AUTONOMOUS WATER SUPPLY SOLUTIONS OPERATING INDEPENDENT OF EXTERNAL POWER

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Abstract
Access to water remains a critical challenge in rural and off-grid regions where electricity and fuel-based pumping systems are either unreliable or economically unviable. In such contexts, traditional and mechanically operated water-lifting devices offer sustainable and accessible alternatives. This paper examines two significant technologies—the Shadoof and the Archimedes' screw—which function without the need for electricity. The study provides a detailed analysis of their working principles, technical efficiency, regional adaptations, and socio-economic relevance in the Indian context. Through case studies from Bihar and Maharashtra, the research highlights how these devices contribute to improving irrigation practices, enhancing agricultural productivity, and reducing dependence on external energy sources. The paper argues that integrating traditional knowledge with modern engineering improvements can play a vital role in achieving sustainable water management and climate-resilient agriculture.

1. Introduction

Water lifting is a fundamental requirement in agricultural systems, particularly in regions where irrigation infrastructure is underdeveloped. In many parts of rural India, farmers continue to face challenges due to inconsistent electricity supply, high fuel costs, and limited access to modern pumping technologies. As a result, there is a growing interest in alternative methods that can ensure reliable water access without dependence on external energy inputs. Traditional water-lifting devices, developed over centuries, represent a form of indigenous engineering that is both resource-efficient and environmentally sustainable. These systems are designed using locally available materials and simple mechanical principles, making them highly adaptable to diverse geographical and socio-economic conditions.

In the context of increasing energy costs and climate variability, non-electric water-lifting technologies are gaining renewed importance. They not only provide a practical solution for irrigation in remote areas but also align with broader sustainability goals by minimizing carbon emissions and promoting self-reliance among rural communities. This study focuses on two such devices—the Shadoof and the Archimedean Screw—to understand their technical functioning, practical applications, and long-term relevance.

2. Need for the Study

Despite significant advancements in irrigation infrastructure, a large proportion of rural and tribal regions in India still lack reliable access to electricity and modern water-lifting systems. Farmers in these areas often depend on diesel-powered pumps, which are expensive to operate and contribute to environmental pollution. Moreover, erratic power supply disrupts irrigation schedules, leading to educed crop yields and economic instability. In such conditions, traditional water-lifting devices offer a viable alternative by providing a low-cost, energy-independent solution.

These devices are particularly important for small and marginal farmers who cannot afford modern irrigation equipment. By utilizing human or mechanical energy, they enable farmers to maintain irrigation practices even in the absence of external power sources. Furthermore, the use of locally sourced materials reduces construction and maintenance costs, making these systems accessible to economically weaker sections. There is therefore a need to systematically analyze these technologies, not only to understand their current applications but also to explore their potential for wider adoption in sustainable rural development

3. Literature Review

The significance of traditional water management systems has been widely documented in academic literature. Studies have shown that indigenous irrigation practices are highly efficient in terms of resource utilization and environmental compatibility. Ghosh (2006) highlights the diversity of traditional water-lifting devices in India and emphasizes their adaptability to local conditions. Similarly, Kshirsagar and Sharma (2010) provide a detailed analysis of indigenous irrigation techniques, noting that such systems are particularly effective for small-scale agriculture.

Research by WaterAid India (2016) and Development Alternatives (2020) underscores the role of traditional technologies in improving water accessibility in rural areas. These studies suggest that integrating traditional knowledge with modern innovations can enhance the efficiency and scalability of such systems. Yadav and Bhattacharya (2015) further demonstrate how the revival of traditional irrigation methods in Bihar has led to increased agricultural productivity and improved livelihoods. Collectively, these studies highlight the importance of preserving and promoting traditional water-lifting technologies as part of sustainable development strategies.

Shadoof: A Traditional Water-Lifting Device Powered by Human Effort

Source : https://en.wikipedia.org/wiki/Shadoof

In the age of advanced irrigation systems and electric pumps, traditional methods of water lifting still hold significant value, especially in remote rural areas. One such age-old device is the **Shadoof** (also spelled **Shaduf**), a simple but effective tool that has been used for over 4,000 years to draw water from rivers, wells, or ponds for irrigation purposes. Originating in **ancient Egypt and Mesopotamia**, the Shadoof continues to serve as a sustainable water-lifting device in parts of Africa, the Middle East, and even rural regions of South Asia.

A Shadoof consists of a long wooden pole mounted on a vertical support, functioning like a seesaw. On one end of the pole hangs a **bucket**, often made of leather or clay, tied to a rope. The opposite end carries a **counterweight**, usually a stone or lump of hardened clay. This counterweight helps balance the load and makes it easier for a person to lift the full bucket with minimal effort. The system is operated manually, requiring the user to pull the bucket end of the pole downward into the water, fill it, and then allow the counterweight to help lift the bucket up. The water is then poured into a channel for use in fields or stored for later use.

