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TRANSFORMING CROP CULTIVATION

Advancing Water Efficiency in Indian Agriculture

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Acknowledgements

Advisory Council

Dr. Ajay Kumar Mishra
Senior Associate Scientist, International Rice Research Institute (IRRI)

Asitava Sen
Agribusiness Subject Matter Expert

B. Rath
Technical Expert (WM), National Rainfed Area Authority,
Ministry of Agriculture & Farmers Welfare

Roshan Lal Tamak
Executive Director & CEO – Sugar Business, DCM Shriram

Expert Contributors

Amit Shekhar, Head- Group Public Affairs & Policy Cell, Mahindra Rise

Arindom Datta, Senior Advisor, NA, ex-Rabobank

Arun Deshmukh, Project Manager, Netafim

B L Sarswat, Senior Technical Consultant (Agri./Hort.), NRAA, Ministry of Agriculture & Farmers Welfare

Bharat R. Sharma, Professor Emeritus, International Water Management Institute

Dr A D Pathak, Director, ICAR

Dr. A K Vishwakarma, Director, Amaya Consultancy

Dr. Dinesh Singh, Project Coordinator, All India Coordinated Research Project (AICRP)

Emmanuel Murray, Investment Director, Caspian Investment

Harish Damodaran, Rural Affairs and Agriculture Editor, Indian Express

Harvir Singh, Chief Guest Editor, Amar Ujala

Jasveer Singh, Founder & CEO, SICCA (Sense it Out Intelligent Solutions Pvt. Ltd.)

Kumarapuram Gopalakrishnan, ESG Manager, Censanext Systems Private Limited (A Waycool enterprise)

Mahamulkar, Business Head, Netafim

Mallesh T M, CEO, Cultyvate

Mithul Etta, Strategic Partner, Phyfarm

O N Singh, Ex-Director, National Rice Research Institute (NRRI)

O P Shringi, Senior Vice President, DCM Shriram Limited

Dr. P. Geetha, Sr. Scientist (Agronomy), ICAR-Sugarcane Breeding Institute

Dr. P Soman, Senior Vice President and Chief Agronomist, Jain Irrigation Systems Limited

Pia Barataki, Partnership Coordinator, World Bank

Puran Singh Rajput, Co Founder, COO, EF Polymer Private Limited

Dr R P Singh, Agriculture Expert, IFC

Dr. R. Vishwanathan, Director, IISR Lucknow

Raja Srivastava, Sugar Unit Head DCM Shriram Ltd, DCM Shriram

Rajat Shubhro Mukherjee, Climate Finance and Sustainable Development Expert, C40 Cities, Prev. GiZ

Rajveer Singh Brar, Agronomist, The Nature Conservancy

Ruchira Saini, Government and Industry Affairs lead, Corteva Agriscience

Dr. Sheetal Sharma, Scientist - Soil Science and Research Leader - Digital Tools & Big Data, International Rice Research Institute (IRRI)

Shenoy Mathew, Chief Sustainability Officer, Arya.ag

Suhas Wani, International Consultant, ADB

Suparana Katyaini, Programme Lead, CEEW

Content Contributors and Reviewers

Ayushi Baloni, Aparna Bhaumik, Tanisha Kouli, Aditi Sharma. Shivangi Sharma, Shristi Sarawgi, Vikramjeet Sharma, Debaranjan Pujahari, Rathish Balakrishnan and Anantha Narayan.

Partners

Aman Pannu
Head of Corporate Communications and CSR, DCM Shriram Foundation

Joy Mukherjee
Team Lead, DCM Shriram Foundation

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Design: **Usha Sondhi Kundu**; *cognitive.designs@gmail.com*

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Executive Summary

India is considered to be one of the most water-stressed countries in the world. The crisis is compounded by the country having 17% of the world's population, but only **4% of the freshwater sources.** In an agrarian country like India, water and agriculture are intrinsically linked, **with 90% of water withdrawals stemming from excessive agricultural usage.** Evolving the sector to avert the impending water crisis is critical at this juncture, especially in the cultivation of certain water-intensive crops.

In Punjab and Haryana, more than 25% of the designated districts cultivating rice have very low groundwater levels, exacerbating water depletion in these regions. Additionally, sugarcane cultivation, contributing 1.1% to India's agricultural GDP, further aggravates water depletion, particularly in Maharashtra, Karnataka, Uttar Pradesh, and Andhra Pradesh.

While various water-saving techniques exist, challenges hinder their widespread adoption. Root causes of the water crisis include **invisible water pricing, a lack of market support** for water-efficient crops, **on- and off-farm water losses,** and **inadequate scaling** of water-efficient conservation techniques. There are also certain barriers to adoption, including a lack of customisation, awareness, financial constraints, misplaced incentives, and resistance to change. Critical levers to scale existing techniques include prioritising farmers' economic benefits, ensuring **sustained access to resources,** and **addressing capacity and information** gaps. Collaboration among stakeholders is essential for addressing the water crisis comprehensively.

Today, efforts to improve water-use efficiency in rice and sugarcane cultivation involve multiple programmes and initiatives driven by industry, government, and philanthropy. Government policies are aiming to promote water conservation, industry leaders are implementing programmes to enhance farming practices, and multilateral organisations are supporting projects to improve water management.

In spite of significant efforts, there are notable gaps hindering greater impact, including over-reliance on philanthropic funding, limited scalability of initiatives beyond pilot projects, and inadequate collaboration among stakeholders. Moreover, challenges persist due to insufficient data for informed decision-making and low adoption rates of proven technologies. To overcome these barriers it is necessary to integrate science and data into decision-making processes of stakeholders, cater to the regional localised needs of ecosystems, and convene industry stakeholders effectively to make commitments that drive intent and action.

As a way forward, this report will share **three key ideas** focusing on how to enable and scale existing innovations by:

- Building a public recommendation engine that can recommend techniques and practices **contextualised to local agricultural ecosystems**.

- Combining **scientific knowledge with existing on-ground implementation** and effectively establishing a **water-positive framework or index for decision-making**.

- Developing a model for collaborative action among industry stakeholders towards water-use efficiency in agriculture and enabling collective **learning and advocacy**.

Decisively moving away from the limited, pilot implementation models, to geographically tailored programmes, that empower farmers with awareness, knowledge, and skills, could catalyse water efficiency in cultivating rice and sugarcane. Strong stewardship of these efforts by private industry and philanthropy will also be key. By enabling this kind of innovation in agriculture, the mounting water scarcity problem in India, with projections estimating a further decrease in per capita water availability by 2050, could be slowed down significantly.

01 India's Water Crisis Begins on its Farms

Currently, two-thirds of India's population grapples with water scarcity, with projections pointing to a 15% decrease in per capita water availability by 2050.

Globally, **around 3 billion people face water scarcity for at least one month each year**, impacting livelihoods, food security and access to electricity.[1] By 2050, the number of people in cities worldwide struggling with water scarcity is expected to surge from 933 million in 2016 to between 1.7 and 2.4 billion. India is predicted to face the most severe impacts.[2]

India is considered one of the most water-stressed countries in the world. India has nearly 17% of the world's population but only 4% of the freshwater resources.[3]

India's current utilisable water resources amount to 1,123 billion cubic metres, roughly equivalent to 40 crores of Olympic-sized swimming pools.[4] Projections indicate a 30% increase in water demand by 2050, coupled with a 15% decrease in per capita water availability, highlighting an impending supply-demand gap.[5,6]

India's existing water sources face increasing pressure from population growth and pollution, with key sectors like agriculture further exacerbating the crisis due to high water withdrawals.

Regions with less than 1,700 cubic metres of water per capita annually are considered to face water scarcity as per the Falkenmark Index.[7] Based on this index, **nearly 76% of the population in India is currently grappling with water scarcity**. Projections for per capita water availability for the year 2050 reveal that more than 50% of districts are expected to face severe scarcity.[8] (See *Figure 1*)

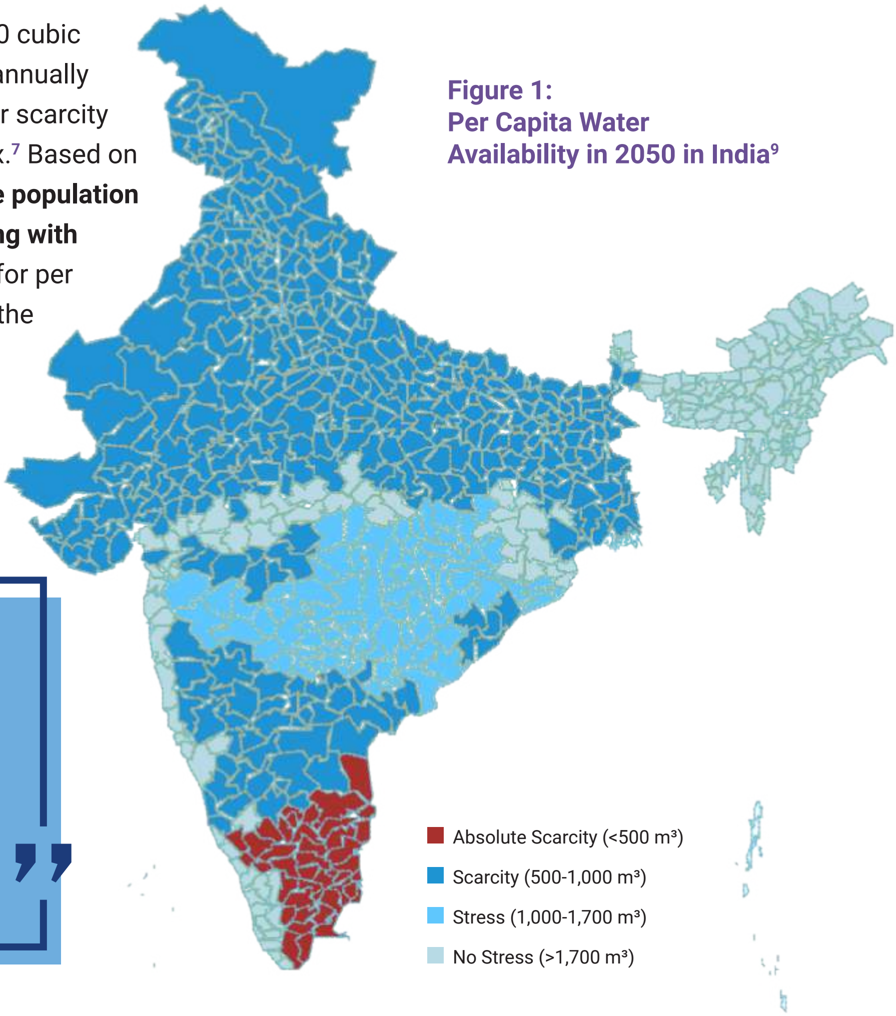


Figure 1: Per Capita Water Availability in 2050 in India[9]

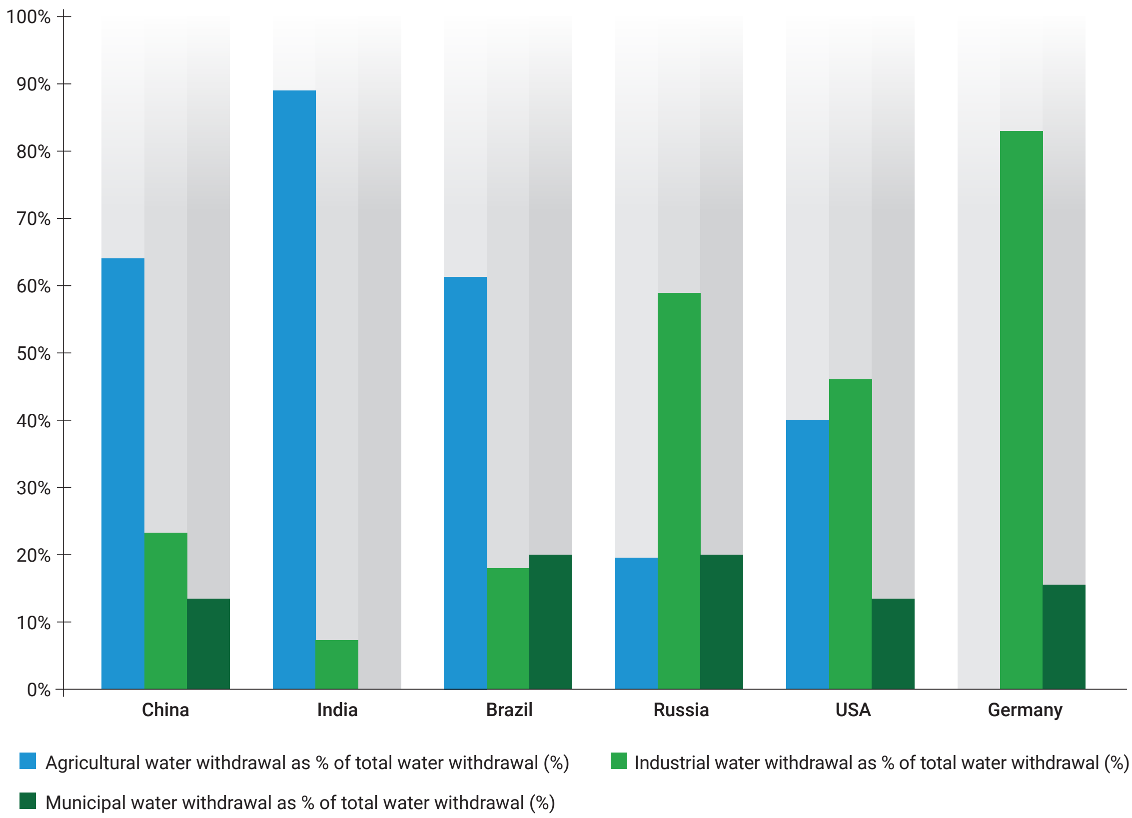
> Nearly **76%** of the population in India is currently grappling with water scarcity.

The **impact of scarcity on groundwater resources** has been most critical. A government-led assessment in 2023 revealed that out of the total 6,553 assessment units (Blocks) in the country, 736 units in various States/Union Territories (UTs) (11%) have been categorised as **'Over-exploited'**, indicating groundwater extraction exceeding the annual replenishable recharge. Additionally, in 199 blocks (3%), the stage of groundwater extraction is between 90-100% and categorised as **'Critical'**.

Agriculture in India worsens the water crisis, with 80-90% of overall water withdrawals.

