



ICID•CIID

International Commission on Irrigation and Drainage (ICID)



Dr Alok Sikka
Emeritus Scientist, IWMI, India

Smart Irrigation for Resilient Water System with a Lens of Water-Energy-Food Nexus

2nd Indo Global Irrigation Summit

24-25 June 2026, New Delhi India

Smart Irrigation for Resilient Water System with a Lens of Water-Energy-Food Nexus

Alok Sikka, Emeritus Scientist, IWMI & Ex, DDG (NRM), ICAR

D. R. Sena, International Researcher, IWMI, Delhi

2nd Indo-Global Irrigation Summit

24-25 June 2026, New Delhi, India



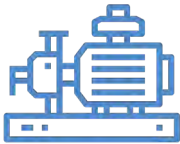
Water and Energy Intensive South Asian Agriculture



About **40% of cultivated land is irrigated**, with agriculture consuming over 90% of water-achieving food security



About **60-80 % of irrigated area is serviced by groundwater** in India, Bangladesh and Pakistan, ageing irrigation systems with low water use efficiency

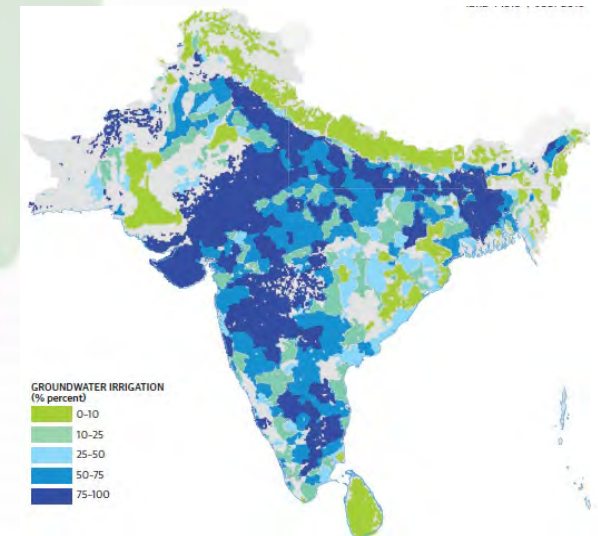
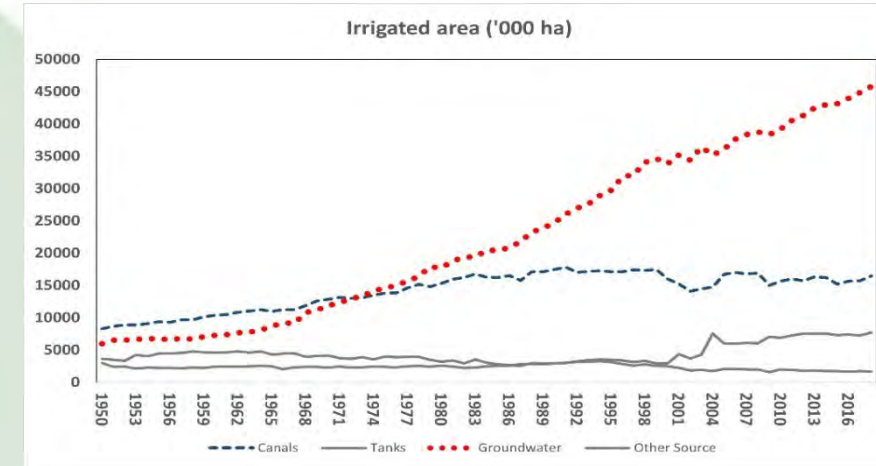


Over **30 million groundwater pumps abstract** about 350 billion cubic meters of groundwater annually



Increasing energy demand-India alone consuming **20% of energy in agriculture** (largely GW pumping, lifting)

Smart irrigation a **MUST** for resilient water systems under growing climate change and widening water supply-demand gap in agriculture



World Bank (2020)



