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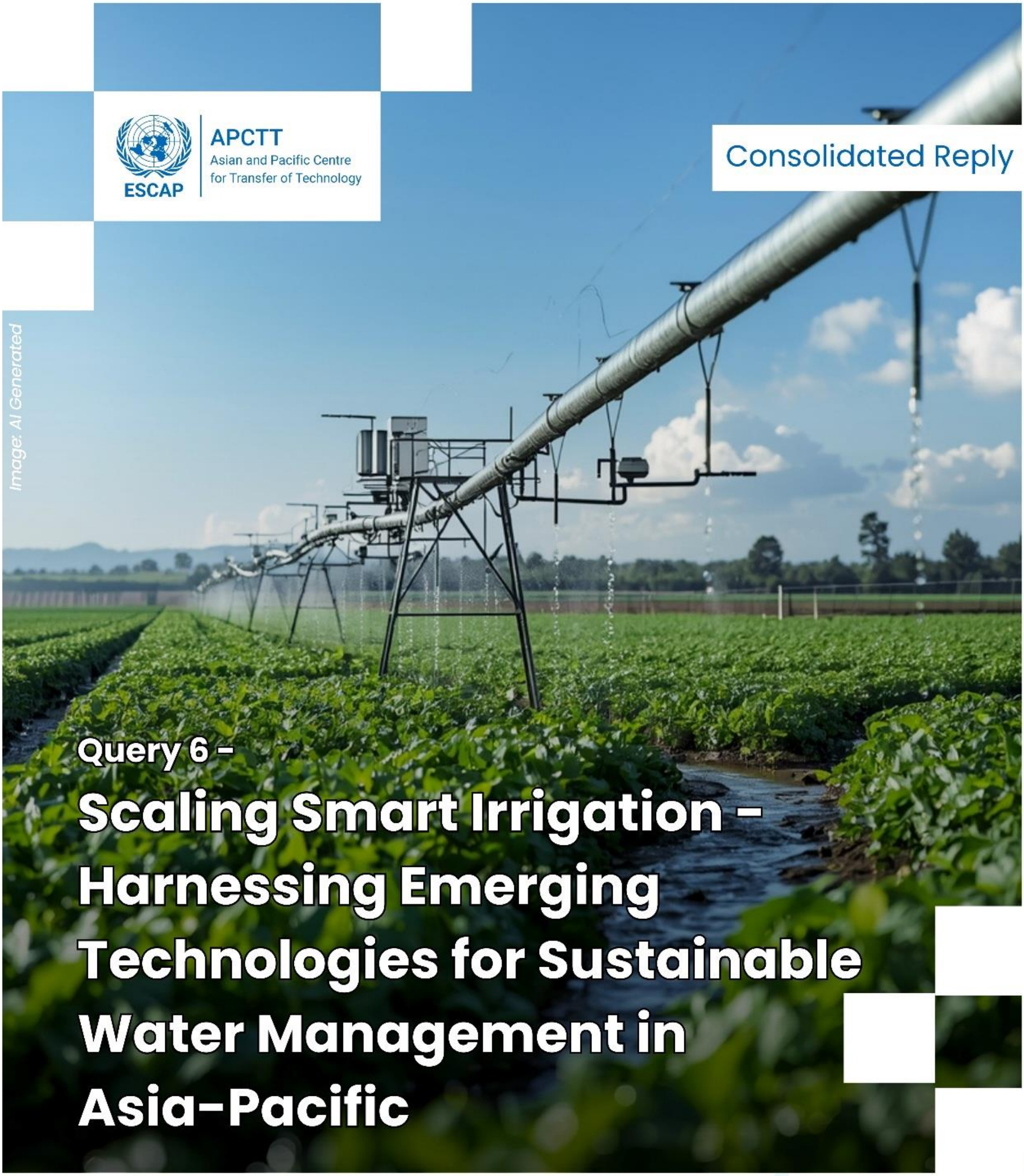
Consolidated Reply



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Query 6 -

Scaling Smart Irrigation - Harnessing Emerging Technologies for Sustainable Water Management in Asia-Pacific

Community of Practice (CoP) on Climate Technologies

APCTT
COMMUNITY OF PRACTICE ON CLIMATE TECHNOLOGIES

Community of Practice (CoP) on Climate Technologies

Shared Experiences, Smarter Solutions for Climate Action and Resilience

The Community of Practice (CoP) on Climate Technologies launched by the Asian and Pacific Centre for Transfer of Technology (APCTT) is dedicated to addressing the multifaceted challenges posed by climate change in the Asia-Pacific region through technology solutions. By leveraging the region's rich innovation capacities and good practices, the CoP aims to enhance access to critical knowledge on climate technologies. The Community connects professionals engaged in delivering technological solutions to climate change.

The objective of this Community of Practice is to:

- Promote collaborative problem-solving and policy-relevant dialogue
- Support the localization and transfer of innovations suited to national priorities
- Enhance institutional capacities for climate technology governance
- Enable matchmaking between solution providers and implementers

The Community is driven by a participatory and adaptive model that combines knowledge generation, engagement, and access to resources through the following mechanisms: monthly Query-Response Consolidated Reply (CR) cycle, webinars and interactive discussions, knowledge repository and much more.

Original Query by: Saeed Eshraghi, Head of Technology, Valuation and Documentation, Iranian Research Organization for Science and Technology, Tehran, Islamic Republic of Iran

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Over 500 million people in the Asia-Pacific region face water scarcity, with water availability projected to decline by around 20% by 2050 due to climate change. This is threatening agriculture-based livelihoods and food security, especially in arid and semi-arid regions[1,2]. Climate-smart irrigation and digital water technologies—such as subsurface drip irrigation (SDI), IoT-enabled irrigation control, and AI-based precision farming—offer potential pathways to improve water-use efficiency and climate resilience[3].

In this context, we invite members to share insights and practical experiences on the following:

1. Members' experience with the successful use of SDI, AI-based precision agriculture or IoT-enabled irrigation systems in water-scarce Asia-Pacific contexts, especially at scale?
2. What are the key enabling or impeding factors (policy-related, socio-economic, behavioural, or technical) that most strongly influence smallholder adoption of the above technologies? Please share examples of interventions that have effectively addressed constraints in uptake.

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[1] Asian Development Bank (ADB) (2021). Contemporary Irrigation Issues in Asia and the Pacific.
[2] Food and Agriculture Organization of the United Nations (FAO) (2021). Water Scarcity and Climate Change in Agriculture.
[3] FAO (2022). Digital Agriculture and Water Management: Opportunities and Risks.

Contributions will help distil practical lessons on technology transfer, inclusive policy design, and accelerated adoption of smart irrigation solutions for climate adaptation.

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Contents

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1. Summary of Responses

The discussions on climate-smart irrigation technologies focused on successful experiences and challenges faced by small farmers in water-scarce Asia-Pacific countries. Participants shared their experiences in India, Pakistan, Bangladesh, Vietnam, Sri Lanka, and Australia.

Among successful experiences, **Sub-soil Drip Irrigation (SDI)** has grown well in the semi-arid regions of India, such as Maharashtra and Gujarat, reporting a 30-50% reduction in water use and a 40% increase in sugarcane and cotton yields. In this context, the **Pradhan Mantri Krishi Sinchayee Yojana (PMKSY)** subsidies of 55% of the cost has helped expand SDI to 9.7 million hectares in India. IoT-based solutions in Vietnam's Smart Agriculture 2030 initiative and Bangladesh's **solar-IoT water pumps** (50,000 units by 2025) are reported to decrease water wastage by 13-40% in rice fields and off-grid areas, with mobile app-based monitoring. **AI precision agriculture** solutions, such as India's ISRO Satellite-based Irrigation Advisory Service for 10 million small farmers and Australia's CSIRO satellite-ML projects, optimise irrigation schedules based on soil, weather, and crop information, with a 40% reduction in water use for high-value crops.

The key enabling factors for this transformation include **policy incentives** such as subsidies (55-80% for micro-irrigation), result-based payments (for example, **Punjab's Pani Bachao Paisa Kamao scheme**, paying farmers INR 4 per kWh saved and covering 52,000 farmers), and public-private partnerships (e.g. **ADB projects** to modernise 215,000 hectares in **Odisha**) encourage adoption. Socio-economic factors include **pay-as-you-go financing**, **farmer producer organizations (FPOs)**, and training for women/youth (for example, **FAO pilots** increasing farmers' incomes by 15-20% through sensor training). Technical success factors include solar integration, low-cost sensors for localised applications, and extension services such as demonstration farms and SMS alerts.

Factors that **prevent scale up for small farmers** include high initial investment costs (USD 500-2,000 per ha), lack of rural connectivity and power (60% of sites), and congestion in saline soils, with only 20% adoption despite subsidies. Behavioural factors such as low digital literacy (60% of farmers) and resistance have been overcome through farmer field schools, social learning, and voluntary schemes, as in Punjab, reducing groundwater extraction by 15%. Interventions such as standard operating procedures, encouragement of community enterprises (e.g. **tank cascades in Sri Lanka**), and gradual scaling up (e.g. beginning with simple sensors) have yielded good results.

In conclusion, farmer-driven bundles that integrate SDI, IoT or AI with solar energy, results-based incentives, **participatory governance**, and gender-centric training for smallholders (which constitute 70% of the region's farmers) have accelerated uptake of smart irrigation systems. For scaling up, standardisation of technology, a sound understanding **of return on investment** and maintenance costs and financial integration could help the Asia Pacific region achieve resilience and alignment to the **Sustainable Development Goals.**

2. Relevant Experiences

Australia: Australia is leading global smart irrigation innovation with commercialized AI and IoT systems that address issues of water scarcity in the fields of sugarcane, cotton, and horticulture. Aglantis' AI-powered platform of La Trobe University is deployed into various Queensland sugarcane fields. IoT sensors, which monitor sunlight, temperature, and humidity, automatically drive the pumps, save water, reduce fertilizer runoffs into the Great Barrier Reef, and do predictive scheduling to optimize yields. CSIRO's Sense-T provides Tasmanian irrigators with real-time water dashboards that balance their productivity with environmental compliance.

Bangladesh: Farmers in the drought-prone northern Barind Tract region experiment with subsurface drip irrigation systems suitable for both rice and wheat cultivation during dry seasons. Department of Agricultural Extension (DAE) coordinates training programs where groups of neighbouring farmers learn to install and manage the systems collectively. Bangladesh Meteorological Department (BMD) provides timely information that helps farmers determine optimal irrigation schedules. Community demonstration plots located in village centres allow neighbours to observe the technology in actual field conditions.

Bhutan: Bhutan's success in climate-resilient irrigation is supported by the use of funded GCF-presurized piped irrigation schemes, as well as novel solar lift schemes that have been developed for overcoming the difficulties posed by mountains. The National Irrigation Master Plan (2016) aims to irrigate a further 62,000 acres through lift irrigation schemes, making it a model for adaptation using renewables in the Himalayas. The National Environment Commission helps coordinate technical assistance as well as training materials with its neighboring countries.

Cambodia: MIDORI AWD, intended for flood-prone rice with the use of sensors controlling the flooding levels of the irrigation system, was started towards the end of the year in 2024. The ADB Integrated Water Resources Management Project will benefit the provinces of Tonle Sap's Battambang, Pursat provinces with climate-resilient irrigation infrastructure upgrades in irrigation systems, irrigating in the dry season, reducing flood risk.

China: The Hetao Irrigation District deploys real-time monitoring across 1,000+ points with smartphone apps tracking water levels and flows, enabling drip irrigation cooperatives that secure 3M tonnes annual grain output while cutting water use. Dayu Irrigation Group's integrated "water network" systems combine smart meters, electric valves, wireless sensors, and centralized control for precision drip irrigation.

Fiji: Farmers on remote outer islands install solar-powered drip systems to irrigate traditional root crops that form the basis of local food security. Community landowning groups negotiate water sharing arrangements and establish collective maintenance schedules for the shared infrastructure. Pacific Community (SPC) provide technical training materials and follow-up support adapted to island conditions. Local weather alert systems help farmers adjust irrigation plans around approaching cyclones and heavy rain events.

India: Farmer producer organizations in different states affected by drought are coordinating the installation of soil sensor networks in rice, cotton, and pulses. The Pradhan Mantri Krishi Sinchayee Yojana (PMKSY) combines data from the India Meteorological Department (IMD) and soil sensor inputs to provide automatic crop-wise irrigation suggestions. The Andhra Pradesh Integrated Irrigation Project (World Bank P160463) enhanced irrigation services in 35,860ha covering 48,502 small farmers through rehabilitation and climate-smart agriculture techniques. The result showed an increased water productivity in paddy from 0.33kg/m^3 to 0.42kg/m^3 with a WUA satisfaction rate of 45%.

