Indian Knowledge Systems: Perspectives and Practices
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REVIVING INDIGENOUS WATER CONSERVATION PRACTICES FOR SUSTAINABLE MANAGEMENT OF THE JOJARI RIVER IN THE SALAWAS REGION, RAJASTHAN: AN INDIAN KNOWLEDGE SYSTEM (IKS)-BASED APPROACH

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Abstract: The Jojari River, flowing through the Salawas region of Rajasthan, is confronted with a complex web of ecological crises progressive water depletion, severe industrial pollution, and rapid biodiversity decline all accelerated by unchecked urbanization and groundwater over extraction. This study proposes a culturally grounded and ecologically viable restoration strategy rooted in Indian Knowledge Systems (IKS), advocating for the systematic revival of indigenous water harvesting structures such as Johads, Baoris, Taankas, and Khadins. Drawing on a mixed-methods research design that integrates GIS-based site suitability mapping, MODFLOW hydrological modeling, and participatory stakeholder engagement, the study synthesizes evidence from comparable restoration initiatives across Rajasthan to project realistic outcomes for the Jojari basin. Findings indicate that IKS-based interventions can facilitate groundwater recharge in the range of 7.91 to 12.50 million gallons per day, reduce pollution-related heavy metal indices by 20 to 46 percent through enhanced natural filtration, and create ecological conditions supportive of at least 40 avifaunal species. The study further anticipates a reduction in groundwater table decline of 25 to 50 percent over the intervention period. By bridging ancestral wisdom with contemporary hydrological and ecological science, this research offers a replicable, community-driven model for sustainable water governance in arid and semi-arid regions of India.

Introduction

Rajasthan, India's largest and most water-stressed state, sits predominantly within the arid and semi-arid climatic zone of the Indian subcontinent. Its fragile ecological balance is perpetually threatened by the dual pressures of an intensifying climate and rapidly expanding human demands on natural resources. Within this landscape, the Jojari River a seasonal watercourse traversing the Salawas region near Jodhpur embodies the cumulative consequences of ecological neglect. Once a life-giving artery for agricultural communities and a thriving habitat for diverse flora and fauna, the river has steadily degraded into a conduit for industrial and municipal wastewater, a stark symbol of environmental mismanagement in an already resource-scarce region.

The hydrological vulnerability of the Jojari basin is well-documented. Annual precipitation in the region ranges between 300 and 400 mm, concentrated almost entirely within the monsoon months of July through September (Maanju, 2014). However, erratic rainfall patterns, compounded by high evapotranspiration rates typical of desert-margin climates, result in minimal natural groundwater recharge. In critical aquifer zones, depletion rates have been recorded at 1 to 2 meters annually a trajectory that, if unchecked, threatens to render the basin hydrologically non-functional within a foreseeable horizon (Maanju, 2013). Simultaneously, industrial discharges predominantly from Jodhpur's textile and chemical processing industries have introduced alarming concentrations of heavy metals, including cadmium (Cd), lead (Pb), and chromium (Cr), into the river system. Studies have revealed that the Water Quality Index (WQI) of Jojari's waters ranges between 62 and 164, rendering them unfit for irrigation or domestic use, while the Heavy Metal Pollution Index (HPI) reaches values between 26,074 and 84,547 figures that exceed Bureau of Indian Standards (BIS) permissible limits by factors of tens of thousands (Kachhwaha et al., 2022).

Against this backdrop of ecological deterioration, Indian Knowledge Systems (IKS) offer a historically validated and contextually relevant pathway to restoration. Rooted in centuries of lived experience in water-scarce landscapes, IKS encompasses a rich repertoire of indigenous hydraulic structures Johads, Baoris, Taankas, and Khadins each

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engineered through generations of observation and refinement to capture monsoon runoff, replenish local aquifers, and sustain agricultural and domestic water needs through dry seasons (Journals, 2018). These systems are not merely technical artifacts; they are embedded in the social and spiritual fabric of Rajasthani communities, sustained by collective labor, communal governance, and an ethos of ecological stewardship. Their revival, therefore, is simultaneously a hydrological intervention and a cultural reclamation.

The literature on IKS in arid India provides compelling evidence for their efficacy. In the Arvari River catchment of Rajasthan, the strategic deployment of check dams and bunds analogous to traditional Johads was found to enhance the hydrological sustainability of the catchment by moderating the balance between groundwater recharge and abstraction (Glendenning & Vervoort, 2010). In the degraded hill landscapes of the Aravali range, rainwater harvesting structures paired with afforestation initiatives yielded measurable gains in both groundwater storage and soil carbon sequestration (Grewal, 2017). GIS-based multicriteria analyses conducted across Rajasthan have further demonstrated that approximately 3.6 to 8.2 percent of the landscape presents high-to-moderate suitability for traditional harvesting structures, with land use, vegetation cover, and slope emerging as primary determinants of site viability (Rawat et al., 2023).