ICID • CIID

2nd Indo-Global Irrigation Summit

24-25 June 2026, New Delhi, India

Smart Irrigation: Building Resilient Systems

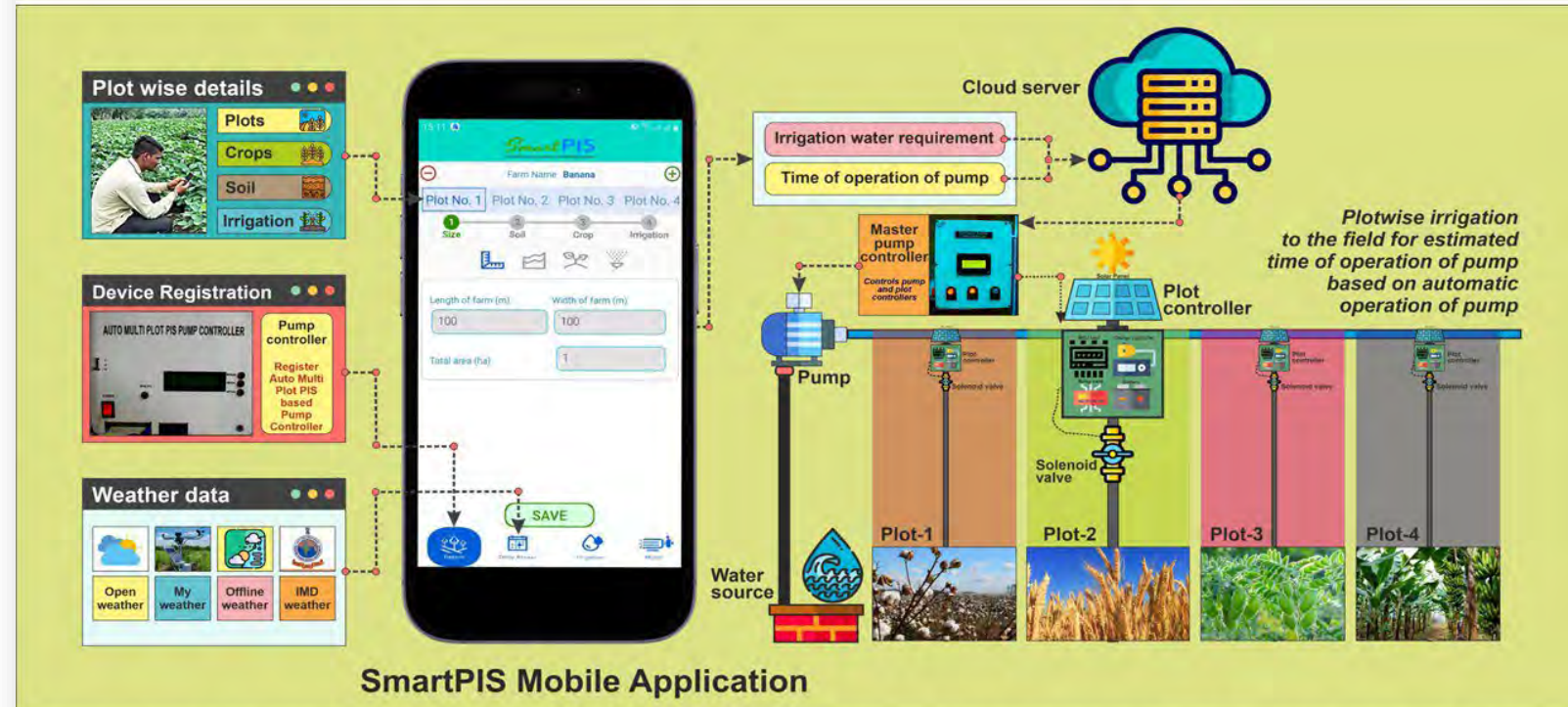
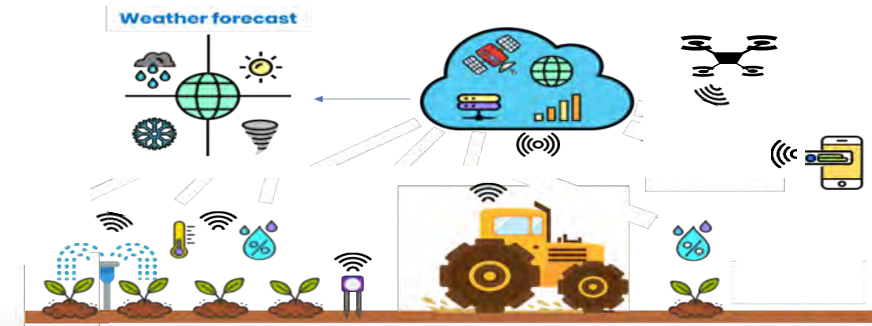
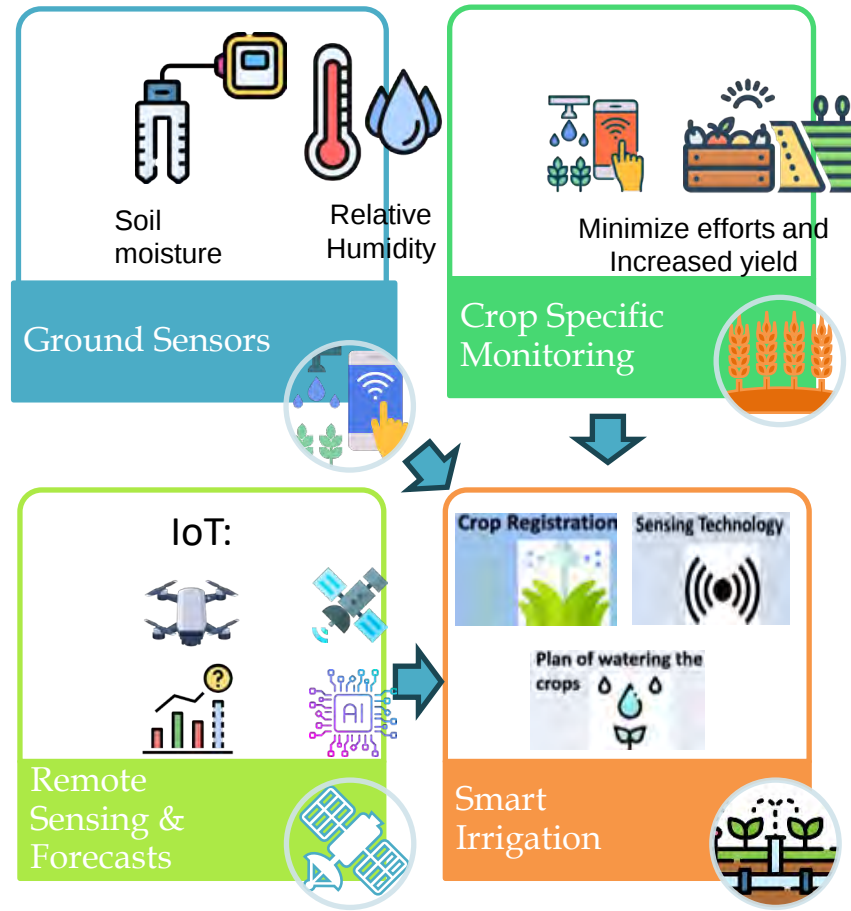
- **Smart irrigation** uses sensors and weather with real time analytics to deliver precise amount of water to
 - Reduces non-beneficial losses,
 - Lowers the energy use required for pumping/lifting water,
 - Maximize crop yields, and enhance water productivity
- Functions as digital water allocation infrastructure integrating sensors, data analytics, and automated controls
- Monitor soil moisture, weather conditions, crop water requirements in real time, for precise irrigation scheduling and distribution.
- Data-driven demand assessment & management, reduces over-irrigation and improves water use efficiency.
- Integration with artificial intelligence, refine irrigation decisions, aligning water delivery with dynamic conditions.