Indonesia: Indonesia leads ASEAN smart irrigation scaling through SIPASI 2.0, Indonesia's national web-based platform launched June 2025 by Universitas Gadjah Mada (UGM) and the Ministry of Public Works. Complementary precision systems include BIOPS Agrotekno's GPS-drone platforms optimizing Java rice/palm oil irrigation and Gunungkidul's IoT rainwater mist systems for drought-prone vegetables. AIIB and ADB modernization programs rehabilitate strategic schemes supporting national food security targets.

Iran: Iranian Research Organization for Science and Technology pilots SDI achieving 30-50% water savings for pistachio orchards. Farmers in arid areas have nut tree plantations under drip irrigation with rudimentary soil moisture feedback. Neighbouring farmers form groups to share installation costs and maintenance responsibilities across larger orchard areas.

Japan: Japan spearheads AI-driven smart irrigation using the ZeRo.agri system deployed across the nation in more than 360 greenhouse installations since 2013. In collaboration with Meiji University, this IoT platform utilize soil sensors, solar radiation forecasts, and AI algorithms to automate drip irrigation and fertigation to keep the soil moisture at optimum levels while minimizing the input of water/fertilizer and CO2 emissions. Thus, allowing farmers-even beginners-to grow crops of consistent high quality. The Ministry of Agriculture, Forestry and Fisheries supports the wider diffusion of smart irrigation technology through smart agriculture policies. These labor-saving technologies address Japan's aging farmer population while advancing sustainable water use in water-stressed regions.

Laos: Rice farmers in parts of the Mekong basin use basic soil sensors combined with weather forecast information to manage irrigation during dry spells. Ministry of Agriculture and Forestry (MAF) oversee shared irrigation infrastructure and coordinate maintenance activities. Regional cooperation initiatives support training for local extension staff. Farmers receive simple irrigation guidance through mobile messaging services where coverage permits.

Malaysia: Rubber and oil palm smallholders in selected hilly regions test drip irrigation systems adapted for tree crop cultivation. Department of Agriculture Malaysia (DOA) establishes demonstration farms to show system performance under local conditions. Farmer associations support group purchasing arrangements to reduce individual costs.

Mongolia: The Vegetable Production and Irrigated Agriculture Project, funded by ADB, aims to modernize inefficient schemes across more than 380 systems, subsidizes 30% for modernization, and fully funds reservoirs/dams supporting potatoes, wheat, and fodder on less than 1% of arable land. Recently, initiatives have been taken to expand irrigated areas by 10-12% across eight provinces by center-pivot systems, each covering 100,000 m² in Winduer Khan, while more than 5,000 wells are made every year to reduce pasture degradation and integrating livestock.

Myanmar: Myanmar develops the water resources of the nation through infrastructure revitalization and solar innovations for smallholder farming. The IWMI's Central Dry Zone project supported the improvement of Pyawt Ywar pump infrastructure and helped establish the country's Water User Association for the benefit of 970 farming families and enabled the supplementation of the dominant chili crop through a doubling of farmer incomes and a reduction of government electricity expenses by half. Yetagon water systems reduce working times from hours to minutes for low irrigating farmland and place Myanmar on the cusp of a scalable water management solution.

Nepal: Nepal pilots smart irrigation through real-time sensor networks of the Babai Irrigation Project. Collaboration IWMI-DWRI installed solar-powered flow sensors over 36,000 ha eastern canals; all installed with soil moisture probes delivering "traffic light" indicators-blue for adequate, green for depleting, and red for dry-to 23 farmers, including 8 women. This resulted in equitable tail-end water allocation along with improvements of more than 30% in scheduling. Future Water's Smart Sprayer tests gravity-fed micro-pivots with WhatsApp satellite advisories in water-scarce Syangja hills.

Pakistan: In its scalability, Pakistan is able to showcase its smarter irrigation through IWMI's WRAP program, placed in the rainfed wheat and garlic crops of Chakwal. The soil moisture sensors improving water savings of 30 to 50% with lower electricity bills and healthy crop output in the irrigation of wheat and garlic, done in real time through "traffic light" indicators of root-zone soil moisture. It helps avert both overwatering and underwatering in well-draining sandy loams. In January 2025, Solar Drip irrigation of 21 Farmer Groups of Rural Aid Pakistan used solar power in increasing crop production between 40 to 50% in water-recharging of the water table, while the ConcaveAgri IoT platforms have been able to conserve 60% irrigation water in its AI-driven Precision Agriculture schedules.

Papua New Guinea: Papua New Guinea small-scale irrigation is emphasized to mitigate climate change-induced dry spells. The TADEP project, an initiative by the ACIAR organization, supplies Highlands sweet potato irrigators with tanks, pumps, and pipes for commercial sweet potato production in sites where drought previously destroyed the farm produce. Rachel Suak Mok's Jiwaka mountain garden is now irrigated from the creeks year-round. Futurepump solar-powered micro-irrigation sustains production and accesses abundant runoff water in an extended drought for cash crops. Tarod village uses traditional taro irrigation and NARI shallow well and/or stream diversion for subsistence irrigators who cannot afford engine-driven irrigation systems.

Philippines: Rice and fruit tree farmers in Mindanao province adopt soil sensor technology through agricultural cooperatives that coordinate group purchasing. Agricultural Training Institute (ATI) programmes emphasize practical repair skills suited to rural conditions. Cooperative bulk purchasing arrangements significantly reduce equipment costs for individual participating farmers. Joint Crediting Mechanism scales alternate wetting and drying (AWD) systems with sensor verification enabling smallholder carbon credit participation.

Samoa: The Small-Scale Irrigation Schemes Project funded by POEC, rehabilitates 20 schemes across four districts, with beneficiaries of 20,000 small farmers, to increase productivity and incomes through improved access to water. The GCF-UNDP project in the Vaisigano River (2017-2025) has been implementing ecosystem-based adaptation through water retention ponds supporting climate-smart agribusiness and flood-proofed infrastructure serving 26,528 residents in Apia's primary economic zone. The Samoa Infrastructure Asset Management Strategy emphasizes integrated water resources management from "ridge to reef" with value added in resilience, though agricultural irrigation remains subordinate to urban flood protection and potable water imperatives.

Singapore: Urban and peri-urban farms pilot compact soil sensor systems designed for high-value crop production. A*STAR, in collaboration with the Singapore Food Agency, supports the integration of smart agriculture into controlled farming spaces. Training programmes are delivered through workshops and innovation hubs. Sensor data is linked with national meteorological services to support real-time decisions.

South Korea: South Korea advances smart irrigation through government-backed precision agriculture initiatives under the Smart Farming Promotion Act. IoT-enabled systems monitor soil moisture, weather, and crop needs in real-time across paddy fields, optimizing water use and boosting rice yields while addressing water scarcity. The Ministry of Agriculture, Food and Rural Affairs provides subsidies for sensor-based drip irrigation and data analytics platforms, with market growth projected at 14% CAGR through 2031 driven by AI integration and greenhouse expansion. These efforts position South Korea as an East Asian leader in sustainable water management for high-value crops. In selected paddy farming areas, soil sensors are tested alongside automated irrigation controls to support water management decisions.

Sri Lanka: Climate Smart Irrigated Agriculture Project rehabilitated tanks serving 372,000 smallholders on 53,000ha, delivering 148% cropping intensity increase through sensor integration and farmer organization strengthening. The tank cascade system is another ancient interconnected irrigation network of small tanks that store and convey water in Sri Lanka's dry zone. Vegetable farmers in dry zone regions adopt drip irrigation through traditional farmer societies that coordinate technology introduction. Mobile applications provide irrigation scheduling guidance based on local weather conditions.

Thailand: Rice farmers in the northern provinces pilot the use of soil moisture sensors integrated with air quality and weather data for irrigation planning. Young Smart Farmer (YSF) Programme capacitates rural leaders to disseminate knowledge. Farmer cooperatives operate joint irrigation systems in the fields. JAICAF ICT networking with sensors tracks water levels in areas prone to flooding or drought to efficiently manage rice irrigation.

Timor-Leste: Timor-Leste advances irrigation resilience through flagship government-led infrastructure projects. The Maliana II Irrigation System, launched January 10, 2025 by Prime Minister Xanana Gusmão with a $9.8M budget, will irrigate 1,400 ha (1,100 ha in Bobonaro, Timor-Leste; 300 ha in Indonesia's Belu) over 30 months, transforming abandoned lands for year-round rice production while supporting youth employment and food security.

Vietnam: Intensive rice cultivators in the Mekong Delta use drip irrigation facilities along with crop residue management. ASEAN-Japan MIDORI Plan implements information communication technology irrigation systems with sensors to manage irrigation for rice in real-time to demonstrate reduction in greenhouse gas in relation to alternate wetting and drying. Vietnamese Cooperative Alliance helps in joint purchases of bulk equipment for their members.

3. Related Resources

Relevant Documentation

ADB Advancing Water Security Across Asia and the Pacific (2020): Regional synthesis by the Asian Development Bank and partners examines comprehensive water security challenges and policy frameworks for sustainable resource management. Addresses irrigation governance structures, institutional coordination mechanisms, and agricultural water planning priorities across diverse Asia-Pacific contexts. Provides foundational context for technology scaling discussions in water-stressed agricultural systems. https://www.adb.org/sites/default/files/publication/663931/awdo-2020.pdfadb

ADB Asian Water Development Outlook (AWDO) 2025 Edition: Latest Asian Development Bank flagship water assessment evaluates regional progress toward water security objectives including agricultural water productivity and irrigation resilience. Analyses climate adaptation measures, institutional performance, and investment requirements across Asia-Pacific countries. Thematic focus on wastewater reuse, groundwater management, and transboundary cooperation complements irrigation modernization discussions.
https://www.adb.org/awdo/editions/2025

ADB Contemporary Irrigation Issues in Asia (2021): Asian Development Bank analytical background paper reviews persistent irrigation sector challenges including modernization requirements, institutional capacity constraints, and technology integration opportunities. Examines labour shortages and water allocation issues affecting system performance across major Asian agricultural economies. Informs strategic policy and investment decisions for sustainable irrigation development.
https://www.adb.org/sites/default/files/institutional-document/731791/adou2021bp-irrigation-issues-asia.pdfadb

ADB Irrigation for Climate Change Adaptation in Viet Nam: Asian Development Bank country study documents climate-resilient irrigation infrastructure upgrading, system rehabilitation approaches, and institutional capacity strengthening in the Mekong Delta rice basket. Details participatory water user association development and modernized service delivery models. Provides practical lessons applicable to regional delta and basin contexts.
https://www.adb.org/publications/irrigation-climate-change-adaptation-viet-nam

ADB Irrigation Modernization Enhancement Project, Nepal: Detailed Asian Development Bank project implementation reports provide practical insights into irrigation infrastructure upgrading, institutional reform processes, and technology deployment strategies. Document financing approaches, stakeholder coordination mechanisms, and scaling methodologies from actual country programs. Offer field-tested lessons for replication.
https://www.adb.org/sites/default/files/project-documents/56218/56218-001-rrp-en.pdfadb

ADB Strategy 2030 Water Sector Directional Guide: Asian Development Bank strategic framework outlines long-term priorities for water sector operations through 2030 including integrated irrigation service improvement and agricultural water productivity enhancement. Guides operational lending, technical assistance, and knowledge products supporting sustainable water management. Emphasizes institutional capacity building and regional cooperation mechanisms.
https://www.adb.org/documents/strategy-2030-water-sector-directional-guide

ADB Water Operations Policy: Asian Development Bank's foundational policy document establishes operational principles for water resource development encompassing irrigation infrastructure, agricultural water allocation, and integrated basin management approaches. Defines safeguard requirements, stakeholder engagement protocols, and performance monitoring standards for irrigation-related investments.

