difference between *Baori* and *Jhalaras* is essentially source of water. The main source of water in *Jhalaras* is surface water. The *Jhalaras* collect subsurface seepage of a talab or a lake located upstream. Surface runoff from surrounding catchment is also allowed to collect in *Jhalaras*. The water from these *Jhalaras* was not used for drinking but only for community bathing and religious rites [41]. *Toor-Ji-Ka-Jhalra* (6th Century), *Mahila-Bagh-ka-Jhalra* and Mahamanir Jhalara (1660 AD) are some the main *Jhalaras* located in Jodhpur city.

Kuis / Beris

Kuis/*Beris* is a unique system of water harvesting in hyper arid region of western Rajasthan. A *Kuis* is in fact a very small dug well (*kuan*), *Kuis* is feminine and *kuan*, masculine. The *Kuis* is actually small only in width, as far as its depth goes, it is quite deep. *Kuis* or *beris* are normally 5 meters (m) to 12 m deep with a very narrow opening. The pit gets wider as it burrows under the ground. The *Kuis* differs from the normal well (*kuan*) in yet another way that *kuan* is dug to tap the water table but the *Kuis* does not access the water table in the same way as the *kuan* does. The *Kuis* collects rain water in a very special way. This system is based on the principle of collection of percolated rainwater deep down from the sandy terrain. In order to harvest percolated rainwater deep from sandy soils, a narrow and deep pit known as *Kuis*/*beris* in local language is constructed in the sandy catchment. The digging and construction of pit is highly specialized work done by specific trained local people known as Chelvanjis or Chejaros [42]. Usually, 30-50 litres of water are collected in a day. Therefore, *Kuis* water is used sparingly, as a last resource in crisis situations [43]. *Kuis* are generally found in Jaisalmer and Barmer [Fig-5] districts of Rajasthan where rainfall is very low and groundwater is very deep and saline.

Fig-5 *Kuis* in Barmer

Kunds/Kundis

The *Kunds/Kundis* are typical rainwater harvesting structures of Thar Desert of Rajasthan. The main different between tanka and *kunds* is the location and shape of the structure. The *Kunds* are essentially constructed outside the home whereas tankas are typically constructed inside the house [44]. The shape of traditional tankas is rectangle depending on the available space within the house whereas *kunds* are essentially circular in shape. *Kunds* have a saucer-shaped catchment area that gently slopes towards the centre where the *kund* is situated [Fig-6]. The catchment of *kunds* is made with lime and mortar for higher runoff generation. The side wall of *kunds* is covered/plastered with lime and ash. Most *kunds* have a dome-shaped cover to protect the water. If Water is withdrawn with help of rope and bucket. For the poor, large public *kunds* have been in the practice in the region. The *kund* system of rainwater collection is reported to very effective even in rainfall as low as 100 mm [45].

Naada/Bandha

Naada/bandha's are the barriers created in the path of flowing channel/stream. The barriers are made of stone or other locally available materials. The main purpose of naada/bandha is to temporary reduce the velocity of flowing water and allowing flowing silt to deposit at upstream [Fig-7] With successive deposition of silt, soil retains substantial amount of nutrients at upstream and land become more fertile [46].

Fig-6 Kunds in Jhunjhunu

Fig-7 Masonry barrier across the stream

Johads

Johads are simple stone/mud/dead vegetation barriers built across the contour on sloping land to arrest rain water. *Johads* have high embankments on three sides while the fourth side is left open for rain water to enter. The main different between Naada/Bandha and *Johad* is that former is constructed on streams/channels whereas later is constructed on contours across the slope. A *Johad* prevent rain water from running off, allowing it to percolate into the ground, recharging water aquifers and improve the water balance of the earth [47]. In the villages, where *Johads* have been revived water is shared among the villagers. *Johads* have played a very important role in the rejuvenation of the *Arvari* and *Ruparel* rivers through rainwater harvesting and groundwater recharge in Alwar district of Rajasthan [48, 4].