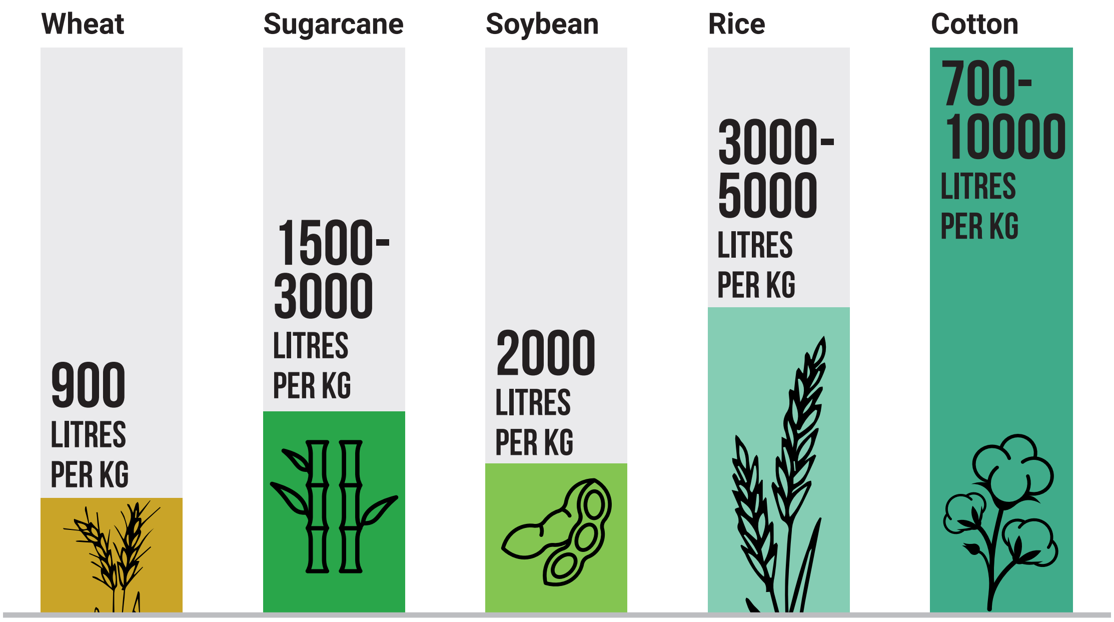
Water scarcity is primarily driven by **excessive agricultural usage, which accounts for around 90% of water withdrawals in India**[10] (See *Figure 2*). Being an agrarian country, irrigation by far is the largest user of India's water reserve with a whooping usage of 84% of the total water reserve, followed by the domestic sector and the industrial sector and this trend is going to persist as per 2025 and 2050 projections.[11]

Figure 2: Industry-wise water withdrawals for China, India, Brazil, USA and Germany[12]



Water and agriculture are intrinsically linked, but how the sector can evolve to use water to avert the impending water crisis is critical at this juncture. The agriculture sector today uses water extensively in the cultivation of certain crops, due to the natural characteristics of these intensively grown crops and the inefficient water usage practices used to grow them.

The top five most water-intensive crops grown in India are:



90% of India's total crop production is reliant on three key crops: rice, sugarcane, and wheat. This dependence is projected to grow further due to the innate preference of the expanding Indian population for these staples. The dependence on these crops is further enhanced by the skewed incentive structures, including the highly subsidised pricing of water, power, fertilisers, assured markets and guaranteed prices through procurement.[13]

Besides water-intensive crop production, India also has **low irrigation efficiency** compared to other countries. Water use efficiency (WUE) can be measured through various metrics; one important indicator is Irrigation Application Efficiency (AE) and it is a performance criterion that expresses how well an irrigation system performs when it is operated to deliver a specific amount of water. The majority of Indian farmers irrigate their crops with conventional surface irrigation methods, which seldom exceed 35% of water use efficiency.[14] Due to excessive reliance on flood irrigation, the overall irrigation application efficiency is only 38% in India, compared to other countries where it is 50-60%.[15]

As per the Water Resources Group, with the current progress towards improving water usage efficiency in India, only 20% of the supply-demand gap by 2030 would be filled, leaving a large deficit.[16]

Water-intensive crop cultivation and inefficient farming practices can lead to a 30-40% reduction in yield and up to 30% lower income for farmers.

Apart from declining water availability, desertification, and land degradation, water-intensive crop cultivation impacts farmers due to various other significant issues, including water and soil quality, climate-related challenges, and declining crop productivity.

Declining Water Quality

High fertiliser consumption, rising from 25.75 kilograms per hectare (kg/ha) in the 1970s to 78.43 kg/ha in the 1990s, has led to declining water quality in India.[17] The growth rate for fertiliser consumption exceeded 5% from 2001-2015. Key states such as Punjab, Haryana, and Andhra Pradesh exhibit high contamination levels, including arsenic, lead, and fluorine, due to excessive use of fertilisers and chemical inputs.

Declining Soil Quality

Overirrigation can lead to 40-50% depletion in soil moisture levels.[18] Additionally, **salinity and alkalinity** affect soil quality further. Salinity-affected soils affect approximately 7 million ha in India.[19] These salinized areas in India continue to increase each year due to the introduction of irrigation in new areas with the rate of increase being around 10% annually.[20] Unless attempts are taken to prevent or lessen the soil, such salt-affected areas are estimated to treble from 6.74 to 16.2 million ha by 2050.

Climate-related Emissions

Rice cultivation in flooded fields leads to the release of greenhouse gases, including carbon dioxide, methane, and nitrous oxide.[21] Additionally, there are significant emissions due to the burning of rice husk residue.

Reduced Crop Quality and Yield

Improper water management practices have been known to reduce sugarcane yields by 5-30%.[22] In rice cultivation, flooding fields due to overirrigation can result in yield losses of 10-15%.[23] As temperatures rise and water resources become scarcer, the duration of crop growth diminishes, exacerbating the challenge of meeting the crops' water requirements. The reduction in rainfall and irrigation water availability due to climate change compounds these issues, leaving crops more vulnerable to water scarcity.[24] **On top of this, salinity stress** can reduce yields by up to 50%.[25] Prevalent in arid and semi-arid regions like Rajasthan, Haryana, Punjab, Gujarat, Uttar Pradesh, Delhi, Andhra Pradesh, Maharashtra, Karnataka, and Tamil Nadu.

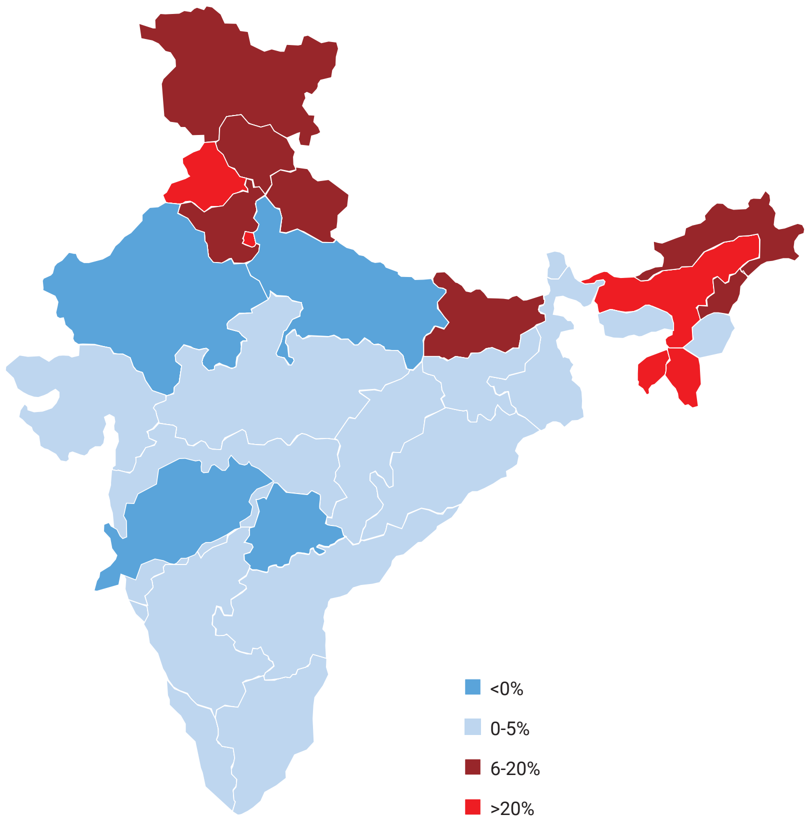
Adverse Impact on Small-holder Farmer (SHF) Communities

Farmers practising inefficient irrigation methods may experience income reductions of 20-30%.[26] Apart from this, there is an increased risk of vector-borne diseases in farming communities due to stagnant water.[27]

Increasing Desertification

Adding to this, the country is undergoing **increasing desertification.** Unsustainable water use in agriculture exacerbates desertification by causing soil salinization, groundwater depletion, erosion, and deforestation, leading to the degradation of fertile land into arid desert areas. In some cases, there is waterlogging due to inefficient irrigation, which indirectly contributes to this process. From 28.8% of desertification of the total geographical area in 2003-2005, it increased to 29.3% in 2011-2013.[28] (See *Figure 3*)

Figure 3: State-wise % Change in Desertification in India from 2003-2005 to 2011-2013[29]



Rice and Sugarcane cultivation, which account for 60% of water withdrawals in the country, demand targeted focus and urgent attention.

Rice and Sugarcane collectively occupy 27% of cultivable land and consume more than 60% of agricultural irrigation water. The focus is on regions where water challenges are particularly pronounced and dominated by **rice cultivation** such as Punjab and Haryana, similarly subtropical areas like Maharashtra, Tamil Nadu, Karnataka, and Andhra Pradesh, where **sugarcane cultivation** is prevalent.[30]

Against this backdrop, our report focuses on the pivotal role of water-efficient and sustainable cultivation practices for two of the most water-intensive crops: **rice and sugarcane**. The following sections delve deeper into the heart of this problem, focusing on **sustainable and water-efficient crop production as a focal point for enabling on-farm water use efficiency**. Through these sections, we will analyse the landscape of emerging water-saving practices during rice and sugarcane cultivation, identify key systemic challenges hindering the adoption of water-saving techniques, and propose robust solutions outlining the roles of key stakeholders.

02 Decoding Rice Farming

Rice plays an irreplaceable role in Indian agriculture with over approximately 55 million agricultural households dependent on its production.

Rice holds an indispensable position in Indian agriculture, serving as a vital staple with significant production and consumption implications. Cultivated for over 7000 years,[31] rice gained massive importance around the 1960s, motivated by food security concerns. The Green Revolution of the 1960s introduced high-yielding rice and wheat varieties to enhance India's self-sufficiency, resulting in a **surge in rice consumption** and a decline in traditional crops, like millets such as sorghum and barley.[32]

Rice production has only grown in recent times, with the total production of rice during 2021-22 estimated at a record 127.93 million tonnes, higher than the last five years' average production.[33] 60% of rice is cultivated during the Kharif (summer) season, while 40% is grown in Rabi (winter season) with assured irrigation. Rice cultivation spans across 10+ Indian states, with Uttar Pradesh, West Bengal, Odisha, Chhattisgarh, and Bihar being the top 5 states. Moreover, within the states, rice is grown in 85% of districts in India, making it the single largest crop in the country.[34] The top 16 rice-producing districts in India, known collectively as the 'Rice Basket', contribute to 20% of the total rice production. Additionally, there are 15 districts known as the 'Bright Spots' with the highest yield of rice.[35] In total, around 55 million households out of a total of 93.04 million households are dependent on rice production in India.[36]

Policy structures, assured markets, and sustained public demand has further cemented the dominance of rice cultivation.

Rice farming in India is deeply entrenched within policy frameworks, with **established government procurement systems** like the Minimum Support Price (MSP) ensuring a stable market for farmers. Procurement, conducted through **centralised and decentralised** systems,[37] involves participation predominantly from six key states, Punjab, Telangana, Andhra Pradesh, Chhattisgarh, Odisha, and Haryana, which collectively make up 74% of total procurement.[38] For example, in Punjab, the entire rice production is procured at a Minimum Support Price (MSP) through 154 Agricultural Produce Market Committees (APMCs). Similarly, in Haryana, nearly 80% of rice is procured by the government through 106 APMCs.[39]

Adding to this, consumption of rice has paralleled the increasing production of rice. Domestically, rice serves as a staple food for over **two-thirds of the Indian population** and is consumed across almost all states of India. However, rice also holds significant export potential, **with nearly 15% of India’s total rice production being exported** due to the steady growth in international demand for rice.[40]

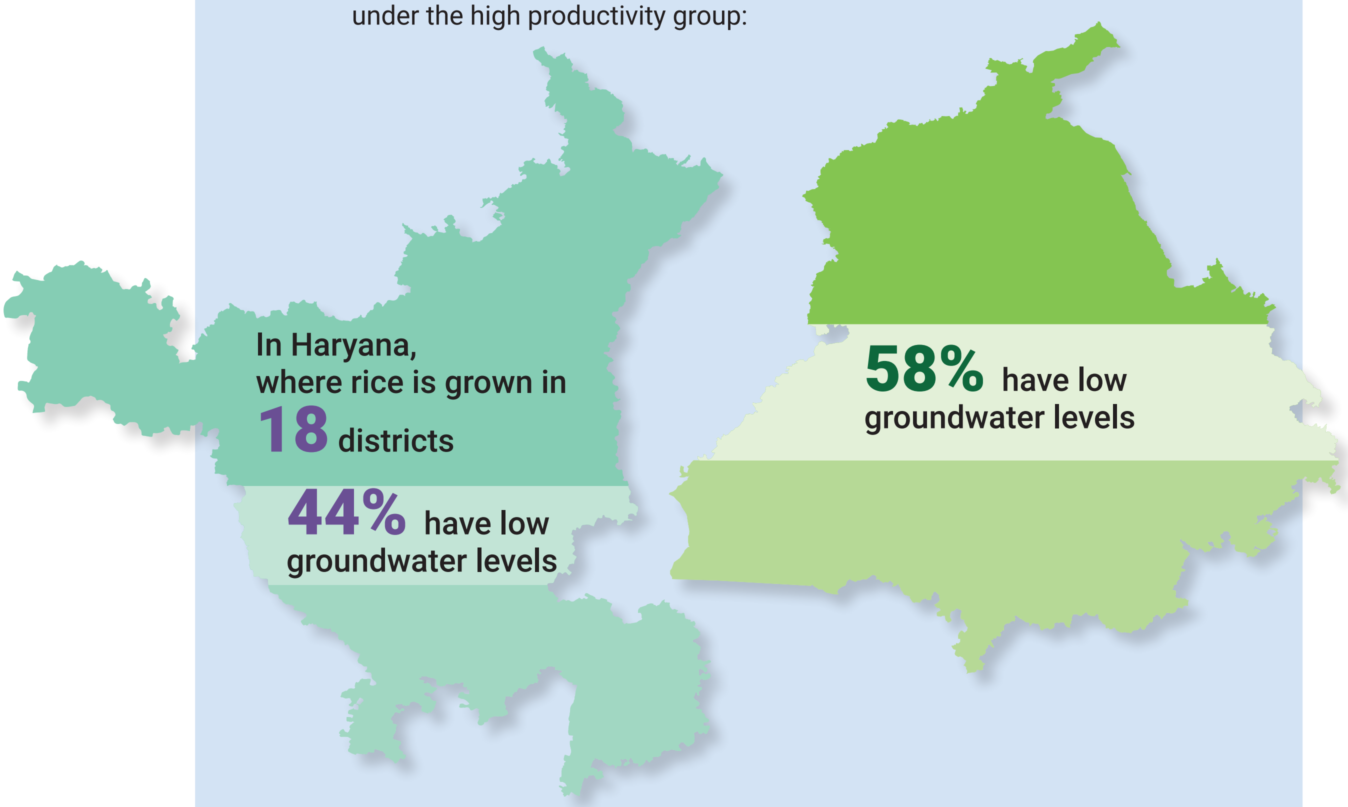
Interestingly enough, it is necessary to note that the majority of rice growers, around **80-90%**, face financial struggles, mainly because they operate on small-scale farms. The recent Agriculture Census data reveals a steady decline in the average size of operational holdings, from 2.28 ha in 1970-1971 to 1.08 ha in 2015-2016.[41] This trend reflects fragmented land division across generations, adding to farmers' woes. Although MSPs have increased over time, rising cultivation costs often erode profits. Moreover, inadequate storage facilities and post-harvest infrastructure further hinder earnings, compounded by fluctuating market demands. Despite these challenges, the **deep-rooted dependence on rice and its consistent demand, both domestically and internationally** perpetuates a vicious cycle, leaving farmers trapped in traditional practices due to limited resources and market uncertainties.

However, rice cultivation alone consumes 45% of the nation's total irrigation water.

