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Rain Pipe Irrigation in India-Reinventing Micro Irrigation

Y. Pavan Kumar Reddy[1,3*], K. Latha Sahiti Yadav[2], A. Subba Rami Reddy[3], V. Siva Jyothi[1] and K. Prabhakar[1]

Abstract

Growing water scarcity and the inefficiencies of conventional irrigation methods have posed significant challenges to sustainable agriculture, especially in semi-arid and rainfed regions. Rain pipe irrigation a low-cost, low-pressure micro-irrigation technology has emerged as a practical solution to enhance water use efficiency while maintaining crop productivity. By simulating natural rainfall through laser-punched perforated pipes, the system offers uniform water distribution, reduced evaporation losses, and minimal soil disturbance under low pressure. This review critically examines the working principles, system components, agronomic and economic advantages, crop suitability, environmental implications, and limitations of rain pipe irrigation. Emphasis is also placed on its relevance to smallholder farmers and its role in climate change adaptation. The paper concludes with strategies to overcome implementation challenges and highlights future directions for research, innovation.

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Corresponding Author

Y. Pavan Kumar Reddy

e-mail: y.pavankumarreddy@angrau.ac.in

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1. Introduction

In the 21st century, Indian agriculture is trekking towards the double-digit growth of agriculture and related sectors (GOI, 2020). Still, Indian agriculture productivity is oscillating like a pendulum on one side with high potential irrigated areas across the length and breadth of country. Irrigation is the key for the crop productivity in the country (Reddy et al., 2022). Irrigation accounts for nearly 70% of global freshwater withdrawals and improving irrigation efficiency is critical for food security and environmental sustainability (Postel, 1999). Traditional irrigation methods such as flood and furrow irrigation are often inefficient, resulting in high water losses through runoff and evaporation. Micro irrigation techniques including drip, sprinkler, and rain pipe irrigation offer water saving alternatives by delivering water directly to the root zone in a controlled manner (Allen et al., 1998). Rain pipe irrigation is a micro irrigation technique that mimics natural rainfall by distributing water through a network of perforated polyethylene pipes. Unlike conventional drip

Author's Address

[1,3]Assistant Professor, ANGRAU-Agricultural College, Mahanandi (518 502), India

[2]P.G.Scholar, ANGRAU-Agricultural College, Mahanandi (518502), India

[3]Professor & Head, ANGRAU-Agricultural College, Mahanandi (518 502), India

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or sprinkler systems, rain pipe irrigation delivers water gently over the crop canopy and soil surface via uniformly spaced micro-holes, providing uniform moisture without causing soil disturbance. It is particularly beneficial in areas where water resources and capital investment for advanced systems are limited. The simplicity, low cost, and water-saving potential of rain pipe irrigation have driven increasing adoption in countries like India, Israel, and parts of Africa (Burt and Styles, 1999; Narayana Moorthy and Patil, 2010). This system is particularly beneficial for smallholder farms in semi-arid and rainfed regions where cost-effective and water-efficient irrigation solutions are essential. Its low-pressure requirement and ease of deployment make it an attractive alternative to more expensive micro-irrigation technologies.

2. Principle of Rain Pipe Irrigation/ Operational Concept of Rain Pipe Irrigation

Rain pipe irrigation works on a basic hydraulic principle wherein water is conveyed through the pipe under low pressure and released through perforations to form fine droplets or mist. The flow and pressure dynamics are governed by Bernoulli's principle and the continuity equation. As water passes through the orifices, pressure energy is converted into kinetic energy, generating spray patterns that mimic natural rainfall. The principle is based on pressurized water flow inside a perforated pipe, which exits through small holes to uniformly wet the soil surface near the plants. This mimics gentle rainfall, reducing evaporation and runoff losses (Keller and Bliesner, 1990; Smith and Allen, 2014).

Water flows inside the pipe under low pressure (approximately 1-2 bar), driven either by pumps or gravity. The perforations typically 1-2 mm diameter are spaced evenly to ensure nearly uniform discharge rates along the pipe's length. Hydraulic design accounts for pressure loss due to friction and water discharge at each hole to maintain uniform flow (Wang and Liu, 2015).