Despite this growing body of evidence, no integrated study has yet examined the Jojari River specifically through the lens of IKS revival, linking hydrological restoration with pollution mitigation, biodiversity recovery, and community participation within a single interdisciplinary framework. This research addresses that gap. By combining GIS-based spatial analysis, MODFLOW groundwater modeling, participatory rural appraisal, and a systematic synthesis of analogous Rajasthan case studies, the study develops and proposes a comprehensive IKS-based conservation framework tailored to the ecological and socio-cultural realities of the Salawas region. In doing so, it aspires not only to offer a practical restoration roadmap for the Jojari basin but also to contribute a scalable model for indigenous water governance applicable to arid regions across India and beyond.

Objectives

The overarching aim of this study is to design and propose an Indian Knowledge Systems-based framework for the sustainable ecological and hydrological restoration of the Jojari River in the Salawas region, Rajasthan. The study seeks to demonstrate how the structured revival of indigenous water conservation practices can simultaneously address groundwater depletion, heavy metal pollution, and biodiversity decline, while reinforcing community ownership of water resources. To achieve this overarching aim, the following specific objectives guide the inquiry:

- To systematically assess the hydrological and ecological challenges confronting the Jojari River, with particular focus on groundwater depletion rates, water quality degradation, and biodiversity stress.
- To document, analyse, and evaluate the functional efficacy of traditional IKS practices — specifically Johads, Baoris, Taankas, and Khadins — in the context of water harvesting and aquifer recharge, drawing on comparative evidence from analogous Rajasthan systems.
- To develop and apply a mixed-methods methodology incorporating GIS-based suitability mapping, MODFLOW hydrological modeling, and participatory stakeholder engagement to identify optimal IKS implementation sites within the Salawas region.
- To synthesize and quantify outcomes from comparable rainwater harvesting initiatives across Rajasthan, including projected recharge volumes, improvements in water quality, and ecological recovery indicators.
- To propose a novel, interdisciplinary conservation framework that integrates IKS with contemporary scientific tools, emphasizing community-driven governance for long-term sustainability.
- To project expected outcomes of the proposed interventions, including a 25 to 50 percent augmentation in groundwater recharge, a measurable reduction in heavy metal pollution indices, and the sustained support of diverse avifaunal and aquatic communities.

Study Area

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The study area encompasses the Jojari River basin and its surrounding Salawas region, located in the Jodhpur district of Rajasthan, covering an area of approximately 400 square kilometres. The river originates in the northern uplands of the district and flows southward over roughly 60 kilometres before dissipating into seasonal drainage networks. The region falls within the transitional zone between the Thar Desert and the semi-arid plains of western Rajasthan, a landscape defined by its climatic extremes and ecological sensitivity.

Climatically, the area receives between 300 and 450 mm of annual rainfall, overwhelmingly concentrated during the monsoon season spanning July to September. Temperatures oscillate between near-freezing winter nights and scorching summer maxima exceeding 45°C, placing extraordinary physiological stress on both human populations and natural ecosystems. The terrain is characterised by undulating sand dunes, isolated rocky outcrops, and intermittent alluvial plains. Soils are predominantly sandy loam in texture — a composition that, while naturally low in cohesion and infiltration capacity, responds well to the structural interventions of traditional water harvesting systems (Rawat et al., 2023).

The Jojari is an ephemeral river, sustaining surface flow only during and immediately following monsoon events. Its shallow alluvial aquifer system, which historically provided a seasonal buffer for agricultural and domestic water needs, has been progressively depleted by intensive tube-well extraction. Over 90 percent of irrigation in the basin is now dependent on groundwater, and water table levels have declined at an annual rate of 1 to 2 metres (Maanju, 2013). The hydrological stress is compounded by industrial contamination: water quality assessments of the Jojari have returned WQI values between 62 and 164 — classifying the water as poor to very poor — while HPI measurements between 26,074 and 84,547 confirm severe heavy metal loading, far exceeding safe benchmarks set by international and national standards (Kachhwaha et al., 2022).

Ecologically, the Jojari's wastewater wetland, despite its degraded state, supports a surprisingly rich avifaunal assemblage of 40 species across 11 taxonomic orders. Winter migratory species such as the Common Sandpiper are among the seasonal inhabitants, though continued habitat deterioration and chemical contamination pose mounting threats to these populations (Das & Tripathy, 2020). Freshwater fish populations, including the Common Carp, face additional pressure from altered seasonal flow regimes and episodic drought conditions (Jhajhria, 2017).

The socio-cultural landscape of Salawas is shaped largely by Bishnoi and Rajput communities, whose traditional value systems historically incorporated a deep reverence for water and nature. Land use across the basin is heterogeneous: approximately 40 percent is under agriculture (primarily millets and pulses), 30 percent comprises scrubland and degraded rangeland, and 20 percent reflects the encroachment of urban expansion, which has intensified surface runoff and accelerated soil erosion. GIS analyses of the basin confirm moderate overall suitability for rainwater harvesting structures, with slope gradients of 2 to 5 percent, drainage density, and normalized difference vegetation index (NDVI) values serving as the primary spatial determinants of site viability (Rawat et al., 2023).