Guides country partnership strategies and project design across member countries. https://www.adb.org/documents/water-all-water-policy-asian-development-bank

ASEAN IWRM Platform: Operational knowledge hub facilitates regional cooperation on integrated water resources management including irrigation modernization roadmaps. Hosts technical working groups addressing scaling barriers through policy harmonization and best practice exchange. https://aseaniwrm.water.gov.my/iwrm/

ASEAN Regional Guidelines for Sustainable Agriculture: Adopted 2023 guidelines integrate water-efficient practices within sustainable intensification frameworks for smallholder systems. Specifies irrigation scheduling, soil moisture conservation, and agroecological approaches supporting climate-smart scaling across ASEAN landscapes.
https://asean.org/wp-content/uploads/2022/10/2023_App-1.-ASEAN-Regional-Guidelines-for-Sustainable-Agriculture_adopted.pdf

ASEAN Strategic Plan of Action on Water Resources Management: Regional action plan coordinates transboundary IWRM implementation prioritizing irrigation efficiency and climate resilience across member states. Establishes monitoring frameworks, capacity building programs, and technology transfer mechanisms for sustainable water governance. Aligns with APCTT technology transfer priorities for agricultural water management. https://oicwater.sesric.org/img/ASEAN-Strategic-Plan-of-Action-on-Water-Resources-Management.pdf

Assessment of Scaling Ingredients for Smart Irrigation Toolkit (SIT): CIMMYT scaling scan evaluates ten critical ingredients for scaling irrigation technologies through farmer collectives in Eastern Gangetic Plains. Documents pilot results showing water efficiency gains and productivity improvements from smart irrigation tools. Identifies institutional, business case, and policy barriers requiring targeted interventions for sustainable scaling. https://dsi4mtf.unisq.edu.au/wp-content/uploads/2020/11/Project-Report-5-Assessment-of-Scaling-for-Smart-Irrigation-Toolkit.pdf

ERIA Symposium Report: Accelerating Digitalization of ASEAN Agriculture (Dec 2024): Proceedings synthesize ASEAN-Japan MIDORI Plan outcomes documenting precision agriculture pilots achieving 10x faster soil analysis via satellites, drone-based input optimization, and ICT water networks reducing rice irrigation losses. Highlights policy recommendations including ASEAN e-commerce platforms, digital traceability integration, and tiered enablers (infrastructure, regulation, farmer capacity) addressing smallholder scaling barriers.
https://www.eria.org/uploads/Accelerating-Digitalisation-Agriculture-Food-System-ASEAN-Ev_Report-Dec-2024.pdf

Estimating Multi-Scale Irrigation Amounts Using PrISM: Agricultural Water Management validates soil moisture remote sensing for irrigation quantification across field-to-regional scales. Segarra-Garrigues district validation shows r=0.81 correlation with in-situ measurements, enabling large-scale irrigation monitoring without site-specific calibration.
https://www.sciencedirect.com/science/article/pii/S0378377423004596

FAO Compendium on Climate-Smart Irrigation: Examines irrigation's role in producing major portion of global crops on limited cultivated land. Addresses water dependency challenges, expansion pressures, and intensification trends facing agricultural irrigation systems. Provides technical guidance for sustainable irrigation practices supporting food security objectives.
https://openknowledge.fao.org/server/api/core/bitstreams/4960dff8-6193-4ce5-8b7c-a331cf47f67b/content

FAO Digital Agriculture Opportunities Report (2022): Food and Agriculture Organization technical analysis explores digital tool applications supporting precision irrigation including sensor networks and data-driven decision systems. Addresses extension service capacity requirements, farmer training methodologies, and infrastructure needs for smallholder adoption. Features regional case studies from water-scarce agricultural zones.
https://www.fao.org/innovation/home/digital-agriculture-and-ai-innovation/enfao

FAO Water Scarcity Agriculture Assessment (AQUASTAT Reports): FAO AQUASTAT database compilation provides systematic irrigation statistics, agricultural water demand analysis, and resource availability assessments across Asia-Pacific countries. Official data establishes credible baselines for irrigation expansion and modernization planning. Enables rigorous cross-country performance comparisons.
https://www.fao.org/aquastat/en/databases/maindatabase/fao

FAO Water for Food, Water for Life (2007): Landmark comprehensive IWMI/FAO assessment establishes foundational principles for agricultural water management reform and irrigation productivity enhancement. Documents global experiences adaptable to Asia-Pacific contexts including institutional innovation and stakeholder coordination models. Remains standard reference for sector strategy development.
https://www.fao.org/nr/water/aquastat/main/index.stmfao

FAO Irrigation and Drainage Paper 56: Crop Evapotranspiration Guidelines: Authoritative FAO technical manual (1998) establishes standardized Penman-Monteith methodology for reference evapotranspiration (ET_0) calculation and crop coefficient (K_s) approach for irrigation scheduling. Provides comprehensive tabulated crop coefficients for major field crops, orchards, and vegetables across growth stages. Essential reference for smart irrigation system calibration and extension service training programs worldwide.
https://www.fao.org/4/X0490E/x0490e00.htm

IFAD Handbook for Scaling Irrigation Systems: Joint IFAD-IFC publication presents practical guidelines, case studies, and best practices for small-scale irrigation development focused on Sub-Saharan Africa and South Asia. Addresses technical design, financial models, asset management planning, and gender-inclusive scaling strategies for farmer-led irrigation systems. Guides stakeholders through overcoming barriers to sustainable irrigation expansion supporting smallholder livelihoods.
https://www.ifad.org/en/w/publications/handbook-for-scaling-irrigation-systems

Impacts of small-scale irrigation on farmers' livelihood: Systematic analysis quantifies livelihood asset improvements from SSI adoption across multiple dimensions including income diversification and resilience gains. Identifies enabling conditions and scaling constraints for smallholder irrigation technologies. Evidence base supports investment prioritization frameworks.
https://pmc.ncbi.nlm.nih.gov/articles/PMC10209411/

IP Annual Report 1975 (Informe Anual CIP 1975): International Potato Center's Spanish-language annual report documents early agricultural research priorities and extension activities from CGIAR system founding period. Provides historical context for crop water management research conducted by international centers serving developing country agriculture. Archived in CGSPACE repository preserving institutional memory for contemporary scaling analysis.
https://cgspace.cgiar.org/items/9a96b186-2fb3-4a8d-8b48-d663a5be3136

Participatory evaluation of irrigation decision support system - Lake Urmia Basin: Field study validates irrigation DSS performance measuring water productivity gains and yield improvements through controlled treatment/control comparisons. Demonstrates farmer adoption pathways for sensor-based irrigation scheduling in water-scarce basins. Documents measurable scheme-level impacts supporting regional policy development.
https://www.nature.com/articles/s41598-025-26567-z

Towards Efficient Irrigation Management at Field Scale: Agricultural Water Management analyzes new technologies for field-level irrigation optimization. Examines sensor integration, predictive analytics, and real-time decision support addressing scaling barriers identified in practitioner handbooks. Demonstrates pathways for precision irrigation adoption through technology readiness assessment.
https://www.sciencedirect.com/science/article/pii/S0378377424000933

UNICEF Multiple Uses of Water: Madagascar Case Study: Practical documentation of integrated water systems serving household, livestock, and productive uses simultaneously. Demonstrates small-scale irrigation models achieving multiple livelihood benefits from single water sources supporting women's time savings alongside agricultural productivity. https://www.unicef.org/media/91361/file/Multiple-Uses-of-Water-in-Madagascar-drinking-water-agriculture-and-livestock.pdf

UNDP-Eurasian Development Bank Sustainable Irrigation Project: 2025 Kazakhstan initiative establishes regional irrigation centres, digital water monitoring systems, and water-saving technology pilots scalable across Central Asia. Implements forecasting tools, optimal allocation mechanisms, and capacity building addressing shared transboundary water challenges. Demonstrates replicable institutional models for smart irrigation infrastructure development. https://www.undp.org/kazakhstan/press-releases/eurasian-development-bank-ministry-water-resources-and-undp-launch-joint-project-advance-sustainable-irrigation-kazakhstan#:~:text=This%20project%20is%20the%20result,training%2C%20and%20piloting%20water%2Dsaving

UNDP Irrigation Needs & Potential Mapping Initiative: Active UN platform maps irrigation development needs and potential across agricultural areas to guide investment decisions. Provides country-specific decision-support systems targeting SDG 2 (Zero Hunger) and SDG 6 (Clean Water) through efficient water resource allocation and sustainable irrigation planning. Supports climate-adaptive agriculture expansion identifying optimal scaling locations. http://sdgs.un.org/partnerships/irrigation-needs-potential-mapping

World Bank AP Integrated Irrigation Project ISR (P160463, Jul 2025): Final Implementation Status Report documents 35,860ha improved irrigation services across Andhra Pradesh tanks benefiting 48,502 farmers (18,350 women). Achieves paddy water productivity gains from 0.33 to 0.42 kg/m³ through climate-smart practices despite having Moderately -

Unsatisfactory ratings. Details WUA satisfaction at 45% with 28.71% female representation in farmer organizations.
https://documents1.worldbank.org/curated/en/099073125070526241/pdf/P160463-37169eb1-9e99-4f73-a5ff-7c5770dff903.pdf

World Bank Sri Lanka Climate Smart Irrigated Agriculture Project: Comprehensive project appraisal establishes performance benchmarks for tank rehabilitation serving 372,000 smallholders across 53,000ha. Documents 148% cropping intensity increase through climate-adaptive irrigation serving as Asia-wide scaling reference.
https://documents.worldbank.org/en/publication/documents-reports/documentdetail/573001550855832859/sri-lanka-climate-smart-irrigated-agriculture-project

Relevant Organizations

Asian Development Bank (ADB)- ADB supports smart irrigation and water-efficient agriculture across Asia-Pacific through investment lending and technical assistance. Its programmes include micro-irrigation, solar-powered irrigation, and digital water management under national schemes such as India's PMKSY and irrigation modernisation initiatives in South and Southeast Asia. ADB has also promoted blended finance and capacity building to improve affordability and extension systems for smallholders. (https://www.adb.org/what-we-do/topics/agriculture)

APN Global Change Research Network (APN)- APN supports regional research and pilot initiatives on climate-resilient water and agricultural systems. Its Smart Irrigation Water Management projects have demonstrated the potential of combining IoT tools and efficient irrigation methods in drought-prone farming systems across South and Southeast Asia. APN also facilitates regional knowledge exchange and documentation of scalable extension models. (https://www.apn-gcr.org/)

ASEAN Agriculture, Food and Forestry Working Group- The ASEAN Agriculture and Forestry Working Groups promote regional cooperation on sustainable agriculture and water management. It has supported the development of regional roadmaps and knowledge sharing on smart irrigation and digital agriculture, particularly in Mekong sub-region rice systems. Its work emphasizes farmer cooperatives, extension coordination, and digital literacy.
(https://asean.org/our-communities/economic-community/enhanced-connectivity-and-sectoral-development/asean-food-agriculture-and-forestry/)

Australian Centre for International Agricultural Research (ACIAR)- ACIAR funds applied research on climate-resilient agriculture, including smart irrigation and solar-powered water management systems. Its projects in Southeast Asia and the Pacific focus on adapting digital and low-energy irrigation technologies to local agro-climatic conditions. ACIAR works closely with national research institutions and extension agencies.
(https://www.aciar.gov.au/)

Bangladesh Agricultural Research Council (BARC)- BARC coordinates agricultural research and pilot programmes on water-efficient irrigation in Bangladesh. Its work in drought-prone regions has explored subsurface drip irrigation, soil moisture monitoring, and the integration of weather data for improved scheduling. BARC also supports training of extension agents and farmer groups.
(https://bangladeshbiosafety.org/website/bangladesh-agricultural-research-council-barc/)

Bhutan Ministry of Agriculture and Livestock- Bhutan's Ministry of Agriculture and Livestock has implemented climate-resilient irrigation initiatives in collaboration with regional partners. These include community-managed micro-irrigation systems in high-altitude and terraced farming areas. The programmes integrate traditional water harvesting with modern drip irrigation and mobile advisory services.
(https://www.moal.gov.bt/)

Chinese Academy of Agricultural Sciences (CAAS)- CAAS conducts national research on digital agriculture and water-efficient irrigation systems. Its work includes the application of IoT sensors, satellite positioning, and data platforms for improving irrigation efficiency in major cropping systems. CAAS also supports rural digital training and technology validation through field pilots.
(https://www.caas.cn/en/)

China Ministry of Agriculture and Rural Affairs- China's Ministry of Agriculture and Rural Affairs promotes digital agriculture and smart irrigation through national programmes. These initiatives focus on integrating sensors, satellite connectivity, and data platforms to improve water use efficiency in key river basins. Demonstration farms and extension training are central components of this approach.
(https://english.moa.gov.cn/)

CSIRO (Australia)- CSIRO undertakes research on smart irrigation, water productivity, and climate-resilient farming systems. Its work includes solar-powered irrigation, remote sensing, and predictive modelling in water-scarce agricultural regions. CSIRO also collaborates with regional partners to adapt technologies for smallholder contexts.
(https://www.csiro.au/en/research/natural-environment/water?start=0&count=12)

Food and Agriculture Organization of the United Nations (FAO) – Regional Office for Asia and the Pacific- FAO provides technical leadership on digital agriculture and sustainable water management in Asia-Pacific. Its programmes document the performance of micro-irrigation, precision agriculture, and advisory services across multiple countries. FAO also supports large-scale capacity building through demonstration farms and mobile extension platforms.
(https://www.fao.org/asiapacific/en)