As water exits the pipe, kinetic energy converts from pressure energy, forming fine droplets that wet the soil slowly and evenly. This gentle application enhances infiltration, reduces soil erosion, and improves root water uptake (Perry, 2007).

3. Components of Rain Pipe Irrigation

The efficiency and functionality of rain pipe irrigation rely on its simple but well-integrated basic components. These include:

3.1. Rain pipes / rain hoses

Made from materials such as HDPE (High-Density Polyethylene), LLDPE (Linear Low- Density Polyethylene), or PVC, these pipes come in various diameters (16 mm to 40 mm) and are embedded with mechanically or laser-punched perforations. Laser perforations provide higher discharge uniformity and reduced clogging risk. (Figure 8 and 9)

3.2. Water source and pump

The system operates using a water source such as a borewell, tank, or canal, supported by a low-pressure pump (12 kg cm $^{-2}$) with even 0.5-1 hp motor is sufficient to run the system. In some cases, gravity-fed systems are also feasible.

3.3. Mains and sub mains

These are existing pipes with PVC/HDPE pipe irrigation system with of 20 feet length/ 6 m length for the conveyance the irrigation to rain pipe irrigation. Now a days these PVC/ HDPE are replaced with complete portable flexible pipes are used for easy conveyance and maintenance.

3.4. End Caps

Used to seal the pipe ends and allow pressure buildup within the system. (Figure 4 and 5)

3.5. Control valves and connectors

Valves regulate flow and pressure across zones. Connectors (couplers, tees, elbows) are used to extend or bifurcate rain pipelines (Figure.2)

4. Advantages, Disadvantages & Applications of Rain Pipe Irrigation

4.1. Applications of rain pipe irrigation

Rain pipe irrigation has found widespread use in various cropping systems, particularly where low-cost, moderate-efficiency solutions are needed.

Row Crops: Groundnut, maize, cotton, and fodder grasses.

Vegetables: Leafy Vegetables, Tomatoes, chillies, brinjal, gourds, etc.

Horticulture: Orchards like guava, citrus, mango (as supplemental irrigation).

Nurseries: Ideal for seedling and sapling growth in controlled environments.

Greenhouses and Polytunnels: As a low-pressure

Figure 1. Field view of Rain Pipe irrigation system

Figure 2: Valve for the rain pipe from main line

Figure 3: Saddle for the rain pipe from main line

Figure 4: End cap for the rain pipe (Side view)

Figure 5: End cap for the rain pipe (Top view)

Figure 6: Rain pipe stright view in the field

Figure 7: Rain pipe with punched laser holes

Figure 8: Rain pipe roll (Top View)

Figure 9: Rain pipe with punched laser holes

Table 1: Advantages of rain pipe irrigation

Feature	Benefit
Water efficiency	Saves 40–60% water over flood methods by minimizing runoff and evaporation
Low pressure requirement	Operates at 1–2 kg/cm², suitable for small pumps and gravity- fed systems
Cost-effective	Requires low initial investment; ideal for small and marginal farmers
Ease of installation	Simple layout and components; deployable without skilled labor
Soil health	Prevents erosion, crusting, and compaction with gentle water application
Portability	Pipes can be rolled and reused across seasons

Table 2: Disadvantages of rain pipe irrigation

Limitation	Description
Clogging risk	Small holes may clog due to sediments or organic matter without proper filtration.
Wind drift	Fine spray may deviate under high wind, reducing application efficiency.
UV degradation	Low-cost pipes may degrade if exposed to direct sunlight for extended periods.
Limited precision	Cannot deliver water as precisely as drip emitters, unsuitable for some crops.
Scalability issues	Less efficient for large farms with complex layouts or undulating topography.

misting system.

Smallholder & Marginal Farms: Especially in rainfed *vertisols* and *alfisols*.

Table 3: Graphical summery of Irrigation systems

Feature	Rain Pipe	Drip	Sprinkler	Flood
Initial Cost	☆☆	☆☆☆☆	☆☆☆	☆
Efficiency	☆☆☆	☆☆☆☆	☆☆☆	☆
Maintenance	☆☆	☆☆☆	☆☆	☆☆
Labor Saving	☆☆☆	☆☆	☆☆	☆
Crop Suitability	☆☆☆	☆☆☆☆	☆☆☆	☆☆

5. Hydraulics and Technical Aspects of Rain Pipe

The performance and longevity of a rain pipe irrigation system significantly depend on the materials used and the dimensional configuration of its components. Rain pipes are generally manufactured from thermoplastic polymers, each offering specific benefits based on usage duration, field conditions, and budget.

