

Water conservation in agriculture: An extension strategies and community participation

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Agriculture consumes nearly 70% of global freshwater and more than 80% of India's utilisable water resources. As per the Central Ground Water Board (2024) assessment, 11.13% of India's groundwater assessment units remain over-exploited, concentrated mainly in Punjab, Haryana, Rajasthan, and Delhi. The Economic Survey of India (2024-25) emphasises that improving irrigation efficiency, promoting climate-resilient agriculture, and enhancing water-use efficiency are critical for ensuring long-term agricultural sustainability. Technologies such as micro-irrigation, laser land levelling, rainwater harvesting, and crop diversification can substantially improve water-use efficiency, currently estimated at only 25–35% in Indian agriculture. Community institutions, agricultural extension, and government programmes such as the Pradhan Mantri Krishi Sinchayee Yojana are central to scaling up adoption. Field experience from villages such as Hiware Bazar (Maharashtra) demonstrates that integrating watershed management with strong community participation can sustainably reverse water scarcity.

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WATER is a critical resource for sustaining crop productivity, soil health, livestock production, and food security. However, in the 21st century, water has become one of the most overexploited natural resources. Agriculture consumes nearly 70% of global freshwater resources and >80% of India's available water resources, making efficient water management essential for ensuring food and livelihood security (Economic Survey of India, 2024-25). Water scarcity in agriculture is mainly driven by rapid population growth, climate change, and inadequate water infrastructure. India's growing population is expected to substantially increase the demand for food and agricultural products by 2050, placing additional pressure on already limited water resources. The Economic Survey of India (2024–25) highlights the importance of improving irrigation efficiency, promoting water-saving technologies, and strengthening

climate-resilient agricultural practices to sustain agricultural growth under water stress.

Climate change has further aggravated the situation through erratic rainfall, frequent floods and droughts, rising temperatures, pest outbreaks, and reduced groundwater recharge. Groundwater depletion has become a major concern in states such as Punjab, Haryana, and Uttar Pradesh, where excessive extraction through tube wells has resulted in declining water tables and increasing cultivation costs (Central Ground Water Board, 2024). Traditional flood irrigation also leads to considerable water losses through seepage, evaporation, and runoff, while agriculture faces increasing competition for water from urban, industrial, and domestic sectors. Therefore, water conservation has become indispensable for sustainable agriculture. Technologies such as drip irrigation, sprinkler systems, rainwater harvesting, laser land

levelling, and IoT-based irrigation management can significantly improve water-use efficiency. However, these technologies can succeed only when farmers are aware of them, adequately trained, and willing to adopt them. Agricultural extension systems play a crucial role in bridging the gap between technological innovations and field-level adoption through farmer training, field demonstrations, ICT-enabled advisory services, Water User Associations (WUAs), and Farmer Producer Organisations (FPOs). Policymakers should further strengthen these efforts through farmer-friendly policies, financial incentives, and improved irrigation infrastructure. A combination of scientific innovation, effective extension services, community participation, and supportive public policies is essential for transforming water-intensive farming into water-smart and climate-resilient agriculture.

Importance of water conservation in agriculture

Ensures sustainable crop production: Water conservation practices such as mulching, drip irrigation and rainwater harvesting augment *in-situ* soil moisture, which is essential for seed germination, root growth and nutrient absorption, helping sustain crop production, even during dry spells.

Enhances water use efficiency (WUE): Scientific water management such as micro-irrigation, laser land levelling, and crop planning based on water availability significantly improves WUE. Drip irrigation, for instance, delivers water directly to plant roots, reducing wastage and translating into 'per drop more crop'.

Reduces risk and vulnerability of smallholders: Recurring droughts and floods disproportionately affect small and marginal farmers. Water-saving measures help them withstand these extremes by conserving soil moisture, supporting aquifer recharge, and ensuring crops receive water at critical growth stages, reducing the risk of crop failure, income loss and distress migration.

Supports ecosystem balance: Excessive water use dries up rivers, depletes wetlands and over-exploits aquifers. Conservation practices restore hydrological balance by augmenting recharge, reducing runoff and preventing degradation, thereby also sustaining biodiversity, fisheries and natural vegetation.

Challenges in agricultural water use

Over-extraction of groundwater: Groundwater has become the main source of irrigation in many parts of India because of large expansions of tube wells and pump sets, subsidised energy supply, and assured nature of irrigation. While this shift has resulted in increased crop yield, it has also led to unsustainable decline in groundwater levels, notably in states like Punjab, Haryana, and Uttar Pradesh. The falling water tables not only make the pumping cost expensive with high energy requirement but also degrade the aquifers, threatening the long-term

viability of farming at risk. In several regions, over extraction has further contributed to the deterioration of groundwater quality, with rising incidences of fluoride and arsenic contamination, posing risks to both agriculture and human health.