International Centre for Integrated Mountain Development (ICIMOD)- ICIMOD supports climate-resilient agriculture and water management in the Hindu Kush Himalaya region. Its initiatives combine precision irrigation technologies with indigenous knowledge systems in mountain farming contexts. Community-managed approaches and cross-border data sharing are key features of its work.
(https://www.icimod.org/)

International Fund for Agricultural Development (IFAD)- IFAD finances smallholder-focused irrigation and water management projects across Asia-Pacific. Its portfolio includes group-based micro-irrigation, training, and digital advisory tools linked with rural finance. IFAD emphasizes inclusive access and scaling through farmer organizations and extension systems.
(https://www.ifad.org/en/asia-and-the-pacific)

International Food Policy Research Institute (IFPRI)- IFPRI conducts policy-oriented research on irrigation, water governance, and agricultural incentives. Its analyses of pilot programmes have informed national strategies on efficient irrigation and farmer adoption. IFPRI's work highlights the role of demonstrations, subsidies, and trust-building measures.
(https://www.ifpri.org/unit/south-asia-regional-office-sao/)

Indian Council of Agricultural Research (ICAR)- ICAR develops and tests cost-effective irrigation technologies suited to smallholders. Its research includes low-cost drip and subsurface irrigation systems, weather-based advisories, and mechanisation support. ICAR also trains extension personnel and supports field-level dissemination.
(https://www.icar.org.in/)

NITI Aayog (India)- NITI Aayog supports national coordination on water-use efficiency and agricultural reform. Its initiatives include monitoring frameworks, data platforms, and convergence of irrigation schemes in drought-prone regions. The emphasis is on scaling efficient practices through institutional coordination and farmer collectives.
(https://niti.gov.in/divisions/division/agriculture-policy)

International Water Management Institute (IWMI)- IWMI conducts applied research on smart water management and irrigation systems across Asia-Pacific. Its synthesis of pilot projects identifies technical, institutional, and behavioural barriers to adoption. IWMI provides policy toolkits and decision support for governments and development partners. (https://www.iwmi.org/)

Iran Agricultural Research Institute- The Institute undertakes research on water-efficient irrigation in arid and semi-arid farming systems. Its work includes subsurface drip irrigation, solar-powered systems, and extension training. Field validation and capacity building are core components of its approach. (https://iar.shirazu.ac.ir/)

Japan International Cooperation Agency (JICA) – Agriculture and Rural Development- JICA supports irrigation modernisation and capacity building in Southeast Asia. Its programmes focus on training extension agents, promoting efficient irrigation practices, and integrating digital tools. Knowledge transfer through regional cooperation is a key emphasis. (https://www.jica.go.jp/english/activities/issues/agricul/index.html)

Lao PDR Ministry of Agriculture and Forestry- The Ministry has promoted digital agriculture and irrigation planning in Mekong rice systems. Its initiatives include pilot use of IoT tools, cooperative-based adoption, and extension support in remote areas. Connectivity solutions are explored to address rural access gaps. (https://landportal.org/organization/lao-ministry-agriculture-and-forestry)

Pacific Community (SPC) – Land Resources Division- SPC supports climate-resilient agriculture and water management in Pacific Island countries. Its work includes solar-powered micro-irrigation and community-managed systems adapted to extreme weather conditions. Regional knowledge sharing and technical assistance are central activities. (https://lrd.spc.int/)

Pakistan Council of Research in Water Resources (PCRWR)- PCRWR undertakes research and advisory work on irrigation efficiency and water conservation. Its activities include developing guidelines for efficient irrigation and testing digital monitoring tools. Collaboration with provincial agencies supports field-level application.
(https://www.pcrwr.gov.pk/)

Philippines Department of Agriculture – Bureau of Soils and Water Management (BSWM)- BSWM leads soil and water management initiatives in the Philippines. Its precision agriculture and irrigation programmes focus on improving water efficiency in major crop systems through subsidies, partnerships, and technical guidance. Public-private cooperation plays a significant role.
(https://www.philchm.ph/bureau-of-soils-and-water-management/)

SAARC Agriculture Centre- The SAARC Agriculture Centre facilitates regional cooperation on sustainable agriculture and irrigation. It supports knowledge exchange on smart irrigation and data platforms among South Asian countries. Harmonisation of practices and regional learning are key objectives.
(https://www.sac.org.bd/)

Secretariat of the Pacific Regional Environment Programme (SPREP)- SPREP works on climate-resilient agriculture and water management in Pacific Island contexts. Its initiatives include solar-powered irrigation and community-based systems designed for climate extremes. Regional collaboration and technical guidance underpin its programmes.
(https://www.sprep.org/)

United Nations Development Programme (UNDP) – Asia-Pacific- UNDP supports climate-smart agriculture and water management through policy advice and blended finance. Its programmes integrate irrigation efficiency, digital tools, and institutional reform. UNDP also develops policy toolkits and supports national implementation.
(https://www.undp.org/asia-pacific)

UNESCAP – Environment and Development Division- UNESCAP conducts regional analysis on climate, water, and digital connectivity challenges. Its work highlights infrastructure and access gaps affecting smart irrigation adoption. The Division supports policy dialogue and regional cooperation on sustainable water management. (https://www.unescap.org/our-work/environment-development)

Vietnam Ministry of Agriculture and Rural Development (MARD)- Crop Production Department- Vietnam's MARD supports modernisation of rice production systems in the Mekong Delta. Its programmes integrate efficient irrigation, mechanisation, and digital advisory platforms. Farmer cooperatives and extension networks are central to scaling efforts.(https://www.mard.gov.vn/en/Pages/default.aspx)

World Bank – South Asia Agriculture and Water Team- The World Bank finances irrigation modernisation and water productivity projects across South Asia. Its portfolio includes infrastructure upgrades, policy reform, and digital monitoring tools. Analytical work supports learning and replication across countries. (https://www.worldbank.org/en/programs/sawi)

World Meteorological Organization (WMO) – Hydrology and Water Management- WMO supports the use of meteorological and hydrological data for water management. Its guidance on satellite and data integration informs irrigation planning and advisory systems. Collaboration with national agencies enhances climate-informed decision-making. (https://community.wmo.int/site/knowledge-hub/programmes-and-initiatives/hydrology-and-water-resources)

Relevant Websites

ADB Agriculture and Food Security Portal: This portal presents the Asian Development Bank's work on agriculture, irrigation, and rural development across Asia-Pacific. It includes project information, policy insights, and technical resources related to irrigation modernization and water efficiency. The site supports understanding of regional investment and institutional approaches.
https://www.adb.org/what-we-do/topics/agriculture

ADB Data Library – Water and Agriculture: ADB's data library provides access to country and regional indicators on water use, irrigation, and agricultural development. The platform supports evidence-based planning and monitoring of water and agriculture programmes. It is used by policymakers, researchers, and development practitioners.
https://data.adb.org

Australia Bureau of Meteorology – Agricultural Water Forecasts: The Australian Bureau of Meteorology provides agricultural water outlooks that integrate satellite soil moisture data with seasonal climate forecasts. These advisories support irrigation planning and drought preparedness, particularly in water-scarce regions. The platform is widely used by farmers and water managers.
https://www.bom.gov.au/watl/

CRDC Smarter Irrigation Project: CRDC's Smarter Irrigation for Profit initiative develops practical tools like automated sensors, precision scheduling, and evaporation controls to enhance water productivity in cotton, dairy, rice, grains, and sugar farming. It supports over 4,000 irrigators through farmer-led demonstration sites and partnerships with research organizations across Australia. The platform promotes cost-effective strategies amid water scarcity, funded by the Australian Government.
https://www.crdc.com.au/smarter-irrigation-profit-phase-2

DAS Digital Agriculture Resources Library: IFAD-funded platform provides toolkits for digital ecosystem assessment, farmer-centric tool design, and digital agriculture scaling across Africa, Middle East, and Central Asia. Features guidance on irrigation advisory services, digital extension delivery, and stakeholder dissemination planning. Supports ICT4D implementation within rural transformation programs.
https://www.digitalagricresources.org/

EU Copernicus Land Services: Satellite-derived land cover, soil moisture, and water body monitoring tools. Provides irrigation-relevant earth observation data through interactive mapping interfaces.
https://land.copernicus.eu/

FAO Agro-informatics Platform: FAO's digital agriculture portal integrates satellite imagery, remote sensing, and AI analytics supporting precision irrigation planning across Asia-Pacific countries. Hand-in-Hand Geospatial Platform provides open-access agricultural data layers including soil moisture and crop water requirements essential for smart irrigation deployment. Climate Risk ToolBox delivers irrigation recommendations tailored to local weather patterns and climate projections.
https://www.fao.org/agroinformatics/en

FAO AQUASTAT Country Profiles (Asia-Pacific): FAO authoritative country-level water resource assessments document irrigation infrastructure coverage, agricultural water withdrawal patterns, and crop water requirement profiles. Include institutional frameworks and water management policy contexts essential for regional comparative analysis. Provide standardized baseline data supporting technology scaling planning.
https://www.fao.org/aquastat/en/countries-and-basins/country-profiles/fao

FAO Digital Villages Initiative (DVI) – GroTron Profile: FAO platform profiles AI-powered precision agriculture solutions like GroTron Autonomous Farm automating irrigation, fertigation, and climate control for smallholders. Catalogues IoT/sensor-based water management systems with measurable impacts on water savings and crop yields. Supports agritech developers and extension services identifying scalable digital irrigation technologies.
https://dvi-ke.fao.org/digital_solutions_details.php?id=548

FAO Regional Office for Asia and the Pacific: Presents FAO’s regional work on agriculture, water management, and climate resilience. It includes programme information, technical publications, and capacity-building initiatives related to irrigation and resource efficiency.
https://www.fao.org/asiapacific

Global Water Partnership (GWP) Portal: International network platform coordinates integrated water resources management across Asia-Pacific through 13 Regional Water Partnerships covering South Asia, Central Asia, and Southeast Asia. Provides IWRM ToolBox with irrigation governance frameworks, agricultural water allocation case studies, and multi-stakeholder dialogue platforms essential for smart irrigation policy coordination. Facilitates cross-border basin management supporting technology scaling.
https://gwpo-gwp.org/

India PMKSY National Irrigation Portal: Official government platform for Pradhan Mantri Krishi Sinchayee Yojana coordinates micro-irrigation expansion ("Per Drop More Crop" component) alongside watershed development and water harvesting initiatives across drought-prone states. Features district-level progress dashboards, farmer producer organization mapping, and convergence guidelines integrating multiple water schemes. Supports transparency through real-time monitoring of drip/sprinkler system adoption.
https://pmksy.gov.in

IFAD Practical Tools Portal: International Fund for Agricultural Development resource hub provides field-tested toolkits, technical notes, and handbooks supporting smallholder irrigation development including group lending models and extension service integration. Features "Handbook for Scaling Irrigation Systems" with case studies on micro-irrigation adoption pathways.
https://www.ifad.org/en/practical-tools

IWMI Research Data Portal: International Water Management Institute's comprehensive data repository provides open-access datasets essential for smart irrigation analysis including irrigated area mapping across Asia and Africa, water productivity atlases, and drought monitoring systems. Water Data Portal serves as one-stop access to satellite-derived irrigation performance metrics, environmental flow calculators, and basin-scale water accounting tools.
https://www.iwmi.org/data/

NASA Earthdata Search: Comprehensive satellite data portal for water balance, evapotranspiration, and irrigation indicators. Supports custom data extraction for policy modeling applications.
https://search.earthdata.nasa.gov/search

OECD Water Policy Sub-Issue Portal: Organization for Economic Co-operation and Development platform consolidates analytical resources on agricultural water management including irrigation governance, water pricing reforms, and policy coherence frameworks. Features reports like "Sustainable Management of Water in Agriculture" and "Navigating Pathways to Reform Water Policies in Agriculture" addressing institutional barriers to smart irrigation scaling.
https://www.oecd.org/en/topics/sub-issues/water.html

Our World in Data - Water Use: Interactive charts visualize agricultural water withdrawal trends using FAO AQUASTAT data. Long-term scarcity analysis supports regional policy discussions.
https://ourworldindata.org/water-use

Pacific Data Hub (PDH): Regional data repository serving 16 Pacific Island Countries through dashboards covering agriculture, population, SDGs, and environmental indicators. Features PDH.Stat Data Explorer with Pacific Sustainable Development Indicators alongside geospatial Pacific Map tool for spatial agricultural analysis. Supports evidence-based agricultural planning and monitoring across Pacific small island developing states.
https://pacificdata.org/

Philippines DA Services Portal: Department of Agriculture online platform coordinates Soils and Water Services alongside Agricultural Extension Services and Training programs supporting irrigation technology adoption. Features Bureau of Soils and Water Management (BSWM) resources including soil testing, irrigation system design guidance, and water conservation practices. Provides Agriculture and Fisheries Information Services with technical advisories and project coordination tools accessible to regional field offices.
https://www.da.gov.ph/services/