The primary hydraulic elements include a low-head pump, HDPE or LLDPE rain pipes, laser or mechanically punched perforations, filters, and control valves. Each of these components contributes to the system's fluid movement

5.1. Materials used

5.1.1. HDPE (High-density polyethylene)

This is the most commonly used material for rain pipes due to its excellent tensile strength, wear resistance, and UV stability. It is highly durable and suitable for long-term field use.

5.1.2. LDPE (Low-density polyethylene)

Known for its greater flexibility, LDPE pipes are easier to handle and lay, making them ideal for seasonal or short-term irrigation needs.

Table 4: Details at field operation and uniformity

Parameter	Details
Material	UV-stabilized HDPE/LLDPE
Pipe size	32 mm (commonly used)
Length per Roll	100 m (Depending on the manufacturer).
Operating pressure	0.8–1.5 kg/cm²
Coverage width	3–5 meters per side (depending on pressure)
Discharge rate	~1–2 liters per hole per minute (varies with pressure)
Filter type	Screen or disc filter recommended

Table 5: Rain Pipe manufactures and costs in India

Brand / Supplier	Pipe Diameter	Length	Material	Price (INR)*	Features
Drip tech	32, 40 mm	50 m	LLDPE and UV coated	₹ 1300 per piece	Suitable for most of the crops with low water pressure system
Swaraj plastic	40 mm	100 m	Plastic	₹ 300 per piece	Suitable for small-scale irrigation
Shri Yedeshwari Agro Industries	40 mm	100 m	PVC	₹ 625 per roll	Agricultural-grade PVC rain pipe
Datta Irrigation Company	40 mm	100 m	Virgin PVC	₹ 700 per roll	High-quality virgin PVC material; suitable for irrigation
V.K. Pack Well Pvt. Ltd.	40 mm	100 m	HDPE	₹ 18 per meter	HDPE material; suitable for vegetable gardens
MIPA Industries	40 mm	100 m	LDPE	₹ 10 per meter	Laser-punched holes; suitable for spray irrigation
PRUTHAA	40 mm	100 m	Virgin Material	₹ 999 per roll	Durable & flexible; ideal for farming and irrigation
V.K. Sarvottam	40 mm	30 m	HDPE	₹ 989 per roll	High abrasion resistance. sprays water up to 20–25 feet
Siddhi Vinayak	32 mm	100 m	HDPE	₹ 530 per roll	Includes accessories; suitable for sugarcane and vegetable crops
Airdrops Irrigation	32 mm	100 m	UV Coated	₹ 868 per roll	UV-coated material; suitable for sugarcane and vegetables
MIPATEX	40 mm	100 m	HDPE	₹ 1,299 per roll	Includes accessories; suitable for spray irrigation

* The prices are approximation only. They may be subjected market dynamics in pan India

5.1.3. PVC (Polyvinyl chloride)

PVC pipes, though more rigid, offer high strength and are often used in fixed-line installations. They are less prone to deformation under pressure but require more careful handling.

5.1.4. Virgin materials

Rain pipes made from virgin (non-recycled) polymers ensure uniformity, better hydraulic characteristics, and extended service life. These are generally preferred over recycled variants for quality assurance.

5.2. Pipe diameters

32 mm Diameter: Recommended for small plots and marginal farmers where water flow requirements are modest.

40 mm Diameter: Suitable for medium to large plots where higher discharge rates are needed for coverage.

Effective design focuses on optimizing **hole spacing (40–60 cm)**, **hole diameter (1–1.5 mm)**, and **lateral run length** (ideally 30–50 meters) to minimize pressure drop and ensure uniform application. The spray pattern typically wets an area 3–5 meters wide, simulating light rainfall. System efficiency is assessed using performance indicators such as **Coefficient of Uniformity (CU)** with values >85% indicating high efficiency. Distribution Uniformity (DU) Compares low quarter average discharge to mean discharge, with higher values indicating better coverage.