What makes the Shadoof remarkable is its **simplicity, affordability, and sustainability**. It does not rely on electricity or fuel, making it ideal for communities where modern infrastructure is limited or unreliable. Farmers often build the Shadoof using locally available materials such as bamboo, wood, rope, and stone, which makes it highly accessible and easy to maintain. Because of its straightforward design, it requires no formal training to operate, and maintenance is minimal, ensuring longevity and reliability even in harsh environmental conditions.

In **modern-day Egypt, Sudan, and Ethiopia**, many small-scale farmers still rely on the Shadoof during dry seasons when water levels are low and the need for irrigation is critical. It allows them to grow vegetables and staple crops without depending on costly mechanical pumps. In some areas, the use of Shadoofs is even encouraged by agricultural extension services as a way to promote water conservation and preserve traditional farming techniques.

Though it may seem outdated in comparison to electric pumps and motorized irrigation systems, the Shadoof continues to play a **vital role in sustainable agriculture**. Its relevance lies not only in its functionality but also in its cultural and environmental value. As we seek to build more sustainable farming systems in the face of climate change and energy scarcity, devices like the Shadoof offer timeless lessons in resourcefulness and resilience.

Working Principle of a Shadoof

The **Shadoof** works on the principle of a **first-class lever**, using **mechanical advantage** to lift water with minimal human effort. It uses a long horizontal pole pivoted near the middle on a vertical support. One end of the pole holds a **bucket**, while the other end has a **counterweight**. The system is manually operated.

When the operator **pulls down the bucket end**, the bucket dips into the water source (such as a river, canal, or shallow well). Once the bucket fills with water, the **counterweight on the opposite end helps lift the full bucket**, reducing the physical effort needed. The user then guides the lifted bucket to pour the water into an irrigation channel, trough, or storage container.

This simple lever system **amplifies the human force**, making it possible to lift heavy water loads using minimal strength. The counterweight plays a crucial role by balancing the load and enabling **smooth, repeated lifting cycles**.

- **Lower** the bucket into the water by pulling down one end of the pole.
- **Fill** the bucket with water.
- **Allow** the counterweight to assist in lifting the bucket up.
- **Swing** the pole to the side and **pour** the water into a channel or basin.

Types and Usage of Shadoof in India

The Shadoof, though ancient in origin, has been locally adapted across various regions of India to suit different geographical and agricultural needs. In India, several types of Shadoofs are in use, largely categorized based on the materials available and the nature of the water source. One of the most common types is the **traditional bamboo Shadoof**, found in states like Assam, Odisha, West Bengal, and Bihar. These are made using locally available bamboo poles, earthen or metal buckets, and mud or stone counterweights. These lightweight and cost-effective systems are primarily used to lift water from ponds or village wells to irrigate small vegetable fields.

Another common variant is the **wooden beam Shadoof**, seen in Madhya Pradesh, Chhattisgarh, and parts of Uttar Pradesh. These use stronger hardwood logs for the beam, mounted on a simple wooden frame, and are preferred in areas where bamboo is less accessible. In drier states like Rajasthan and Gujarat, farmers often use **Shadoofs mounted on brick-lined or stone-lined dug wells**, adapted to lift water from greater depths. These setups use longer beams and heavier counterweights to balance the load effectively.

In recent years, some NGOs and rural development programs have introduced **portable iron pipe Shadoofs**, using galvanized iron pipes as beams, rubber or plastic buckets, and cement blocks as counterweights. These versions, used in regions like Maharashtra and Karnataka, offer improved durability and mobility, making them suitable for small-scale farming and community water access.

In terms of usage, Shadoofs are still employed across India for **manual irrigation of small plots**, particularly by marginal farmers who cannot afford electric or diesel-powered pumps. In Bihar, West Bengal, and Odisha, farmers commonly use Shadoofs to irrigate vegetables and short-cycle crops. In Assam and Tripura, they are used to lift water from irrigation canals into elevated fields. In arid zones like Rajasthan, they serve both agricultural and domestic water-lifting needs, especially during dry seasons. Additionally, in tribal and hilly regions of Jharkhand and Chhattisgarh, traditional Shadoofs continue to be a vital water-lifting tool, often shared by the community.

These region-specific adaptations reflect the Shadoof's **flexibility, sustainability, and enduring relevance** in Indian agriculture. Its low cost, ease of use, and independence from electricity make it an invaluable asset in India's efforts to promote traditional, eco-friendly farming practices.