PRISM- Situation Monitoring: World Food Programme platform visualizes climate and vulnerability data on interactive maps. Real-time agricultural risk assessment supports irrigation response.
https://innovation.wfp.org/project/prism

SAC Knowledge Portal: SAARC Agriculture Centre's online platform features specialized sections on Natural Resource Management covering irrigation technologies alongside Crops, Livestock, Fisheries, and Horticulture programs. Provides access to SAC Library digital repository, regional training modules, and Climate Smart Agriculture Technologies validation workshops. Supports South Asian extension networks with technology transfer materials and priority program development resources.
https://www.sac.org.bd/

Space4Water Case Studies Portal: Interactive case studies on rotational irrigation systems and water demand forecasting. Practical decision support tools for water managers.
https://www.space4water.org/

UN Water SDG 6 Data Portal: Live tracking of water use efficiency and stress indicators with interactive country dashboards. SDG-aligned irrigation policy monitoring platform.
https://sdg6data.org/

UNDP Climate Promise Portal: Interactive platform tracks country progress on Nationally Determined Contributions (NDCs) with focus areas including agriculture, water resources, and climate-resilient farming systems. Country profiles visualize climate adaptation investments supporting irrigation infrastructure and water management priorities. Features technical resources across 15 climate action areas serving 140+ countries.
https://climatepromise.undp.org/

WEAP – Water Evaluation and Planning System: Interactive software platform models irrigation demand scenarios, reservoir operations, and water allocation priorities for integrated basin planning. User-friendly interface supports dynamic scenario comparison for smart irrigation optimization and climate adaptation strategies. Features real-world case studies from agricultural watersheds worldwide.
https://www.weap21.org/

World Bank Water Global Practice: Interactive project database filters irrigation investments by region and outcome. Supports evidence-based investment planning.
https://www.worldbank.org/en/topic/water#1

4. Responses in Full

1. Bilal Saleem, Individual Consultant, India
2. Sohail Akhtar, Senior Scientist, Pakistan Council of Scientific & Industrial Research (PCSIR) Lab Complex, Karachi, Pakistan
3. Md Selim Reza, System Analyst, Ministry of Finance, Bangladesh
4. Muhammad Usman Iqbal, Assistant Director Agriculture (OFWM), Government of Punjab, Pakistan
5. Dr Sonia Grover, Associate Director, Mu Gamma Consultants Pvt Ltd, India
6. Chaman Kumar, Remote Sensing and AI Expert, India
7. Mahadi Sabdow, Visionary Technologist and Youth Advocate, Ethiopia
8. Upali Imbulana, Consultant (WR and Irrigation), Sri Lanka
9. Gireesh Chandra, Assistant Professor, Bansal Institute of Engineering and Technology, Lucknow, India
10. Wasswa Shafik, Dig Connectivity Research Laboratory, Canada
11. Vikas Goyal, Water Resources Specialist, Agriculture, Food, Nature, and Rural Development (AFNR) Sector Group, Asian Development Bank- India Resident Mission
12. Rohit Raj, Research Trainee, Plant Science, BITS Pilani
13. Irum Tariq, Member Standing Committee (SC) for Smog and Climate Lahore Chamber of Commerce and Industry (LCCI), CEO at Exodus Green Pvt. Ltd., Pakistan
14. Ali Ajaz, Ph.D., Snr. Engineer-Global Irrigation Applications, Lindsay Corporation, United States
15. Dr. Rohit Sharma, Capacity Building Specialist Capacity Building Specialist, FAO
16. Prabhakar S.V.R.K., Principal Policy Researcher (adaptation) at Institute for Global Environmental Strategies (IGES), Kanagawa, Japan
17. Inputs from APCTT

Responses:

1. Bilal Saleem, Individual Consultant, India

Across the Asia-Pacific region, increasing water scarcity, climate variability, and rising energy costs are placing significant pressure on agricultural systems, particularly for small and marginal farmers. In this context, social entrepreneurship offers a scalable and inclusive pathway to promote smart irrigation solutions that simultaneously address water efficiency, clean energy access, and livelihood resilience. The promotion of solar-powered water pumps (SWPs) has emerged as a practical climate technology that supports sustainable water management while strengthening rural economies.

Solar water pumps provide a clean and reliable alternative to diesel- and grid-based irrigation systems. When integrated with smart irrigation technologies such as drip and micro-irrigation systems, soil moisture sensors, and automated controllers, SWPs enable precision irrigation based on actual crop water requirements. This integration significantly reduces water wastage, limits over-extraction of groundwater, and improves agricultural productivity, while also lowering greenhouse gas emissions. Such technology convergence is particularly relevant for climate-vulnerable regions across Asia-Pacific, where efficient water use is critical for long-term sustainability.

Social enterprises play a vital role in scaling solar irrigation by addressing key barriers to adoption, including high upfront costs, limited technical awareness, and inadequate last-mile service delivery. Through innovative business models such as pay-as-you-go financing, lease-to-own arrangements, and community or cooperative ownership, social enterprises make solar water pumps accessible to smallholder farmers. Additionally, engaging women- and youth-led enterprises in installation, operation, and maintenance creates local employment opportunities and ensures the long-term functionality of irrigation systems.

The integration of emerging digital technologies further enhances the impact of solar irrigation solutions. Remote monitoring systems, data analytics, and mobile-based advisory platforms enable real-time tracking of water use, pump performance, and irrigation schedules. These tools support informed decision-making by farmers and implementing agencies, ensuring that solar-powered irrigation remains both energy-efficient and water-smart. Digital solutions also contribute to better resource planning and adaptive responses to climate variability.

Effective scaling of smart irrigation through social entrepreneurship requires strong ecosystem collaboration. Alignment with national and sub-national policies on renewable energy, climate-smart agriculture, and water governance is essential, along with partnerships involving governments, financial institutions, and development organizations. Blended finance mechanisms and results-based incentives can further support the expansion of socially driven solar irrigation initiatives across diverse agricultural contexts in the region.

Social entrepreneurship-led promotion of solar water pumps demonstrates strong potential to deliver multiple climate and development co-benefits. These include reduced carbon emissions, improved water-use efficiency, enhanced farm incomes, and increased resilience of rural communities to climate shocks. By combining clean energy, smart irrigation technologies, and inclusive business models, solar-powered irrigation can play a transformative role in advancing sustainable water management and climate resilience across the Asia-Pacific region.

2. Sohail Akhtar, Senior Scientist, Pakistan Council of Scientific & Industrial Research (PCSIR) Lab Complex, Karachi, Pakistan

The need for smart irrigation and freshwater feed resources is escalating by global population and arid land increased (due to shortage of rainfall). Effective irrigation/agriculture water management is essential to address the global water crisis. Water is most crucial and demanding entity of our food production cycle and is a foundation stone of food security in recent times. Currently, agricultural water systems can sustainably feed only up to less than 5 billion world’s population.

Since the pressure on food eco systems is rising and growing food insecurities demands smart agricultural water management (SAWM), for strive through issues such as global water scarcity, population growth, increased agricultural activity from family farmers, rising food demands, and climate change disasters. Smart irrigation water management is essential to address the world's water crisis. These systems achieve significantly higher water use efficiency (up to 95% for drip irrigation) compared to traditional, gravity-driven methods. The transition from conventional, gravity-driven irrigations to modern-day, pressure-driven smart/precision irrigation methods used to address the difficulties associated with water-intensive irrigation, but the opportunities of updating conventional techniques towards smart and precision irrigation technologies are very limited. The increasing drought indices in the world's agricultural zones also required attention for stake holders to invest in Smart Irrigation Tools. Smart irrigation/agriculture water also reduces pressure on water and food ecosystems

The agriculture is the backbone of economies, while precision irrigation is a cutting-edge tool to make agriculture smarter, more sustainable, and climate-resilient. The shift for how precision irrigation fits into the broader agricultural system is very much technological dependent. That could visually highlight the relationship. Likewise, technologies for a more sustainable agricultural future, required algorithms based on AI/ML techniques, and datasets from IoT. Also, wireless sensor networks, be utilized as for deep learning (logic effects on crop performance and water conservation across various crops).

Smart irrigation, rainwater harvesting, and dam utilization are critical tools to strengthen food security, boost GDP through agricultural productivity, and conserve freshwater resources. The effective Smart farming management systems and water resource utilization fulfils the increased demand of new agricultural civilization. For example, adopting precision irrigation would ultimately yield sustainable development goals (SDGs).

Land drought accompanied with food insecure or scarcity of food demand are unavoidable demolishing outcomes of climate change and global warming. Such circumstances give rise to smart irrigation. The least awareness for solving these issues compelled researchers and scientists are to develop and make out innovative ways, for smart irrigation. By using techniques particularly real-time monitoring and control systems for precision agriculture solution may be pointed in water scarcities area and towards sustainable Agri land.

Smart irrigation systems face challenges to adopt AI/ML and highlights the limitations and challenges of implementing water smart irrigation in agriculture. Prior and pertinent research on water conservation in agriculture formed the basis for smart irrigation or precision irrigation systems which in turns enhance water monitoring, and control techniques thus water savings increases, crop production enhances, with optimized for energy utilization. The issues required financial incentives, technological innovation, comprehensive training, robust data management, and strategic infrastructure development.

3. Md Selim Reza, System Analyst, Ministry of Finance, Bangladesh

Scaling smart irrigation in the Asia-Pacific region requires an integrated approach that combines emerging technologies with local context and institutional readiness. IoT-enabled soil moisture sensors, satellite-based remote sensing, AI-driven predictive analytics, and climate data integration can significantly optimize water use efficiency while improving crop productivity.

However, technology alone is not sufficient. Successful scaling depends on **affordability**, **interoperability**, and **capacity building** for farmers and local water authorities. Public–private partnerships, open data platforms, and regionally harmonized standards can reduce costs and accelerate adoption. Community-based pilots and climate-smart financing mechanisms are essential to ensure inclusivity, especially for smallholder farmers.

Smart irrigation should be aligned with **national water policies, climate adaptation plans, and SDG 6 & SDG 13**, ensuring resilience against droughts, floods, and climate variability. Shared regional experiences through this CoP can help translate innovation into scalable, sustainable solutions for climate action.

4. Muhammad Usman Iqbal, Assistant Director Agriculture (OFWM), Government of Punjab, Pakistan

In the Asia-Pacific region, agriculture remains the largest consumer of freshwater — yet farmers are increasingly expected to produce more with less. For me, "smart irrigation" is not just about adopting technology; it is about reshaping how we value and manage water at the farm level.

Emerging tools such as soil-moisture sensors, automated drip systems, satellite-based monitoring, and AI-driven decision support are helping farmers match water application to real crop needs. When these solutions are combined with practices like precise land levelling and efficient conveyance systems, the result is genuine water productivity — more crop per drop, and more resilience against climate variability.

However, technology alone cannot deliver sustainability. Scaling smart irrigation in Asia-Pacific requires three things:

- **Localization, not duplication**

Solutions must be adaptable to smallholders, fragmented landholdings, and diverse agro-ecologies. A low-cost sensor that works for a Punjab farmer may be far more transformative than a high-end imported system.

- **Capacity and behaviour change**

Farmers do not simply adopt technology; they adopt trust. Demonstration plots, farmer-to-farmer learning, and on-ground technical support are essential if smart irrigation is to move beyond pilot projects.

- **Policy and financial enabling environments**

Incentives for efficient irrigation, concessional financing, and results-based subsidies can accelerate uptake — especially when linked with digitized service delivery and reliable data systems.

5. Dr Sonia Grover, Associate Director, Mu Gamma Consultants Pvt Ltd, India

I have a case study to share where efforts were made to incentivize farmers for conserving water in fields and were also provided with the needed knowledge, access to schemes and some demonstration/ farmer's school. Punjab in India, famously known as the bread basket of India has exploited groundwater at an alarming rate in past few decades after independence to ensure the food security for the whole country. The policies were shaped in a linear thought process that encouraged generous water withdrawal, because of free electricity provision to farmers. Also, the government has been providing, subsidies in various domains such as credit, power, water, and seed. The consequences on the groundwater table were not well comprehended. In addition to these, the guaranteed procurement of specific crops and minimum support price (MSP) has coincidently led to a shift from traditional to water-intensive crops such as paddy in many states.