Among the top five most water-intensive crops grown in India, **rice stands out as one of the most water-intensive, requiring between 2500-5000 litres per kg.**[42] A significant portion, accounting for 28% of India's irrigated land is solely allocated to rice cultivation.[43] Despite only 60% of rice fields [44] having assured irrigation, **they consume a significant 45% of India's total irrigation water**.[45] This situation is further fuelled by traditional and water-inefficient cultivation practices, such as transplanting rice in puddled soil and flood irrigation, resulting in overall low irrigation efficiency rates of **30-40%.**[46]

INSIGHTS

The major issue is that there is an **over-reliance on groundwater in northern rice-growing states** which heavily rely on tube wells and other sources of groundwater for irrigation. In both Punjab and Haryana, rice cultivation covers all 17[47] and 18[48] districts, respectively, with each district classified under the high productivity group:



There have also been reported instances [52] where the level of groundwater has gone deeper every subsequent year, highlighting depleting water tables. This groundwater exploitation is worsened by significant electricity subsidies and the absence of water pricing, which promote indiscriminate groundwater extraction via tube wells. Currently, the government supplies free power to over 20 million water-pumping wells, incentivising their excessive and unchecked use, due to the lack of electricity charges and assured irrigation.

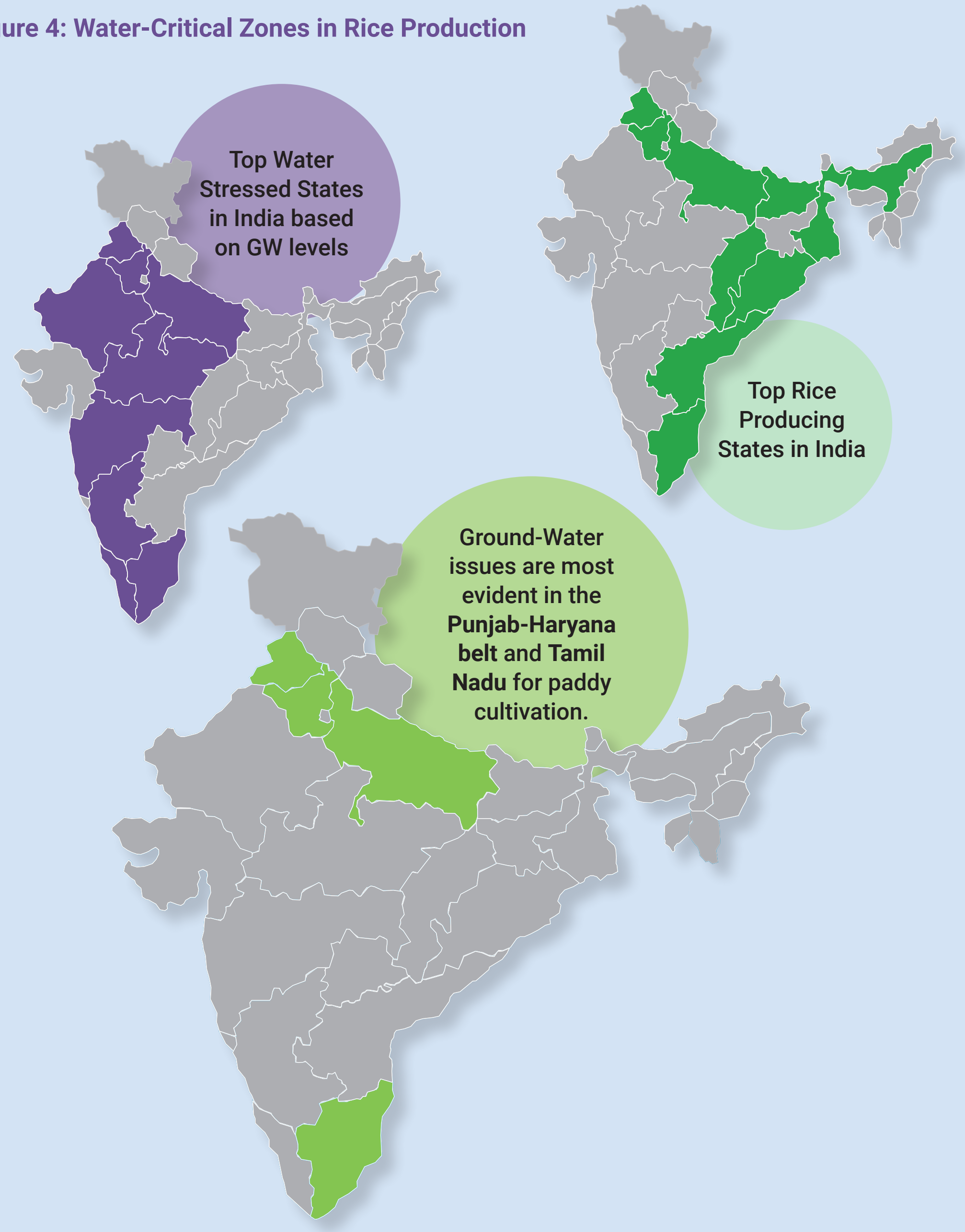
Moreover, these regions face challenges such as **low irrigation water productivity and poor indices for physical and economic water productivity** since their hydrological suitability contradicts natural water endowments. For instance, in the Punjab-Haryana belt, rice cultivation has expanded extensively. Surinder Singh Kukal, Dean of the College of Agriculture at PAU, explains this phenomenon by stating, "Rice originates from [a] wild plant species and was traditionally cultivated in naturally flooded areas. However, as farmers began cultivating it in non-naturally flooded areas, they artificially flooded their fields." This practice has led to the widespread adoption of water-intensive rice cultivation even in regions with limited water resources. This misalignment contributes to unsustainable water use practices in rice farming.

"Rice originates from [a] wild plant species and was traditionally cultivated in naturally flooded areas. However, as farmers began cultivating it in non-naturally flooded areas, they artificially flooded their fields."

INSIGHTS

On the other hand, states like Kerala, Andhra Pradesh, and Tamil Nadu heavily rely on monsoon rainfall. **Climate change-induced erratic weather patterns** have led to water shortages, resulting in significant yield reductions of up to 30%.[53] For example, in Tamil Nadu's Thiruthuraipoondi, farmers faced **crop losses due to insufficient water**, forcing them to abandon their crops after exhausting resources. The ongoing dispute between Tamil Nadu and Karnataka over the Kaveri river water exacerbates the situation, with Tamil Nadu requesting more water to protect paddy crops, while Karnataka cites deficits in rainfall and water scarcity for its inability to release additional water.

Figure 4: Water-Critical Zones in Rice Production



The ecosystem has identified the need for sustainability, and emerging techniques for water conservation in rice farming have shown a positive impact of 30-40% on water savings, improved cost-effectiveness, energy efficiency, and crop yields.[54]

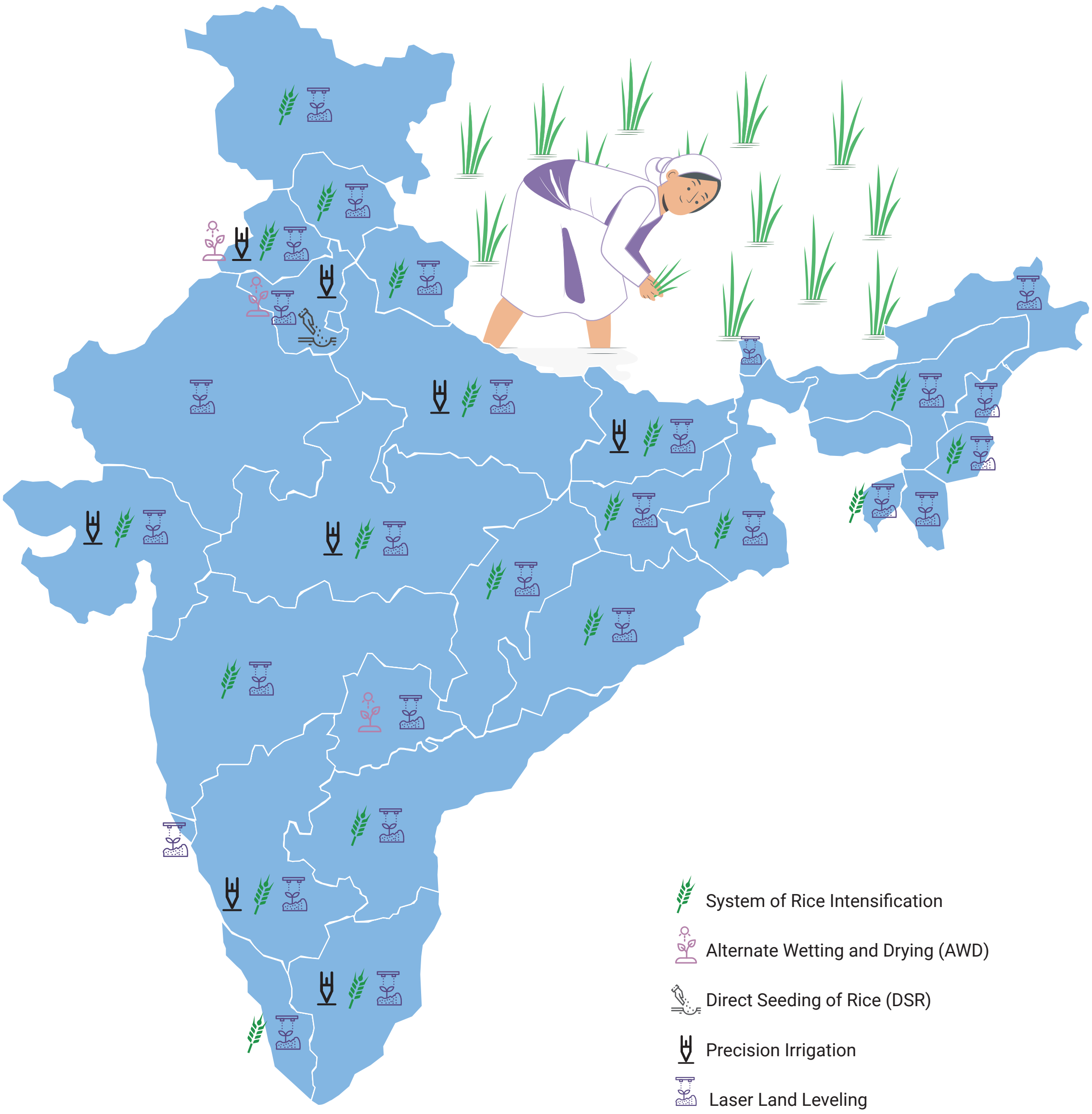
The adoption of innovative cultivation techniques for rice presents promising solutions for enhancing water efficiency and crop productivity. (See *Table 1*)

Table 1: Techniques for water saving in rice cultivation

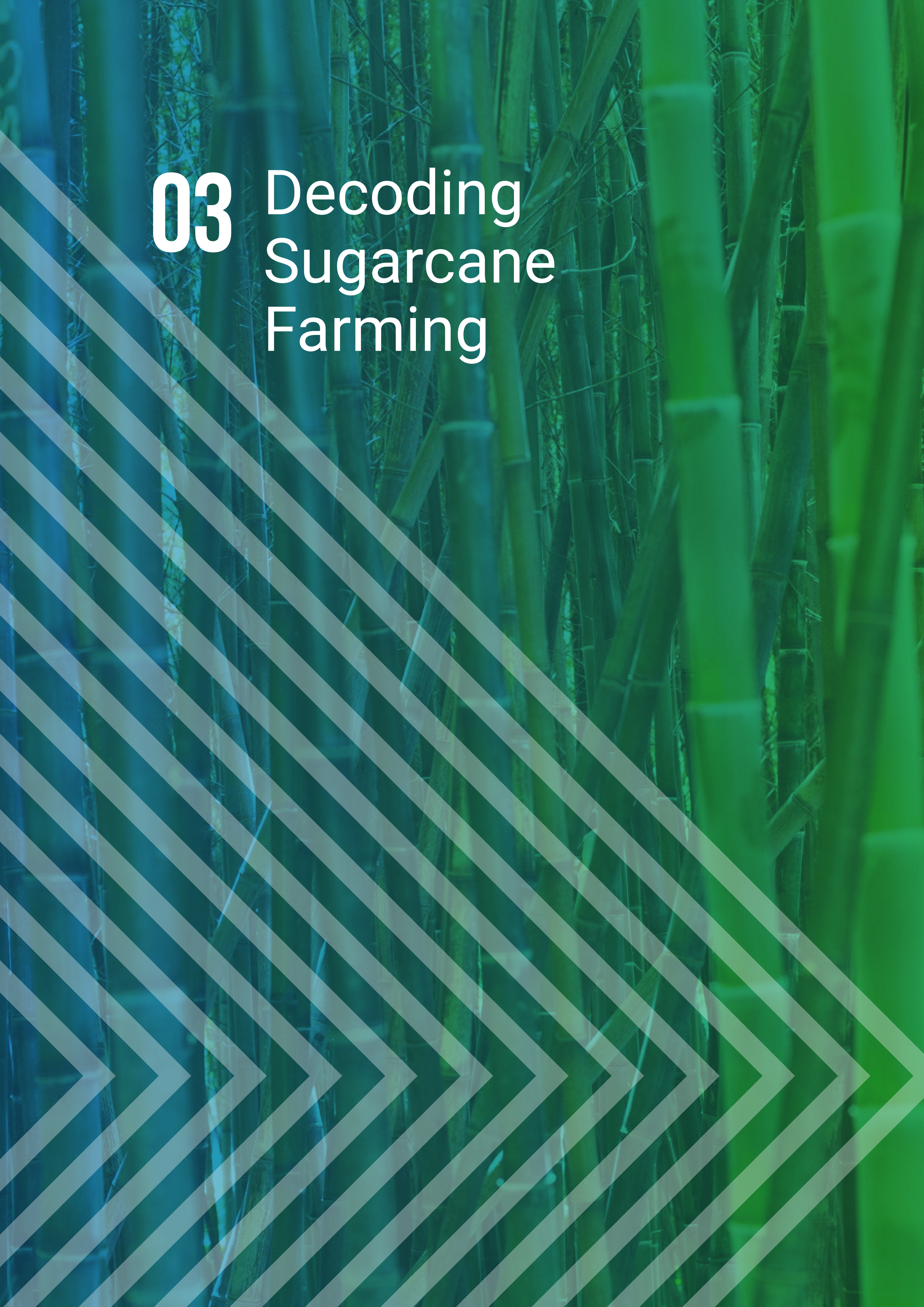
These technologies hold promise for sustainable rice cultivation practices, addressing water scarcity challenges while ensuring economic viability for farmers. Additionally, there have been varying effects on cost effectiveness, energy efficiency and crop yields.

Technology/ Solution[55]	Effectiveness of the Technique	Economic Considerations		Crop Suitability
	Water Saving Achieved	Cost-effectiveness	Energy Efficiency	Effects on Crop Yield[56]
Alternate Wetting and Drying (AWD)	**23-33%**[57]	• Lower irrigation costs and pest control costs for farmers • Increased grain productivity	• Minimises water loss • Reduced energy requirements for water pumping and distribution	• Improvement in paddy crop yields by up to **20%**[58]
System of Rice Intensification (SRI)	**40%**[59]	• **23%** lower cost of cultivation[60]	• Significant **water savings,** reducing the electricity needed for irrigation[61]	• SRI recorded **higher grain yield** by as much as **80%**[62]
Direct Seeding of Rice (DSR)	**18%**[63]	• Reduced fertiliser and land preparation costs • Eliminates the need for herbicides	• **Energy savings** attributed to reduced irrigation requirements and less intensive field tillage	• DSR leads to **yield improvements** up to 50%[64]
Laser Land Levelling	**18-21%**[65]	• Data not available	• Significant energy savings, with farmers able to save energy by **24%**[66]	• Yielded **14.7%** higher output, resulting in 62.5% higher net returns than non-laser levelled fields[67]
Precision Irrigation	**50-55%**[68]	• Cost savings in terms of water, electric power, and overall expenses, with a low-cost microtube drip system	• Energy savings by 4.5% to 5% and increased profitability by 12.5-24%[69]	• Although more suitable for horticultural crops in India, precision systems like drip can lead to yield increase by upto **40-50%**[70]

Figure 5: Coverage of Water-Efficient Rice Cultivation Techniques Across India



03 Decoding Sugarcane Farming



Sugarcane single-handedly contributes to 1.1% of India's agricultural GDP.