Indian Knowledge Systems and Water Conservation

Indian Knowledge Systems represent a vast and largely uncodified body of ecological intelligence — one developed not in laboratories or universities, but through generations of intimate human engagement with the land, water, and seasons of the subcontinent. In the arid landscapes of Rajasthan, where survival has always depended on the ability to capture, store, and judiciously distribute the scarce monsoon gift, this knowledge crystallised into a suite of ingenious hydraulic structures, each adapted to the specific geomorphological and hydrological conditions of its local context. Far from being mere engineering artifacts, these systems are living expressions of a philosophy that regards water not as a commodity but as a communal inheritance to be safeguarded across generations.

Johad: The Johad is perhaps the most iconic of Rajasthan's traditional water conservation structures — an earthen embankment, typically square or rectangular in plan, built across seasonal streams and drainage channels to impound monsoon runoff. These structures, which range from 2 to 5 metres in height and 50 to 100 metres in width, function

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primarily as percolation reservoirs, allowing impounded water to seep gradually into the underlying aquifer rather than being lost to evaporation or downstream flow. Historical records document their construction during periods of acute climatic stress, including the Chhapniya famine of the early twentieth century, when Johads served both as community lifelines and as expressions of collective resilience (Journals, 2018).

Comparative hydrological assessments from the Arvari River catchment in Rajasthan — a system geographically and climatically analogous to the Jojari basin — have demonstrated that Johad-type structures can significantly enhance the sustainability of local groundwater systems by moderating the balance between seasonal recharge and year-round extraction demands (Glendenning & Vervoort, 2010). When combined with afforestation programmes on the surrounding catchment slopes, Johads have been shown to facilitate soil carbon sequestration rates of up to 5.24 tonnes per hectare per year, contributing to both hydrological and atmospheric benefits (Singh, 2017). For the Jojari basin, it is estimated that a network of strategically sited Johads could capture 10 to 15 percent of annual monsoon runoff, directly offsetting the 1 to 2 metre annual groundwater decline currently observed (Maanju, 2013). Importantly, Johads also embody the principle of collective stewardship: in Bishnoi tradition, their construction and maintenance are community endeavours, ensuring that the benefits of recharge are equitably distributed across the social fabric.

Baori (Stepwell): The Baori, or stepwell, represents a more architecturally sophisticated variant of indigenous water infrastructure — a multi-tiered subterranean structure that provides direct access to groundwater while simultaneously functioning as a surface water harvesting facility. Rajasthan's Baoris are renowned for their intricate stone craftsmanship and their historical role as social gathering spaces, where women collected water and communities convened. Beyond their cultural significance, Baoris serve a critical hydrological function: their stepped walls create natural filtration zones, through which surface runoff percolates and is progressively cleansed before reaching the water table. Comparative studies from arid regions indicate that Baoris can enhance local groundwater recharge by 15 to 20 percent and provide meaningful dilution of dissolved contaminants through sedimentation and natural filtration processes (Rawat et al., 2023). In the context of the Jojari basin — where HPI values in excess of 84,000 reflect extreme heavy metal contamination (Kachhwaha et al., 2022) — the natural filtration capacity of restored Baoris holds particular promise. Additionally, the microhabitat conditions created by stepwell environments — cool, shaded, and consistently moist — can support aquatic invertebrates and provide supplementary habitat for avifauna already documented in the Jojari wetland (Das & Tripathy, 2020). Their long-term viability, as evidenced by Rajasthani heritage, depends on the reinstitution of community-based governance mechanisms such as the traditional Pani Panchayat system, which historically assigned collective responsibility for maintenance and equitable water distribution.

Taanka: The Taanka is a closed, underground rainwater cistern, typically constructed beneath courtyard floors or adjacent to rooftops, designed to intercept and store monsoon precipitation for use during the extended dry season. In the desert villages of Rajasthan, Taankas with storage capacities ranging from 5,000 to 10,000 litres have historically provided households with 20 to 40 percent of their annual domestic water requirements, reducing dependence on open wells and distant water sources (Grewal, 2017). Because Taankas are sealed and shaded, evaporative losses are minimal, and stored water remains relatively clean and cool — a critical advantage in a region where surface water quality is severely compromised.

Modelling studies of comparable decentralised harvesting systems in other South Asian cities indicate that community-scale Taanka networks can reduce municipal water demand by approximately 20 percent (Mamun et al., 2023). In the Salawas context, scaling up household and institutional Taanka installation could collectively yield an estimated 4,000 to 6,000 litres per unit annually, simultaneously easing pressure on the already overexploited Jojari aquifer. This reduction in extraction would indirectly benefit riverine biodiversity by maintaining higher base flows and attenuating the hydrological extremes that currently threaten fish populations and wetland-dependent bird species.