To arrest this, a pilot project was launched by the World Bank with the Punjab Government and a scheme called 'Pani Bachao, Paisa Kamao' (PBPK) was initiated. This scheme literally means, save water and earn money and also termed as Direct Benefit Transfer for Electricity (DBTE) to agriculture on a pilot basis on six feeders in three districts—Fatehgarh Sahib, Hoshiarpur, and Jalandhar. The scheme in the state offers a choice to the farmers to increase their income while using groundwater and electricity more efficiently. The scheme design considers two prerequisites— the current policy of free power to agriculture cannot be discontinued, and crop diversification will not occur in the near future. The conceptual framework of the PBPK scheme was designed based on consultations with multiple stakeholders, recommendations from fieldwork with farmers, a review of global experiences, and a critical analysis of multi-sectoral data and policies. It is aimed to develop a strategy that addresses the electricity–water–agriculture cross-sectoral issues and meets the requirements of agriculture and farmers.

The PBPK is a voluntary scheme that does not change the present policy of free electricity supply to agriculture pump (AP) consumers in Punjab. Instead, it has a provision to pay farmers for saving electricity with no charge for the excess consumption. f the electricity consumption is less than the allocation, the units of electricity saved are paid at the rate of INR4.00 per kWh, and the amount is transferred into the bank account of the respective enrolled AP consumer.

To bridge the knowledge gap regarding energy and water-saving practices, 15 demonstration farms, five at each feeder, were set up on farmers' fields with their consent. Supported by the inter-departmental schemes, farmers on a farm section experimented with new seed variety and irrigation techniques to minimise water losses during paddy and wheat cultivation. These plots soon became farmer field schools for other farmers popularising the adoption of the water- and energy-efficient technology. Apart from these interventions, the state of Punjab offers up to 80% subsidy for MIS and approximately 50% for UGPS. The agronomic practices adopted in demo farms proved to be feasible for the farmers in terms of ease of application as well as cost-effectiveness. Apart from showcasing a significant reduction in water withdrawal for their cultivation, it also resolved farmers' worry about yield penalty and farm economics, which led to their opinion into adopting efficient interventions for upcoming cropping seasons.

The state officially recorded payments to farmers during the 2019–20 season (e.g., payments of about **₹8.19 lakh to roughly 972 farmers** under the pilot). The *Pani Bachao, Paisa Kamao* scheme attempts to **align economic incentives with sustainable resource use**, offering a model that policymakers and researchers can use to think about broader reforms in water-energy-agriculture linkages.

6. Chaman Kumar, Remote Sensing and AI Expert, India

More than 500 million people in Asia-Pacific grapple with water scarcity, and by 2050, water availability is expected to drop another 20%. That is a big blow for farmers and food security especially in the driest regions. Climate-smart irrigation is no longer just an option; it is turning into a necessity. Technologies like subsurface drip irrigation (SDI), AI-powered precision farming, and IoT-based systems can lift water-use efficiency by 30-50%. Yields climb, too up to 40% higher in some cases. These tools do not just save water; they help farmers weather tough seasons.

Look at what is happening on the ground. In India, the Pradhan Mantri Krishi Sinchayee Yojana (PMKSY) Per Drop More Crop (PDMC) scheme has rolled out micro-irrigation across 9.7 million hectares as of August 2025. The results: 30% water savings, plus smallholders receive subsidies covering 55% of costs for drip and SDI setups. Australia's CSIRO is taking a tech-first approach, using satellite data and machine learning in their precision horticulture projects. They have fine-tuned irrigation for 500,000 hectares of high-value crops think grapes and almonds and managed to cut water use by 40% while boosting yields by 20% by late 2025.

India's making the most of its space assets, too. The Indian Space Research Organisation's (ISRO) Satellite-based Irrigation Advisory Service (SIAS) now reaches over 10 million smallholders, offering AI-driven, crop-specific advice by SMS and mobile apps. It pulls in satellite imagery, soil, and weather data to build precise watering schedules. The 2025 NISAR satellite launch with NASA has taken this further, enabling real-time monitoring of crop health and irrigation needs, especially in drought-prone states like Rajasthan. Early SDI pilots in vineyards have slashed evaporation losses by 70%. Agritech startups like Fasal are also moving fast, connecting IoT soil sensors directly to SIAS and riding a wave of venture capital $350 million in 2023, topping $400 million by 2025. These bundled solutions are already cutting farm operational costs by 25%.

Vietnam is leaning into the Smart Agriculture 2030 program, rolling out IoT sensors for Alternate Wetting and Drying (AWD) in rice paddies. These sensors nudge farmers when it is time to irrigate, saving 13-20% water without sacrificing yields. By 2025, pilots in Ninh Thuan and Binh Thuan provinces touched 50,000 smallholders across 100,000 hectares. SDI is getting a try out in salty coastal soils to battle sea-level rise, backed by hefty 70% government grants and World Bank support. Over in

Bangladesh, the Infrastructure Development Company Limited (IDCOL) scaled up solar-IoT irrigation pumps to 50,000 units by 2025 under the SoLAR Phase II initiative. Diesel costs dropped by 60%, and now farmers can monitor pumps remotely even in off-grid river deltas. The next step: public-private partnerships aiming for carbon-neutral farming.

The UN Food and Agriculture Organization (FAO) is pushing digital advice further with its 2025 Inter-regional Digital Agriculture Forum (IDASF). They are piloting natural language chatbots in Indonesia and Vietnam, delivering tailored pest and irrigation tips in Bahasa for just $0.30 per farmer down from $3 using the old extension system. Built with Digital Green, these tools already reach a million users, using IoT data to nudge behaviour and address adoption barriers like risk aversion.

Still, technology on its own is not enough. Smallholders who make up 70% of Asia-Pacific's farmers are adopting these tools at rates below 20%. The main blocker: money. SDI or IoT system costs run from $500 to $2,000 per hectare. Without credit, that is out of reach. Informal lenders charge punishing 20-50% interest, and formal banks stay wary, seeing smallholders as risky due to limited collateral and unpredictable crops. Even with subsidies, a 2025 study found 40% of Indian smallholders skip installation, deepening the affordability gap for marginalized groups.

Technical and infrastructure headaches pile on. Rural broadband still covers less than half the region, causing lags in cloud-based AI services. Power outages hit 60% of remote sites, frying sensors and stalling automation. SDI clogs in salty soils tack on another $200 per hectare for filtration. Non-standardized equipment fragments the supply chain Vietnam's AWD pilots saw 20% failure rates from compatibility problems. Socio-economic and behavioural hurdles slow things down further. According to a 2024-2025 report, 60% of smallholders lack digital skills or even basic awareness of these technologies. Scepticism runs high, especially when new tools are unproven. Many farmers stick with familiar flood irrigation, even if it wastes water. Women, who make up half of smallholders, adopt tech 30% less often mainly because they have less access to devices and face mobility hurdles. In India, IIT Kanpur found 40% of systems fail within a year due to neglected maintenance, undermining trust. And only 15% of agricultural workers receive any agri-tech training, according to ILO data.

Government policies set the stage for breakthroughs. Take PMKSY covering 55% of costs for smallholders this pushed SDI adoption up 25% in Gujarat by 2025. National strategies matter too. China's Digital Agriculture Plan and Vietnam's 2030 framework both focus on making IoT standard in farming. Then there is the real power of public-private partnerships. India's Micro Irrigation Fund, with its Rs. 10,000 crore pool, helped finance an extra 2.3 million hectares by October 2025. It is not just about the money mixing loans with private know-how means new ideas actually work on the ground.

Money matters, but the way it flows matters more. Punjab's Pani Bachao Paisa Kamao (PBPK) scheme, now running across all smart-metered feeders as of 2025, rewards farmers Rs. 4 for every kWh saved no penalties, only incentives. That has reached 52,000 farmers and cut groundwater depletion by 15%. Voluntary sign-ups and field schools drive the change. Meanwhile, pay-as-you-go models and equipment leasing, tested by FAO partners, pushed adoption up 35% in Bangladesh's off-grid areas.

Training fills the behavioural gap. FAO's co-creation pilots trained 500,000 women in Indonesia on AI tools, using women-only apps. This closed gender gaps and sparked a 40% jump in tech adoption, thanks to group-based IoT demos. Farmer field schools, like those in PBPK, show SDI in action delivering 20% higher off-season yields. IIT-Bombay's SoilSens offers $10 sensors with instant, local-language alerts.
Bundling tech speeds things up. Systems that pair agronomic advice, weather forecasts, and maintenance like CSIRO's open satellite portals deliver real value. Affordable LPWANs connected 30% more rural sites by 2025. Solar-powered SDI in Australia's dry zones cut energy use in half.

Transferring technology works best when everyone is involved. Top-down does not cut it. PDMC brought together governments, NABARD, and startups to co-design new solutions like saline-resistant SDI for Vietnam. Mixing irrigation with fertigation and early warning systems cuts rice emissions by 25%. For real inclusion, target women and youth UNDP pilots in Bhutan saw female groups top 35% higher adoption rates. New trends, like AI-blockchain for transparent subsidies (piloted in China in 2025), promise even fairer scaling.

By 2025, Asia-Pacific is in the midst of a transformation. PMKSY's 9.7 million hectares and FAO's million-user AI show what smart irrigation can do. But it is policy, finance, and training that keep the momentum going. Insights like lessons from SDI in Iran or new behavioural nudges will only make this movement stronger and more adaptable for the world.
More information

7. Mahadi Sabdow, Visionary Technologist and Youth Advocate, Ethiopia

Start with high-value crops and reliable water sources to maximize ROI and demonstrate success quickly.

Use modular stacks: Begin with moisture sensing + advisory; add automated valves and fertigation after proof of benefit.

Standardize design and O&M protocols for SDI (depth, spacing, filtration, flushing schedules) and document them in pictorial guides.

Build local tech support through cooperative technicians and vendor SLAs with spare-parts commitments.

Measure and communicate KPIs monthly: litters saved per kg yield, energy per mm irrigation, net income change, and system uptime.

Align finance to harvest cycles and include maintenance in the total cost of ownership.

In Asia-Pacific, **subsurface drip irrigation (SDI), AI-driven precision agriculture, and IoT-enabled irrigation systems** have been successfully scaled in water-scarce regions like India, China, and Australia. Adoption is enabled by **government subsidies, digital literacy programs, and cooperative models**, but impeded by **high upfront costs, fragmented policies, and limited farmer awareness**. Effective interventions include **public-private partnerships, farmer training, and bundled financing schemes** that reduce barriers to uptake.

1. Successful Use of Technologies

a. Subsurface Drip Irrigation (SDI): Widely adopted in India's semi-arid states (Maharashtra, Gujarat), SDI reduces water use by up to 40% while increasing yields in crops like sugarcane and cotton.
b. AI-based precision agriculture: China and Australia deploy AI models for crop water stress detection, optimizing irrigation schedules and fertilizer use.
c. IoT-enabled irrigation systems: In Vietnam and Thailand, IoT sensors monitor soil moisture and automate irrigation, reducing water waste and labour costs.
d. Decision support systems: AIoT platforms using LSTM time-series models help farmers predict drought stress and adjust irrigation.
e. Digital water management: Smart irrigation pilots in China integrate AI with weather forecasts to improve water allocation.

2. Enabling & Impeding Factors

a. Policy-related: Subsidies and national water-use efficiency programs accelerate adoption; lack of harmonized standards slows scaling.
b. Socio-economic: High upfront costs and limited access to credit impede smallholders; cooperative models and microfinance enable uptake.
c. Behavioural: Farmer scepticism and low digital literacy hinder adoption; peer learning and demonstration farms improve trust.
d. Technical: Poor connectivity in rural areas limits IoT deployment; low-cost sensor innovations and mobile-based platforms mitigate this.

8. Upali Imbulana, Consultant (WR and Irrigation), Sri Lanka

The village irrigation systems of Sri Lanka comprise small reservoirs (generally ranging from a storage capacity of 1000 m3 to more than 1.0 million m3) and small diversion structures. Many of these reservoirs in the Dry Zone of Sri Lanka are hydrologically linked and form networks called tank cascades, enabling water reuse. They have provided critically important services for rural livelihoods, water security, disaster risk reduction, and ecosystem services for more than a millennium.

However, these systems are experiencing sustainability issues due to years of anthropogenic pressures, neglect, climate change, and poorly functioning governance arrangements. Traditional local institutions that historically organized irrigation maintenance and water distribution have weakened over time, while state and external institutions have tended toward centralized and top-down control. Moreover, climate change necessitates a mix of modern technology and traditional knowledge to make the systems resilient and sustainable.

The government of Sri Lanka implemented the Climate Resilient Integrated Water Management Project from 2017 to 2025, with the funding support of the Green Climate Fund and the technical support of the United Nations Development Programme, aiming for a paradigm shift in the development and management of tank cascade systems. New technologies introduced by the project included the provision of improved weather forecasts, on-farm and off-farm water management, and climate-resilient irrigation infrastructure. Off-farm technologies included reservoir storage and rainfall-based reservoir operation, while on-farm technologies included (among others) alternating wetting and drying method for irrigated command and drip irrigation for uplands. Adopting an IWRM-based approach, drinking water solutions and ecosystem conservation measures were also introduced. A major paradigm shift in the approach was introducing governance structures and institutional arrangements that are supportive of the decentralized and community-driven management of tank cascade systems holistically, with due attention to drinking water and ecosystems.