Mulching to control Soil erosion

Among the soil conservation practices that are used, mulching has been successfully applied to reduce soil and water losses in different contexts, such as agricultural lands, rangelands and anthropic sites [50]. Indigenous knowledge of conservation strategies provides evidence that crop residues, manure and leaves of vegetation were used for mulching the fields. Mulching is done by collecting locally available brushwood which is buried vertically, crown-downward, two to five meters apart in lines, to reduce the wind velocity on the dune surface. Growing of legumes like cowpea, green gram, kidney bean and creepers like watermelon, muskmelon, snap melon, desert gourd and fodder crops (cluster beans) provide improved protection against soil erosion. Another important practice is the stubble mulching that is followed for checking sand movement. Stubble and roots bind the soil and prevent erosion. Mulching can stabilize soils, and reduce storm water runoff velocity [3]. This age old traditional practice can now be used to facilitate the combating of desertification [51].

Med-Bandi/Field Bunding

Med-Bandi is essentially field bunding practiced by the farmers of arid zone. The main purpose of this type of bunding is primarily to demarcate field boundary and, to control soil erosion by wind and to prevent outflow of rainwater from their fields. In *med-bandi* a mud wall is raised on a field boundary to height of 0.9 to 1.2 m. To strengthen the med-bund local vegetation *i.e.*, *Crotolaria burhi, Panicum turgidum, Leptadenia spartum, Calliogonum polygonoides* and others are planted in the beginning. In 2-3 years, bunds become very strong and helps to prevent the trespassing of men and animals and to reduce wind velocity. Farmer prefers field bunding rather than contour bunding for soil and water conservation.

Kana Bunding/Micro Wind Break

Kana bunding is traditional practice of arid zone farmers to control wind erosion from arable lands. It is an indigenous technique and adopted in the field after harvesting of *kharif* crops. In this technique twigs and branches of bushes are fixed in a rectangle to stabilise the fertile topsoil of the field. The local material like *Crotalaria burhia, Leptadenia pyrotechnica*, pruning of *Ziziphus mauritiana, Prosopis cineraria, Calligonum polygonoides* also local grasses such *Lasiurus scindicus, Saccharum munja* are embedded in the soil leaving 30-45 cm length of the material vertically on the ground in lines 2-5 m apart [52]. This practice checks soil erosion to a great extent [Fig-8]. For sand dune stabilization Kana bunding is done in square or rectangular manner (chessboard fashion 2 to 3 m^2). During *Kharif* the organic material is incorporated in the soil, thereby help in increasing organic matter content.

Fig-8 Micro Wind Break to control soil erosion on sand dunes

Night Penning

Soils in the arid regions are mostly sandy with poor fertility and very little water holding capacity. Night penning is the traditional practice in this region. Night penning of the animals like cattle, sheep, goats and camels is one of the traditional methods of enhancing soil fertility. Penning is a fascinating cooperative effort between pastoralists and farmers and facilitates the collection of organic manure. Night penning of increases soil fertility by adding humus to the soil. It improves the soil condition, increasing aeration, water retention and converting complex substances into simpler forms for increased fertility [53]. Owners of the large fields offer shelter to the herds of sheep and goats so that the excreta of these animals remain in their fields and add organic material. There is a tradition of compensating the shepherds during the penning, either by cash, kind or both. The farmer in whose field penning is being done, would supply food materials, two times a day [4].

Rela Farming

This traditional technique of farming is very location specific. The technique involves diversion of ephemeral stream flowing at level lower than the adjacent field where irrigation water is needed. In this technique a more intricate dam is first built to raise the water level and subsequently to water is diverted to adjoining field located at little higher level in the monsoon.

This technique is practices in Sanchor tehsil of Jalore district in Rajasthan is known as rela farming [49]. The success of this technique primarily depends on the topography of the area. The bed of the flowing stream should not be sandy and stream must be full (spate) of water flowing at faster speed in monsoon season. The kinetic energy of flowing water is used to raise the level of water and then subsequently water is diverted at higher level to adjoining field

Tillage Practice

Tillage (Ploughing) is the practice of breaking and working the soil to the desired depth prior to sowing. At the onset of the monsoon season sandy soils are tilled to absorb more moisture. Timing and depth of tillage are the two important factors, which need special attention. Tillage should be done immediately before the crop season to take advantage of one or two early showers for land preparation [54]. In arid region, land tilled into ridges and furrows across the wind direction has been found to reduce the effects of wind erosion during the summer months. Traditionally at the time of clearing of the field, all the weeds are uprooted either manually or mechanically but shrubs like *Bordi* (*Z. nummularia*) and trees like *Khejri* are left for checking erosion and adding fertility to the soil. Excessive tillage before the monsoon lowers the percentage of clods and accelerated the wind erosion [55]. Therefore, proper tillage is very important to take advantage of moisture conservation during rain and at same time should avoid soil erosion by wind.