2nd Indo-Global Irrigation Summit

24-25 June 2026, New Delhi, India

Smart Irrigation: Combining Sensors, Space Technology & ICT



IoT-enabled AWD-based Irrigation for Transplanted Rice



- IoT-enabled Smart irrigation scheduling in the paddy field based on water level below ground level
- Saves 20% of water in rice farming without minimal yield loss of 5%
- Low-cost farmer-friendly device (₹10,000/- ; 115US\$) consists of a sensing unit, a pump controller and a mobile App for irrigation automation

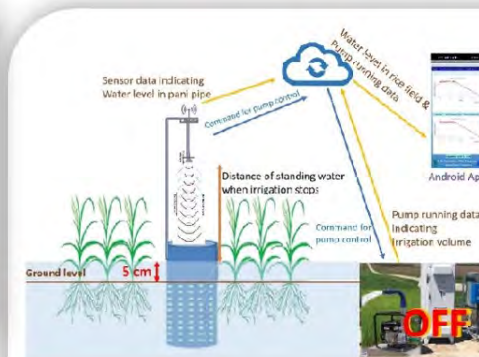
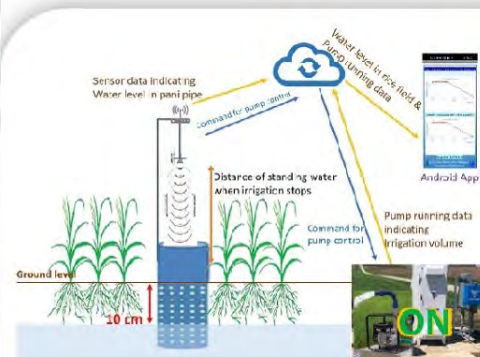
Detection of water level in paddy field using ultrasonic sensor

Water level = 10 cm below ground level in the pipe

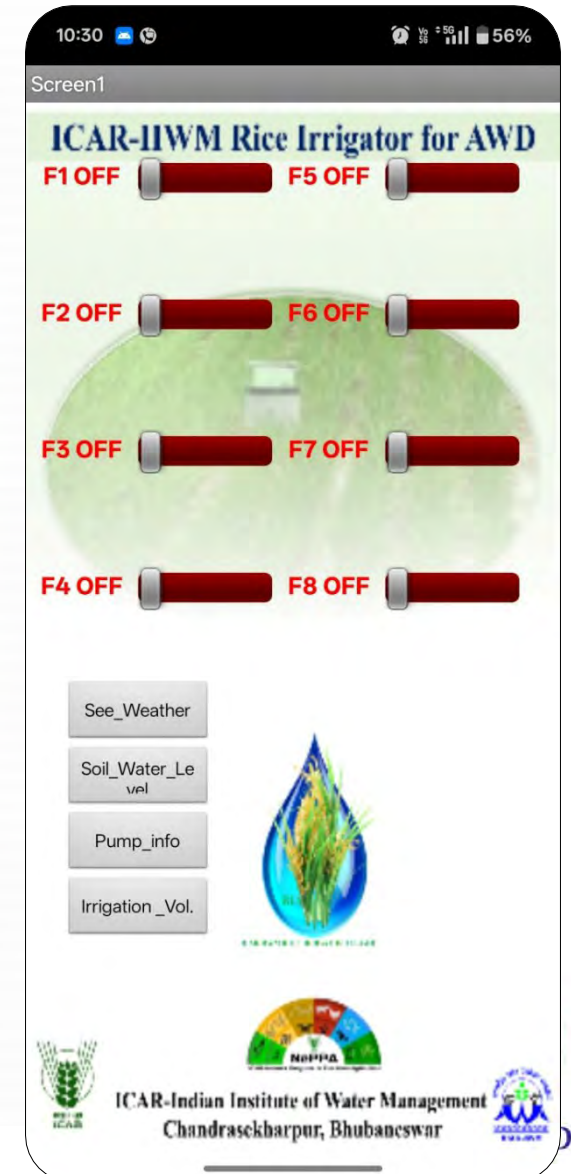
Pump ON

Water level = 5 cm above ground level in the pipe

Pump OFF



2nd Indo-Global Irrigation Summit
24-25 June 2026, New Delhi, India

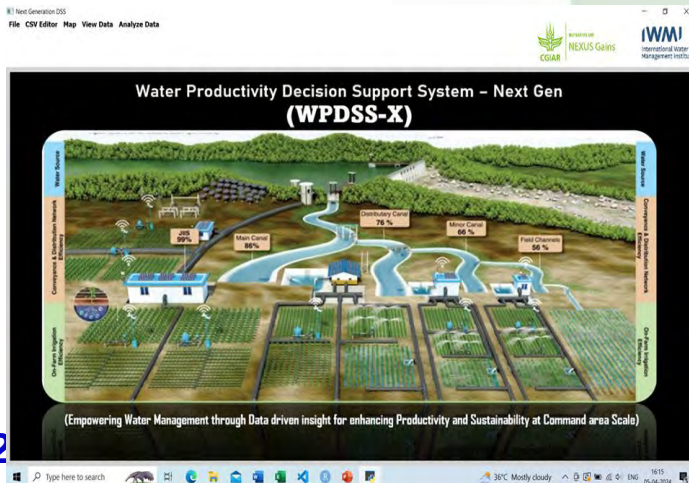


Smart Agricultural Water Management: Building On-farm Resilience in Water Systems