Inefficient irrigation practices: Despite technological advances, much of Indian agriculture still relies on traditional flood irrigation, which causes substantial water loss through evaporation, seepage and return flow. Frequent flooding also causes waterlogging and secondary soil salinisation, reducing fertility and productivity. Such inefficient practices put additional stress on already scarce water supplies, particularly in semi-arid and drought-prone regions.

Climate variability: Climate change has made agricultural water availability far less predictable. Erratic monsoon rainfall, prolonged dry and wet spells, recurring floods and droughts, and sudden pest outbreaks are disrupting sowing and harvesting schedules, raising the cost of cultivation and depressing yields. Flood-prone areas lose crops and topsoil, while drought-prone areas suffer crop failure and reduced groundwater recharge, together intensifying agriculture's water crisis.

Competing water demands: Agriculture increasingly competes for limited water with urbanisation, industrial and domestic use. As cities and industries expand, a growing share of available water is diverted away from irrigation, often leaving agriculture the lowest priority in water-stressed regions. This reduced allocation lowers crop yields and threatens the livelihoods of millions of small and marginal farmers.



Loose boulder check dam

Water conservation techniques in agriculture

On-farm water management:

- **Micro-irrigation (drip and sprinkler):** Delivers water directly to the root zone, minimising evaporation and seepage losses. Drip irrigation is especially effective for fruits, vegetables, sugarcane and cotton, saving 30–50% water compared with flood irrigation and often raising yields by 20–40%. Sprinklers suit for uneven or sandy soils where uniform distribution is difficult.
- **Laser land levelling:** Corrects uneven fields that otherwise cause water stagnation in some patches and deficiency in others, improving distribution, lowering input costs, and reducing weed pressure.
- **Mulching and zero tillage:** Organic residues, plastic sheet mulch or crop biomass reduce evaporation and conserve soil moisture, while zero tillage maintains organic matter and improves infiltration particularly valuable in rainfed systems.

Rainwater harvesting and groundwater recharge:

- **Farm ponds, check dams and trenches:** Capture and store rainwater and runoff for later irrigation use. Percolation tanks additionally recharge groundwater, sustaining tube wells through dry months.
- **Rooftop harvesting:** Rainwater collected from farm-household and institutional rooftops supplements water for domestic use, livestock and kitchen gardens, reducing dependence on external sources.



Water absorption trench

Table 1. Major water conservation technologies with their benefits and limitations

Technologies	Key benefits	Typical water Saving	Limitations
Drip irrigation	Direct root-zone delivery; higher yield	30–50% in comparison to flood irrigation	High initial cost; clogging in poor water quality
Sprinkler irrigation	Suited to uneven/ sandy soils	25–40%	Evaporation losses in windy/ hot conditions
Laser land levelling	Uniform water distribution	15–25%	Requires capital equipment and skilled operators
Rainwater harvesting (ponds/ check dams)	Groundwater recharge; dry spells buffer	Site-specific	Siltation; Regular desilting/ maintenance
Mulching/ zero tillage	reduces evaporation; builds soil organic matter	10–20%	Residue availability; pest/residue management
Watershed management	Soil and water conservation including erosion control	Watershed specific	Sustained collective action

- **Recharge wells and shafts:** Recharge shafts, injection wells and trenches allow excess rainwater to percolate into aquifers, maintaining water tables in regions facing decline.

Crop diversification and selection:

- **Shifting from water-intensive crops:** Rice and sugarcane consume disproportionate amounts of water in already stressed regions. Diversifying toward millets, pulses and oilseeds that use 70–80% less water than paddy are good option and nutritionally richer.
- **Climate-resilient varieties:** Drought-tolerant rice varieties (e.g. *Sahbhagi Dhan*), maize hybrids, and short-duration varieties use less water while stabilising yields under uneven rainfall.

Integrated watershed management:

- **Catchment level conservation:** Treating an entire watershed through gully plugging, *nala* bunding and diversion channels extends conservation benefits from individual farms to the whole community.

- **Contour bunding and vegetative barriers:** Bunds along contour lines slow runoff and enhance infiltration. Grasses, shrubs or trees planted along them further check erosion and promote recharge.
- **Afforestation and agroforestry:** Integrating trees with crops improves water retention, reduces evapotranspiration and diversifies farmer income while conserving natural resources.

Public awareness, extension and community engagement

Role of public awareness and extension: Water conservation depends as much on behavioural change as on technology. Farmers and rural communities are the frontline users of water, and their engagement is essential for lasting impact.

- **Educating farmers on economic benefits:** Demonstrating how water-saving techniques cut irrigation and fertiliser costs while raising profits like drip-irrigated vegetable crops.
- **Encouraging indigenous knowledge:** Traditional systems such as *Zai* pits in Africa or

bamboo drip irrigation in north-eastern India show how local wisdom can complement modern technology and build farmer trust.