4. Case Study

4.1 Case Study: Shadoof Use for Sustainable Irrigation in Rural Bihar

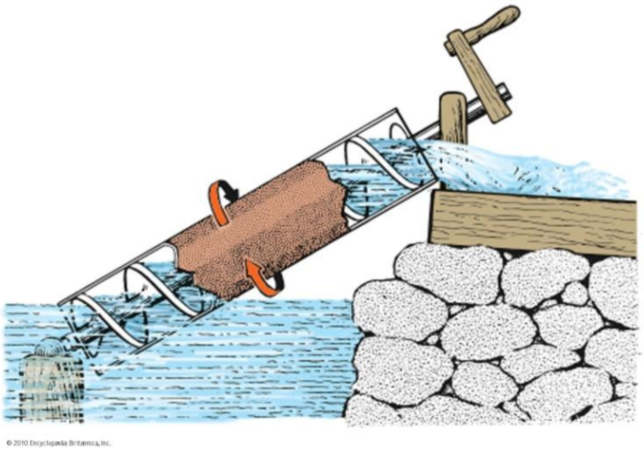
In the small village of **Amlori**, located in the **Nalanda district of Bihar**, a farmer named **Ramesh Yadav** has been using a traditional **Shadoof** to irrigate his vegetable farm for over five years. With just 1.5 acres of land and no access to electricity or diesel-powered pumps, Ramesh was heavily dependent on manual methods to water his crops. Initially, he used buckets to draw water from a shallow well, a process that was physically exhausting and time-consuming. Upon learning about the Shadoof from a local NGO working on sustainable agriculture, he decided to install one using bamboo poles, a clay pot, rope, and a stone as a counterweight—all sourced locally for under ₹1,000.

The Shadoof allowed Ramesh to lift water efficiently with minimal effort. Using the counterweight system, he could draw up a full bucket of water in seconds and irrigate his crops more regularly. This simple device significantly reduced his labor and enabled him to water his field twice a day during the dry season. As a result, his vegetable yield improved by **30%**, and he was able to sell surplus produce at the local market, increasing his household income.

Other farmers in the village, seeing the results, began adopting similar setups. Today, more than **20 households** in Amlori use Shadoofs for both irrigation and domestic water needs. The device has empowered these families to become less dependent on erratic rainfall and expensive mechanical alternatives. Ramesh now serves as a local advocate for traditional irrigation methods and often helps neighbors build their own Shadoofs.

This case highlights how a **simple, ancient technology** can still have a profound impact on modern rural livelihoods. The Shadoof has not only improved crop productivity but has also strengthened the community's resilience to water scarcity, all while being environmentally sustainable and economically viable.

Archimedean Screw: A Timeless Water-Lifting Innovation



Source : https://en.wikipedia.org/wiki/Shadoof

The Archimedes' screw, also known as the Archimedean screw, hydrodynamic screw, water screw or Egyptian screw , is one of the earliest documented hydraulic machines. It was so-named after the Greek mathematician Archimedes who first described it around 234 BC, although the device had been developed in Egypt earlier in the century . It is a reversible hydraulic machine that can be operated both as a pump or a power generator.
As a machine used for lifting water from a low-lying body of water into irrigation ditches, water is lifted by turning a screw-shaped surface inside a pipe. In the modern world, Archimedes screw pumps are widely used in wastewater treatment plants and for dewatering low-lying regions. Run in reverse, Archimedes screw turbines act as a new form of small hydroelectric powerplant that can be applied even in low head sites. Such generators operate in a wide range of flows (0.01 to 14.5) and heads (0.1 m to 10 m), including low heads and moderate flow rates that is not ideal for traditional turbines and not occupied by high performance technologies.
The **Archimedean Screw** is an ancient water-lifting device that remains relevant even today for small-scale irrigation and drainage systems. Originally attributed to the Greek mathematician **Archimedes** in the 3rd century BCE, the device was designed to transfer water from a lower level to a higher elevation, often used to irrigate fields or drain waterlogged land.

Working Principle
The Archimedean Screw works based on the principle of a **helical screw** rotating inside a hollow tube or cylinder. One end of the screw is placed in water, and as the shaft is rotated—either by hand, foot pedal, or animal—the screw traps water in its helical grooves. As the rotation continues, water is gradually carried upward through the spiral and discharged at the top. This continuous lifting action relies purely on **mechanical rotation**, and no electricity is required.

Design Components
- **Screw (Helix):** Typically made of metal or PVC.
- **Casing or Trough:** A pipe or open channel encasing the screw.
- **Rotating Mechanism:** Can be hand-cranked or pedal-operated.
- **Inclination Angle:** Usually set at 30° to 45° for best efficiency.