Agri Water Management Solutions

- Laser land levelling
- Micro irrigation (Drip, sprinkler, raingun)
- Smart Irrigation Scheduling (sensors- based)
- Direct-seeded rice (DSR), Conservation agriculture
- Alternate wetting & Drying (AWD) in rice
- Crop diversification
- Pressurized piped distribution
- Participatory water management

DSS Linking Canal Operation & OFWM

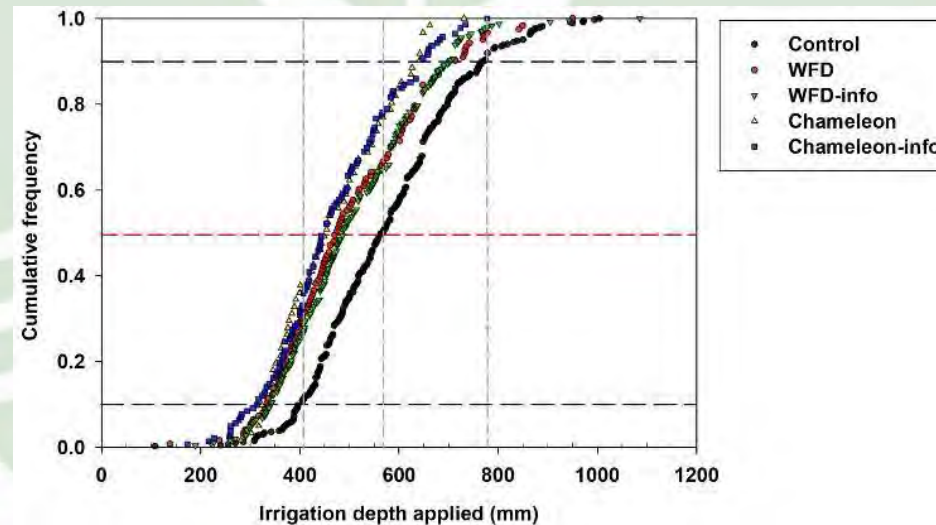


24-25 June 2026, New Dehli, India

Chameleon Soil Moisture Sensor



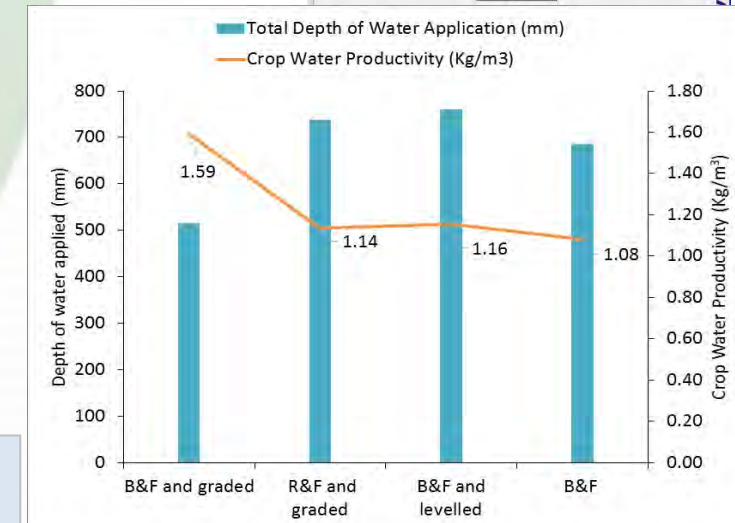
Reduced water use by 20-255%



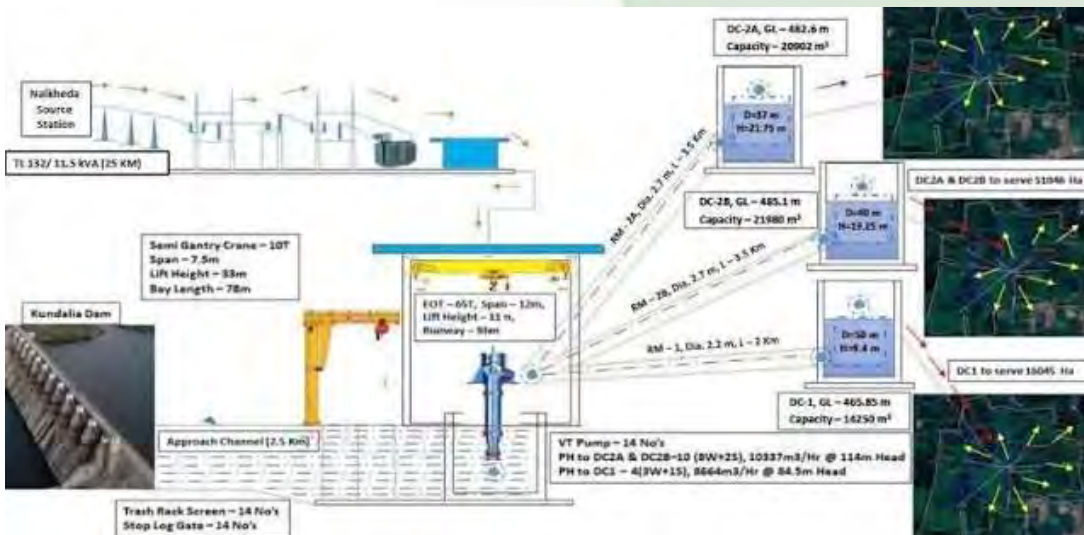
Significant reduction of 21% when WUG build information networks using chameleon sensors

WinSRFR -a software for the hydraulic analysis of surface irrigation systems- for designing and evaluating performance of irrigation systems