Sugarcane is a vital economic force in India's agricultural landscape, contributing a substantial **1.1% to the nation's agricultural GDP** while occupying merely **2-3% of the total production area.** Despite its limited footprint, the sugarcane and sugar industry **ranks second** in India's agro-based sectors, closely following cotton. Uttar Pradesh, Maharashtra, and Karnataka emerge as key players in sugarcane production, with Uttar Pradesh leading the pack. This concentration of production is evident in the location of the **top 10 districts, which alone contribute to 40% of India's total sugarcane yield,** primarily in Uttar Pradesh and Maharashtra. Furthermore, the significant dependency on sugarcane cultivation is underscored by the estimated **50 million farmers and their dependents** engaged in its cultivation across the nation.[71] This widespread cultivation sustains rural livelihoods and provides employment opportunities for approximately **0.5 million workers in sugar factories and related industries,** illustrating the extensive socioeconomic impact of sugarcane farming in India.

Growing demand projections, thriving markets and policy incentives have further cemented the importance of sugarcane cultivation.

The **demand for sugar is expected to surge by around 70%** to reach nearly 48 million tonnes by 2050, compared to the current average domestic sugar consumption demand of **27.85 million tonnes.** Hence, its role as a crucial commodity is undeniable.[72] On the international front, India's sugar exports increased by a staggering **189%** from 2018-19 to 2021-22.[73] Out of the total production, India exported around **18% (33.7 million metric tonnes)** in the 2023-24 marketing year.[74] The data suggests a growing domestic demand, coupled with a substantial increase in India's international market presence and export contribution, indicating a **robust and dynamic sugar industry.**

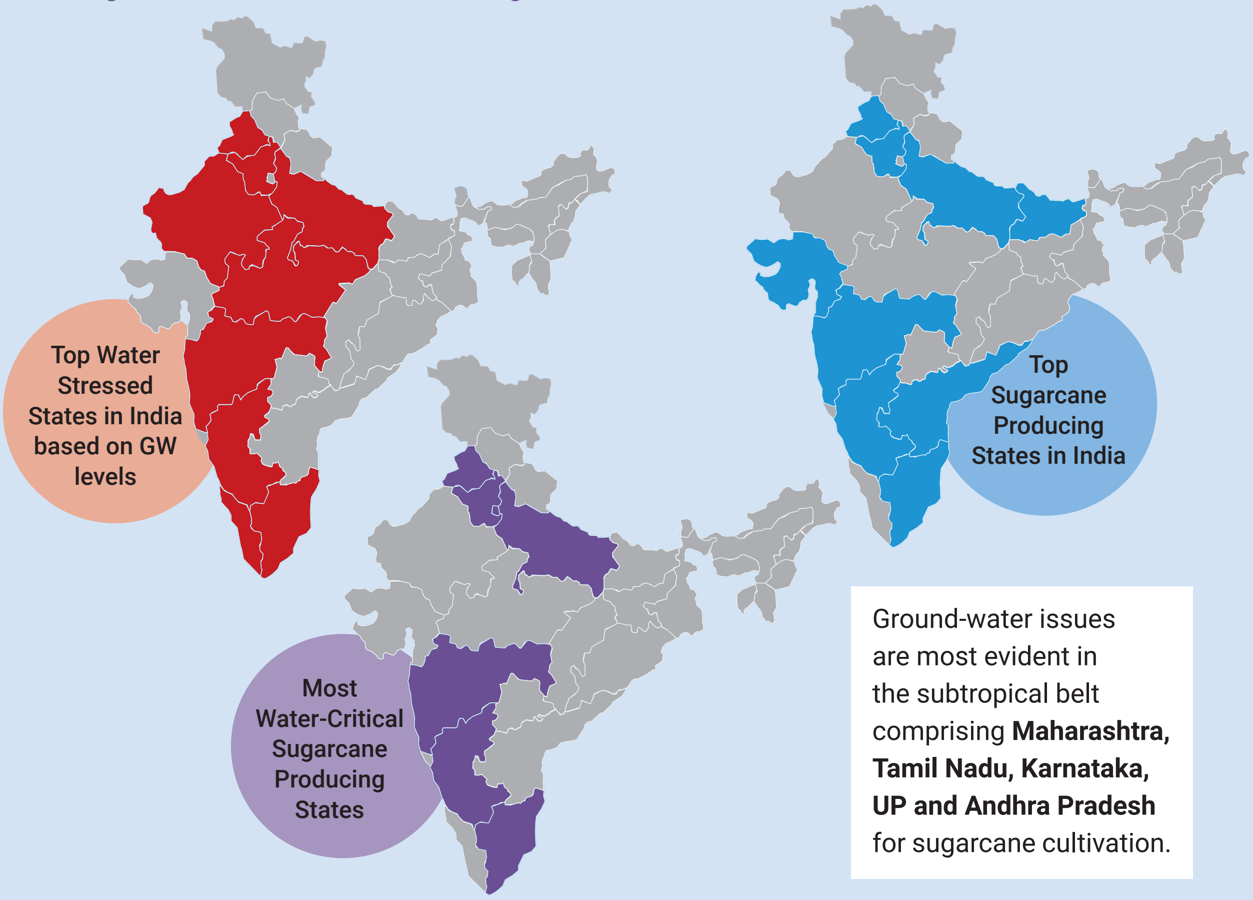
Notably, India's yield per hectare lags behind other major sugarcane-producing nations, standing at just 64.5 tons/hectare, notably lower than other sugarcane producing regions like Java which has yield of 90 tons/ha and Hawaii's 121 tons/ha. Despite this, sugarcane cultivation offers **comparatively higher profit margins**, which is typically **60%-70%** higher than most other crops.[75] However, it is important to note that increasing costs of cultivation in recent years also pose some challenges. The all-India per hectare gross returns over costs of cultivation for Andhra Pradesh, Maharashtra and Tamil Nadu have lower returns than all-India. The returns were lowest in Andhra Pradesh at ₹17,130 per hectare and ₹4,927 per hectare, respectively, due to lower yield and significantly high cost of production.[76] However, the **fundamentals of the industry stay quite strong**.

The sugarcane industry in India benefits from **highly regulated prices and assurance for farmers,** with prices determined by both the central and state governments. Mills are obligated to purchase sugarcane from farmers at or above the **Fair and Remunerative Price (FRP)** set by the Union Government or the **State Advised Price (SAP)** fixed by the State Government, reducing risks for farmers, and providing a degree of assurance regarding returns. The Government of India has effectively upheld stable retail prices of sugar across the country. For example, despite international sugar prices reaching their highest level in a decade in April-May 2023, domestic sugar prices experienced only nominal inflation, hovering around 3%. This increase is in line with the hike in the FRP of sugarcane, ensuring fair compensation for farmers while maintaining affordability for consumers.[77]

However, it is cultivated in water-scarce regions of India and exhibits low water-use efficiency of 35% to 45%.

Sugarcane, as a highly water-intensive crop, presents a significant challenge to water management in India, particularly in regions already facing water scarcity. Its prolonged growth cycle of **12-18 months** demands a considerable quantity of water, with subtropical states like Uttar Pradesh, Punjab, Haryana, and Bihar requiring **1,400-1,500 mm** annually.[78] Throughout the cropping season, sugarcane absorbs between 1,500-2,500 mm of water, exceeding the average water needs of most crops which stand at 300-500 mm. This heavy reliance on irrigation exacerbates the strain on water resources, with **80% of sugarcane's irrigation needs** in India met through **groundwater** sources.[79] In some regions, sugarcane cultivation consumes a disproportionate amount of irrigation water, accounting for up to **60% of total usage** despite occupying only **3-4% of agricultural land.** Moreover, the production process of ethanol, a by-product of sugarcane, also contributes to water usage concerns, with every litre of ethanol requiring a **staggering 2,860 litres** of water.[80]

Figure 6: Water-Critical Zones in Sugarcane Production



Ground-water issues are most evident in the subtropical belt comprising **Maharashtra, Tamil Nadu, Karnataka, UP and Andhra Pradesh** for sugarcane cultivation.

Conventional methods employed by sugarcane farmers further compound water inefficiency, with practices like flood or furrow irrigation, resulting in a **low irrigation efficiency of just 35-45%.**[81] This inefficiency leads to significant losses of irrigation water, aggravating water scarcity issues in critical regions like Uttar Pradesh and Maharashtra. Geographical realignments within the sugarcane belt, driven by shifts towards cooperatives, have relocated the production hub to regions like Maharashtra, Karnataka, and Tamil Nadu, which lack the water resource endowment of historical centres such as Bihar and eastern Uttar Pradesh.

Given its importance, it is essential to address the question of sustainability in sugarcane production, by identifying key factors behind water use inefficiency.

Established and highly regulated systems for the sugarcane industry ensure that farmers are **less incentivised** to switch to other crops. Moreover, **robustness** of the sugarcane industry, and more than sufficient production of sugarcane to meet domestic as well as international demand, make it much more imperative to work on issues that can help the sector build sustainability in the long run. Within this ambit, water efficiency is an important area to address, given the **low irrigation efficiencies** for cultivation of sugarcane across Indian farms.

Emerging techniques for water conservation in sugarcane farming, especially micro irrigation, have shown improvements in irrigation efficiency by up to 40%.

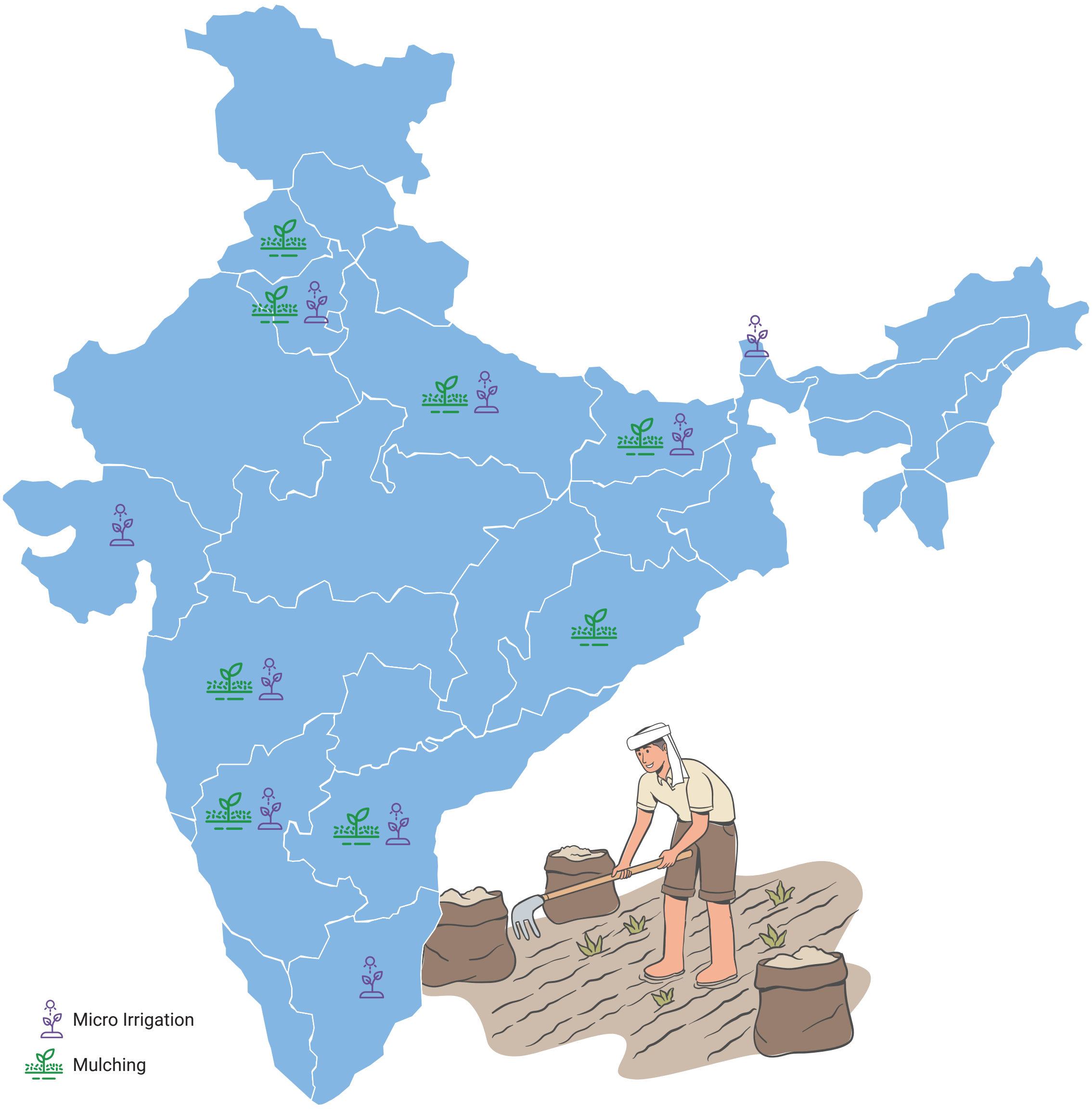
The adoption of innovative cultivation techniques in rice cultivation presents promising solutions for enhancing water efficiency and crop productivity (See *Table 2*).

These technologies hold promise for sustainable sugarcane cultivation practices, addressing water scarcity challenges while ensuring economic viability for farmers.

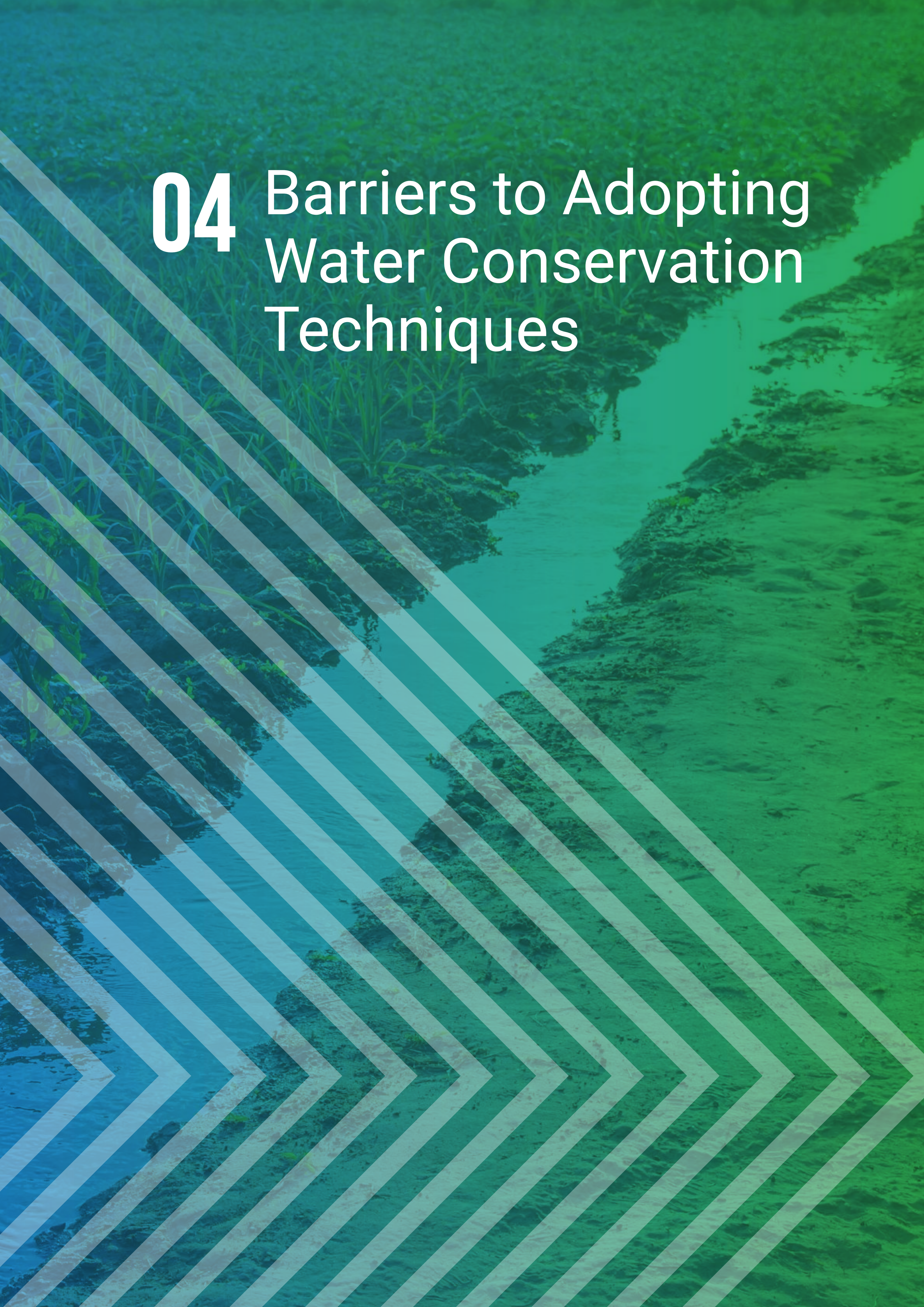
Table 2: These techniques have reported evidence that leads to water savings in rice cultivation. Additionally, there have been varying effects on cost-effectiveness, energy efficiency and crop yields.

