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International journal of agriculture extension and social development indigenous technical knowledge for water conservation: A review

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Abstract

Water is a fundamental natural resource essential for sustaining life, supporting agriculture and enabling economic development. However, growing demand, declining availability and increasing pollution have made water scarcity a major global concern. Across many regions, the pressure on water resources is rising due to population growth, urbanization, changing climate patterns and unsustainable extraction. In this context, indigenous technical knowledge for water conservation offers time-tested, eco-friendly and community-driven solutions that remain highly relevant today. Indigenous knowledge systems represent the wisdom developed through generations of observation, experimentation and adaptation to local environments. These systems include traditional methods for harvesting rainwater, storing surface runoff, managing groundwater and ensuring equitable water distribution. Examples such as stepwells, tanks, johads, ahar-pynes, zings, kunds, khadins and qanats demonstrate deep scientific understanding, social cooperation and sustainable engineering practices. These structures not only ensure water availability during dry periods but also support groundwater recharge, reduce soil erosion, protect biodiversity and strengthen community resilience. Traditional water conservation techniques are particularly effective because they are low-cost, climate-resilient and culturally embedded. They minimize water loss, improve soil moisture and support agriculture in arid and semi-arid areas. In modern times, rapid urban development and technological advancement have caused many of these methods to be neglected. However, their relevance has re-emerged as countries seek sustainable and environmentally friendly solutions to water crises. This review paper discusses the significance of indigenous technical knowledge, outlines major traditional water conservation systems across different regions and highlights their role in addressing present-day water challenges. It also emphasizes the need to integrate traditional wisdom with modern approaches to ensure long-term water security and strengthen community-based resource management.

Keywords: Indigenous technical knowledge, water, water conservation, groundwater recharge, rainwater harvesting

Introduction

Water, also known as Paani, Jal, Tanni, L'eau, Wasser and Acqua, is arguably the most well-known and often used term in the world. There is no need to introduce water because everyone understands its significance. Water is a basic human necessity, but it is being squandered, contaminated and exhausted. Despite the fact that every drop of water is valuable, we continue to waste it as if it were a free natural resource (Kumari and Singh 2016) [18]. About 96 per cent of Earth's water is salty and therefore not drinkable while only 4 per cent exists as fresh water. Out of this fresh water, only about 0.5 per cent is actually usable for drinking purposes and remaining fresh water is trapped in glaciers, located deep underground, or polluted and thus not easily accessible for human use (United Nations Department of Economic and Social Affairs, 2017). Due to decreased rainfall, artificial climate change, declining groundwater levels, population growth, industrialization and a startling amount of water waste from user carelessness and outdated water supply systems, many cities in India and around the world are already experiencing severe water shortages. Many regions of India struggle with issues such water pollution, lack of drinking water, poor sanitation, open trash disposal and loss of forest cover. Inadequate sanitation, poor waste management, a high infant mortality rate from water-borne illnesses and daily difficulties obtaining water are all prevalent issues that have detrimental effects on both the nation's economic and public health. The situation necessitates quick action to control these quickly expanding challenges, particularly by using an integrated strategy for water, sanitation and associated difficulties (Kumari and Singh 2016) [18].

Since ancient times, India has developed diverse traditional systems to collect and reuse rainwater, river water and groundwater, as reflected in the Vedas, Ramayana and Mahabharata. Water was regarded as sacred, inspiring

communities to build durable structures like tanks, wells and ponds to conserve and manage it for future needs (Sarma and Aggarwal 2023) [24]. Water conservation refers to the efficient and planned management of water resources to reduce wastage, improve use efficiency and ensure long-term availability. It includes practices and techniques that support sustainable water use across domestic, agricultural and industrial sectors while protecting ecosystems (Kumari and Singh 2016) [18]. These include both traditional and modern approaches adapted to environmental conditions. Traditional techniques such as stepwells (*baolis*) in Gujarat and Rajasthan, *johads* and *kunds* in Rajasthan, *khadins* in western Rajasthan, the *zabo* system in Nagaland demonstrate community based and climate resilient practices for capturing and storing rainwater (Murthy *et al* 2022) [20]. Traditional water harvesting systems offer climate-resilient, low-cost solutions that mitigate floods, droughts and heatwaves while enhancing groundwater recharge, supporting agriculture and biodiversity and strengthening overall community resilience (Jain *et al*. 2024) [17]. Modern techniques focus on advanced techn/ologies for improved efficiency, such as drip and sprinkler irrigation, rainwater harvesting systems, grey water recycling, smart irrigation using sensors and water-efficient fixtures (Gorde 2025) [15]. Agricultural production accounts for nearly 72 per cent of global freshwater withdrawals (UNESCO 2024), making efficient water management in farming systems critically important. To address this high demand, indigenous and sustainable practices such as intercropping, cover cropping, mulching, contour ploughing, in-situ rainfall harvesting and the construction of check dams help reduce evaporation, minimise runoff and enhance groundwater recharge, thereby supporting the long-term sustainability of water resources (Mishra 2007) [19].