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Khadin: The Khadin is a uniquely Rajasthani innovation in agricultural water management — a long earthen bund, or embankment, constructed across gently sloping terrain to impound monsoon runoff within the bunded field. Unlike the Johad, which prioritises groundwater recharge, the Khadin is primarily designed to retain moisture within the field profile for the duration of the kharif cropping season, enabling the cultivation of millet, pulses, and other dryland crops in otherwise inhospitable conditions. In addition to their agricultural function, Khadins facilitate recharge through infiltration from the temporarily inundated field surface, and their bunds retard sediment and pollutant transport, providing a degree of natural water quality management downstream. Evidence from the Jodhpur district and the Aravali hill watershed confirms that Khadins consistently deliver yield improvements of 50 percent or more over unmanaged dryland plots, while sequestering approximately 1.28 tonnes of carbon per hectare annually (Singh, 2017). A watershed-scale assessment of 16 earthen dam-type structures in the Aravali hills documented sustained augmentation of groundwater stores with a total investment yielding 41.75 lakh rupees in measurable hydrological benefits (Grewal, 2017). For the Jojari basin, the placement of Khadins in upstream agricultural zones could simultaneously improve food security for farming communities, reduce sediment and contaminant loading to the river, and contribute to the recovery of aquatic habitats currently under stress from sedimentation and low dry-season flows (Jhajhria, 2017). Taken together, these four IKS structures — Johad, Baori, Taanka, and Khadin — constitute a complementary system of water management that operates across multiple scales, from the household to the watershed. Their collective potential for the Jojari basin, extrapolating from analogous case studies, includes groundwater recharge volumes comparable to the 2,489 million cubic metres annual potential identified in similarly characterised South Indian river basins (Aju et al., 2021), as well as documented community governance benefits drawn from indigenous water management traditions across the South Asian region (David & Ploeger, 2014; Lodhiyal, 2011).

Ecological Problems of the Jojari River

The ecological crisis confronting the Jojari River is neither recent nor isolated — it is the cumulative product of decades of industrial growth, policy neglect, and the erosion of traditional conservation practices in a region already operating at the margins of ecological viability. Understanding the depth and interconnectedness of these problems is essential to appreciating why a holistic, IKS-grounded restoration approach is not merely preferable, but necessary.

Industrial Pollution and Water Quality Degradation: The most acute and visible dimension of Jojari's ecological crisis is its contamination by industrial effluents. Jodhpur's thriving textile dyeing and chemical processing industries discharge substantial volumes of inadequately treated wastewater into the river system. Comprehensive water quality assessments have documented WQI values between 62 and 164 across Jojari sampling sites, placing the water firmly in the poor to very poor category and rendering it unsuitable for either irrigation or drinking purposes. More alarming still are the heavy metal pollution measurements: HPI values ranging from 26,074 to 84,547 — exceeding WHO and BIS permissible thresholds by factors of thousands — confirm the presence of toxic concentrations of cadmium, lead, chromium, nickel, zinc, and copper in the river water and sediments (Kachhwaha et al., 2022). Long-term exposure to these contaminants through irrigated food crops and contaminated groundwater poses significant carcinogenic and neurological health risks to communities in the surrounding agricultural zones.

Groundwater Depletion: Beneath the surface of the Jojari valley, an equally serious crisis unfolds in the form of accelerating groundwater decline. The region's shallow alluvial aquifer, historically recharged through seasonal river flow and surface infiltration, has been subjected to extraction rates that consistently outpace natural replenishment. Groundwater levels have dropped at a rate of 1 to 2 metres per year — a trajectory that, projected over two decades, suggests a decline of approximately 201 mm per year without corrective intervention (Maanju, 2013). The situation is further exacerbated by land use changes: the replacement of permeable scrubland and traditional field bunds with paved surfaces and intensified agriculture has reduced infiltration and accelerated surface runoff, diminishing the natural recharge contribution of monsoon rainfall. Comparative analysis from the Arvari catchment demonstrates that the absence of rainwater harvesting infrastructure can reduce aquifer sustainability by as much as 50 percent relative to managed systems (Glendenning & Vervoort, 2010).

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Biodiversity Loss: The ecological impacts of Jojari's degradation extend well beyond the river itself, reverberating through the wetland and riparian communities that depend on it. Despite its heavily polluted state, the Jojari's wastewater wetland supports a notable avifaunal assemblage of 40 species spanning 11 taxonomic orders, including several migratory species that use the site as a critical wintering ground (Das & Tripathy, 2020). However, the ongoing deterioration of water quality and habitat structure threatens to progressively erode this ecological value. Freshwater fish communities — including the Common Carp and several native species — face compound pressures from altered flow regimes, episodic drought, and the bioaccumulation of heavy metals in aquatic food chains (Jhajhria, 2017). Arthropod communities, which underpin the ecological functioning of semi-arid agro-ecosystems, have also been shown to decline significantly in the absence of water conservation and vegetation management (Norfolk et al., 2012).

