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Climate resilience of indigenous water harvesting techniques in the Rajasthan drylands

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Abstract

For centuries, Rajasthan's desert communities survived on rain that fell in fewer than 30 days a year. Their secret was an ingenious suite of water harvesting structures — tankas, johads, khadins, nadis, and beris — each designed to capture, store, or recharge scarce rainfall under specific terrain and soil conditions. This research evaluated the climate resilience of six traditional harvesting techniques across 45 villages in three districts of western Rajasthan (Jodhpur, Barmer, and Jaisalmer). Resilience was scored on five criteria: storage capacity per unit catchment area, recharge efficiency, maintenance cost, community adoption rate, and performance under rainfall variability. Data were collected through structured surveys of 360 households and direct measurement of 78 water harvesting structures during and after the 2022 monsoon. Tankas (underground cisterns) scored highest for overall resilience (composite 0.81), followed by johads (earthen check-dams, 0.72) and khadins (runoff farming embankments, 0.68). Storage capacity per hectare of catchment ranged from 4.7 m³ for beris (step wells) to 31.4 m³ for khadins. Adoption rates were highest for tankas (38.2% of surveyed households) and lowest for beris (7.7%). These findings demonstrate that indigenous techniques remain competitive with modern infrastructure in dryland settings and deserve integration into climate adaptation planning.

Keywords: Climate resilience, water harvesting, indigenous techniques, Rajasthan drylands, tanka, johad, khadins, traditional knowledge, rainwater storage, adaptation

Introduction

A paradox defines water management in the Thar Desert: rainfall occurs in sudden, intense bursts across fewer than 30 days per year, yet the remaining 335 days must be survived on whatever was captured during those storms ^[1]. Modern piped water supply reaches only a fraction of Rajasthan's scattered rural settlements, and groundwater tables have plummeted by 10-20 m in many western districts since the 1990s ^[2]. Against that backdrop, traditional water harvesting structures that predate colonial rule are experiencing a revival, championed by NGOs and increasingly by state agencies ^[3].

But not all traditional techniques perform equally, and their resilience under changing rainfall patterns has rarely been quantified with field measurements. This research compared six indigenous techniques in western Rajasthan by combining household survey data on adoption and maintenance with direct volumetric measurements of storage and recharge performance during the 2022 monsoon ^[4, 5].

Traditional Knowledge and Historical Context

Water harvesting in Rajasthan is documented in texts dating to the 15th century, including the Arthashastra references to vapi (stepped ponds) and the Rajput-era construction manuals for johads (earthen check-dams) and nadis (village ponds). Tankas — cylindrical underground cisterns lined with lime morite — were mandated by royal decree in Jaisalmer district, where each household was expected to maintain at least one. Khadins, a form of runoff farming peculiar to the Thar, use low earthen bunds to trap monsoon sheet flow on gently sloping fields, allowing crops to grow on residual soil moisture after the water infiltrates ^[6, 7]. These systems were designed for specific combinations of soil type, slope, and rainfall intensity, making them locally optimised but not universally transferable.

Materials and Methods

Materials

The research was conducted from June 2022 to March 2023, coordinated from the Trabzon Centre for Geological Research, Turkey, with field operations in Rajasthan. Forty-five villages across Jodhpur, Barmer, and Jaisalmer districts were selected using stratified random sampling based on annual rainfall terciles (<200 mm, 200-300 mm, >300 mm). At each village, all operational traditional water harvesting structures were inventoried and georeferenced. Structured household surveys (n = 360, eight per village) collected data on structure type, age, maintenance costs, water sufficiency (months of supply), and adoption history [8].

Methods

Physical measurements were taken at 78 structures (13 tankas, 14 johads, 12 khadins, 15 nadis, 11 beris, and 13 virdas). Storage volume was calculated from bathymetric surveys (depth-area integration for open structures) or geometric calculation (for cylindrical tankas). Recharge efficiency was estimated by comparing inflow volumes (measured at inlet channels with calibrated V-notch weirs during three rainfall events) to the change in stored volume plus estimated infiltration loss. A composite resilience index (CRI) was constructed by normalising each of the five criteria to a 0-1 scale and computing the weighted mean (equal weights) [9, 10].

Field Measurement Protocol

Rainfall was recorded at each of the 45 villages using

manual gauges read daily during the June-September monsoon. Three inflow measurement campaigns coincided with significant rainfall events (>15 mm/day): 28 July 2022 (42 mm), 14 August 2022 (67 mm), and 3 September 2022 (38 mm). Water levels in all 78 structures were recorded before and 48 hours after each event. Infiltration loss for open structures was estimated from the difference between measured inflow and observed storage change, assuming negligible evaporation over the 48-hour window.