Ancient rainwater harvesting (RWH) systems were crucial to local livelihoods in arid and semi-arid regions. Earlier generations developed ingenious RWH methods to make scarce water resources available and acceptable for numerous applications, including residential, animal, and irrigation (Beckers *et al* 2013) [9]. For example, a many of agricultural systems relied used water runoff by diverting flash floods from big wadis or collecting surface flow from small basins and slopes (Shanan and Schick, 1980) [25]. Archaeological discoveries support the importance of RWH in sustaining native populations and creating new communities in arid and semi-arid regions (Wessels 2005) [26]. Indigenous RWH techniques can be applied to multiple objects instead of just one. (Beckers *et al* 2013) [9]. Iraq employed a variety of RWH techniques for both agricultural and residential uses around 6500 years ago (Oweis *et al*., 2012) [22]. The Ma'rib Dam in Yemen is used to divert floodwater for irrigation, whereas the Resafa Dam in Syria was used to supplement the city's drinking water supply (Beckers and Schutt 2013) [9]. The ancient, abandoned ponds constructed by the Mayans in Central America had capacities between 2500 and 10,000 m3 and were used for both domestic and agricultural purposes (Ferrand and Cecunjanin 2014) [13].

Indigenous Technical Knowledge (ITK), built through generations of experience, observation and adaptation, represents a community-owned heritage that provides practical, context-specific solutions and a valuable foundation for research, extension and sustainable development (Angadi *et al* 2021) [4]. Indigenous Technical Knowledge (ITK), also referred to as traditional or local knowledge, is the collective wisdom developed and passed down through generations based on experience, observation and adaptation to local conditions. It is dynamic, community-owned and reflects people's creativity in responding to social, cultural and environmental challenges over centuries. (Mishra, 2007) [19]. The United Nations Educational, Scientific and Cultural Organization (UNESCO) defines Indigenous Knowledge (IK) as, "Local and indigenous knowledge refers to the understandings, skills and philosophies developed by societies with long histories of interaction with their natural surroundings." Indigenous Knowledge (IK) is locally rooted, experience-based and practical, evolving independently and transmitted orally or through imitation, often remaining undocumented yet widely shared (Bar-On 2014) [8]. The terms indigenous knowledge and traditional knowledge are largely used interchangeably because they share similar characteristics (Borthakur and Singh 2020) [10].

In this background, the present review paper on "Indigenous Technical Knowledge for Water Conservation" aims to organise and synthesise the available literature with special reference to traditional, community-based and ecologically harmonious water management practices. It highlights the major indigenous techniques documented across diverse regions, examines their relevance and effectiveness in addressing present-day water scarcity and identifies the challenges that hinder their wider adoption.

2. Types of indigenous water conservation technologies (Aklan *et al* 2024) [1]

a. Rooftop rainwater harvesting

Rainwater harvesting is an ancient practise that has persisted over the years of time. This system has been used since ancient times in many countries including India, China, Mexico and Yemen (Ferrand and Cecunjanin 2014) [13]. Rainwater harvesting is the gathering and storage of rainwater in tanks or underground structures for later use for a variety of applications such as irrigation, residential consumption and replenishment of groundwater reserves. It helps reduce water shortage in rural and urban areas and also controls flooding during heavy rainfall (Al-Houri and Al-Omari 2022) [2]. Ancient societies on multiple continents employed this age-old technique, illustrating the wisdom of utilizing natural water sources to meet human needs while reducing environmental harm (Amos *et al*., 2016) [3].