Conclusion

Frequent droughts in hot arid zone of Rajasthan call for drought proofing, mitigation and relief strategies involving traditional drought-coping mechanisms, water harvesting and its utilization, and diversification. Local communities through a long experience have develop sophisticated and specific ecological knowledge, manifested as agriculture and acquaintance with plants and animals, codified in cultural laws to preserve nature. Natural resources are products of culture and society, when working harmoniously with nature. These are not merely a resource, waiting to be mined from the earth using aggressive and obstructive technologies. Traditional social, cultural, religious, spiritual and people's science has greater significance for mitigating drought and combating desertification in great Indian Desert. Indigenous governance of water is needed from social and environmental points of view as well as a means to ensure water as a human right [56]. Rediscovery of traditions, with all their respective aspects, can restore and create just and sustainable livelihoods in India and globally.

Application of research: Study of Hot Arid Zone of India. Traditional social, cultural, religious, spiritual and people's science has greater significance for mitigating drought and combating desertification in great Indian Desert

Research Category: Natural Resources and traditional knowledge

Acknowledgement / Funding: Authors are thankful to ICAR-Central Arid Zone Research Institute (CAZRI), Jodhpur, 342003, Rajasthan, India

****Principal Investigator or Chairperson of research: Dr Mahesh Kumar Gaur**
Institute: ICAR-Central Arid Zone Research Institute (CAZRI), Jodhpur, 342003, Rajasthan, India
Research project name or number: Research station study

Author Contributions: All authors equally contributed

Author statement: All authors read, reviewed, agreed and approved the final manuscript. Note-All authors agreed that- Written informed consent was obtained from all participants prior to publish / enrolment

Study area / Sample Collection: Hot Arid Zone of Western Rajasthan, India

Cultivar / Variety / Breed name: Nil

Conflict of Interest: None declared

Ethical approval: This article does not contain any studies with human participants or animals performed by any of the authors.
Ethical Committee Approval Number: Nil