While the technology-driven and governance-based interventions were acceptable to the community and the policy makers, the sustainability of the interventions depends on finances and policy support. Post-project assessments revealed the need for community-based enterprises with sound business plans to minimize the dependence of village irrigation on state support. However, governance and technical support are still required from the state. Moreover, policy recognition and legal backing are essential for community empowerment to sustain.

The experiences in Sri Lanka have shown that new technology should be affordable to the local economy. Many automated and sophisticated instruments are found to be malfunctioning due to inadequate maintenance support. In the case of community-managed systems, this aspect is very important when new technologies are introduced, especially at a time when the country is recovering from an economic crisis.

9. Gireesh Chandra, Assistant Professor, Bansal Institute of Engineering and Technology, Lucknow, India

Scaling Smart Irrigation for Sustainable Water Management in the Asia-Pacific

1. Background and Context

The Asia-Pacific region faces increasing pressure on water resources, with agriculture consuming nearly 70–80% of available freshwater. Climate change, declining groundwater levels, irregular rainfall, and rising food demand have intensified the need for efficient and climate-resilient irrigation solutions. Smart irrigation technologies are emerging as a key adaptation strategy to improve water-use efficiency while sustaining agricultural productivity.

2. Intervention Overview

This case study highlights the deployment of sub-surface drip irrigation (SSDI) combined with IoT-enabled irrigation systems and AI-based precision agriculture in water-scarce and semi-arid agricultural landscapes.

3. Technology Description

a) Sub-Surface Drip Irrigation (SSDI)

SSDI delivers water directly to the root zone below the soil surface, minimizing losses due to evaporation and runoff.

Key features:

-Underground drip lines placed near crop roots

-Integrated fertigation for efficient nutrient delivery

-Reduced weed growth and soil salinity risks

b) IoT-Enabled Irrigation and AI-Based Precision Agriculture

IoT systems use soil moisture sensors, weather stations, and flow meters to generate real-time irrigation data. AI tools analyse historical datasets, weather forecasts, and crop growth stages to optimize irrigation scheduling.

Key features:

-Real-time monitoring through mobile/cloud platforms

-Data-driven irrigation decisions

-Early detection of crop stress

4. Implementation Experience and Results

Observed outcomes:

a. 30–50% reduction in water use
b. 20–40% increase in crop yields
c. Improved fertilizer efficiency through targeted fertigation
d. Reduced energy and labour costs
e. Enhanced resilience to dry spells and rainfall variability

The combined use of SSDI and digital tools enabled farmers to shift from calendar-based irrigation to need-based irrigation, improving overall farm efficiency.

5. Challenges Encountered

i) High upfront capital costs for infrastructure and sensors

ii) Technical complexity related to filtration, maintenance, and data interpretation

iii) Limited digital literacy among small and marginal farmers

iv) Inadequate rural connectivity and power supply in some areas

6. Enabling Factors for Scale-Up

A. Policy Factors

Government subsidies and incentives for micro-irrigation systems

National programs promoting digital and smart agriculture

Supportive policies for digital infrastructure development

B. Technical Factors

Localization of sensor technology for diverse agro-climatic conditions

Availability of local service providers and after-sales support

Integration of renewable energy solutions (e.g., solar pumps)

C. Socio-Economic Factors

Collective adoption through Farmer Producer Organizations (FPOs) and cooperatives

Capacity-building and training programs for farmers

Inclusion of women and youth as technology adopters and service providers

Demonstration farms showcasing cost–benefit advantages

7. Key Lessons Learned

-Technology adoption improves when solutions are farmer-centric and context-specific

-Blending physical irrigation systems with digital intelligence maximizes impact

-Financial support and technical handholding are critical for smallholder adoption

-Trust-building through local institutions accelerates technology uptake

8. Conclusion

Smart irrigation technologies—especially sub-surface drip irrigation combined with IoT and AI-based precision agriculture—offer a scalable pathway toward sustainable water management, climate resilience, and food security in the Asia-Pacific region. Successful scale-up depends on integrated policy support, localized technical solutions, inclusive financing, and strong capacity-building efforts.

When implemented as farmer-focused climate solutions, smart irrigation systems can significantly contribute to long-term water security and sustainable agricultural development.

10. Wasswa Shafik, Dig Connectivity Research Laboratory, Canada

The Asia-Pacific region faces acute water scarcity, climate variability, and rising food demand due to rapid population growth and economic development. Agriculture consumes the bulk of freshwater resources in many countries, and traditional irrigation techniques often result in significant water waste, reduced soil health, and diminished crop resilience. Smart irrigation—leveraging digital technologies such as sensors, artificial intelligence (AI), the Internet of Things (IoT), and data analytics—is fundamental to achieving sustainable water management that enhances water use efficiency, improves crop yields, and builds climate resilience across diverse landscapes in the Asia-Pacific.

1. What Is Smart Irrigation?

Smart irrigation refers to systems that automate and optimize water delivery based on real-time environmental and crop needs rather than static schedules. Core technologies include:

IoT Sensors: Soil moisture, temperature, and weather sensors gather real-time field data.
AI and Analytics: Machine learning models process sensor data to recommend or automatically execute irrigation actions.
Automated Controllers and Valves: These devices adjust watering rates and timing based on analytics and weather forecasts.
Remote Monitoring: Farmers and water managers can monitor systems and adjust settings via mobile apps or centralized dashboards.

By accurately targeting water application, these technologies dramatically reduce water waste while maintaining or improving crop health. Smart irrigation can lower water use by 10 – 40 % compared with traditional methods, depending on crop and climate.

2. Emerging Technologies Driving Smart Irrigation

IoT and Sensor Networks

Sensor networks deployed across fields collect hyper-local moisture and climate data, enabling precision decisions about when and how much to irrigate. These networks often integrate with cloud platforms for data aggregation and insights, allowing irrigation to respond dynamically to field conditions.

Artificial Intelligence and Predictive Models

AI algorithms analyze historical and real-time data to forecast irrigation needs and adjust schedules proactively. Machine learning models can learn cultivation patterns, weather impacts, and soil responses, enabling efficiency gains beyond basic threshold-based systems.

Advanced Drip and Micro irrigation Systems

Micro irrigation, including drip and micro-sprinkler technologies, delivers water directly to plant roots, reducing evaporation and runoff. Such systems are now integrated with smart controllers and sensor feedback loops that tailor irrigation to precise crop needs.

Mobile and Remote Solutions

Remote control systems—like automated pump controllers that farmers operate via basic phone networks—enable efficient irrigation even in regions with limited infrastructure. Devices such as Nano Ganesh allow remote management of irrigation pumps via mobile communications—an accessible innovation for smallholders.

Research-Level Innovations

Cutting-edge technologies are pushing boundaries further. For example, neuromorphic edge computing enables ultra-low-power local decision-making in irrigation controllers, enhancing autonomy and sustainability without cloud dependency. Similarly, multi-sensor fusion and robotics offer automated irrigation platforms with high precision across varying terrain.

3. Drivers of Smart Irrigation Adoption in Asia-Pacific

Water Scarcity and Climate Change

Frequent droughts, erratic monsoons, and rising temperatures heighten water stress across the region. Smart irrigation provides a climate-resilient approach by optimizing water use and adapting irrigation schedules to real-time environmental conditions, thus reducing vulnerability to hydrological shocks.

Policy Support and Investment

Government subsidies and programs—such as those promoting micro irrigation and precision agriculture in India, China, and Vietnam—are key enablers of adoption. National schemes help reduce upfront costs and encourage technology uptake among smallholders and commercial farms alike.

Agritech Market Growth

The Asia-Pacific agritech sector, including smart irrigation, is poised for robust expansion and is projected to grow rapidly through 2030 as digital farming solutions gain traction.

Food Security Imperatives

Meeting future food demand requires boosting yields while conserving scarce water. Smart irrigation contributes to both objectives by improving productivity and resource efficiency.

4. Strategies for Scaling and Impact

Integration with Broader Water-Smart Frameworks

Smart irrigation should align with adaptive water management strategies that consider watershed dynamics, land-use change, and climate impacts. Frameworks like the SIWAMA initiative in the Asia-Pacific combine digital monitoring with participatory governance to ensure sustainable irrigation outcomes.

Capacity Building and Farmer Engagement
Training programs, extension services, and agritech hubs play a crucial role in helping farmers understand and adopt smart irrigation tools. Youth-led innovation programs demonstrate how local leadership can accelerate technology diffusion.

Affordable Financing and Business Models
To reach smallholder farmers, innovative financing—such as sensor-as-a-service or pay-as-you-grow models—can reduce barriers to entry. Public-private partnerships further stimulate investment in rural water infrastructure enabling scalable impact.

5. Conclusion

Smart irrigation represents a transformative opportunity for the Asia-Pacific to manage water resources sustainably, adapt to climate variability, and meet rising food demands. Through harnessing emerging technologies—IoT, AI, precision sensors—and aligning policy, finance, and capacity building, the region can scale smart irrigation systems from pilots to landscape-level adoption. The result will be improved water governance, resilient agricultural systems, and sustainable water management that supports both rural livelihoods and environmental stewardship across Asia-Pacific.

11. Vikas Goyal, Water Resources Specialist, Agriculture, Food, Nature, and Rural Development (AFNR) Sector Group, Asian Development Bank- India Resident Mission

Since 2003, the **Asian Development Bank (ADB)** has supported multiple water resources and irrigation sector projects across Indian states, focusing on institutional strengthening and policy reform; irrigation infrastructure development and modernization; capacity building of water user associations (WUAs); deployment of digital solutions; promotion of gender equality; application of social and environmental safeguards; and strengthening of procurement, operations, and maintenance (O&M) systems. Selected completed and ongoing projects are summarized below.

1. Climate Adaptation in Vennar Subbasin, Cauvery Delta – *Completed*

The project enhanced climate resilience in cyclone- and flood-prone coastal districts through climate-resilient irrigation and drainage infrastructure, improving flood risk management, reducing salinity intrusion, and ensuring equitable irrigation water delivery, including to tail-end areas. Key interventions included rehabilitation of 378 km of main channels, construction of 328 irrigation and drainage structures, and upgrading of 13 pumping stations.

Aligned with India's Twelfth Five-Year Plan and ADB's Strategy 2030, the project contributed to poverty reduction, disaster resilience, food security, and gender equality. It benefited over 1.0 million people, including more than 0.5 million women, strengthened women's participation in agriculture training and stakeholder groups, and established sustainable O&M systems with strong institutional ownership.

2. Orissa Integrated Irrigated Agriculture and Water Management Investment Program – *Completed*

This multi-tranche financing facility supported modernization of irrigation systems across major river basins in Odisha, covering about 215,000 hectares and benefiting approximately 1.7 million people. The program improved irrigation reliability, water use efficiency, agricultural productivity, and participatory irrigation management through strengthened WUAs and revised state water policies.

The investment resulted in increased irrigated areas, higher crop yields, improved cropping intensity, and enhanced institutional performance. Sustainability was supported through strengthened state institutions, dedicated O&M budgeting, trained WUAs, and increased participation of women in irrigation management and agricultural decision-making.

3. Climate-Adaptive Community-Based Water-Harvesting Project, Meghalaya – *Ongoing*

ADB is supporting climate resilience and rural livelihoods in Meghalaya through the establishment of 532 climate-resilient water-harvesting systems, with a total project cost of $62.5 million (ADB loan: $50 million). The project strengthens state and community institutions to integrate climate adaptation into village water security planning, agriculture, fisheries, horticulture, and other livelihood activities.

The project has developed a state-wide water-harvesting master plan incorporating gender and social inclusion, disaster risk considerations, and alignment with the Meghalaya State Water Policy 2019. High-level technologies such as remote sensing, GIS, and decision support systems are being introduced, positioning the project as a lighthouse model for the northeastern and Himalayan regions.

4. Madhya Pradesh Irrigation Efficiency Improvement Project – *Ongoing*

The project supports expansion of efficient, climate-resilient irrigation through the Kundalia Irrigation Project, covering over 130,000 hectares via a greenfield piped irrigation network implemented under design-build-operate contracts. Physical works have been completed, and the system is now under a performance-based O&M phase extending to December 2029, with loan closure in March 2026.

Current activities focus on strengthening farmer organizations, SCADA- and IoT-based water distribution, farmer capacity building (including women), operation of farmer service centres and field schools, irrigation service charge collection, and asset management. O&M budgets are ring-fenced, ensuring sustainability and service reliability.
More details

12. Rohit Raj, Research Trainee, Plant Science, BITS Pilani

Water scarcity in the Asia-Pacific region is not only a climatic challenge but also an institutional and behavioural one. From my academic exposure and field-based observations across agriculture-dependent regions in India, I have seen that climate-smart irrigation technologies can be transformative but only when embedded within supportive socio-economic systems.