b. Flood and overland flow harvesting

This method collects floodwater or surface runoff and diverts it to fields for growing crops and supporting livestock. In order to increase agricultural productivity and livestock production, spate irrigation or flood water diversion systems are developed to capture flood water (NWP 2007) [21]. These are some of the most significant indigenous systems, and many of them are still in use today, especially in arid regions. Traditional spate irrigation systems use diversion weirs to transfer water to nearby agricultural fields while withstanding all or part of floods. This method can reduce erosion processes and lessen the

effects of droughts and floods (Edmunds and Cardona 2006) [12]. Runoff farming systems collects rainwater that flows from nearby slopes or rocky areas and directs it to small fields for growing crops during drought. Warping system in China that harvested water and sediments (Prinz 1996) [23]. The warping system is a traditional water and soil conservation method in China's Loess Plateau. Small dams are built across gullies (deep and narrow channels formed on soil due to continuous water flow during heavy rain) to slow floodwater, allowing silt to settle and form fertile flat land for farming. It helps recharge groundwater, reduce soil erosion and protect downstream areas from floods. For domestic, animal, or irrigation uses, overland flow is collected and stored in tanks, cisterns, or ponds. Different kinds of historically used water collection ponds served as the foundation for livestock and agricultural operations in arid and semi-arid regions. With a capacity of 80,000 m3, the UNESCO World Heritage Listed Ancient Basilica Cistern in Istanbul, Turkey, is regarded as the largest in the Mediterranean region and among the top 10 sites in Turkey (Aydıngün *et al*. 2020) [7]. In Jordan's Edom Mountains, the first RWH storage facilities for providing drinking water to humans and animals were constructed 9000 years ago (Prinz 1996) [23].

c. Groundwater harvesting

Groundwater harvesting refers to the sustainable extraction and use of groundwater stored in underground aquifers through wells, boreholes and springs. Groundwater recharge means increasing the amount of water that goes back into the ground to refill aquifers. Together, these practices help maintain a balance between water use and natural replenishment (Hazarika and Hazarika 2023) [16]. Conserving groundwater ensures a long-term supply of clean water for drinking, irrigation and household needs. It helps prevent the depletion of aquifers, controls land subsidence and maintains the flow of wells and springs. Groundwater conservation also supports agriculture and protects ecosystems that depend on underground water sources. Rainwater, rivers, canals and floodwater are common sources used for groundwater recharge. Different methods are used to allow this water to seep underground, such as recharge wells, percolation tanks, check dams, farm ponds, contour trenches and subsurface barriers. These structures slow down the flow of water and increase its infiltration into the soil, helping restore groundwater levels (Gebreslassie *et al* 2025) [14]. The qanat system, developed in ancient Persia over 3000 years ago and later adopted in regions such as Syria, Morocco, Spain and Oman, is an underground tunnel network that uses gravity to convey water from high aquifers to lower fields without pumps. Its vertical shafts aid construction and maintenance, while the underground flow minimizes evaporation, maintains water quality and supports groundwater recharge, making it highly effective for water collection and conservation in arid regions (Aklan 2024) [1].

3. Indigenous water management technologies in different regions of India (Murthy *et al* 2022) [20]

a. Northern Region

1. **Zings:** Ladakh is a cold desert in northern India, located on the highest plateau and surrounded by mountains, resulting in extremely cold and dry conditions. Due to low rainfall and scarce vegetation, glaciers are the main accessible source of fresh water in the region. Glacier ice melts in the sunlight during the day and the water is collected into small tanks called "Zings" using channels. These channels are kept clean and not too steep and a local official called "Chirpun" makes sure everyone gets water fairly for farming.
2. **Kuhls:** Kuhls are traditional water channels in the Kangra Valley of Himachal Pradesh. They carry melted glacier water from nearby mountains to the fields. There are more than 1000 major and minor Kuhls that were built by public donations or royal orders and were to be maintained by the users.
3. **Johads:** In Punjab, Rajasthan, Haryana and Uttar Pradesh, people use Johads (Earthen Ponds) to save water. A Johad is like a small pond made by excavation of earth and dumping it on the banks around. Johads vary in shape, size (generally less than one hectare) and depth (about six meters). a wall of soil on one side. It is designed to trap and store rainwater, have significantly enhanced water percolation and groundwater replenishment. In places with a lot of rain, Johads are joined with small channels that can direct extra water to a stream or river so the Johad does not break**.** In Rajasthan's Alwar district, more than 650 villages have constructed around 3,000 johads. These water harvesting structures have significantly raised the groundwater level by about 6 meters and increased forest cover by 33 per cent Consequently, five rivers that once dried up soon after the monsoon now maintain year-round flow (Dande *et al* 2016) [11].
4. **Baoli:** Baolis are step wells found in places like Delhi, Rajasthan and Gujarat. They have steps going down to the water and sometimes beautiful designs and rooms on the sides.