- **Promoting collective responsibility:** Because water is a shared resource, community institutions such as Water User Associations (WUAs) play a vital role in equitable distribution, maintenance of common structures, and rotational water use (*Warabandi* system).

Tools for farmer awareness:

- **Extension campaigns:** On-field demonstrations, Farmer Field Schools (FFS) and exposure visits let farmers observe real-time benefits as peer learning is often more persuasive than lectures.
- **Mass media and ICT:** Rural radio, agricultural TV programmes, WhatsApp groups and mobile advisories deliver timely information on irrigation scheduling and government schemes, extending reach to remote smallholders.
- **Educational programmes:** Introducing water literacy in schools, colleges and agricultural universities including campus rainwater-harvesting projects as learning models builds conservation values in the next generation.
- **Community movements:** Government-led drives such as Jal Shakti Abhiyan and 'Catch the Rain' mobilise villages for water harvesting, desilting and afforestation, fostering a sense of collective duty.

National schemes:

- **Pradhan Mantri Krishi Sinchayee Yojana (PMKSY):** Promotes micro-irrigation under the 'Per Drop More Crop' motto. By March 2025, the scheme had covered about 96.97 lakh ha nationally (46.37 lakh ha drip, 50.60 lakh ha sprinkler), with over ₹21,968 crore released to states since Financial Year 2016.
- **Jal Shakti Abhiyan (JSA):** A mass movement for rainwater



Field bunding with plantation



Percolation tank

harvesting, revival of traditional water sources, *Amrit Sarovar* creation and large-scale afforestation.

- **MGNREGA:** Wage-based employment has supported construction of thousands of check dams, ponds and irrigation channels, contributing substantially to rural water harvesting.
- **Atal Bhujal Yojana (ATAL JAL):** A World Bank-assisted programme promoting participatory groundwater management in water-stressed states.
- **Jal Sanchay Jan Bhagidari (JSJB) Campaign:** A national groundwater recharge drive built on the '3 Cs' i.e. Corporate social responsibility, Community participation, and Cost efficiency, support borewell recharge to recharge shafts and rooftop systems.

ICAR and state initiatives:

- **ICAR Water Technology Centre:** Develops precision irrigation, fertigation and water-budgeting technologies.
- **Mission Kakatiya (Telangana):** Restoration of village tanks to improve recharge and irrigation.
- **Sujalam-Sufalam (Gujarat):** State-wide desilting of reservoirs and canals.
- **CHHATA:** State-led rooftop rainwater harvesting from

A success story of Hiware Bazar, Maharashtra

Hiware Bazar in Ahmednagar (now Ahilyanagar) district, Maharashtra, illustrates how watershed-based water conservation combined with community discipline can transform a drought-prone village. Since 1989, under the leadership of Sarpanch Popatrao Pawar, villagers constructed contour trenches, earthen and stone bunds, percolation tanks and check dams across the village watershed, while collectively adopting rules such as a ban on open grazing and on water-intensive crops like sugarcane. As groundwater recharge improved, the area under irrigation in the village rose several-fold between the early 1990s and 2009, milk production increased manifold, and the village became a widely cited national model for community-led watershed development. The experience underlines that conservation infrastructure delivers lasting results only when paired with locally enforced rules on crop choice and water use.

private and government buildings in urban local bodies and water-stressed blocks.

Emerging digital technologies

Digital tools are beginning to reshape farm-level water management. IoT-based soil-moisture sensors and automated valves can trigger irrigation only when needed, cutting both water and labour use; satellite and remote-sensing platforms can map crop water stress and guide scheduling across large command areas; and AI-driven mobile advisories can combine weather forecasts with soil and crop data to recommend irrigation timing. These approaches promise real-time precision that manual scheduling cannot match, and several Indian states are piloting them alongside AgriStack and the Digital Agriculture Mission.

Adoption, however, remains limited by high upfront device and

subscription costs, patchy rural internet connectivity, low digital literacy among smallholders, and the absence of localised data and advisory content in many regions. Realising the potential of these technologies will require bundling them with affordable financing, last-mile extension support in local languages, and demonstration on farmer fields rather than research stations alone.

SUMMARY

Water conservation in Indian agriculture is as much a social and institutional challenge as a technological one. Micro-irrigation, rainwater harvesting, watershed management and emerging digital tools can meaningfully raise water-use efficiency, but their impact depends on farmer awareness, behavioural change and sustained community participation as the Hiware Bazar experience demonstrates. For extension agencies, this means prioritising field demonstrations, peer learning and locally adapted advisories over generic messaging. For policymakers, it suggests aligning schemes such as PMKSY, Jal Shakti Abhiyan and Atal Bhujal Yojana for water-efficient cropping, and support for digital extension. For farming communities, it implies embracing collective institutions such as WUAs, FPOs and SHGs that can enforce equitable, disciplined water use even after project support ends. Bringing these three strands together offers a path toward productive, resilient and water-smart agriculture in India.

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Watershed planning through community participation