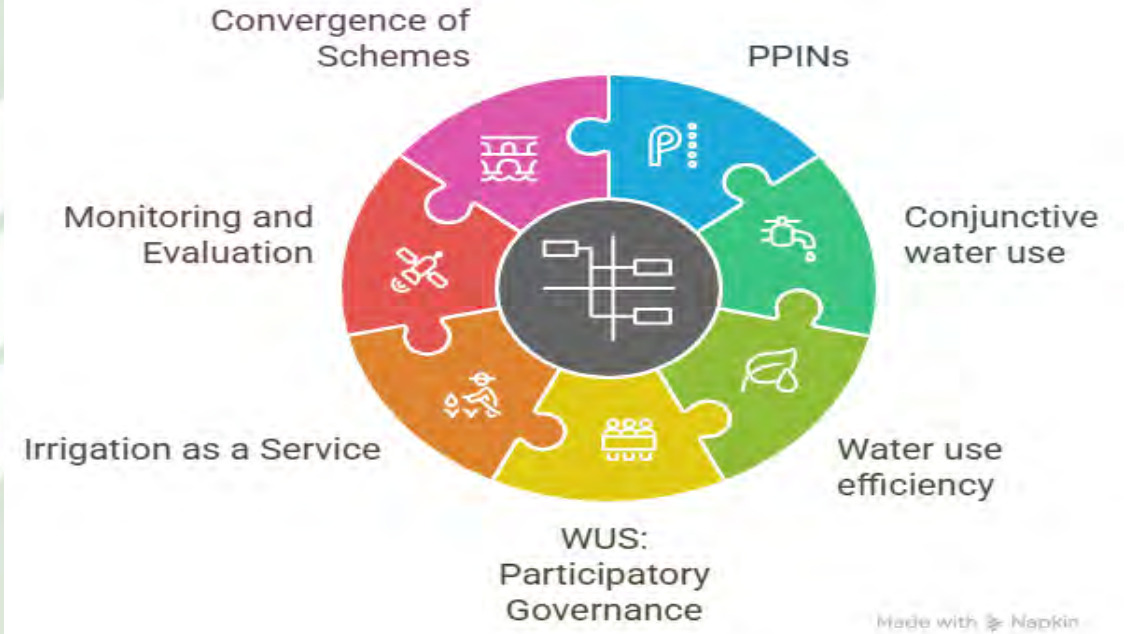
Precision surface irrigation with SIP (Kharif Maize)



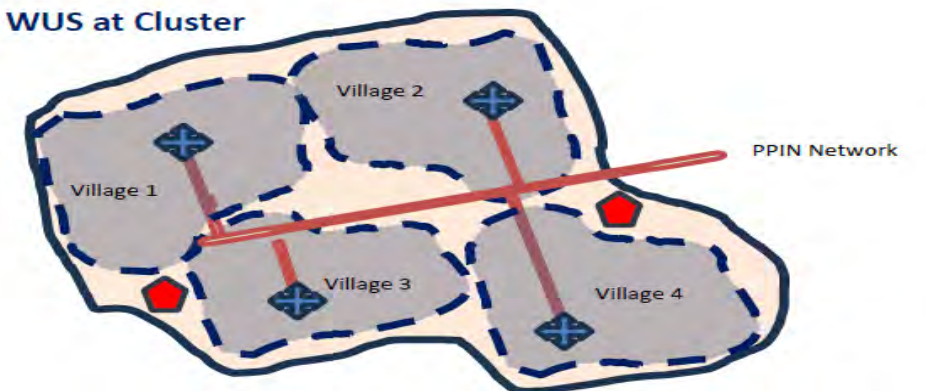
Madhya Pradesh Irrigation Efficiency Improvement Project (MPIEIP)-ADB Supported Smart Irrigation Project



MCAD scheme: MoJS



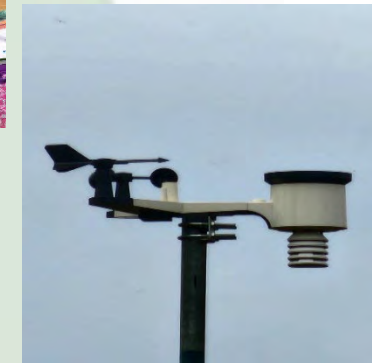
WUS at Cluster



Use cases of Irrigation Modernization with co-design as the instrument

Rahul Rasal is a good example of a next-generation farmer/entrepreneur.

- ❑ Has **40 acres of land in Nighog** (minor 20 in Kukdi Left Bank Canal of Maharashtra)
- ❑ Own a **weather station (RF. & ET gauges)**
- ❑ Use advanced irrigation - **drip, sprinkler, underground drip, lined storage**
- ❑ Grow high-value crops (grapes, Pomegranate in **10 acres**) and papaya, onions, vegetables, and other seasonal crops.
- ❑ High-value production for export markets.
- ❑ Annual income **30 million INR (~380K USD)**