Their use depends on where they are built: In villages, people used them to meet and do daily work. Near travel routes, travelers used them to rest and drink water. Near farms, Baolis supplied water to fields through small channels.

Ahar Pynes: Ahar Pynes in Bihar are traditional systems native to the South Bihar plains in India, used to save rainwater and control floods. This system has evolved from a thorough knowledge of the area's distinct agro-climatic characteristics. An Ahar is like a pond with walls on three sides. On the fourth side, a Pyne (a man-made channel) brings water from a nearby river. The collected water in the Ahar is stored and used later in the hot, dry months.

b. North Western Region

1. **Bawaris:** Bawaris are very old stepwells. Rainwater was guided into these big tanks using canals from nearby hills. The water would then soak into the ground and refill the groundwater. Steps were built going downwards so the well became deeper and narrower, which helped stop the water from drying up fast**.**
2. **Kunds:** Kunds are built mainly to collect drinking water. They look like a shallow bowl with sloping sides that lead rainwater into a round well in the center. People have been making Kunds since about 1600 AD.

3. **Talabs:** Talabs were more simple catchment areas that could be either natural or man-made and the water stored was mostly used for domestic usage. Artificially built traditional talabs are found mostly in Rajasthan whereas the natural talabs are found in most regions of India.
4. **Taankas**: Taankas are traditional water storage systems in the Thar desert, Rajasthan. Rainwater from roofs and open areas is collected into a round underground tank called a Taanka. It is covered so the water does not evaporate. When full, a Taanka can provide enough water for a family for the whole summer.

Khadins: Khadins (also called Dhora) are very long wall made of soil, about 100-300 meters long, is built across the lower slopes, are used in the Thar desert to save rainwater on farms. Rainwater is collected on the fields and extra water is sent to storage pits. The wet soil then helps farmers grow crops.

Virdas: Virdas (also known as Sand Bores) in Gujarat are traditional water systems in the Rann of Kutch, Gujarat. Since most water there is salty, people dig small shallow wells in low-lying areas to collect rainwater. The top layer has grass and just below it, fresh rainwater gets stored. Deep down, the groundwater is salty, but the rainwater stays at least 1 meter above it. Between these two layers, there is a layer of slightly salty water. The layers do not mix because they have different densities, so people can easily take the fresh rainwater for daily use.

c. North Eastern Region

1. **Zabo**: Zabo is a traditional water system in Nagaland. The word "Zabo" means collecting rainwater. In this system, rainwater from forest hills is guided through channels into a pond on the terraced slopes. The channels pass through cattle areas and collect animal waste, which makes the water rich in nutrients. This stored water is then used for raising fish and growing medicinal plants.
2. **Bamboo Drip Irrigation:** Bamboo Drip Irrigation is a very old method used in Northeast India. Water from natural springs is carried to fields through bamboo pipes. The water slowly drips near the roots of the crops, so there is very little waste. This system works best for crops that need less water, like black pepper and is mainly used in the Khasi and Jaintia hills.

d. Central Indian Region

1. **The Pat system:** The Pat system in Madhya Pradesh is a traditional way to bring water from hill streams to farms. People build strong walls of stone, mud and leaves to guide the water into channels. These channels move through deep ditches and paths cut into rocks, so farmers can easily get water for their fields.
2. **Phad**: Phad is a traditional irrigation system. A small dam is built on a river and canals carry the water to farming areas called "phads." If there is too much water, it is released through special outlets so the fields do not flood. People in the community manage this system and it is mostly used in the Tapi river area.

e. Southern Indian Region

Eris: Eris are one of the oldest water management systems in Tamil Nadu, built to irrigate agricultural lands in the absence of perennial rivers. These tanks also help in controlling floods, recharging groundwater and preventing soil erosion by reducing surface run-off during rainfall.