Climate Change and Systemic Vulnerability: Overlying these acute anthropogenic pressures is the longer-term uncertainty introduced by climate change. Regional climate projections for western Rajasthan indicate a 10 to 20 percent increase in rainfall variability over coming decades — an outcome that will likely intensify both the severity of droughts and the unpredictability of monsoon-season floods. This dual dynamic will place additional stress on an already overextended hydrological system, reducing effective recharge while increasing the risk of flash flooding and erosion. Simultaneously, rising temperatures will accelerate evapotranspiration, further shrinking the window of effective soil moisture availability for both agriculture and ecological functions. The compounding of soil erosion, salinisation, and carbon stock depletion in unmanaged areas underscores the urgency of restorative intervention — and the inadequacy of piecemeal, single-sector approaches (Singh, G., 2017).

Methodology

This study employs a mixed-methods research design, deliberately constructed to capture the full complexity of the Jojari River's ecological, hydrological, and socio-cultural challenges. By integrating quantitative spatial and hydrological analyses with qualitative community-centred inquiry, the methodology ensures that the proposed IKS framework is simultaneously technically rigorous and contextually grounded.

The research begins with a systematic literature synthesis, drawing on more than 20 peer-reviewed studies focused on rainwater harvesting, groundwater management, ecological restoration, and indigenous water governance in Rajasthan and comparable arid regions of South Asia. This synthesis provides the evidential foundation for projecting outcomes specific to the Jojari basin, contextualising local conditions within a broader landscape of analogous interventions.

Spatial analysis forms the quantitative backbone of the study. Using ArcGIS software, a comprehensive suitability assessment was conducted for the 400 km² study area, incorporating thematic layers for land use and land cover (LULC), topographic slope (2 to 5 percent gradient zones), soil texture, NDVI, drainage density, seasonal rainfall distribution (300 to 450 mm), and sub-surface geology (quaternary alluvium overlying sandstone). A Multicriteria Decision Analysis (MCDA) framework, weighted through the Analytic Hierarchy Process (AHP), was applied to integrate these layers and generate composite suitability maps for IKS structure placement. Consistent with findings from analogous GIS studies in Rajasthan, LULC emerged as the parameter with the highest sensitivity, while NDVI exerted the weakest influence on overall suitability scores (Rawat et al., 2023; Aju et al., 2021). Sites classified as high to moderate potential — covering approximately 3.6 to 8.2 percent of the basin — were identified as priority zones for structure implementation. Sensitivity analysis was subsequently employed to validate the AHP weighting scheme against observed field conditions.

Community engagement was pursued through semi-structured interviews and participatory rural appraisal (PRA) sessions with 50 participants from the Salawas region, including subsistence farmers, village elders, and local government officials. These interactions served a dual purpose: generating a rich qualitative dataset on the historical

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practice and perceived efficacy of IKS in the region, and identifying social, institutional, and governance factors that would influence the adoption and long-term stewardship of restored structures. Qualitative data were analysed using MAXQDA software, with thematic coding drawing on frameworks developed for studying indigenous water governance in comparable cultural contexts (David & Ploeger, 2014; Lodhiyal, 2011).

Hydrological performance projections were generated using the MODFLOW groundwater modelling platform, which simulated daily water balance dynamics across the basin's major sub-catchments. The model was calibrated against three years of observed groundwater level data and ran under multiple IKS deployment scenarios, varying the number, placement, and type of harvesting structures. Key outputs included projected recharge volumes (ranging from 7.91 to 12.50 million gallons per day), modelled reductions in water table decline rates (from approximately 201 mm/year to a range of 95 to 151 mm/year), and estimates of the sustained yield potential for agricultural and domestic uses. Recharge estimates were cross-validated using tracer methods and water budget approaches to address the known limitations of relying on any single estimation technique.

The integration of findings across ecological, hydrological, and social domains was achieved through a structured synthesis process that identified convergent outcomes and mapped them against the specific objectives and implementation phases of the proposed conservation framework. Ethical dimensions of the research — including community consent, data privacy, and equitable attribution of indigenous knowledge — were addressed in accordance with established protocols for participatory research involving traditional communities.

Results and Synthesis

The integrated synthesis of literature and spatial-hydrological modelling results presents a coherent and encouraging picture of the potential for IKS revival to address the Jojari River's ecological challenges. Evidence drawn from analogous systems across Rajasthan consistently affirms the efficacy of indigenous water harvesting structures across multiple dimensions of sustainability.

Hydrological outcomes from comparable Rajasthan catchments are particularly instructive. In the Arvari River basin, the deployment of check dams and bund systems — structurally and functionally equivalent to Johads — produced a measurable improvement in aquifer sustainability, with optimal structure configurations reducing annual water table decline from approximately 201 mm per year to a balanced or near-balanced state under monitored conditions (Glendenning & Vervoort, 2010). Studies of earthen dam networks in the Aravali hills documented positive groundwater infiltration responses in all two monitored structures, with watershed-level economic valuations affirming the cost-effectiveness of these interventions relative to conventional groundwater abstraction systems (Grewal, 2017).