Technology/ Solution[82]	Effectiveness of the Technique	Economic Considerations		Crop Suitability
	Water Use Efficiency	**Cost-effectiveness**	**Energy Efficiency**	**Effects on Crop Yield**
Drip irrigation	**60-200%**[83]	Reducing fertilisation requirements by **20-33%.**[84]	Reducing electricity costs by **45%.**[85]	**20-50%** yield improvement. [86]
Skip Furrow Irrigation	**60-70%**[87]	Automated furrow irrigation systems resulted in significant reductions in energy, water, labour, and travel associated with irrigation management.	The ability to schedule irrigation events based on electricity tariffs rather than labour availability improved energy cost-effectiveness.	Yield increase of 60-65%.[88]
Trash Mulching	**40%**[89]	**13.8%** reduction in fertiliser use.[90]	Reducing electricity costs by **14-41%**[91]	Yield increase of **10-25%.**[92]
Scheduling Irrigation	Data not available	**20-25%** reduction in fertiliser use.[93]	Reducing electricity costs by **67.35%.**[94]	Yield increase of **22.58%.**[95]

Figure 7: Coverage of Water-Efficient Sugarcane Cultivation Techniques Across India



04 Barriers to Adopting Water Conservation Techniques



Rice and sugarcane cultivation occupies a pivotal position within the Indian agricultural fabric, but their inefficient farming practices have led to serious water issues. While there have been attempts to address these water-inefficient practices through innovation and technology, the challenge to actually scale and drive the adoption of these solutions remains.

Understanding **the root causes of why the water crisis has persisted** will better inform the approach for solutions. While there are multiple root causes that have perpetuated the water crisis in India, there is a key issue to focus on in agriculture: **why on-farm water conservation techniques have not achieved scale.** By unpacking this and uncovering the barriers, the report aims to identify a few critical insights, examine existing responses, and present recommendations towards accelerating water-resilient agriculture in India.

Root Causes of the Water Crisis

The true price of water is invisible to farmers due to the current subsidies and benefits.

The cost of switching to water efficient crops is high, due to a lack of robust procurement systems.

Avoidable loss of groundwater due to inefficient on- and off-farm activities.

Existing models of driving on-farm water conservation techniques have not achieved scale.

The true price of water usage remains invisible to farmers, leading to water stress.

In the context of groundwater extraction for irrigation, the **highly subsidised electricity rates, which range from 75% to 90%,** pose a significant concern. This is a particularly visible issue in states actively cultivating water-intensive crops. Additionally, the state governments of Punjab, Karnataka, and Andhra Pradesh, known for their robust production of rice and sugarcane, offer **free agricultural power supplies,** making the overexploitation of groundwater easier with little to no barriers to access.

On top of this, irrigation pricing is a sensitive issue from a socio-economic and political standpoint. Pricing of water in India is non-volumetric, which assumes that higher output entails higher water usage but disregards notions of resource-use efficiency and factor productivity. Under the volumetric water pricing, which is adopted across Mexico, the USA and other countries, charges are levied for the quantities of water consumed. In India, although volumetric water pricing is recommended in the National Water Policy, it has not been implemented due to a lack of development of water metering infrastructure in the field, pertaining to the high costs of installation.[96]

The high costs associated with transitioning to water-efficient crops are compounded by the absence of robust procurement systems.

As discussed previously, there are assured markets and procurement systems for rice and sugarcane. 42% of rice grown in India is procured, usually at an average rate of ₹20 per kilogram. Especially for rice, there are highly established procurement systems in the water-stressed regions of Punjab and Haryana. Similarly, sugarcane, too, has a Fair Remunerative Price (FRP) set at ₹3.40 per kilo in Maharashtra and State-Advised Price (SAP) of ₹3.70 per kilo in Uttar Pradesh. Both of these states are again water-stressed regions.

However, for water-efficient crops like millets, pulses, or other perishables, there is a lack of assured prices making them prone to market risks. Transitioning to these crops will not only be cost-intensive but at present would be a risk for farmers without the promise of significant economic benefits for them in the near future.

The avoidable loss of groundwater due to inefficient on- and off-farm activities like leakages, watershed management and ineffective piping.

Poorly managed watersheds often suffer from soil erosion and inadequate vegetation cover. This reduces the ability of rainwater to infiltrate the ground and replenish groundwater aquifers.[97] Further, poorly maintained irrigation systems are prone to leaks that reduce the overall efficiency.[98] A larger volume of water needs to be pumped to compensate for the lost water, putting additional strain on groundwater resources.

Additionally, unlined canals[99] contribute to seepage losses as water seeps through the porous walls of the canal, this reduces the amount of water flowing towards the intended destination, leading to significant water loss.[100]

The existing models of driving on-farm water conservation techniques have not achieved scale.

While sustainable rice cultivation techniques are gaining importance in India, their implementation remains mainly in the pilot stages. Research on the System of Rice Intensification (SRI) technology was promoted in 2002-2003 by state agricultural universities in Tamil Nadu and Andhra Pradesh. Despite these efforts, success stories, and policy recognition under the National Food Security Mission (NFSM), SRI's adoption remains only at 3% of India's total cultivable area. Similarly, with sugarcane, the total area under cultivation in our country for this crop is around 46 lakh ha out of which only around 3.95 lakh ha is covered under drip irrigation in India.[101]

There are five major barriers to scaling the adoption of on-farm water conservation techniques.

1 Lack of customisation

Water-efficient cultivation techniques can not be a one-size-fits-all in a country like India where the geography and land are as diverse and varied as the people. The issue of customisation in solutions results from **a lack of the following factors:**

- **Local Agro-Ecological Conditions:** Consideration of soil types is crucial, as certain techniques like Direct Seeded Rice (DSR) may not be suitable for regions with light and sandy soils, which have low water retention capacity, potentially increasing water usage unintentionally.
- **Farmers' Economic Status:** High production costs associated with technologies like drip-irrigated rice and IoT-based automated irrigation make them impractical for poor farmers, even with subsidies.Research conducted in two districts of Rajasthan uncovered that 90% of farmers refrained from adopting micro-irrigation systems, despite the availability of subsidies. Their reluctance stemmed from their incapacity to cover the substantial initial investment costs, as well as the subsequent expenses associated with operation and maintenance for these technologies.[102]
- **Resource Availability:** Labour-intensive techniques such as aerobic rice, drip-irrigated rice, and the System of Rice Intensification (SRI) may not be feasible in areas with labor shortages. Similarly, practices like Alternate Wetting and Drying (AWD) are less practical in rainfed areas compared to regions with assured irrigation. Laser land leveling, while effective, requires a level terrain for optimal results and may be disruptive in uneven landscapes.

2 Lack of awareness amongst smallholder farmers

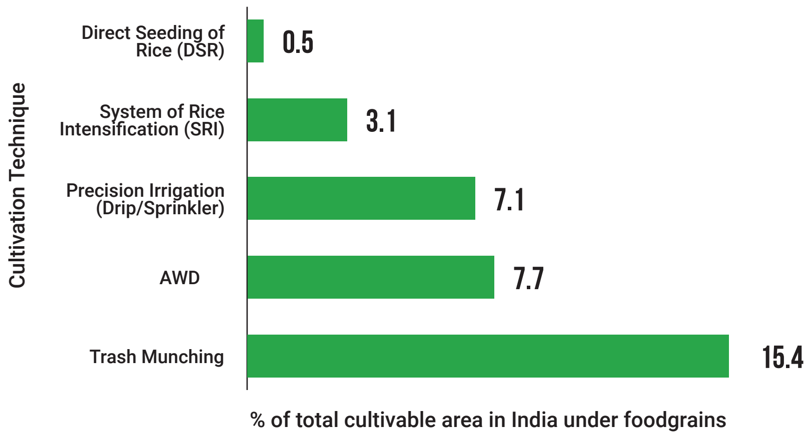
Farmers often have a limited understanding of new irrigation technologies, such as smart irrigation that uses sensors and IoT, and they have not been exposed to knowledge about the herbicide and mechanical methods of weed management. A study conducted in South Punjab revealed that the level of farmer awareness regarding sprinkler, drip irrigation, and solar water pump systems was notably low.[103] 72.5% of farmers were unaware of the Sprinkler Irrigation System, 70% were unfamiliar with the Drip Irrigation System, and 54.2% had no knowledge of the Solar Water Pump System.

As per the Farmers' Participatory Research Programme, **a lack of technical knowledge prevents most of the farmers from using improved technology.** For example, SRI's emphasis on organic fertiliser use adds complexity; farmers face challenges in judging nutrient needs and applying suitable organic fertilisers. This sheds light on the need to customise future promotions of SRI to inform prospective users of the degree to which it is more profitable than competing rice farming systems in both the short and long run.

Additionally, a lack of awareness and access to information in the agricultural ecosystem creates barriers to accessing quality inputs and up-to-date information for farmers and stakeholders. This can lead to inefficiencies in decision-making processes and limit the effectiveness of interventions and technologies designed to improve water efficiency.

Due to the various systemic challenges hindering their scale up, the adoption of sustainable water-efficient cultivation techniques still remains in the early stages.[104, 105, 106, 107]

Figure 8: Proportion of the total cultivable area in India under sustainable crop cultivation techniques



3 Financial constraints of smallholder farmers

According to a study in Pune's districts, 70% of farmers find it challenging to adopt modern irrigation technologies due to the high initial costs. The financial conditions of smallholder farmers are especially difficult, as their annual income is less than ₹4 lakhs.[108] This is a major constraint, as the adoption of Drip or Sprinkler irrigation for these smallholder farmers would require external financial assistance, to enable wider adoption of these modern water-saving devices.

Farmers also might experience income loss caused by yield losses after adopting some of these techniques. For example, compared to the traditional method of puddle transplanted rice, DSR may lead to up to 12-15% of yield loss. The decrease in yield observed in DSR is caused by factors such as soil sickness, increased weed growth due to favourable conditions from alternate wetting and drying, moisture stress resulting from a higher percolation rate, and other factors.[109]

This situation is further exacerbated due to the fragmented land of Indian farmers. In the case of micro-irrigation, for example, the high levels of initial investment needed have been raised as an issue by non-adopters of micro-irrigation across six Indian states.[110]

4 Misplaced incentives for agricultural inputs

Scaling the adoption of technologies like DSR requires meticulous planning to ensure the availability of appropriate seeds, herbicides and machinery. For SRI, **despite subsidies, there are supply shortages of affordable organic fertilisers.** High demand outstrips the availability of subsidised fertilisers, leading to unmet needs.

However, **the lack of incentives to reduce water consumption has negative impacts.** In Uttar Pradesh, for example, of the **75 districts, 34 are overexploited for groundwater** as farmers are charged a fixed amount per electricity connection, no matter how much water they consume.[111] When it comes to fertilisers they too tend to be heavily subsidised, leading them to be used excessively rather than optimally, as a greater use of fertilisers is wrongly perceived to improve crop yield.

5 Behavioural stickiness and a resistance to change

Despite years of experience, the familiarity with **traditional rice farming practices and the culture around it** continue to limit the adoption of System of Rice Intensification (SRI) techniques. Innovative practices related to sugarcane cultivation face similar challenges. Shortages of essential resources force farmers participating in SRI programs to create their own compost, adding an additional task that hinders the scalability of SRI adoption. This drudgery and inefficiency in labour could also affect the effectiveness of other agricultural techniques, thereby leading to lesser adoption.

Identifying levers to scale existing water conservation techniques through a farmer-centric approach

Many of these challenges to adopt and scale, are anchored around the experience and acceptance of the smallholder farmer. Therefore, the smallholder farmer needs to be at the centre of how we address water-inefficient practices in agriculture. By focusing on the smallholder farmer experience, certain insights can be developed to help us identify key levers and then the solutions.

Three key insights need to be considered from the smallholder farmer experience:

Farmers' economic benefits and incentives towards adoption need to be prioritised.

While there might be mid- to long-term gains in adopting water-efficient farming practices, farmers are unwilling to adopt practices that may lead to losses in the short-term. Focusing solely, therefore, on long-term sustainability and the benefits of water conservation will not be the most effective strategy.

Additionally, incentives for farmers need to be restructured to **drive the adoption of water use efficiency in agriculture.** This might mean that not only should there be positive incentives for efficient water usage, but policies that disincentivise the overexploitation of water may need to be considered. These regulatory changes would be a critical lever through which adoption can be accelerated.

Farmers' sustained access to resources, including finance, inputs and supplies should be ensured.

Water-efficient farming technologies require specific equipment and inputs, the unavailability of which can be a disincentive towards adoption. The sustained availability of herbicides, fungicides and other essential inputs that support water-efficient farming technologies will be a crucial first step. Expanding this to include access to finance and working capital for the farmer population will also be vital.

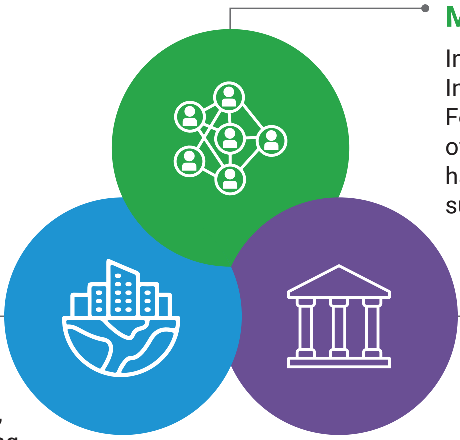
Farmers' capacity and information gaps need to be addressed through a customised package of practices, demonstrations, and last-mile training services.

Given the complexity of certain water-efficient farming technologies, it is crucial not to underestimate the challenges they present. Building trust and confidence in new agricultural techniques among farmers requires providing evidence of their efficacy, offering post-sale support, and establishing a robust network of last-mile extension workers embedded within local communities. **Effective demonstration of technologies to farmers** will play a crucial role in convincing farmers to adopt new practices by providing tangible evidence of the benefits. By gradually closing the information gap, and simultaneously enhancing the capacity of smallholders, the environment and opportunity to adopt water-efficient practices can be enabled.