There are two types of Eris: system Eris, which receive water from rivers through channels and non-system Eris, which depend entirely on rainwater. Many of these tanks are interconnected to extend water supply to distant villages and to balance water levels in case of excess availability**.**

1. **Oorani**: Ooranis are shallow reservoirs designed to gather rainwater and surface runoff, providing crucial water supplies for daily needs such as drinking, bathing and washing in nearby villages. These traditional systems have existed for thousands of years and are deeply rooted in Tamil Nadu's cultural and historical heritage. In Tamil Nadu, every village has three water ponds: one for farming, one for animals and one for drinking water called Oorani. All of them store rainwater. Because of these ponds, many villages have survived for thousands of years. Traditional water systems like Ooranis are very important. They were made long ago by the local people. These ponds are built with soil walls and are designed in such a way that they always have enough clean water for daily use.
2. **Panam Keni**: The Mullu Kuruma people have used Panam Keni wells for hundreds of years. These round wells, about four feet wide and four feet deep, are found near forests or in the middle of paddy fields. Their walls are made from the strong outer part of toddy palm trunks, which are soaked for a long time so the inside rots away. The wooden cylinder is then placed where groundwater springs are present, which helps the well provide plenty of water even in dry areas.

4. Agricultural practices for water conservation

Category	Selected Common ITKs
Agronomic Measures	Intercropping
	Cover Cropping
	Wider row spacing and deep interculturing
Tillage and Land Configuration	Conservation furrows with traditional plough
	Broad bed and furrow with indigenous plough
	Plot levelling with local leveler
	Deep pluoghing
Bunding and Terracing	Earthen/Stone bunding
	Vegetative barriers
	Nala checks with soil filled in cement bags
Mulching	Mulching with crop residues / leaves/ pebbles
Water Harvesting and Groundwater Recharge	Farm ponds / Percolation ponds
	Rainwater harvesting from rooftops/roads
	Dug wells / Well recharge pits / Tanka

Indigenous agricultural practices contribute significantly to water conservation by improving soil moisture, reducing runoff and enhancing groundwater recharge. Agronomic

methods such as intercropping, cover cropping, wider row spacing and deep interculturing help minimise evaporation and improve moisture retention. Traditional tillage practices like conservation furrows, broad bed and furrow systems and proper field levelling ensure better rainwater distribution and infiltration. Bunding, terracing, vegetative barriers and nala checks slow down runoff, reduce erosion and increase percolation. Mulching with residues, leaves or pebbles further limits evaporation and protects the soil. Water harvesting structures such as farm ponds, percolation pits, rooftop harvesting, dugwells and tanka systems capture and store rainwater or recharge groundwater for use during dry periods. Together, these ITK-based methods offer sustainable and low-cost solutions for efficient water management in agriculture (Mishra 2007) [19].

5. Conclusion

Indigenous Technical Knowledge for water conservation represents a time-tested, ecologically grounded and socially embedded system of resource management that has supported communities for centuries across diverse climatic regions. The review shows that traditional water harvesting structures—such as tanks, stepwells, johads, kunds, khadins, zings, kuhl systems, bamboo drip irrigation and eris—demonstrate remarkable hydrological insight, engineering skill and community organisation. These systems not only ensured reliable water availability for domestic, agricultural and livestock needs but also contributed to groundwater recharge, soil conservation, flood moderation and ecological stability. Indigenous agricultural practices further strengthened water-use efficiency through moisture conservation, runoff reduction and improved infiltration. Despite their proven effectiveness, many of these systems have declined due to neglect, urbanisation, technological shifts and weakening community institutions. However, with growing water scarcity, climate variability and environmental degradation, the relevance of Indigenous Technical Knowledge has become increasingly evident. Integrating traditional practices with modern scientific approaches can provide sustainable, low-cost and climate-resilient solutions to contemporary water challenges. Revitalising these systems through policy support, community participation, research, documentation and capacity building can significantly enhance water security and strengthen the resilience of rural and urban ecosystems. Thus, indigenous water conservation knowledge is not only a cultural heritage but also a vital resource for achieving long-term sustainability in water management.

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