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Towards A Water Secure World Free From Poverty & Hunger

KHETTARAS



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An International Periodical of
International Commission on Irrigation and Drainage



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Cover Page Story

The Khetaras still constitute today, in the oases of southern Morocco, an ingenious system for collecting groundwater from the water table. This hydraulic structure allows the collection of water underground at its end while minimizing losses through evaporation. They are also known in other countries under the name of Foggara or qanât. In Morocco, the first use of khetaras dates several centuries back. More details in next issue.

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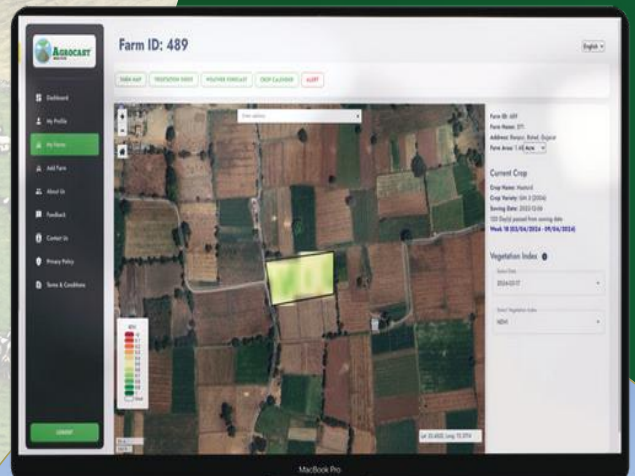
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Dr. Marco Arcieri *President, ICID*



Dear Colleagues, partners and friends,

Greetings from International Commission and Irrigation and Drainage (ICID).

Water is the cornerstone of agricultural production, food security, and rural development. Globally, agriculture consumes nearly 70% of accessible freshwater resources, making efficient water management essential for sustainable development. At the same time, women constitute approximately 43% of the global agricultural labor force, with their participation exceeding 50% in many parts of sub-Saharan Africa and Asia. Despite their indispensable role in agricultural production and household water management, women have historically been excluded from water governance, policy formulation, and decision-making processes.

As climate change, rapid population growth, and increasing water scarcity place unprecedented pressure on global water resources, strengthening agricultural water management has become more urgent than ever. Recent evidence clearly demonstrates that sustainable water management and climate resilience cannot be achieved without recognizing and empowering women as equal partners in water governance and agricultural development.

Women are the backbone of rural agriculture in many developing countries. Beyond their contribution to crop production, they are responsible for securing, managing, and utilizing water for both household and agricultural purposes. Their daily activities include manually carrying water for seedling nurseries, transplanting, weeding, and irrigating small plots of land. Women also play a central role in managing household water supplies, collecting water for drinking, cooking, sanitation, and cleaning.

An often-overlooked contribution is their management of greywater. By recycling household wastewater, women support kitchen gardens, small-scale horticulture, and livestock production, thereby improving household nutrition while reducing pressure on limited freshwater resources.

However, these responsibilities come at a considerable social and economic cost. In many rural communities, women spend several hours each day collecting water, often walking

long distances while carrying heavy loads. This unpaid labor creates severe time poverty, limiting opportunities for education, income-generating activities, skills development, and participation in local governance. Consequently, women's potential contributions to agricultural innovation and rural economic development remain underutilized.

Water Security and Climate Change

Water availability has become one of the defining challenges of the twenty-first century. Climate change has altered rainfall patterns, increased the frequency of droughts and floods, and intensified competition among agricultural, domestic, industrial, and environmental water users. Simultaneously, global population growth continues to increase demand for food, requiring greater agricultural productivity with increasingly limited water resources.

These interconnected challenges highlight the importance of sustainable agricultural water management. Efficient irrigation systems, improved water-use practices, and integrated water resource management are no longer optional but essential for ensuring food security, reducing poverty, and strengthening climate resilience.

Because women are among the primary users and managers of agricultural water at the household level, empowering them through improved access to water resources, modern technologies, financial services, training, and leadership opportunities directly contributes to higher agricultural productivity, better household nutrition, and more resilient farming systems.