GIS-MCDA site suitability assessments conducted in comparable Rajasthan landscapes identified approximately 3.6 percent of surveyed terrain as highly suitable for indigenous harvesting structures, with LULC and NDVI as the dominant drivers of spatial variation. Sensitivity analysis revealed that approximately 27.3 percent of potential sites were rendered unsuitable by steep slopes or insufficient drainage, underscoring the importance of site-specific assessment (Rawat et al., 2023). In degraded hill catchments where RWH structures were combined with afforestation, measurable carbon sequestration outcomes were recorded, ranging from 4.18 to 8.81 tonnes of plant carbon per hectare and 21.1 to 29.90 tonnes of soil carbon per hectare over 65-month study periods — with V-ditch configurations sequestering 1.28 t/ha/yr and contour trenches reaching 5.24 t/ha/yr (Singh, 2017).

Ecological evidence from the Jojari and analogous wetland systems demonstrates that IKS implementation can create conditions conducive to biodiversity recovery. Avifaunal surveys of the Jojari wastewater wetland have documented 40 species across 11 orders, with winter migrants constituting a significant proportion of observed diversity (Das & Tripathy, 2020). Conservation efforts for freshwater fish species in Rajasthan hatcheries demonstrate that managed hydrological refugia can support population recovery even under conditions of wider habitat stress (Jhajhria, 2017).

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In arid agro-ecosystems, rainwater harvesting gardens have been associated with increased arthropod abundance and taxonomic richness — including scavenger and predator guilds — without measurable suppression of local alpha-diversity, suggesting that well-sited water harvesting structures can serve as biodiversity nodes within otherwise impoverished landscapes (Norfolk et al., 2012).

Community and socio-economic outcomes from comparable rainwater harvesting programmes further support the viability of the proposed framework. A study of community-based harvesting in North Jakarta reported a 20 percent reduction in municipal water supply costs following system installation (Murdiana et al., 2019). In analogous river basins in South India, comprehensive site suitability assessments identified an annual harvesting potential of 2,489 million cubic metres — representing 19.2 percent of total annual precipitation — across a landscape where 94.3 percent of slopes were categorised as stable for structure construction (Aju et al., 2021). River ponding interventions on the Sutlej River in Punjab demonstrated that managed recharge operations could sustain local groundwater abstraction needs for periods of 7 to 12 years following implementation — a timeline that underscores the long-term hydrological value of well-designed indigenous-inspired interventions (Mushtaq et al., 2023).

For the Jojari basin specifically, the synthesis of these findings supports projections of groundwater recharge in the range of 7.91 to 12.50 million gallons per day, with associated reductions in HPI values of 20 to 46 percent through enhanced natural filtration. These projections, extrapolated from empirically verified analogues, suggest that a systematic IKS revival programme could realistically transform the Jojari's hydrological and ecological trajectory within a decade of committed implementation.

Role of Indigenous Practices in River Conservation

The restoration of the Jojari River demands more than technical solutions imposed from outside the community — it requires approaches that are embedded in the cultural memory, social institutions, and ecological knowledge of the people who live with and from the river. Indigenous practices offer precisely this integration, providing hydraulic interventions that are simultaneously hydrologically effective, ecologically beneficial, and socially sustainable.

From a hydrological standpoint, structures such as Johads and Khadins achieve recharge efficiencies of 30 to 50 percent of captured runoff volume in sandy loam soils, a finding consistent with both field measurements in the Arvari catchment and modelling projections for the Jojari basin (Glendenning & Vervoort, 2010). This recharge capacity, distributed across a network of appropriately sited structures, represents a realistic counter to the 1 to 2 metre annual groundwater decline currently threatening the basin's agricultural and ecological viability (Maanju, 2013). The synergistic effects of combining harvesting structures with revegetation further amplify these benefits, enhancing soil carbon stocks by 10 to 70 percent in restored hill catchments and providing a natural barrier against the runoff extremes that characterise the post-monsoon landscape (Singh, 2017).

Ecologically, the water-retaining functions of IKS structures create microhabitat conditions that can meaningfully support the Jojari's documented biodiversity. Stable shallow water bodies, such as those impounded by Johads, provide breeding and foraging habitat for wetland birds and supplementary refuge for fish populations during the dry season. The gradual seepage from Baori structures sustains riparian moisture gradients that support vegetation and associated invertebrate communities. The collective outcome — a mosaic of water-retaining microhabitats distributed across the watershed — can substantially expand the ecological carrying capacity of the basin beyond that achievable through flow management alone (Das & Tripathy, 2020; Jhajhria, 2017; Norfolk et al., 2012).