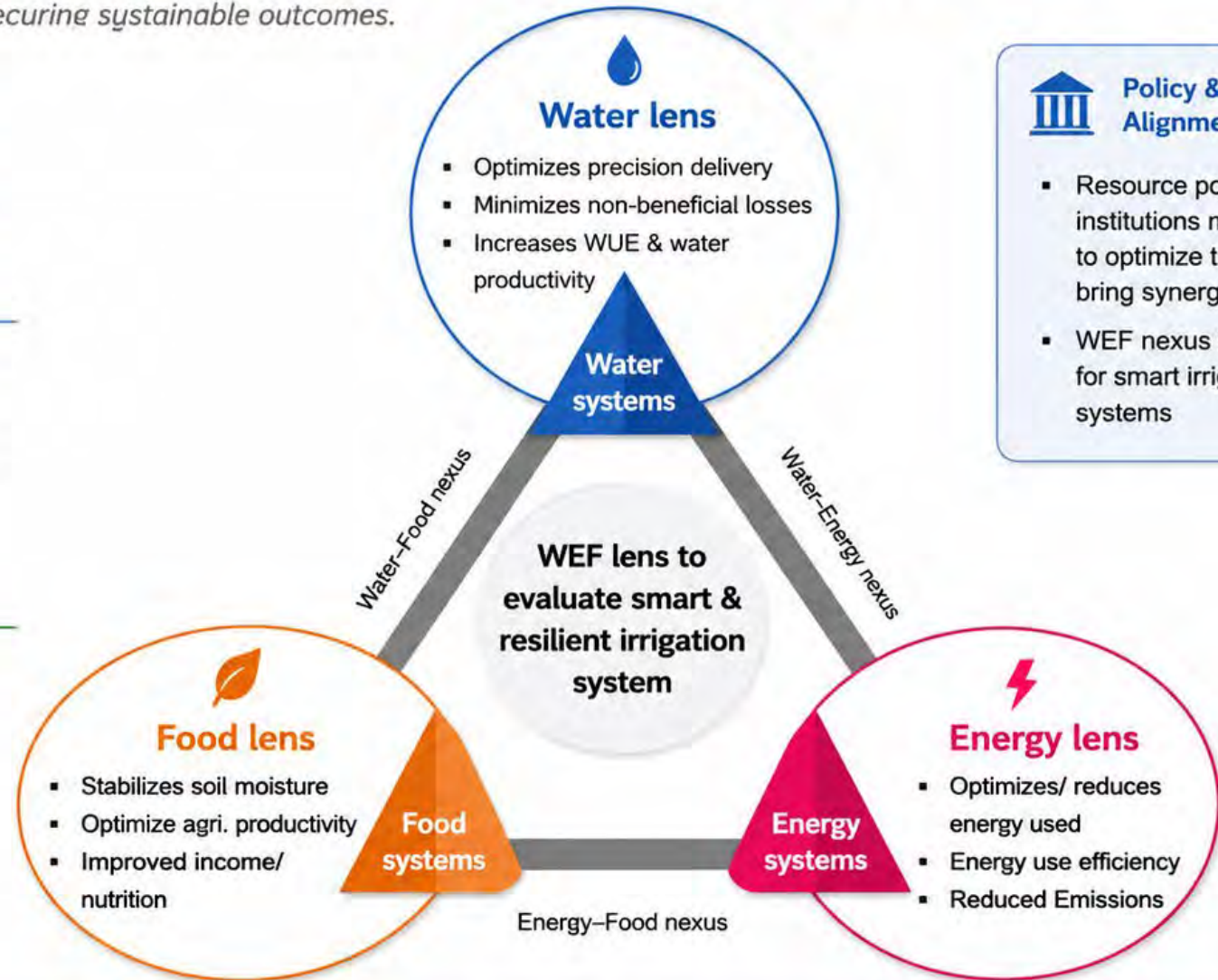
Smart Irrigation: with Water-Energy-Food Lens

Optimizing synergies. Managing trade-offs. Securing sustainable outcomes.

 **Smart irrigation systems** operate at the intersection of **Water-Energy-Food (WEF) Nexus** loop.

 **WEF nexus lens** to optimize the water savings plus energy used for pumping & conveying water and secure sustainable agricultural yield.

 **Trade-offs and synergies** including environ-economics of water saved, energy used and food produced.



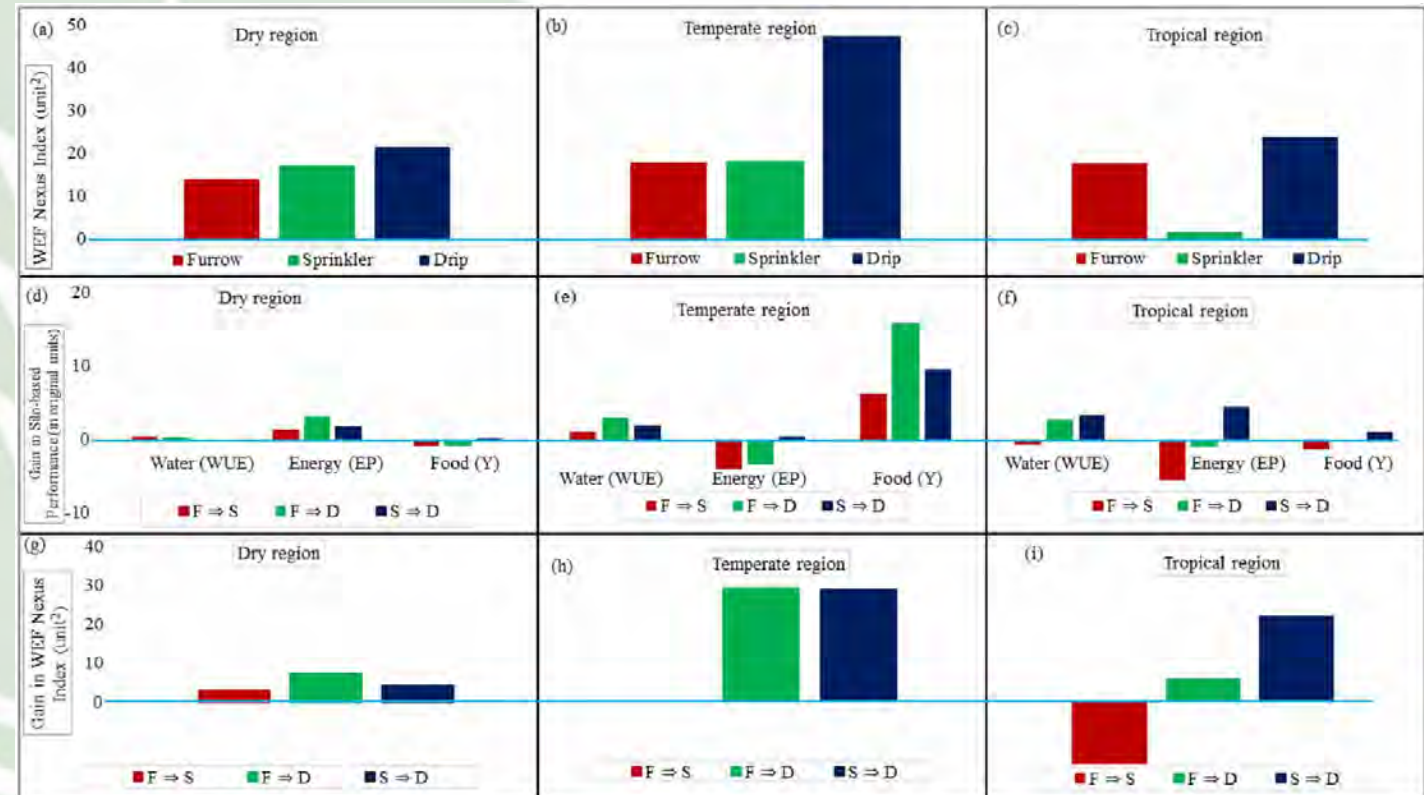
Smart irrigation systems must optimize the WEF nexus