References

[1] Goyal R.K. and Gaur M.K. (2020) *International Journal of Agriculture Sciences*, 12(22), 10386-10388.
[2] Rao A.S. and Singh R.S. (1998) *Climatic Features and Crop Production. In A.S Faroda, and Manjit Singh (Eds.) Fifty Years of Arid Zone Research in India, Central Arid Zone Research institute, Jodhpur*, 17-38.
[3] Gaur M.K., Goyal R.K. and Shiran K. (2020b) *J. Rangeland Science*, 10(1), 57-72.
[4] Das S. (2010) *Journal of Geological Society India*, 75(2), 446-447.
[5] Goyal R.K. and Issac V.C. (2009) *Rainwater Harvesting Through Tanka in Hot Arid Zone of India. Central Arid Zone Research Institute, Jodhpur*, 33.
[6] Narain P., Rathore L.S., Singh R.S. and Rao A.S. (2006) *Drought Assessment and Management in Arid Rajasthan. Central Arid Zone Research Institute, Jodhpur*, 64.
[7] Ramakrishna Y.S., Rao A.S., and Joshi N.L. (1988) *Fertilizer News,* 4, 29-34.
[8] Ramakrishna Y.S., Rao A.S., Singh R.S. and Joshi N.L. (1991) *Proceedings of the National Seminar on Hydrometeorology, MPKV Res. Pub. No.* 8, Rahuri, 13-17.
[9] Anonymous (1992) *Managing fragile ecosystems, Combating desertification & drought. In Chapter 12, Agenda 21, United Nations Conference on Environment & Development, Rio de Janeiro. A/CONF.151/4 (Part II), United Nations, New York, pp*. 44-66.
[10] Safriel U. and Adeel Z. (2005) *Dryland systems. In Ecosystems and Human Well-being, Current State and Trends (Eds. R. Hassan, R. Scholes and N. Ash),* Vol. 1, pp. 625-658. Island Press, Washington.
[11] Ghose B., Singh S. and Kar A. (1977) *Annals of Arid Zone,* 16, 290-301.
[12] SAC (2016) *Desertification and Land Degradation Atlas of India (Based on IRS AWiFS data of 2011-13 and 2003-05), Space Applications Centre, ISRO, Ahmedabad, India*, 219.
[13] Santra P., Moharana P.C., Kumar M., Soni M.L., Pandey C.B., Chaudhari S.K. and Sikka A.K. (2017) *Aeolian Research,* 28, 71-82.
[14] Sarkar S., Padaria R.N., Vijayragavan K., Pathak H., Kumar P., Jha G.K. (2015) *Indian Journal of Traditional knowledge*, 14(2), 251-257.
[15] Singh H.P., Kavia Z.D., and Narain P. (2004) *Bharatiya Thar registan mein paramparik tarike se varsha jal ka sangrahan. In, Bharatiya Thar Registan Mein Paramparik Cyan ka Bhandar va Upayog* (in Hindi). *CAZRI, Jodhpur*, pp.1-15.
[16] Patil N.V., Mathur B.K., Khan M.S., Bohra H.C., Patel A.K., Patidar M., Rohilla P. P., Saha D.K., Khem Chand, Mathur A.C., Kachhawaha S., Kaushish S.K., Karim S.A., Shinde A.K., Pathak K.M.L. and Lal C. (2009) *In Trends in Arid Zone Research in India (Eds. Amal Kar, B.K. Garg, M.P. Singh and S. Kathju), Central Arid Zone Research Institute, Jodhpur*, 180-209.
[17] Gaur M.K., Mathur, B.K. and Chauhan, J.S. (2018) *International Journal of Agriculture Sciences*, 10(16), 6920-6929.
[18] Narain P., Sharma K.D., Rao A.S., Singh D.V., Mathur B.K. and Ahuja U.R. (2000) *Strategies to combat Drought and Famine in the India Arid Zone. Central Arid Zone Research Institute, Jodhpur*, 65.
[19] Bhati T.K., Kumar S., Amare H. and Whitbread A.M. (2017) *Assessment of Agricultural Technologies for Dryland Systems in South Asia, A Case Study of Western Rajasthan, India. Patancheru 502 324. Telangana, India, International Crops Research Institute for the Semi-Arid Tropics*, 68.