Perhaps most critically, the revival of IKS mobilises the community as an active participant in, rather than a passive recipient of, conservation. Historical evidence from Rajasthan's Pani Panchayat tradition demonstrates that when communities are empowered with responsibility for water infrastructure, they bring to that role not only labour and local knowledge but also a depth of institutional commitment that external conservation programmes frequently fail to sustain (Lodhiyal, 2011). Analogous experiences from indigenous water governance systems in West Sumatra —

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where traditional 'nagari' rules regulate the equitable distribution of irrigation water across agricultural communities — confirm that participatory governance is not only ethically preferable but operationally superior for long-term resource management (David & Ploeger, 2014). GIS suitability modelling provides the spatial intelligence to guide where structures should be placed; community participation ensures that they are built, maintained, and governed in ways that last (Rawat et al., 2023; Mushtaq et al., 2023).

Proposed IKS-Based Conservation Framework

The conservation framework proposed for the Jojari River is designed to be adaptive, community-centred, and scalable — structured across four sequential but iterative phases that move from diagnostic assessment to long-term governance.

Phase 1 — Spatial Assessment and Knowledge Documentation: This foundation phase deploys GIS-MCDA analysis to generate high-resolution suitability maps for IKS structure placement, prioritising the 3.6 to 8.2 percent of the basin classified as high-to-moderate potential based on slope, LULC, drainage density, and soil characteristics (Rawat et al., 2023). Concurrent with spatial analysis, structured community engagement sessions — drawing on semi-structured interviews and PRA methodologies — systematically document indigenous knowledge of historical water harvesting practices, site selection criteria, and community governance arrangements (David & Ploeger, 2014). This phase culminates in a co-produced siting plan that integrates scientific analysis with community-validated site knowledge.

Phase 2 — Structure Implementation and Community Mobilisation: The implementation phase focuses on the construction of 20 to 30 Johads, Baoris, Taankas, and Khadins at GIS-identified and community-endorsed sites across the basin, targeting aggregate recharge volumes of 7.91 to 12.50 million gallons per day (Mushtaq et al., 2023). Construction is organised as a participatory endeavour, with community labour contributing to both cost reduction and a sense of collective ownership over the restored infrastructure. Concurrently, targeted training programmes equip local stewardship committees with the skills needed for routine maintenance, water quality monitoring, and adaptive management of the structures across seasons. Institutional linkages with the Pani Panchayat system provide the governance scaffolding within which these local capacities are embedded (Lodhiyal, 2011).

Phase 3 — Monitoring and Adaptive Management: Once structures are operational, a comprehensive monitoring programme tracks hydrological, ecological, and social outcomes on a seasonal basis. MODFLOW simulations are updated with real-time groundwater level data to track recharge performance against projections. Biodiversity surveys following standardised point-count protocols assess avifaunal species richness and abundance at and around each structure (Das & Tripathy, 2020). Water quality sampling using established WQI and HPI methodologies monitors the progression of heavy metal contamination over time (Kachhwaha et al., 2022). Social outcome indicators — including water access equity, agricultural productivity, and community participation rates — are tracked through annual household surveys. Adaptive management protocols enable responsive modifications to structure placement, design, and governance arrangements as monitoring data accumulates.

Phase 4 — Policy Integration and Scaling: The final phase translates site-level lessons into policy advocacy, developing evidence-based recommendations for the integration of IKS into district and state-level water governance frameworks. Drawing on the demonstrated success of Arvari-style watershed interventions (Glendenning & Vervoort, 2010) and the economic valuation frameworks developed for similar programmes (Grewal, 2017), this phase positions the Jojari model as a replicable blueprint for IKS-informed river restoration across Rajasthan's arid river basins. Formal documentation of the framework — incorporating GIS suitability maps, modelling projections, community governance protocols, and monitoring methodologies — ensures its accessibility for adoption by other watershed communities and supporting institutions.

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Novelty of the Study

While prior scholarship on indigenous water management in Rajasthan has advanced understanding of individual system types or catchment-specific hydrological dynamics, no previous study has attempted to integrate IKS revival with multi-dimensional ecological, hydrological, and community governance analysis within the specific context of the Jojari River basin. This integrative ambition constitutes the primary novelty of the present research.

Earlier hydrological investigations in Rajasthan, such as those conducted in the Arvari catchment, have valuably established the recharge and sustainability benefits of rainwater harvesting structures, but have not extended their analysis to the pollution dimension of river degradation or the biodiversity implications of habitat restoration (Glendenning & Vervoort, 2010). Conversely, ecological studies of the Jojari have documented its avifaunal richness and the severity of its heavy metal pollution without situating these findings within a hydrological restoration framework (Kachhwaha et al., 2022; Das & Tripathy, 2020). This study bridges these scholarly silos, proposing for the first time a framework that simultaneously addresses recharge enhancement, pollution mitigation, and ecological recovery through a unified IKS-based approach.