More crop per drop | Less energy per yield | Better lives, sustainably

Assessing WEF nexus in Irrigation Water Management

- Integrated modelling frameworks
- Composite/integrated WEF indices as aggregation of indicators
- Sustainability polygons / radar charts / spider diagrams



Impacts of irrigation modernisation on the water, energy, and food performance from a silo approach in (d) dry, (e) temperate, and (f) tropical climates; and impacts of irrigation modernisation on the WEF nexus in (g) dry, (h) temperate, and (i) tropical climates.

IOP Publishing Environ. Res. Lett. 17 (2022) 073003 <https://doi.org/10.1088/1748-9326/ac7b39>

ENVIRONMENTAL RESEARCH
LETTERS



TOPICAL REVIEW

Sustainable irrigation technologies: a water-energy-food (WEF) nexus perspective towards achieving more crop per drop per joule per hectare

RECEIVED
1 April 2022

REVISED
16 June 2022

ACCEPTED FOR PUBLICATION

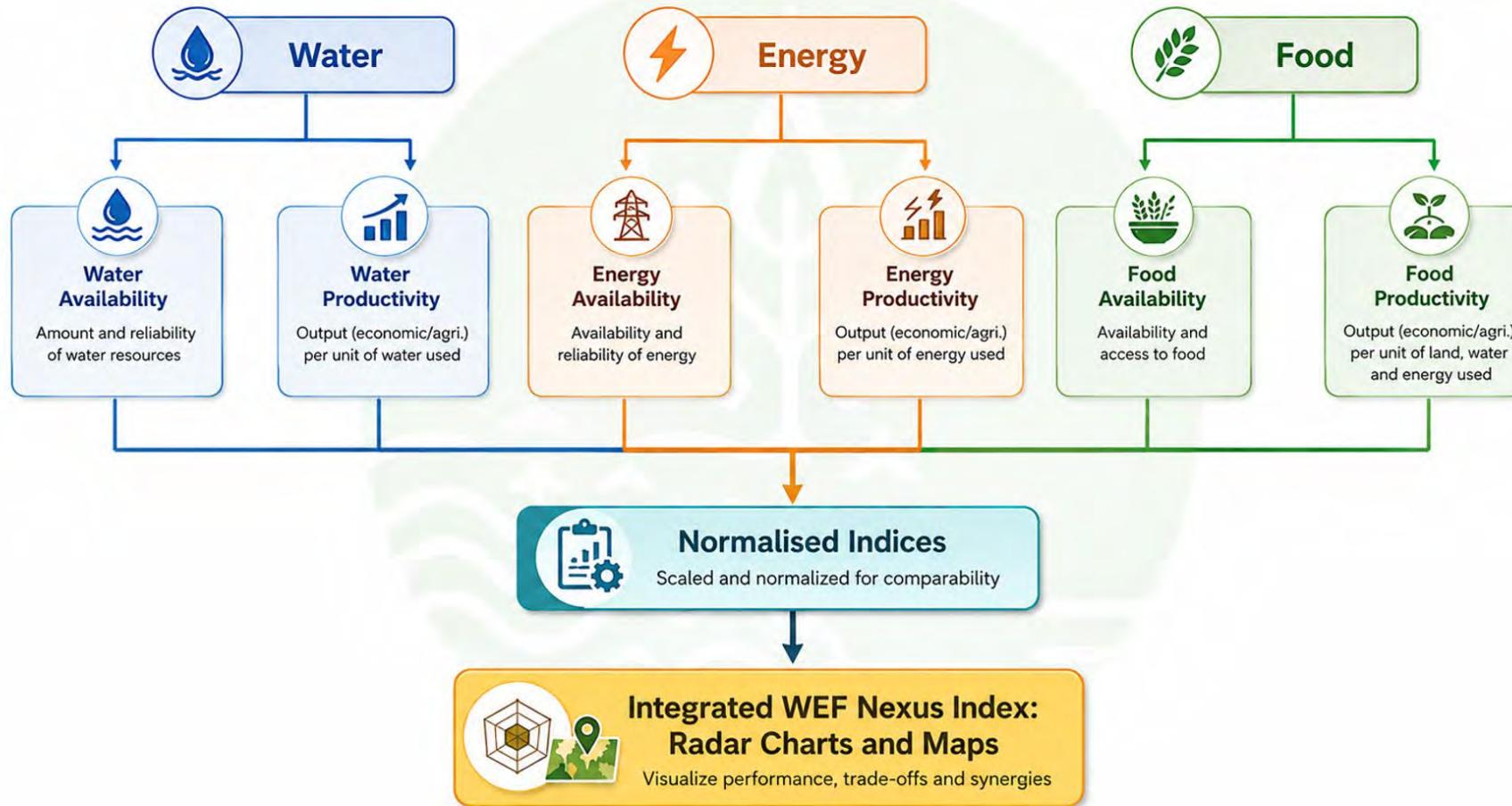
Cuthbert Taguta^{1,2,*}, Tinashe Lindel Dirwai^{3,4}, Aidan Senzanje^{1,5}, Alok Sikka⁶ and Tafadzwanashe Mabhaudhi^{1,2,7,*}