Subsurface drip irrigation (SDI) has demonstrated clear water-use efficiency gains (30-50%) in horticultural and cash crops, particularly in arid and semi-arid regions of Rajasthan and parts of central India. However, adoption at scale among smallholders remains uneven due to high initial costs, maintenance complexity, and limited technical literacy. Government-backed interventions under India's **Pradhan Mantri Krishi Sinchayee Yojana (PMKSY)** and **Clean Development Mechanism (CDM) projects** have helped offset costs through subsidies and carbon-credit linked financing, improving uptake where extension services are strong.

My observations also highlight emerging alternatives such as **hydroponics and vertical (sky) farming**, especially in peri-urban and water-stressed regions. These systems drastically reduce water consumption (up to 80-90%) and bypass soil degradation issues, but remain capital-intensive and energy-dependent. Their success depends on access to renewable energy integration and market-linked value chains.

IoT-enabled irrigation and AI-based precision farming pilots supported by India's **Digital Agriculture Mission** and state-level smart irrigation policies have shown promise in optimizing irrigation scheduling and reducing over-extraction. Yet, behavioural resistance, fragmented landholdings, and weak last-mile digital connectivity remain significant barriers.

In conclusion, technology alone is insufficient. Scalable adoption requires integrated policy design, financial risk-sharing, farmer-centric training, and localization of digital tools. Climate-smart irrigation must evolve as a socio-technical transition rather than a purely technological intervention to ensure inclusive and climate-resilient agricultural futures.

13. Irum Tariq, Member Standing Committee (SC) for Smog and Climate Lahore Chamber of Commerce and Industry (LCCI), CEO at Exodus Green Pvt. Ltd., Pakistan

Scaling smart irrigation refers to the widespread adoption and integration of advanced technologies, such as sensors, Internet of Things (IoT), satellite remote sensing, artificial intelligence, automation, and mobile decision-support systems, to optimize agricultural water use in a sustainable and climate-resilient manner. In the Asia-Pacific context, it involves expanding these solutions beyond pilot projects to reach smallholders and large farms alike, enabling precise, real-time irrigation based on crop needs, soil conditions, and weather patterns. By reducing water losses, improving productivity, conserving groundwater, and enhancing resilience to climate variability, scaling smart irrigation supports sustainable water management, food security, and long-term environmental and economic stability across the region.

14. Ali Ajaz, Ph.D., Snr. Engineer-Global Irrigation Applications, Lindsay Corporation, United States

In the context of Pakistan, one of the largest countries in the Asia-Pacific region in terms of irrigated area, discussions around SDI and IoT-enabled irrigation systems may be premature. The agricultural sector is still largely in the early adoption phase of pressurized irrigation systems, primarily surface drip and sprinkler irrigation. Also, the use of sensors (i.e., soil moisture meters) is still in its early phases of adoption.

One of the key enabling factors driving adoption is increasing water scarcity, coupled with government subsidies for irrigation equipment and the added incentive of solar system subsidies. However, it is important to remain realistic. Smallholder farmers generally have limited interest in IoT-based solutions, often perceiving them as an additional burden due to cost, complexity, and low technical familiarity.

Medium- to large-scale growers may experiment with sensor technologies, typically in their most basic and cost-effective forms, to test feasibility and value. Nevertheless, expectations of rapid or widespread adoption of advanced digital irrigation technologies would be overly optimistic and, at this stage, largely wishful thinking.

15. Dr. Rohit Sharma, Capacity Building Specialist Capacity Building Specialist, FAO

Question 1 Response -

Across water-scarce Asia–Pacific contexts, these smart irrigation technologies have successfully scaled depending on strong institutional arrangements, gradual capacity building, and alignment with local governance structures. A recurring observation is that technology adoption is more sustainable where farmers are not merely end-users but are actively involved in water management decisions through participatory frameworks. Digital tools and automation tend to perform best when they complement clearly defined water allocation rules, collective operation and maintenance arrangements, and trusted local leadership. Where such institutional foundations are weak, advanced technologies often remain under-utilized or dependent on external technical support.

With respect smallholders, they are more likely to engage with smart irrigation when systems are introduced progressively, starting with assured and equitable water delivery, followed by basic scheduling and efficiency practices, and only later integrating advanced digital decision-support features. Continuous handholding, practical demonstrations, and peer learning have been more effective than one-time technical training, particularly in addressing behavioural barriers and building confidence. At scale, successful initiatives have emphasized simplicity, reliability, and transparency over technological sophistication. While digital monitoring and analytics can support better planning and accountability, farmers tend to value visible improvements in water reliability, reduced conflict, and flexibility in crop planning as the primary drivers of acceptance. Integration with local extension services and community institutions has further helped translate improved water control into productivity and livelihood gains.

Overall, smart irrigation technologies scale most effectively when embedded within participatory irrigation management systems, supported by sustained capacity development and adaptive governance. In such settings, digital and precision tools act as enablers of collective action and climate resilience, rather than as isolated technological interventions.

Question 2 Response-

Smallholder adoption of smart irrigation technologies in the Asia–Pacific region is shaped less by the availability of hardware alone and more by a combination of policy, institutional, behavioural, socio-economic, and technical factors. In Indian context these factors can either constrain or enable uptake. Hence, effective adoption requires moving beyond a purely technical focus toward farmer-led governance models that ensure long-term ownership and institutional sustainability. A key enabling policy shift has been the transition from top-down irrigation management to participatory and decentralized frameworks, such as the Water User Association (WUA) models being scaled under the Government of India's Modernization of Command Area Development (MCAD) guidelines led by the Ministry of Jal Shakti. For such systems to function effectively, farmers must play a central role in decision-making and day-to-day management. Common impeding factors include weak legal recognition of farmer institutions, limited operational capacity, and behavioural passivity resulting from long-standing supply-driven irrigation practices. These constraints have been addressed through the formation of legally recognized WUAs with clearly defined rules for water allocation, scheduling, cost sharing, and system maintenance. Complementary capacity development focuses on irrigation planning, basic upkeep, and adaptive crop choices, including diversification strategies suited to periods of water stress.

From a socio-institutional perspective, anchoring smart irrigation initiatives within existing local governance structures, has proven critical. Grassroots leadership roles such as Jal Mitras (volunteer motivators), Jal Pradhans (community leaders) , Chak Committees, and Chak Leaders strengthen accountability at the field level and help translate system-level rules into routine practice. Regular awareness activities and sustained handholding have contributed to reduced vandalism and misuse, improved compliance, and greater trust in collectively managed infrastructure.

These Participatory Irrigation Management (PIM) approaches are more effective in overcoming adoption barriers than technology-led interventions alone. Strengthening WUAs and embedding them within local governance systems enables farmers to collectively plan water use, oversee operations, and manage routine maintenance. Continuous, phased capacity development focused on practical water management and crop planning under variable water availability has been central to building confidence, accountability, and collective ownership. Overall, this approach reinforces the "resource-to-root" concept as a social and institutional process, not merely a technical one. By placing farmers at the centre of governance and management, PIM frameworks promote equitable and efficient water use, reduce conflict and system misuse, and enhance livelihood resilience. These institutional gains provide a scalable pathway for climate-resilient irrigation development across smallholder systems in the Asia–Pacific region.

16. Prabhakar S.V.R.K., Principal Policy Researcher (adaptation) at Institute for Global Environmental Strategies (IGES), Kanagawa, Japan

I might have a different opinion, so please forgive me if this is not the viewpoint you anticipated. With that in mind, I would like to express my thoughts openly.

Although technologies like SDI, IoT-enabled irrigation control, and AI-driven precision farming are attracting interest from tech-oriented farmers/agricultural departments and the private sector, they are still quite disconnected from the realities faced by smallholder farming communities or /agricultural departments designed to support them. Many small farmers find it hard to make a profit from systems that are already low-margin and expensive. For them, these technologies are not just tools; they represent a significant financial, technical, and institutional challenge.

We need to consider what these technologies require from farmers whose average education may not exceed high school and whose yearly income might only be a few hundred dollars. Do the expected benefits truly justify the considerable capital investment and skill requirements? And are agricultural extension services ready to support such advanced tools when they often struggle to provide even basic advice on planting times, seed choices, and pest control?

There is no doubt that these technologies can be beneficial, but likely only in specific situations and for a group of farmers who have the means and skills to utilize them effectively or local agriculture departments capable enough to deploy/work with the private sector/provide useful advice for the users. The current strategy of testing these "high-tech solutions" with wealthy and well-educated farmers may actually strengthen the belief among regular farmers that such technologies are "not meant for us," further deepening the digital and innovation gap in agriculture (these technologies are still seen as "Boys' Toys").

For most farmers and agricultural institutions in Asia, there is an urgent need for access to simpler, affordable, and reliable technologies, along with strong support for building their skills. For now, these advanced tools can be reserved for a small, privileged group. Current experiences show that while precision agriculture is high-tech, it often falls short in delivering real-world cost-benefit results for smallholder farmers. However, it is important to note that there is still a lack of systematic research to definitively confirm this.

These technologies could be truly beneficial when implemented at the community or landscape level, with centralized analysis from local agricultural departments or farmer organizations, supported by trusted advisory systems, and backed by clear demonstrations of costs, benefits, and suitability. Only then can farmers make informed choices about whether these tools meet their needs.

ICAR has initiated national programs and research networks focused on precision agriculture, such as the ICAR Network Programme on Precision Agriculture (ICAR-NePPA). This program involves multiple institutes working on data, analytics, precision livestock, aquaculture, and agritech solutions to enhance input use efficiency and productivity. Research shows that precision nutrient management and irrigation adjustments can boost crop performance and input efficiency.

Despite these encouraging findings, there is limited large-scale evidence of widespread adoption or systemic impact across India's mainly smallholder farms. Most demonstrations of precision technology are localized, and many solutions (like drones, smart sensors, and AI tools) are still in pilot phases. Adoption is generally higher among better-resourced or larger farms rather than typical smallholders, partly due to costs, technical complexity, and gaps in capacity.

My general evaluation is that it is effective in certain areas, holds great potential, and has inconsistent success rates. There is a significant gap in implementation, as adoption relies on factors like capacity, cost, support for extension, and the readiness of farmers. These remain crucial barriers to turning research innovations into widespread effectiveness.
I hope this is helpful. I am happy to provide further clarification if needed.

17. Input from APCTT

We wish to thank all members for the rich discussion on smart irrigation in the Asia Pacific region.

Several common factors for success have been mentioned - robust farmer organizations, demonstration plots, extension support. In my humble opinion, four critical gaps could convert these good examples into scalable public goods.

1. Evidence for decision making
Many members report savings of 30 to 50 percent water and increases in crop yield of 20 to 30 percent. However, as a policy maker, , a more precise investment logic is required for policymakers and investors:
- What is the cost per hectare?
- How soon do farmers repay their investment?
- What is the public return on subsidy programmes?
This analysis would enable the government to focus on investments and technology transfer.

2. Inclusion: Who Benefits and Who Is Missing?

Smallholder farmers featured prominently in the discussion, but gender and youth are invisible in the answers. However, women constitute almost half of the agricultural labour force in the region, but the adoption rate of technologies is usually based on male-dominated cooperatives. FAO pilots in Indonesia demonstrate that women trained in sensor-based irrigation systems increased household incomes by 15-20 percent. The Drone Didi experiment in India has also yielded good learnings. Youth-driven digital platforms in Pakistan are also accelerating climate advice adoption and preventing migration.

3. Learning from What Did Not Work

A more honest assessment of failures and risks would help us avoid expensive repetition. For e.g. SDI systems were abandoned due to clogging and spare part shortages; Flood-prone pilots were affected by cyclones in Pacific islands; Imported technologies often do not match local soils and cropping systems; Post subsidy maintenance gaps causing 20-30 percent attrition of use

4. Institutional Readiness and Data Integration

Technology alone is not sufficient. Upscaling requires extension workers trained in digital agronomy and local service ecosystems for maintenance and spare parts and interoperable data platforms need to connect sensors, weather, soil, and advisory services.

The above points are for members’ reference.

Many thanks to all who contributed to this query!

The Community of Practice on Climate Technologies aims to foster technology cooperation and transfer through enhanced knowledge exchange and cross-border collaboration in Asia Pacific.

If you have further information to share on this topic, please send it at apctt@un.org.

This Consolidated Reply is a systematic compilation of all responses received and additional desk research. It has been compiled by the Research Team at APCTT: Pankaj Kumar Shrivastav, Programme Management Officer, APCTT and Jigya, Intern, APCTT.

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