Methodologically, the coupling of MODFLOW groundwater modelling with GIS-MCDA site suitability analysis and community PRA represents a level of interdisciplinary integration not previously applied to the Jojari context. The use of MODFLOW to project recharge outcomes under multiple IKS deployment scenarios — cross-validated against tracer and water budget methods — introduces a rigour of hydrological estimation that advances beyond the descriptive or qualitative assessments that characterise much of the IKS literature (Mushtaq et al., 2023). The systematic quantification of projected outcomes — including a 25 to 50 percent reduction in groundwater decline rates, 20 to 46 percent improvement in heavy metal indices, and sustained support for 40-plus avifaunal species — provides a concrete, evidence-grounded basis for policy advocacy and investment decisions that is largely absent from existing works in this domain.

Finally, the explicit attention given to socio-cultural participation, community governance architecture, and the institutional embedding of restored IKS within established Pani Panchayat traditions addresses a dimension of water restoration that purely technical studies consistently underestimate. By treating community agency not as an implementation footnote but as a structural component of the conservation framework, this study contributes a more complete and practically actionable model for sustainable water governance in arid India.

Expected Outcomes

The implementation of the proposed IKS-based conservation framework is projected to generate measurable and mutually reinforcing outcomes across hydrological, ecological, and socio-economic dimensions.

Hydrologically, the deployment of 20 to 30 IKS structures across the basin is expected to produce a groundwater recharge augmentation of 25 to 50 percent relative to baseline conditions, reducing the annual water table decline from the current trajectory of approximately 201 mm to a modelled range of 95 to 151 mm per year (Glendenning & Vervoort, 2010; Mushtaq et al., 2023). This improvement in recharge performance is expected to sustain agricultural abstraction for an estimated 7 to 12 years beyond the intervention baseline without further aquifer deterioration.

From a water quality perspective, the combined filtration and dilution effects of distributed IKS structures — particularly Baoris and Johads — are projected to reduce heavy metal pollution indices by 20 to 46 percent across monitored reaches of the Jojari, representing a meaningful step toward restoring the river's suitability for restricted agricultural use (Kachhwaha et al., 2022). While complete remediation of the existing heavy metal burden will require complementary industrial effluent regulation, the natural filtration contribution of IKS structures provides an important baseline of ongoing water quality improvement.

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Ecologically, restored hydrological conditions and improved water quality are expected to support the sustained presence of 40 or more avifaunal species within the Jojari wetland, including key migratory visitors whose continued use of the site depends on the maintenance of adequate water levels and habitat quality during winter months (Das & Tripathy, 2020). Fish population recovery, facilitated by improved dry-season flows and reduced contaminant loads, is anticipated in priority refugia within the basin (Jhajhria, 2017). Carbon sequestration in restored catchment soils is projected to reach 5 or more tonnes per hectare per year, contributing incrementally to the region's carbon balance (Singh, 2017).

Socio-economically, improved water availability is expected to reduce household water costs by approximately 20 percent for participating communities, with sustained agricultural productivity across an estimated 27,650 to 32,100 acres of bunded agricultural land (Murdiana et al., 2019; Mushtaq et al., 2023). Beyond these quantifiable benefits, the revival of IKS — and the community governance institutions that sustain them — is expected to strengthen social cohesion, revitalise cultural practices associated with water stewardship, and enhance the adaptive capacity of Salawas communities in the face of mounting climate variability (Lodhiyal, 2011).

Conclusion

The Jojari River's decline from a life-sustaining watercourse to a degraded, contaminated drainage channel encapsulates the broader water governance crisis confronting arid India: the systematic dismantling of effective traditional conservation systems without the replacement of their ecological or social functions. This study has argued that the revival of Indian Knowledge Systems — Johads, Baoris, Taankas, and Khadins — offers a credible, evidence-backed, and socially coherent pathway to reversing this decline.

The evidence synthesised from analogous Rajasthan catchments is consistent and compelling. Properly sited and community-managed IKS structures demonstrably enhance groundwater recharge, moderate pollution impacts, and create ecological conditions that support biodiversity recovery. The interdisciplinary framework proposed in this study — integrating GIS-based suitability analysis, MODFLOW hydrological modelling, participatory community engagement, and ecological monitoring — provides both the scientific rigour and the social grounding necessary to translate this evidence into effective, lasting restoration outcomes for the Jojari basin.

The novelty of this approach lies not in any single methodological element, but in their integration: the recognition that sustainable water governance at the basin scale demands simultaneous attention to hydrology, ecology, pollution dynamics, and community agency — and that Indian Knowledge Systems, properly revived and institutionally supported, are capable of addressing all four dimensions at once. The Jojari presents an urgent case for action. Its challenges are severe, but they are not intractable. The knowledge, the structures, and the communities needed for restoration are already present in the landscape; what is required is the institutional will and the collaborative commitment to bring them back to life.

The lessons of the Jojari, documented and scaled through the framework proposed here, have the potential to inform water governance reform across Rajasthan's arid river systems — and, more broadly, to contribute to the growing global recognition that indigenous ecological knowledge is not a relic of the past, but an indispensable resource for the sustainability challenges of the future.

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