2nd Indo-Global Irrigation Summit
24-25 June 2026, New Delhi, India



ICID • CIID

• WEF Nexus Composite Index: Framework •



WEF NEXUS IN SMART IRRIGATION COMMAND FRAMEWORK

Using the Water–Energy–Food (WEF) Nexus lens to evaluate smart irrigation interventions for **maximizing yields** while **optimizing water, land, and energy use**. HYPOTHETICAL EXAMPLE



Command Area: 10,000 ha
Cropping System: Paddy–Wheat
Water Source: Canal + Groundwater
(Conjunctive Use)

SMART IRRIGATION INTERVENTIONS



Canal modernization (Lining, automation, flow measurement)



Solar-powered pumping systems



Soil moisture sensors & IoT monitoring



Remote sensing & weather information



AI-based irrigation scheduling & advisories



Precision irrigation (Drip / Sprinkler)

WATER OUTCOMES

Indicator	Before (Traditional)	After Smart Irrigation
 Irrigation water use	120 MCM	90 MCM
 Groundwater pumping	40 MCM	20 MCM
 Water productivity (kg/m ²)	0.42	0.69



Water saving = 30 MCM (25%)



Reduced conveyance losses



Improved groundwater sustainability

ENERGY OUTCOMES

Indicator	Before (Traditional)	After Smart Irrigation
 Pumping energy use	18 GWh	8 GWh
 Energy productivity (kg grain/kWh)	2.8	7.8
 GHG emissions (ton CO ₂ e)	9,200	3,900



Pumping energy reduced by 56%



Lower diesel/electricity demand



Reduced GHG emissions by 58%

FOOD OUTCOMES

Indicator	Before (Traditional)	After Smart Irrigation
 Crop yield (t/ha)	5.0	6.2
 Cropping intensity (%)	160%	185%
 Net return (₹/ha)	52,000	78,000



Yield increased by 24%



Higher cropping intensity



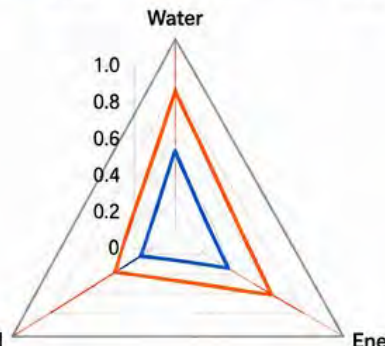
Improved farm income & livelihoods

WEF NEXUS SCOREBOARD (Composite Performance)

Before

After

Ideal



Water Score

0.82

(↑ 64%)

Energy Score

0.558

(↑ 179%)

Food Score

0.434

(↑ 24%)

COMPOSITE WEF INDEX

Before	After	Ideal
0.350	0.604	1.000

OVERALL NEXUS GAIN

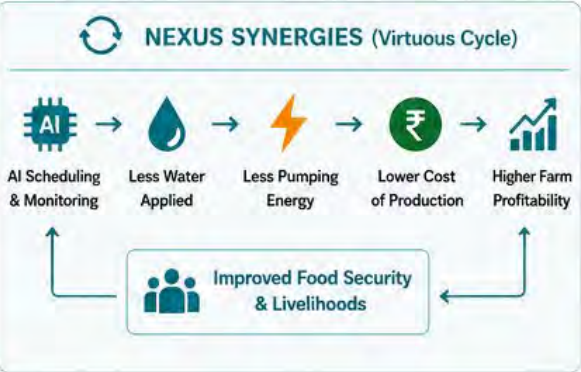
★★★★☆

72.6%

Improvement

NEXUS TRADE-OFFS

Intervention	Water Impact	Energy Impact	Food Impact
Pressurized irrigation	Positive	Negative (higher pumping)	Positive
Solar pumps	Neutral	Positive	May increase water abstraction
Deficit irrigation	Positive	Positive	Potential yield reduction
Precision scheduling	Positive	Positive	Positive



SCENARIO CONTEXT

Baseline: Traditional flood irrigation

Interventions: As listed in left panel

Evaluation Year: Year 5

Prices: Stable (real terms)

Climate: Normal year



KEY TAKEAWAY

A smart irrigation system should not be judged solely by water saved. The true performance metric is the net **WEF Nexus Gain**—simultaneously improving **water productivity**, **energy efficiency**, **agricultural output**, and **system resilience**.

 Water Productivity ↑

 Energy Efficiency ↑

 Agricultural Output ↑

 System Resilience ↑

Key Takeaways ...

- WEF nexus is important to assess trade-offs and synergies of smart irrigation systems to maximize yields while optimising water, land, and energy use.
- WEF nexus framework demonstrates how digital and integrated resource systems can function for optimizing water allocation/use and reducing cross-sector pressures.
- Aligned through coordinated planning and governance, it strengthens resilience and supports long-term sustainability by ensuring resources are managed within interconnected and resource-constrained environments.
- Irrigation modernization and smart irrigation systems must be examined with a WEF lens for Nexus Gains

Thank You

a.sikka@cgiar.org

aloksikka@gmail.com

2nd Indo-Global Irrigation Summit
24-25 June 2026, New Delhi, India