Usage in India
While the Archimedean Screw is not native to India, it has found use in **experimental farms, eco-parks, and rural irrigation projects**, especially where sustainable and low-cost water-lifting options are needed. Organizations like **IITs**, **NGOs**, and **watershed management groups** have implemented small-scale versions for:
- **Lifting water from canals to fields**
- **Draining water from paddy fields**
- **Irrigating terrace farms and gardens**

In states like **Maharashtra, Karnataka, and Tamil Nadu**, modified versions have been demonstrated in tribal or hilly regions where traditional diesel pumps are too expensive or impractical. Some government polytechnic colleges have also developed low-cost, pedal-powered models for educational use.
The **Archimedean Screw** comes in several types, depending on its design, material, and power source. The most common is the **manual Archimedean Screw**, operated by hand or foot pedal, ideal for small-scale irrigation in rural or off-grid areas. A more advanced version is the **animal-driven screw**, where livestock rotate the screw using a gear system,

enabling greater lifting capacity. In modern adaptations, **motorized Archimedean Screws** are also used, especially in urban settings or larger farms, though they require electricity or solar power. Additionally, **open-channel screws** are used in drainage systems to move wastewater or floodwater, particularly in areas with poor slope. In India, the **manual and low-cost PVC versions** of the screw have been promoted by NGOs and rural engineering colleges for lifting water from shallow canals, ponds, or tanks to irrigate vegetable patches, paddy fields, and terrace farms. These versions are especially useful in hilly or tribal regions of Maharashtra, Tamil Nadu, and Jharkhand, where traditional pumps are unaffordable or unavailable. The Archimedean Screw's adaptability and simplicity make it an effective tool for both irrigation and drainage, contributing to sustainable farming and water management in underserved areas.

4.2 Case Study: Sustainable Water Lifting Using Archimedean Screw in Nashik, Maharashtra

In the tribal village of **Pimpaldhara**, located in the hilly region of **Nashik district, Maharashtra**, a small community of marginal farmers faced a recurring challenge: lifting water from nearby check dams to irrigate their crops located at higher elevations. With no access to electricity and the high cost of diesel pumps being unaffordable, the farmers struggled to maintain their crops during dry months. In 2021, a local NGO working on sustainable agriculture collaborated with engineers from a nearby polytechnic college to introduce a **manual Archimedean Screw system**. Using locally available materials like PVC pipes, recycled metal, bamboo supports, and a hand-crank mechanism, they built a simple yet efficient water-lifting device.

The Archimedean Screw was inclined at about 40 degrees and allowed farmers to lift water up to 2 meters, sufficient to fill storage drums for **gravity-fed irrigation**. With just two people operating the crank, they could lift nearly **1,000 liters per hour**, enough to irrigate a half-acre vegetable plot daily. Over the next season, farmers reported increased yields in crops like tomatoes, onions, and spinach, and reduced dependency on external water sources. Encouraged by the success, three more families adopted similar systems with the NGO's guidance.

This initiative not only revived interest in ancient, sustainable technologies but also **empowered a low-income farming community to become self-reliant**, reduce costs, and conserve energy. The Archimedean Screw proved to be a cost-effective, eco-friendly alternative, particularly in regions where water access and electricity are limited.

5. Comparative and Sustainability Analysis

The Shadoof and the Archimedean Screw represent two distinct approaches to non-electric water lifting, each with its own advantages and limitations. The Shadoof is simple, low-cost, and easy to construct, making it ideal for small-scale applications. However, its output is limited and requires continuous manual effort. In contrast, the Archimedean Screw offers higher efficiency and continuous water flow but requires more complex construction and slightly higher initial investment.

From a sustainability perspective, both devices are environmentally friendly, as they do not rely on fossil fuels or electricity. They contribute to reducing carbon emissions and promote sustainable agricultural practices. However, their applicability is limited to small and medium-scale irrigation, and they may not be suitable for large-scale farming operations.

Future developments in this field could focus on integrating these traditional devices with modern technologies such as solar power or improved materials to enhance their efficiency and scalability. Such innovations could play a significant role in addressing water and energy challenges in rural areas.

6. Conclusion

Non-electric water-lifting devices such as the Shadoof and the Archimedean Screw demonstrate the value of traditional engineering solutions in addressing modern challenges. These technologies provide sustainable, cost-effective, and accessible means of water management, particularly in regions where conventional systems are not feasible. By reducing dependence on external energy sources and promoting efficient resource use, they contribute to both environmental sustainability and socio-economic development.

The continued relevance of these devices underscores the importance of integrating traditional knowledge with modern innovation. With appropriate support from policy frameworks and technological advancements, these systems can play a crucial role in achieving sustainable and resilient agricultural practices.

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