05 Solving the Water Crisis: Efforts from all Quarters

There is an integral **collaborative role** between industry stakeholders, government bodies, multilateral organisations and civil society organisations required to improve water-use efficiency in rice and sugarcane cultivation. However, while these bodies have attempted to implement multiple programmes and initiatives to optimise water usage and promote sustainable agriculture practices, they have not yet been able to stem the growing water crisis problem.

A wide range of initiatives are being driven by industry, government and philanthropy



Multilaterals and CSOs

International Water Management Institute, GiZ, USAID, Deshpande Foundation, WOTR are some of the key organisations who have focused on water and sustainable agriculture.

Private Industry

Various corporates like Bayer, Olam, DCM, and Nestlé, among others, have collaborated with NGO partners, on-ground service companies, and other corporates to improve water-use efficiency in rice and sugarcane cultivation.

Government bodies

Government programmes range from incentivising reducing groundwater consumption, and promoting rainwater harvesting and groundwater management to sustainable cultivation.

The government has implemented various policies to address the water crisis in India. This is mainly done through two methods, improving water usage efficiency, and promoting water conservation efforts. Towards this end, the government has spearheaded multiple initiatives such as:

- **National Water Policy 2012**
- **National Project on Aquifer Management (NAQUIM)**
- **National Mission for Sustainable Agriculture (NMSA),** encompassing:
  - On Farm Water Management (OFWM)
- **Climate Change and Sustainable Agriculture programme**
- **Pradhan Mantri Krishi Sinchayee Yojana (PMKSY)** which consists of:
  - Accelerated Irrigation Benefit Programme (AIBP)
  - Har Khet ko Pani, Per Drop More Crop
  - Watershed Development

There are also region-specific endeavours, including "**Paani Bachao, Paisa Kamao**" in Punjab and the **Atal Bhujal Yojana** which is implemented in select water-stressed areas across Gujarat, Haryana, Karnataka, Maharashtra, Madhya Pradesh, Rajasthan, and Uttar Pradesh.

One of the most major schemes is the Pradhan Mantri Krishi Sinchayee Yojana (PMKSY). IT was **initiated in 2015-16** to bolster on-farm water accessibility, increase cultivable land under assured irrigation, enhance water use efficiency, and introduce sustainable water conservation measures, among other objectives. PMKSY has 4 components within it: i) **Accelerated Irrigation Benefit Programme (AIBP),** ii) **Har Khet ko Pani,** iii) **Per Drop More Crop** and iv) **Watershed Development.**[112]

The Per Drop More Crop initiative, a part of PMKSY, offers financial assistance of 55% for small and marginal farmers, and 45% for other farmers, to install Micro Irrigation systems. It has significantly enhanced **micro-irrigation coverage, spanning 7.8 million hectares from 2015-16 to 2022-23**.[113]

Additionally, within the Watershed Development programme, from 2014-15 to 2021-22, a total of **7.65 lakh water harvesting structures were created or revitalized,** an additional area of 16.41 lakh hectares was brought under protective irrigation, and **36.34 lakh farmers experienced benefits from these initiatives.**[114] Within Har Khet ko Pani, from 2016 -2022, there has been a creation of 3.7 lakh hectares of irrigation potential.[115]

Many programmes led by industry, multilateral organisations, and civil society organisations have had impactful changes in improving water-use efficiency in agriculture. Industry leaders like Walmart, Pepsico, DCM Shriram Ltd., Nestle, Olam, and Bayer actively support capacity building and technology demonstrations.

Through ITC's Mission Sunehra Kal, 7,100 Farmer Field Schools (FFS) and more than 18,700 demonstration plots were built to spread knowledge of scientific and technological farming methods to over 246,000 farmers. By the year 2023, this led to **496.5 million kiloliters of water saved due to crop-efficient practices.**[116]

DCM's Meetha Sona project, aimed at providing a customised package of practices and training farmers to become change agents, led to **an average 25% increase in yields** across the catchment areas. Over the past five years, the **initiative has conserved more than 574 billion litres of water,** a figure authenticated by the Indian Institute of Sugarcane Research (Lucknow).[117]

Multilaterals such as the **World Bank, Asian Development Bank (ADB),** and civil society organisations like **Solidaridad** and **Aga Khan Rural Support Program** are also crucial in driving solutions within the ecosystem.

The World Bank-backed Andhra Pradesh and Telangana State Community-Based Management (APCBTM) project, running from 2007 to 2016, targeted tank-based producers and Water User Associations (WUA) in Andhra Pradesh and Telangana. By providing training, capacity building activities and crop technology demonstrations to 42,000 farmers, it resulted in a **57.4% adoption rate of improved production techniques** among farmers in tank command areas.[118]

These tailwinds from across these stakeholders are encouraging, however, there are significant gaps hindering the scale and wider adoption of water-efficient technologies. These gaps are being perpetuated by issues like the limited efficacy of the capital being deployed, a lack of synergies among stakeholders trying to address the same problem, a lack of reliable, publicly available, and up-to-date data, and limited influence to incentivise greater adoption of water-efficient practices.

Ecosystem gaps preventing collaborative action for the scale and adoption of water-efficient technologies

Reliance on philanthropic capital without long-term sustainability.

A significant gap lies in **the reliance on philanthropic capital,** which has proven effective in initiating projects, but often lacks long-term sustainability required beyond the initial implementation phase.

Key organisations have worked on providing interest-free loans to smallholder farmers to promote the adoption of drip irrigation. However, sustaining such efforts beyond the initial funding period may pose challenges without continued external support for smallholder farmers, highlighting the myopic tendency of philanthropic funding sources.

Overall, while philanthropic funding can play a valuable role in addressing **immediate needs and catalysing innovation,** it should ideally complement other funding sources and be part of a broader strategy for achieving solutions at scale. Diversifying funding sources, fostering partnerships with government and private sector actors, and promoting sustainable financing mechanisms are essential steps towards achieving long-term impact in addressing the water crisis in agriculture.

Limited pathways to scale due to a one-size-fits-all approach beyond pilots.

Scaling initiatives beyond pilot phases pose a significant challenge. While successful projects, like the one mentioned above, have shown effectiveness through a tailored approach, expanding such models to other states and regions demands adaptive strategies. For example, although projects trained several farmers on effective agricultural and water management practices, extending these customised approaches to other cohorts of smallholder farmers requires greater flexibility and resource allocation.

Lack of effective synergies across various initiatives and high levels of redundancy in effort.

Despite the multitude of initiatives, effective synergies among them are lacking, leading to redundancy and inefficiencies. For example, each initiative operates independently, as seen in the efforts observed across various projects. The absence of coordination and collaboration among stakeholders hinders the overall effectiveness of the response.

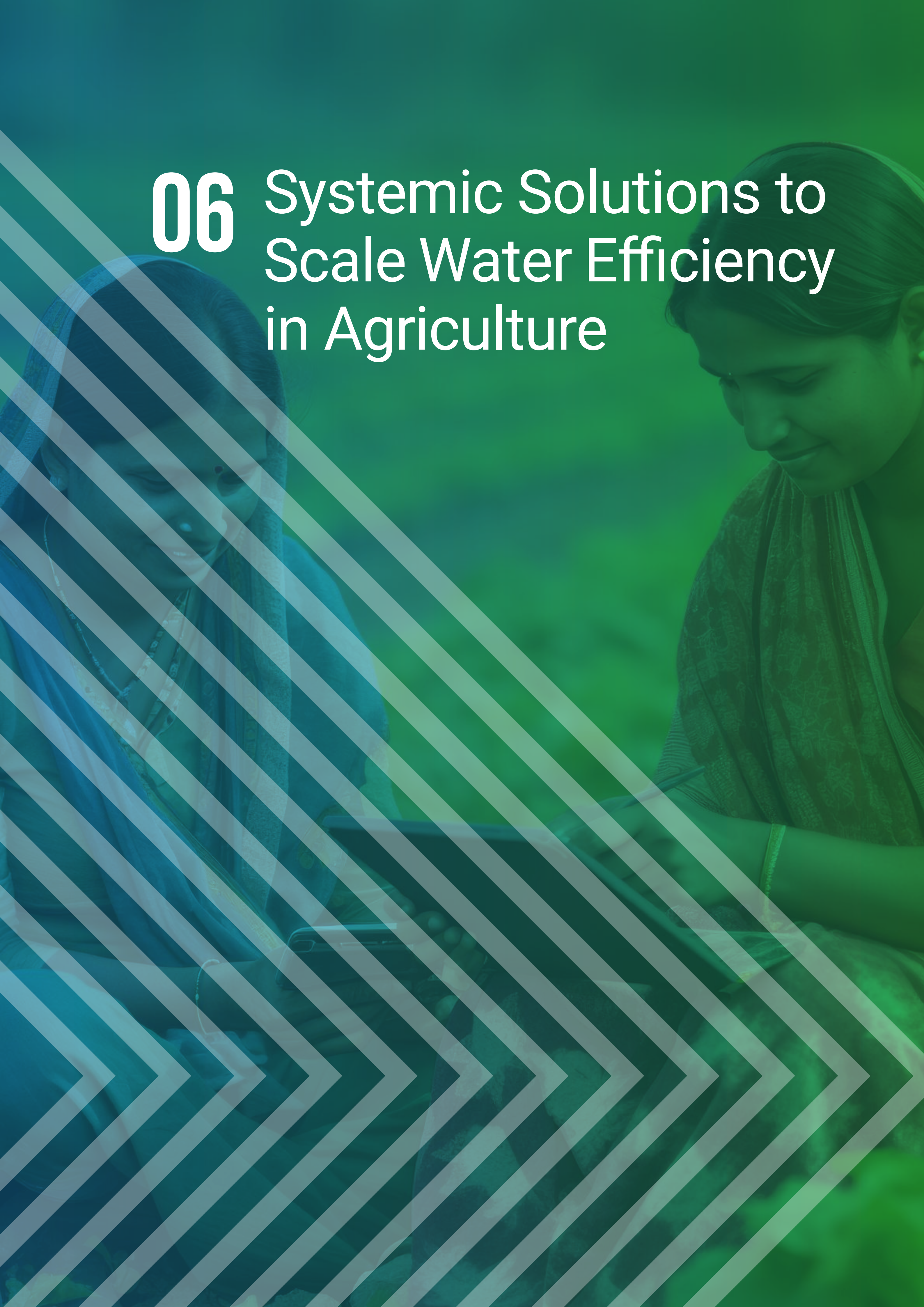
Lack of reliable and up-to-date data for effective decision-making and collaboration.
While there is a need for collaborating to drive action, success in forming effective collaborations to solve issues relies on having comprehensive data about existing water resources, available infrastructure and asset status, metering coverage, cost recovery records, etc. Without this information, initiatives are unlikely to succeed. Many programmes have often reported the lack of reliable data as a strict challenge while implementing projects due to the lack of systemic data which is updated and reliable.[119]

Limited influence in driving greater adoption of proven technologies and innovations.
Despite the availability of proven technologies and innovations, adoption rates remain relatively low. While various initiatives engage thousands of farmers, broader adoption may require more targeted dissemination strategies and supportive policy environments.

Overcoming barriers to adoption and ensuring the integration of proven technologies into mainstream practices is essential for achieving sustainable water management goals. For instance, in certain programmes beneficiaries encountered technical obstacles, like water pressure control, and the unsuitability of drip irrigation for field crops. Moreover, challenges such as electricity shortages, inadequate after-sales support, and complex subsidy procedures hindered effective implementation, requiring intervention for improved efficacy.

To achieve widespread adoption of on-farm water management technologies and enhance water usage in sustainable crop cultivation, it's crucial to **identify key solutions that can scale adoption nationwide, while acknowledging the diversity of local agricultural ecosystems.** Additionally, understanding **the importance of collaboration** is integral in driving this endeavour. In the final chapter of this report, we detail 3 key ideas towards enabling scale.

06 Systemic Solutions to Scale Water Efficiency in Agriculture



In response to the identified barriers in the previous chapters, this chapter discusses recommendations that have been crafted in order to prioritise scaling water-efficient practices, tailored to local ecosystems, while prioritising farmer incentives at scale.

The insights in the report have been generated following a mixed methodology relying on the quantitative and qualitative data of the following:

1. Through the review of 50+ public reports focusing on water and agriculture.
2. Extensive focus group discussions and interviews with more than 40 experts from diverse backgrounds, including government stakeholders, private sector corporations, research organisations, and civil society organisations.

Emphasising science and data driven narratives, the recommendations call for enhanced collaboration within industries and strategic investments in publicly driven and accessible goods and networks. The aim is to mobilise capital towards initiatives capable of driving impactful change at the ecosystem level, thereby promoting sustainable water management practices at scale across farms in India.

Principles of our Recommendations

For the recommendations, a few key principles have been considered which have been derived from our analysis of the root causes, understanding of the existing crop cultivation landscape, and the barriers that hinder scale up through conversations and dialogues with key stakeholders in the ecosystem:

Main Principles	
Building a value proposition for farmers	Establish a compelling value proposition for farmers through any solution and recommendation proposed.
System approach	Understand all the incentives and challenges in driving adoption of a technique.
Scale design	Move away from pilot implementation ideas and enable a tailored approach across more regions.
Ecosystem-wide action	Build recommendations that can be used by a wide range of stakeholders.
Collaborative action	Identify areas of work that can bring diverse stakeholders to work together.
Build influence	Design solutions that can influence government, and farmer behaviour at scale.

- **Building a value proposition for farmers**
  It is essential to keep farmers at the centre and establish a compelling value proposition for them in devising solutions. Within this, it will be paramount to prioritise economic benefits and incentives, in order to address small and marginal farmers' hesitancy to embrace water-use efficiency practices. Which they perceive as having losses in the short-term, or might be too costly for adoption due to high initial capital investments required.

- **System approach**
  There is an interconnectedness between the issues creating a low adoption of innovation and technology. From the lack of infrastructure or its limited affordability and accessibility, to established norms that are difficult to change, it is important to understand the interactions of the parts within a system. Therefore, a full systems approach to recommendations is essential. This allows for a comprehensive understanding of all incentives and challenges involved in driving adoption. Taking into consideration factors such as supply chain logistics, digital and financial infrastructure available, existing policies and schemes, and localised understanding of traditional farmer behaviours. By taking a holistic view of the system, recommendations can be tailored to address these complex interdependencies and promote the sustainable adoption.

- **Scale design**
  To effectively enable scale, it is imperative to move beyond pilot projects at an individual level and adopt a comprehensive approach to tailoring across diverse regions. This involves identifying commonalities and variations across regions through the identification of localised agricultural ecosystems and adapting strategies accordingly to ensure widespread implementation and impact. By embracing design that prioritises scale, we can look at how to address the unique needs and challenges across different areas, maximising the effectiveness and sustainability of our initiatives.

- **Ecosystem-wide action**
  Ecosystem-wide action entails developing recommendations that are inclusive and applicable to a diverse range of stakeholders. By considering the needs and perspectives of various actors within the ecosystem, such as farmers, policymakers, industry players, community institutions and philanthropy, we can ensure that our recommendations are relevant, accessible, and actionable by all parties involved.

- **Collaborative action**
  Leveraging collective expertise is essential for addressing multifaceted challenges effectively. Recognising that no single stakeholder can address all aspects alone, collaboration enables the pooling of diverse capabilities, experiences, and resources to achieve broader outreach and impactful outcomes. By working together towards common goals, stakeholders can complement each other's strengths, fill gaps in expertise, and maximise their collective impact.

- **Build influence**
  To build influence, it's imperative to design solutions that can effectively **shape government policies and influence farmer behaviour** at scale. By developing initiatives that demonstrate tangible benefits, such as increased productivity or cost savings, to both government officials and farmers, we can garner their support and engagement. Additionally, employing evidence-based approaches and showcasing successful case studies can bolster credibility and persuade stakeholders to adopt recommended practices. Through strategic advocacy efforts and targeted communication, we can drive widespread adoption of sustainable practices among farmers, ultimately fostering positive change across the agricultural sector.