[20] Mann H.S. and Saxena S.K. (Eds.) (1980) *Khejri (Prosopis cineraria) in Indian Desert-Its Role in Agroforestry. CAZRI Monograph* 1, *CAZRI, Jodhpur*, 93.
[21] Mann H.S. and Saxena S.K. (Eds.) (1981) *Bordi (Z. nummilaria) in Indian Arid Zone-Its Role in Silvipasture. CAZRI Monograph* 13, *CAZRI, Jodhpur*, 93.
[22] Nair P.K.R. (1995) *An Introduction to Agroforestry. Kluwer, Dordrecht, The Netherlands.*
[23] Saxena S.K. (1994) *Annals of Arid Zone,* 33, 279-285.
[24] Yadava N.D., Soni M.L., Rathore V.S., Bagdi G.L., Subulakhsmi V. and Gaur M.K. (2018) *Annals of Arid Zone* 57(3&4), 89-96.
[25] Gaur M.K., Goyal R.K., Kalappurakkal S. and Pandey C.B. (2018) *Int. Journal of Sustainable Development & World Ecology*, 1-10.
[26] Sehgal K.K. (1973) *Rajasthan district Gazetteers-Jaisalmer, 8, 82-121, Jaipur, India. Director, District Gazetteers, Govt. of Rajasthan*
[27] Singh N., Kolarkar A.S. (1983) *Indian Journal of Soil Conservation*, 11 (2-3), 5-11.
[28] Prasad R., Mertia R.S. and Narain P. (2004) *Journal of Arid Environments,* 58, 87-96.
[29] Goyal R.K., Singh J.P. and Gaur M.K. (2018) *Indian Farming,* 68(09), 26-28.
[30] Vangani N.S., Sharma K.D. and Chatterjee P.C. (1988) *Tanka - a reliable system of rainwater harvesting in the Indian desert. CAZRI Bulletin No. 33, CAZRI, Jodhpur, 16*.
[31] Khan M.A. (1995) *Journal of Natural Heritage Institute*, 4, 53-59.
[32] Goyal R.K., Ojasvi P.R. and Bhati T.K. (1995) *Indian Journal of Soil Conservation,* 23(1), 74-76.
[33] Goyal R.K., Ojasvi P.R. and Gupta J.P. (1997) *Asian Watmanet*, *newsletter*, 11, 12-13.
[34] Goyal R.K. and Sharma A.K. (2000) *Intensive Agriculture*, 38(5-6), 12-14 & 26.
[35] Sharma K.D. and Joshi D.C. (1981) *Journal of Arid Environment*, 4, 247-251.
[36] Sharma K.D. and Joshi D.C. (1983) *Journal of Arid Environment*, 6, 277-281.
[37] Khan M.A. (1989) *Water and Irrigation Review*, *Israel*, 19, 20-23.
[38] Goyal R.K., Dorjey A., Tsering S., Singh S.B., Kumar H. (2009) *Surface and Groundwater Resources of Arid Zone of India, Assessment and Management. Trends in Arid Zone Research in India (Eds. Amal Kar, B.K.Garg, M.P.Singh and S. Kathju)*, 113-150.
[39] Davies P. (1989) *The Penguin guide to the monuments of India. London, Viking*
[40] http, //jatinchhabra.com/indian-stepwells/ (accessed 05/12/2020)
[41] Saxena D. (2017) *International Journal of Engineering Trends and Technology,* 52(2), 91-98.
[42] Mishra A. (2001) *The Radiant Raindrops of Rajasthan. Gandhi Peace Foundation, New Delhi, Published by Research Foundation for Science, Technology and Ecology, India,* 143.
[43] Bhattacharya S. (2015) *International Letters of Natural Sciences,* 37, 30-38.
[44] Gaur M.K., Chauhan J.S., Mishra S.A., Ismail Sheikh I., Mehrishi P. and Goyal P. (2020a) *International Journal of Current Microbiology and Applied Sciences*, 912, 1553-1568.
[45] Bhalge P. and Bhavsar C. (2007) *International History Seminar on Irrigation and Drainage, Tehran-Iran*, 423-428.
[46] Agarwal A., Narain S. (ed.) (1997) *Dying wisdom, Rise, fall and potential of India's traditional water harvesting systems. (State of India's Environment - A Citizens' report, No. 4). Centre for Science & Environment (CSE), New Delhi*, 11-12.
[47] Borthakur S. (2008) *Indian Journal of Traditional Knowledge*, 8(4), 525-530.
[48] Sharma A. (2006) *Water harvesting context in the Indian Subcontinent. UNESCO G-WADI meeting on water harvesting Aleppo Syria 20-22, November*, 2006, 63-70.
[49] Das P., Das S.K., Arya H.P.S., Reddy G.S. and Mishra A. (2002) *Inventory of Indigenous Technical Knowledge in Agriculture-Document 1. Indian Council of Agricultural research, New Delhi*, 411p.
[50] Massimo P. & Artemi C. (2016) *Earth-Science Reviews*, 161, 191-203.
[51] Gaur M. and Gaur H. (2004) *Internat. J Environmental Monitoring and Assessment*, 89-103.
[52] https://krishi.icar.gov.in/PDF/Selected_Tech/swm/26-swm-sand%20dunes %20stabilization. pdf (Accessed on 06/12/2020)
[53] Zhang Y.J., Jiang W.L. & Ren J.Z. (2001) *New Zealand Journal of Agricultural Research*, 44(2-3), 151-157.
[54] Goyal R.K., Khan M.A., Bhati T.K., Pandey C.B. and Roy M.M. (2013) *Watershed Management for Development of Hot Arid Zone of India. Central Arid Zone Research Institute, Jodhpur, India*, 46p.
[55] Gupta J.P. (1993) *Wind erosion of soil in drought prone areas. In, Desertification and its control in the Thar, Sahara and Sahel Regions (Eds. A.K. Sen and Amal Kar), Scientific Publishers, Jodhpur*; 91-105.
[56] Risse M. (2013) *The Human Right to Water and Common Ownership of the Earth. HKS (the Harvard Kennedy School) Faculty Research Working Paper Series RWP13-003*, February 2013.