6. Cost Breakdown: Micro Irrigation Systems vs Rain Pipe Irrigation (Per hectare)

Initial investment covers pipes, pump, installation, and maintenance. Operational costs are low due to reduced water consumption. Subsidies from government schemes in India further enhance feasibility (Narayanamoorthy and Patil, 2010).

Table 6: Comparison of different micro irrigation prices in the market

Component	Rain Pipe Irrigation	Drip Irrigation	Sprinkler Irrigation
Mainline pipe	₹ 3,000–₹ 4,500	₹ 10,000–₹ 15,000	₹ 6,000–₹ 10,000
Lateral pipes	₹ 6,000–₹ 8,000 (rain pipes)	₹ 20,000–₹ 30,000 (laterals with emitters)	₹ 10,000–₹ 15,000 (riser + laterals)
Emitters / Nozzles / Perforations	Included in pipe (laser punched)	Included in lateral cost	₹ 4,000–₹ 6,000
Connectors and fittings	₹ 2,000–₹ 3,000	₹ 5,000–₹ 7,000	₹ 3,000–₹ 5,000
Filters (Screen or Sand)	₹ 2,000–₹ 3,000	₹ 5,000–₹ 8,000	₹ 3,000–₹ 5,000
Pump/Pressure source (shared)	₹ 4,000–₹ 6,000 (1–1.5 hp)	₹ 5,000–₹ 8,000 (2–3 hp)	₹ 5,000–₹ 8,000 (2–3 hp)
Fertigation unit (Optional)	₹ 1,000–₹ 2,000	₹ 5,000–₹ 15,000	₹ 3,000–₹ 5,000
Installation cost (Labor)	₹ 1,000–₹ 2,000	₹ 5,000–₹ 10,000	₹ 3,000–₹ 6,000
Total cost (Approx.)	₹ 18,000 – ₹ 28,000	₹ 55,000 – ₹ 90,000	₹ 35,000 – ₹ 55,000

Table 7: Comparison of rain pipe irrigation and micro irrigation systems

Parameter	Rain Pipe	Drip	Sprinkler
Initial cost	₹ 18,000–₹ 28,000	₹ 55,000–₹ 90,000	₹ 35,000–₹ 55,000
Water use efficiency	60–70%	90–95%	70–80%
Lifespan	2–3 years	7–10 years	5–7 years
Maintenance cost/Year	₹ 2000–₹ 4000	₹ 5000–₹ 1000	₹ 3000–₹ 6000
Fertigation capability	Basic	Advanced	Limited
Best for	Pulses, vegetables, field crops	Orchards, vegetables, row crops	Field crops, pulses
Subsidy available * (Varies with policy)	NA	Yes (up to 90%)	Yes (up to 75%)

7. SWOT Analysis for Rain Pipe Irrigation System

Strenghts	**Weakness**
Cost effective Water efficency Energy saving Ease of installation & maintenece Adopatability Soil health	emission uniformity durability Limited pressure control scalability constraints
Opprtunities	**Opprtunities**
Technology innovation Renwable energy coupling Climate change adption Local manfucturesrs growth	Competettion from advanced micro Irrigation systems Water quality challenges Lack of awareness Material quality & avalibility Policy & fund availability

SWOT

8. Conclusion

Rain pipe irrigation is a cost-effective, easy-to-install micro-irrigation technique that offers substantial water savings and yield improvements, especially for small and marginal farmers in water-limited regions. Its hydraulic design principles enable uniform water distribution mimicking rainfall. While it cannot fully replace advanced systems like drip irrigation with automation, it fills an important niche by balancing affordability and efficiency. Promoting rain pipe irrigation through policy support, farmer education, and continued innovation will be essential for enhancing global irrigation sustainability

9. Prospects

Rain pipe irrigation is emerging as a key tool for sustainable agriculture, especially in water-scarce regions. Integration with IoT, soil sensors, and smart controls enhances efficiency and scheduling. It supports fertigation, reduces energy use and carbon footprint, and is affordable for small farmers. With government support, education, and local manufacturing, adoption can grow. Rain pipe systems boost productivity, conserve water, and create rural jobs, making them vital for climate resilience and sustainable agricultural growth (Kumar and Singh, 2023; Narayanamoorthy and Patil, 2010).

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