Limitations of recommendations

The following have been deliberately excluded from the scope of these recommendations:

- **Structural shifts in crop selection and government incentives**
  While critical, we are not focusing on actionable steps towards enabling structural recommendations at this time, such as shifting crop selections, or changing subsidy structures for farmers.

- **Identifying and promoting newer innovations towards water use efficiency**
  We are more focused on building effective models to scale adoption of existing innovations for farmers, to address the challenges in water use efficiency.

- **Addressing off-farm challenges through recommendations**
  While off-farm infrastructure (conveyance efficiency), watershed management, and renewable energy access are important, we are focusing on driving **on-farm adoption models.**

RECOMMENDATION 1

Develop a tool to recommend water use efficiency practices based on Local Agriculture Ecosystems (LAE).

Multiple existing initiatives focusing on enabling on-farm water use efficiency driven by government, philanthropy as well as industry have demonstrated impact. However, these initiatives are still not able to cater to the specific nuances and localised contexts of regions, crops as well as varying farmer profiles.

In agriculture, a tailored approach is paramount because one-size-fits-all strategies fall short in driving scale. Currently, there's a lack of collaboration and knowledge-sharing among stakeholders, resulting in small-scale, isolated efforts that struggle to support small farmers effectively. Moreover, there has been limited identification of recurring patterns from past failures.

By developing a tool that offers customised solutions for specific local contexts, we can seamlessly integrate it into ongoing initiatives that have shown impact. This not only fosters localised insights, but also mobilises effective government and industry involvement. The identification of **Local Agriculture Ecosystems (LAE)** plays a key role here.

What are Local Agricultural Ecosystems (LAE)?

The recommendations provided should be connected to the unique characteristics of local agriculture ecosystems and tailored to address specific challenges and opportunities within these ecosystems. These ecosystems are influenced by **two important parameters: the external environment** and **farmer-specific parameters.**

Regarding the external environment, each recommendation should be carefully aligned with the geographical and ecological context of the region, taking into account the criticality of the problem at hand. Farmer agency should be central to every recommendation, prioritising incentives that benefit farmers and integrating them into proposed interventions. Additionally, key players within the agricultural value chain should be actively involved in guiding and anchoring the change process. The presence of digital infrastructure should be considered to ensure that recommendations align with digitally equipped systems, thereby enhancing effectiveness.

When considering farmer-specific parameters, recommendations should take into account the context of individual farmers. This includes acknowledging the significance of access to on-farm labour and inputs, which can facilitate improved short-term income generation. Furthermore, clear pathways to access phygital (physical and digital) markets should be provided, enabling farmers to efficiently connect with markets and maximise their agricultural outputs. By addressing both external environmental factors and farmer-specific parameters, tailored recommendations can effectively support the improvement of on-farm water use efficiency within local agriculture ecosystems. (See Annexure for example)

Ecosystem Context	Farmer Context
Ecological nature and criticality: Each recommendation is mapped to geography, ecology and criticality of the problem.	**Access to Labour:** Each recommendation has a critical presence of on-farm labour.
Agency of the farmer: In each of the recommendations, the farmer's incentivisation is kept at the centre.	**Access to Inputs:** Each recommendation provides accessibility to the farmer's inputs.
Key orchestrator in the value chain: With each recommendation, a key orchestrator is present to guide or anchor change.	**Improved short-term income:** Each recommendation is linked to driving incentivised change for farmers.
Prevalence of digital infrastructure: Each recommendation is linked to digitally equipped infrastructure.	**Access to markets:** Each recommendation enables clear routes of access to phygital markets for farmers.

Therefore, this recommendation centres on **creating a tool which will evolve in effectiveness and maturity over time to suggest** innovative practices that are proven to be effective within a specific LAE. The tool shall aim to provide personalised recommendations that align with the unique characteristics of both ecosystem and farmer context. It would further utilise data and insights gathered over time to suggest practices that have demonstrated success within similar contexts. By continuously learning and adapting to the local environment, the tool can offer increasingly relevant and impactful suggestions tailored to the specific needs and challenges of farmers.

Value to Stakeholders

Stakeholder	Value Proposition
Private industry players	Access to ready-made and updated insights and data on local agricultural ecosystems would significantly benefit stakeholders by streamlining the development of tailored products and services. For instance, companies could utilise this tool to provide their local plant managers with efficient mechanisms for deploying the most suitable solutions for specific contexts, saving time and effort. This streamlined process not only reduces avoidable loss of revenue associated with identifying and deploying water-efficient solutions but also contributes to enhanced brand reputation and competitive advantage, by reinforcing a company's commitment to responsible practices and water stewardship initiatives.
Governments	By incorporating localised data into agricultural policies and programmes, the local governments can tailor interventions to address the specific needs and challenges of each LAE. This targeted approach leads to more effective policy outcomes, such as increased agricultural productivity, improved water management, and enhanced environmental sustainability. Focusing on high-impact initiatives within LAEs allows the government to optimise resource allocation and budget utilisation. By directing resources towards projects with the greatest potential for positive impact, the government maximises the efficiency of its investments, ensuring that limited funds are used effectively to achieve desired outcomes.
Research Institutions and Community Organizations	Engaging in collaborative initiatives for scaling up adoption of water efficient agricultural solutions, enhances visibility and recognition for research institutions and community stakeholders. By participating in collaborative initiatives that address pressing issues in sustainable agriculture, research institutions and community stakeholders can attract funding from government agencies, philanthropic organisations, and private sector partners to work on the research and development of more effective solutions that can be deployed on the ground.

Initiating Recommendation 1

To develop a comprehensive tool that recommends water use efficiency practices based on LAE, various stakeholders will need to play essential roles.

Who will be the custodian for this tool?

A government entity, such as NITI Aayog, should spearhead the development and operation of the tool, be a designated Centre of Excellence for it, and host the tool. Leveraging its resources and authority, NITI Aayog could build the necessary digital infrastructure and make it accessible to a wide range of stakeholders, ensuring widespread adoption and effectiveness.

Who are the key stakeholders involved?

Other relevant stakeholders who will play a key role in making this tool functional include **academic institutions** like IRRI, NRRI, IISR, etc. who would offer a non-partisan perspective and access to expertise in data analysis and interpretation. Academic partners would contribute their research capabilities to enhance the tool, ensuring a rigorous and evidence-based approach to catering to local agriculture ecosystems.

Moreover, **a consortium of industry partners** would need to take the lead in establishing the infrastructure needed to define LAEs. This collaboration would involve consolidating relevant data and identifying LAEs across the country, and leveraging the expertise and resources of various stakeholders in the industry.

SIMILAR INITITATIVES

The International Rice Research Institute (IRRI)'s Rice Crop Manager is a tool designed to empower rice farmers with data-driven decision-making throughout the crop management cycle. Based on a similar concept of specifications for local agricultural ecosystems, it offers guidance on seed selection, crop establishment, nutrient management, pest and disease control, water management, and harvesting, to provide customised recommendations tailored to individual field conditions, crop stages, and local weather patterns. Leveraging factors such as soil type, crop variety, historical weather data, and pest prevalence, farmers can optimise for input use and maximise yield and quality. With a user-friendly interface accessible via web or mobile, the tool accommodates farmers with varying technological literacy levels. By following its recommendations, farmers can enhance productivity and sustainability, minimising costs, reducing environmental impact, and increasing profitability. Accompanied by training materials and support services, the IRRI Rice Crop Manager serves as a valuable resource, empowering farmers to improve their agricultural practices and outcomes.

RECOMMENDATION 2

Establish an Industry Network for Collective Action of On-farm Water Use Efficiency

To drive industry action on water sustainability beyond the largest players and establish robust industry networks to enable cross-learning, we propose an **Industry Network for Collaborative Action.**

Drawing inspiration from successful initiatives such as STEM pledges, we propose implementing this collaborative network model to drive action on water sustainability. Just as companies like IBM and Amazon have pledged to upskill in STEM fields, leading to significant advancements in workforce diversity, this recommendation encourages companies to commit to increasing water efficiency in areas of their operation.

At its core, this model centres on companies and other relevant stakeholders working in agriculture, committing to increasing water efficiency in areas where they have a water footprint, alongside stakeholders voluntarily pledging support for improvements in areas where farm-level involvement is vital. Through this collective effort, we aim to achieve three primary objectives:

1. **Building a network**
   By bringing together a diverse array of industry players, this model fosters collaboration and knowledge sharing. The idea is to ensure all companies make a public and voluntary commitment to reduce water stress in their value chains, and eventually garner commitment from industry stakeholders towards driving industry action at scale. Companies are provided with science-based tools to aid decision-making, empowering them to make informed choices about water management strategies within this network.
2. **Sharing best practices**
   The network will further encourage participants to exchange best practices and lessons learned. The idea is to ensure transparency of progress against the proposed targets along with learnings from the ground. By consolidating successful initiatives, companies can accelerate progress towards water efficiency goals and drive innovation in sustainable water management practices.
3. **Advocacy and influence**
   By convening stakeholders and sharing impactful work, this initiative aims to amplify advocacy efforts. Through collective influence, participants can advocate for policy changes, communicate their progress openly, drive industry standards, and mobilise support for water conservation initiatives on a broader scale.

By framing this initiative as an Industry Collaborative Action, we emphasise the collective advantage of bringing impact through collaborative efforts, and highlight the shared commitment of industry players to drive meaningful change in water sustainability.

Value to Stakeholders

Stakeholder	Value Proposition
Industry Players	Access to a collaborative network offers opportunities for knowledge sharing, enabling companies to learn from industry peers and adopt best practices in water management. Additionally, participation provides access to science-based tools and resources for informed decision-making, empowering companies to implement effective water efficiency strategies. Moreover, engagement in industry-wide initiatives enhances companies' reputation and brand differentiation, positioning them as leaders in sustainable and water-efficient agriculture practices.
Governments	Industry can help inform decisions of policymakers (by informing relevant insights to influence policy changes and industry regulations), and governments by providing access to data and insights on industry-wide water management practices.

Initiating Recommendation 2:

Participating companies in this collaborative initiative may encounter several challenges as they navigate the complexities of addressing water sustainability issues as a collective.

One such challenge is the potential gap in incentives or recognition for their involvement. Some companies may question the tangible benefits of participating in the initiative, particularly if they perceive a lack of immediate rewards or acknowledgment for their efforts. To overcome this challenge, it's essential to clearly articulate the value proposition for participating companies, highlighting potential benefits such as enhanced reputation, access to shared resources, and potential cost savings through improved water efficiency. **Annual rewards and recognition programmes** can serve as powerful motivators, provided they are administered by an unbiased and credible organisation. Additionally, highlighting **CEO pledges and their impact** can inspire other industry leaders to join, leveraging competitive dynamics for broader participation and impact. Here, branding products based on water-use efficiency and **implementing consumer-based market systems** to focus on incentives can drive awareness and demand.

Ensuring that the interests of stakeholders and investors are not overlooked is another critical consideration. Balancing the diverse needs and expectations of various stakeholders and investors is crucial to the success and sustainability of the initiative. Companies must actively engage with stakeholders and investors to understand their priorities and concerns. By incorporating their inputs into decision-making processes and providing transparent reporting on progress and outcomes to maintain trust and accountability.

Additionally, some companies may face gaps in terms of capability or establishing strategic value internally, to effectively engage in water sustainability efforts. This could stem from a lack of internal expertise or resources dedicated to addressing water-related challenges. To address this challenge, the initiative should provide support and resources, and guide companies to develop and implement effective strategies. This support could include training, guidance, access to technical expertise, and collaborative opportunities with other participating companies to share best practices and lessons learned.

Who will drive this collaborative initiative?

To address the potential challenges outlined above, we propose implementing **an industry partnership model with the government.** This collaborative approach aims to foster greater involvement and inclusion of various industry stakeholders in a collaborative action initiative. By partnering with the government, we can leverage its resources, regulatory authority, and credibility to overcome barriers. The government’s involvement shall ensure constant reporting and transparency from all stakeholders, driving action at scale and promoting cross-learning and healthy competition among participants. Additionally, government involvement can provide strategic direction, regulatory support, and policy frameworks to guide the initiative's implementation and ensure alignment with broader sustainability goals. The government's endorsement and support can further enhance the perceived value proposition of the initiative, encouraging more companies to participate and invest in water sustainability efforts through this network.

Who are the key stakeholders involved?

The industry network should include stakeholders such as **government representatives** from ministries like Agriculture and Water, **industry leaders, civil society organisations, policymakers, think tanks, and international groups** like World Resources Group (WRG) and SBTi. Collaboration should extend from the central level to the district level to ensure effective action. Industry-specific participants, particularly those in the agricultural value chain, should be prioritised, with a focus on companies with significant water consumption. Key players like ITC and other commodity-specific industries should be engaged, alongside academia, think tanks, and innovators to drive voluntary standards and share best practices. Building advocacy through voluntary certification standards is essential for driving action and fostering sustainable water management practices. Additionally, a dedicated leader, like a Sherpa, should spearhead this initiative, driving mission-mode efforts.

In addition to industry and government collaboration, **philanthropy plays a crucial role in advancing these goals.** While businesses can leverage their capital through direct investments or CSR initiatives, philanthropy can add another dimension to these efforts. Philanthropic capital can unlock additional business investment and enhance the impact of this network. This multi-stakeholder approach ensures that we maximise the collective impact and drive meaningful change in water sustainability.

SIMILAR INITITATIVES

This collaborative effort mirrors the success of STEM pledges by bringing together industry players, sharing best practices, and advocating for change. Through this collective action, we can harness the power of collaboration to address water challenges effectively, much like STEM pledges have transformed the landscape of workforce development.

Additionally, the success of industry consortiums like RE100, Steel Zero, and the CEO Water Mandate demonstrates the power of collaborative initiatives in driving impactful change towards sustainability. RE100, led by The Climate Group, boasts over 400 members committed to transitioning to 100% renewable electricity, surpassing 500TWh per year by 2050. Similarly, Steel Zero aims to achieve net-zero steel production with 40+ leading companies already committed to decarbonizing around 10 million tonnes of steel. Meanwhile, the CEO Water Mandate, led by the UN Global Compact, mobilises business leaders to promote water stewardship and sustainable water management; resulting in billions of litres of water saved annually and has enabled meaningful engagement with local communities for water conservation. These consortiums exemplify the effectiveness of collective action, sharing best practices, and engaging stakeholders in addressing global challenges for a more sustainable future.

RECOMMENDATION 3

Implement a Water Index to Enable Science-based Business and Policy Decisions

To effectively guide decision-making at all levels towards the adoption of a particular water efficient solution in a specific local agriculture ecosystem, it is imperative to integrate **scientific insights and data analysis** into the decision making process. For industry and policymakers, particularly since there are broad incentives at an ecosystem level (government subsidies, traditional biases, industry interests, etc.) which often shape these decisions. Although, many significant water-based indices exist today, notably, the NITI Aayog Water Index, WRI's Aqueduct Water Atlas, and CDP's Water Impact Index, among others, there is a need for the development of a non-partisan, science and data led, **publicly accessible water index.** Such a resource could help guide decision making of industry and government stakeholders based on their specific objectives and need for data. This recommendation suggests establishing such an index delving into multiple layers of data, encompassing spatial, water, and crop-related metrics, among others. This comprehensive index would consolidate diverse data parameters, serving as a reliable resource for various stakeholders in the ecosystem. Initiatives such as Agristack would further enhance data availability at a granular level throughout India for feeding into the index.