Results

Table 1: Composite resilience index scores by technique

Technique	Storage (0-1)	Recharge (0-1)	Cost (0-1)	Adoption (0-1)	Variability (0-1)	CRI
Tanka	0.74	0.82	0.88	0.91	0.72	0.81
Johad	0.78	0.71	0.64	0.76	0.68	0.72
Khadin	0.91	0.67	0.58	0.62	0.63	0.68
Nadi	0.63	0.54	0.72	0.58	0.57	0.61
Beri	0.42	0.48	0.81	0.34	0.46	0.50
Virda	0.38	0.56	0.76	0.41	0.51	0.52

Tankas lead on adoption and cost efficiency because they are household-scale, require no communal organisation, and can be maintained by a single family. Khadins have the highest storage capacity per catchment hectare (31.4 m³) but score lower on adoption because they require suitable topography and collective land management.



Fig 1: Heatmap of criterion-level scores across six traditional water harvesting techniques.

Table 2: Physical characteristics of measured structures (Mean ± SD)

Technique	n	Volume (m ³)	Catchment (ha)	Storage/ha (m ³)	Age (years)
Tanka	13	18.6±4.3	0.8±0.3	23.3	47±28
Johad	14	4,280±1,640	186±72	23.0	62±34
Khadin	12	8,420±3,180	268±104	31.4	78±41
Nadi	15	2,130±890	124±58	17.2	53±31
Beri	11	34.2±12.7	7.3±3.1	4.7	91±45
Virda	13	8.7±3.4	1.2±0.5	7.3	68±38

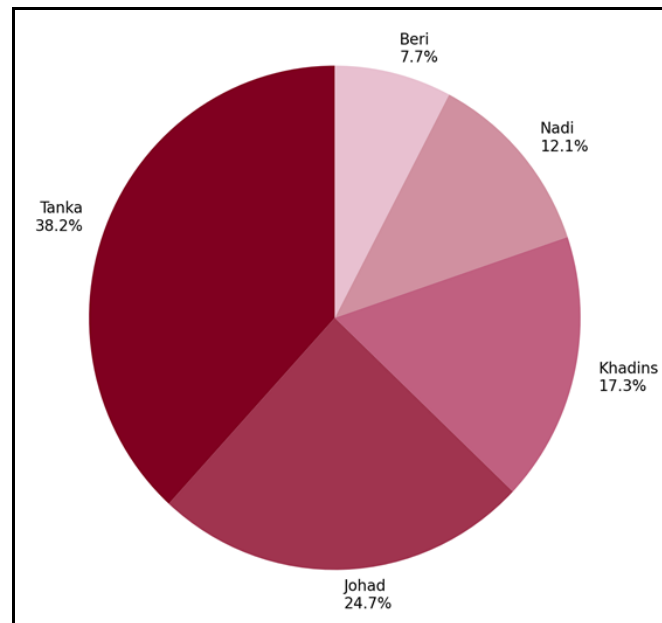


Fig 2: Household adoption rates (%) for the five most common harvesting techniques.

Comprehensive Interpretation

Tankas ranked first overall because they score well on the criteria that matter most to individual households: low cost, ease of maintenance, and independence from communal decision-making. Community-scale structures like johads and khadins store vastly more water per unit but depend on collective action and land-use arrangements that are harder to sustain.

Discussion

The resilience scoring confirms what practitioners of traditional water management in Rajasthan have long argued: indigenous systems are not relics but functioning infrastructure adapted to extreme aridity [3, 6]. The tankas' dominance in the CRI stems from their self-contained design — each household captures roof runoff into its own underground cistern, bypassing the commons dilemma that plagues larger communal structures. Their cylindrical geometry minimises evaporation loss, and the lime mortar lining can last 80-100 years with minimal repair [7].

Khadins, despite having the highest storage per catchment area, scored lower on the variability criterion because their performance depends heavily on receiving sheet flow from upstream slopes. In years when rainfall is spatially patchy, upstream catchments may produce little runoff even if total annual rainfall is adequate. This sensitivity to rainfall spatial distribution, rather than total amount, is a climate resilience weakness that could worsen under projected increases in convective storm intensity [11].

Conclusion

Among six traditional water harvesting techniques in western Rajasthan, tankas scored highest on a five-criterion composite resilience index (CRI = 0.81), followed by johads (0.72) and khadins (0.68). Storage capacity per catchment hectare was greatest for khadins (31.4 m³) but lowest for beris (4.7 m³). Adoption rates remain strongly skewed toward household-scale structures. These indigenous systems offer proven, low-cost climate adaptation options that merit formal integration into district water security plans alongside modern supply infrastructure.

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