Value to Stakeholders

Stakeholder	Value Proposition
Private industry players	**Influence how the industry assesses, plans and evaluates its impact on water across its value chain.** Businesses can leverage this tool for ESG (Environmental, Social, and Governance) and sustainability reporting, enabling them to evaluate their water sustainability practices. By utilising this science-based index, companies can establish their sustainability agendas and ESG reporting standards. This index would serve as an effective and regularly updated resource, guiding corporations in aligning their practices with scientific insights and best practices in water management.
Government and Policy	**Establish feedback loops for Governments to assess the impacts of their subsidies and incentives to farmers.** Data-driven analysis through the index would allow for using valuable insights to drive advocacy efforts, such as identifying correlations between water usage and available subsidies in specific regions. For instance, understanding how subsidies impact water usage patterns can help advocate for more efficient allocation of resources or incentivise sustainable practices. This data-driven approach enables informed advocacy efforts aimed at promoting better resource management and policy interventions tailored to regional needs.
Financial Institutions and Investors	**Enable banks and financial institutions to assess the risk of water and provide positive or negative incentives to drive water stewardship.** Investors with a sustainability mandate have increasingly prioritised environmental risk assessments to develop investment propositions and attract financial backing to crucial and feasible areas. By conducting thorough risk assessments, investors can identify high-priority sectors where sustainable investments can yield significant returns while mitigating environmental and social risks. This index will thus help investors and financial institutions not only align with their sustainability goals but also attract financial investments by showcasing viable opportunities in areas crucial for sustainability and feasible for long-term growth.
Smallholder Farmers	**Promoting water sensitivity and engaging farmers in dialogues on water conservation**. By accessing information on water availability, usage patterns, and future projections through the index, farmers can gain a deeper understanding of the importance of water conservation and the challenges posed by water scarcity. This data-driven approach enables farmers to make informed decisions about their water usage and encourages them to adopt more sustainable practices. Additionally, the index can serve as a platform for civil society to design educational outreach and awareness campaigns, helping to highlight the significance of water conservation and promote behavioural shifts towards more responsible water management practices among smallholder farmers.

Initiating Recommendation 3

Who will host the index?

A middle-ground approach involving public and private stakeholders should be considered, where a consortium led by industry stakeholders, but supported by a government entity like NITI Aayog could strike the right balance. NITI Aayog's involvement would lend credibility and regulatory oversight, while the consortium's industry expertise and partnership with technology providers could drive innovation and adoption of the index at the farmer level. With involvement of the government, the index will be treated as a public good, with data publicly sourced and transparently managed. Government hosting could also facilitate broader accessibility and regulatory support for the index. Involving industry stakeholders on the other hand would emphasise the importance of industry involvement in ensuring the credibility, usability, and neutrality of the index.

Who are the key stakeholders involved?

Philanthropic capital can be more effectively leveraged as a catalytic player to build the infrastructure required to develop this index and establish a platform for collective knowledge that can eventually influence government and industry action at scale. Moreover, projects and learnings from individual philanthropy-led efforts focusing on enabling water-use efficiency solutions across ecosystems can also feed and contribute into the data driving this index, and make it more rigorous and updated.

SIMILAR INITITATIVES

The collaborative efforts between TNC, Vasudha Foundation (VF), CSTEP, and Foundation for Ecological Security (FES) have yielded the SiteRight tool, aimed at aiding decision-makers in making **informed siting choices for renewable energy** projects.

Comprising three modules, SiteRight offers a comprehensive approach to site assessment and planning. The ***Awareness*** module furnishes extensive information on potential ecological conflicts in the area, while the ***Site Assessment*** module evaluates conflicts across ecological and social variables, providing insights into site suitability. The ***Planning*** module assists developers in identifying conflict parcels and optimising site selection to meet renewable energy goals efficiently. In partnership with the Uttar Pradesh New & Renewable Energy Development Agency, SiteRight prioritises minimising environmental impact while meeting regional energy needs.

Conclusion

Our recommendations focus on a stakeholder-centric approach, emphasising tailored solutions to address the diverse challenges within the agriculture ecosystem. By adopting a holistic systems approach, we recognize the interconnectedness of factors influencing water sustainability, ensuring solutions that consider external environmental factors and farmer-specific parameters.

To achieve widespread impact, we advocate for scale design and ecosystem-wide action, emphasising collaboration among diverse stakeholders to drive collective impact at scale. By leveraging collaborative action and influence, stakeholders can amplify advocacy efforts, drive cross-industry learnings, and mobilise support for water conservation initiatives on a broader scale.

The recommendations offer compelling value propositions for various stakeholders, including private industry players, governments, financial institutions, smallholder farmers, and research institutions. Benefits include access to publicly available data-driven insights, enhanced reputation, improved resource allocation, and increased engagement for effective collaboration opportunities.

The first recommendation emphasises the importance of tailored solutions through a recommendation engine for water use efficiency practices based on Local Agriculture Ecosystems (LAE). By providing personalised recommendations aligned with the unique characteristics of each ecosystem, the aim is to empower industry players, policy and smallholder farmers to make informed decisions, driving sustainable practices at the grassroots level.

The second recommendation introduces the concept of a Water Index, enabling science-led business and policy decisions. This comprehensive index consolidates diverse data parameters, offering stakeholders a reliable resource to guide their actions. By integrating scientific insights into decision-making processes, we pave the way for more effective water management practices and informed policy interventions.

Lastly, our final recommendation proposes an Industry Network for Collective Action for on-farm water use efficiency, inspired by various other successful industry network initiatives across other sectors. By fostering collaboration among industry players and other stakeholders, this network promotes knowledge sharing, innovation, and advocacy efforts. Through collective action, we harness the power of collaboration to address water challenges effectively and drive impactful change towards sustainability.

By focusing on the identified water-intensive crops of rice and sugarcane, together with scaling these recommendations, a roadmap to create a more sustainable future for water as a resource in agriculture lends hope at this critical phase of mounting water scarcity.

Annexure

1. Ecosystem-Recommended Optimal Water-Saving Strategies for Rice Cultivation

Table 1: Ecosystem-Recommended Optimal Water-Saving Strategies for Rice Cultivation: Assessing Effectiveness of Techniques

Technology	Description	Suitability
AWD	AWD involves alternating periods of flooding and non-flooding in the rice field. In AWD, the field is flooded to a certain depth and then allowed to dry out before being flooded again. This wetting and drying cycle helps reduce water use while maintaining or even increasing productivity.	Alternate wetting and drying (AWD) irrigation is suitable for **lateritic soil blocks** stabilised with lime and fly ash.
System of Rice Intensification (SRI)	SRI combines several innovative practices, including changes in nursery management, the time of transplantation, and water and weed management. It is not a fixed package of technical specifications but a production system with four main components: soil fertility management, planting method, weed control and water (irrigation) management.	SRI is most suitable for highly weathered and infertile soils, with high levels of iron and aluminium oxides.
Direct Seeding of Rice (DSR)	Direct Seeding of Rice (DSR) involves directly sowing rice seeds in the field instead of transplanting seedlings.It can be done through dry direct seeding and wet direct seeding. In dry direct seeding, pre-germinated seeds are broadcasted on dry or moist soil, either manually or using a tractor-drawn seeder. On the other hand, wet direct seeding involves sowing pre-germinated seeds on or into puddled soil, either manually or using a drum seeder.	DSR can be grown in almost all types of soils suitable for rice, but **medium-textured soils** are more suited to DSR.
Precision Irrigation	Precision irrigation in rice refers to the application of water in a precise and targeted manner, taking into account the specific water requirements of the crop at different growth stages. It involves using advanced technologies such as sensors, remote monitoring, and automated irrigation systems to optimise water use efficiency and minimise water wastage.	Precision irrigation methods are suitable for **clay soils** but will be challenging to implement in sandy ones.
Laser Land Levelling	Laser land levelling involves laser technology to level the land surface, ensuring uniform water distribution during irrigation.	Laser land levelling is suitable for various types of soil. Different types of levelling machines are made for different soil types.

2. Ecosystem-Recommended Optimal Water-Saving Strategies for Sugarcane Cultivation

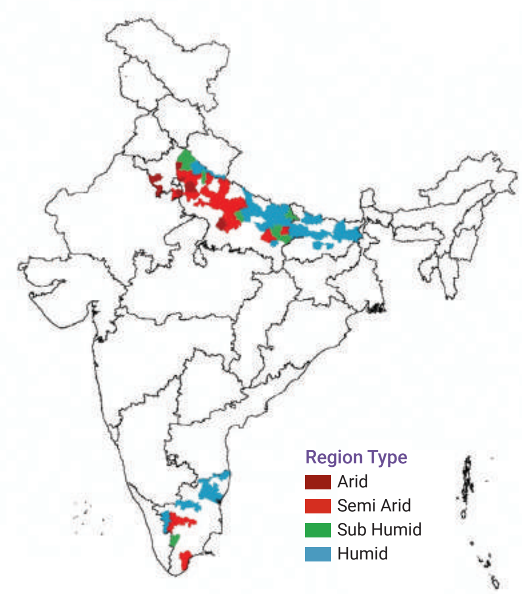
Table 2: Ecosystem-Recommended Optimal Water-Saving Strategies for Sugarcane Cultivation: Assessing Effectiveness of Techniques

Technology	Description	Suitability
Drip irrigation	The objective of drip irrigation in sugarcane cultivation is to ensure water and fertiliser supply according to the growth rhythms of Sugarcane, resulting in high yield and high sugar content. Drip irrigation helps maintain the soil humidity at optimal levels during different stages of sugarcane growth, such as seedling, tillering, elongation, and maturation.	On-surface systems are best for small to medium-scale sugarcane growers or for use on highly sandy soil plots. They are also an excellent option for plots that are deep-tilled.
Furrow Irrigation	Furrow irrigation is a method of laying out the water channels in such a way that gravity provides just enough water for suitable plants to grow. It involves creating small channels or furrows along the rows of sugarcane plants and allowing water to flow through these furrows, directly irrigating the roots of the plants. This method helps in conserving water as it reduces evaporation and runoff.	Sandy clay loam soil is suitable for furrow irrigation in sugarcane cultivation.[82] It has been observed that this type of soil allows for optimal water and fertiliser application for sugarcane crops. Additionally, sandy clay loam soil has been found to conserve soil moisture efficiently, resulting in higher soil moisture content and cane yield.
Scheduling Irrigation	Scheduling irrigation in sugarcane farms refers to the planned program of applying irrigation at specific dates and amounts to achieve particular objectives. It involves measuring evaporation rates using a pan evaporimeter and calculating the irrigation water required based on cumulative pan evaporation and crop coefficient.	The soil most suitable for scheduling irrigation in sugarcane cultivation is sandy clay loam.
Mulching	Mulching refers to covering the soil surface with materials such as plastic film, paper, or plant mulch. Mulching helps to keep the soil humid and prevents excessive water loss from the soil surface.	The no-tillage system combined with bagasse mulch is the most suitable soil for mulching in sugarcane cultivation. This combination is beneficial for soil chemical properties, such as soil C-organic and soil P-available, which are important for soil fertility and sugarcane productivity.
Regulated Deficit Irrigation (RDI)	Regulated Deficit Irrigation (RDI) in sugarcane cultivation is a water management strategy that involves intentionally applying less water to the crop than its full water requirement. RDI uses water stress to control vegetative and reproductive growth. This technique optimises water use efficiency and improves crop productivity by subjecting the crop to controlled water stress during specific growth stages. RDI can be implemented by reducing the amount of irrigation water applied or by adjusting the irrigation frequency.	Regulated Deficit Irrigation (RDI) in sugarcane cultivation is most suitable in sandy clay soil.

3. Local Agriculture Ecosystems

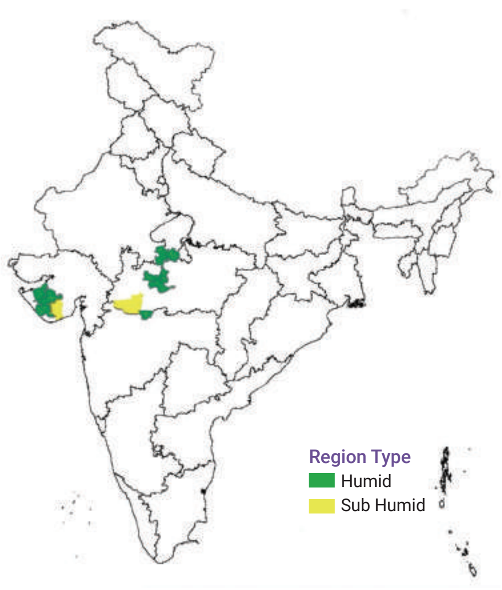
Example (For Indicative Purposes): Taking the case of **Context 1:** LAE for Sugarcane Production in semi-arid regions of UP vs **Context 2:** LAE for Sugarcane Production in West India.

Local Agriculture Ecosystem: Sugarcane production in semi-arid regions of UP



Feature	Local context
Ecological Nature and Criticality	• Arid/semi-arid and sub-tropical zone • High irrigation water productivity contrasted with low land productivity
Agency of Farmers	• Small and marginal farmers • Assured income due to SAP for sugarcane • Assured cash, despite delays in payment
Key Orchestrator in the Value Chain	• Strong industry-led linkages • Direct purchase from farmers without middlemen • Out of 37 districts, 21 districts have concentration of sugar mill (~44 sugar mills in 21 districts).
Prevalence of Digital Infrastructure	• Lower digital literacy compared to West Region • Emerging digital infrastructure across areas

Local Agriculture Ecosystem: Sugarcane production in West India



Feature	Local context
Ecological Nature and Criticality	• Arid/semi-arid tropical zone • Low irrigation productivity with high land productivity; high ground water distress
Agency of Farmers	• Medium to large farmers • Assured income due to FRP for sugarcane • Stronger co-operative structures
Key Orchestrator in the Value Chain	• Strong industry-led linkages • Direct purchase from farmers without middlemen
Prevalence of Digital Infrastructure	• Higher than average digital literacy • Stronger digital infrastructure across areas

Based on the understanding of the differences and specifications of both the ecosystems, the solutions will thus be tailored eventually. (See Table below for example)

<table>
<tr><th>Feature</th><th>Recommendation for UP</th><th>Recommendations for West India
(Changes compared to UP mentioned separately)</th></tr>
<tr><td rowspan="2">Package of practices</td><td colspan="2">• Industry-academia partnership to build contextualised, location-specific practices to drive adoption of drip irrigation practices specific to farmers</td></tr>
<tr><td>• Focus on improving land productivity and yield along with water efficiency</td><td>• Deep focus on water efficiency while sustaining productivity</td></tr>
<tr><td>Capacity building of farmers</td><td>• Leveraging extension workers of the company to enable farmers with integrated practices</td><td>• Initial support through extension workers of the company to enable farmers
• Promote local entrepreneurship to provide capacity as a service to farmers
• Digital integration through SMS and phone alerts for farmers to adopt practices</td></tr>
<tr><td>Demonstration evidence</td><td colspan="2">• Model farms established to demonstrate value to farmers
• Periodic review of water consumption and throughput with farmers for ongoing engagement</td></tr>
<tr><td rowspan="2">Sustained access to necessary inputs</td><td colspan="2">• Ensuring partnerships with MI providers to ensure service and support infrastructure</td></tr>
<tr><td>• Investments by the company in enabling access to necessary herbicides</td><td>• Advisory support through local vendors and digital solution providers on necessary inputs</td></tr>
<tr><td rowspan="2">Working capital support to farmers</td><td colspan="2">• Partnerships with banks and financial institutions for working capital loans for older farmers</td></tr>
<tr><td>• Loans against proven track record of production and payment</td><td>• Engagement with co-operatives to drive access to capital through tailored financial products</td></tr>
<tr><td>Positive/ negative incentives</td><td>• Rewards and recognition for farmers demonstrating sustained adoption (especially small and medium farmers)
• Negative incentives for farmers who do not adopt water conservation practices</td><td>• Stronger negative incentives for farmers who do not adopt water conservation practices</td></tr>
</table>

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