Global Commitment to Water and Gender Equality

Recognizing the critical importance of water for sustainable development, the United Nations General Assembly designated 22 March as World Water Day in 1993. Since then, governments, United Nations agencies, research organizations, and civil society institutions have organized annual events to raise awareness of global water challenges and promote sustainable water management.

Gender equality has become an increasingly important component of these global efforts. The International Commission on Irrigation and Drainage (ICID), under its

Message from the President, ICID

Vision 2030, adopted "Water and Gender" as a major theme with the slogan:

"Where water flows, equality grows."

This vision reflects the close relationship between water security and gender equality and aligns with several United Nations Sustainable Development Goals (SDGs), particularly: SDG 2: Zero Hunger; SDG 5: Gender Equality; SDG 6: Clean Water and Sanitation; SDG 13: Climate Action

Achieving these goals requires ensuring that women have equal access to water resources, agricultural technologies, education, financial services, and participation in water governance.

Non-Conventional Water Resources: Expanding Water Availability

Growing freshwater scarcity has increased interest in alternative water resources capable of supporting sustainable agriculture. Treated wastewater, brackish water, saline water, and properly managed agricultural drainage water are increasingly recognized as valuable non-conventional water resources.

Among these options, treated wastewater represents a particularly important opportunity. Rather than being considered waste, properly treated wastewater can become a reliable irrigation source that reduces dependence on freshwater while supporting agricultural production. In regions experiencing severe water stress, wastewater reuse contributes to environmental sustainability, protects freshwater ecosystems, and enhances resilience against climate variability.

Similarly, agricultural drainage water, when appropriately managed and monitored, can supplement irrigation supplies while minimizing environmental and public health risks. These approaches not only increase water availability but also contribute to circular water management by promoting the efficient reuse of existing water resources.

Since women often manage household water reuse and small-scale agricultural production, their participation is essential for successfully implementing these sustainable water practices.

Agricultural Water Management and Rural Development

Reliable access to water has become a central pillar of national and regional development strategies worldwide. This priority is reflected in the United Nations 2030 Agenda for Sustainable Development, which recognizes the close relationship among water security, food security, energy security, and poverty reduction through the Water-Food-Energy Nexus.

Agricultural water management therefore represents one of the most important investments for sustainable rural development. Without improving irrigation efficiency, strengthening water governance, and promoting inclusive rural development, achieving the Sustainable Development Goals will remain difficult.

During recent decades, many developing countries transferred irrigation management responsibilities from governments to Water Users' Associations (WUAs). While some irrigation management transfer programs successfully increased local participation and improved system performance, others experienced limited success because of institutional weaknesses, inadequate technical capacity, financial constraints, and insufficient stakeholder participation.

These experiences provide valuable lessons for future irrigation reforms. Understanding both successful and unsuccessful cases can help governments design more effective irrigation governance systems that are technically sound, socially inclusive, and environmentally sustainable.

Continuing the tradition established in previous years, the International Commission on Irrigation and Drainage (ICID) successfully organized the 2nd Indo-Global Irrigation Summit on 24–25 June 2026 in New Delhi, India, commemorating the 76th Anniversary of ICID's establishment. The Summit brought together policymakers, water professionals, researchers, industry representatives, international organizations, academia, and other stakeholders to deliberate on emerging challenges and innovative solutions for sustainable irrigation and agricultural water management.

I extend my sincere appreciation to all stakeholders, including the Ministry of Jal Shakti, Government of India, water professionals, researchers, industry partners, international organizations, academic institutions, and delegates from across the world for their enthusiastic participation and valuable contributions through technical papers, presentations, panel discussions, and exhibitions. Your support and commitment made the Summit a remarkable success and a fitting celebration of ICID's 76 years of dedicated service in advancing irrigation, drainage, water management, and international cooperation.

In 2026, the International Commission on Irrigation and Drainage (ICID) will organize its flagship triennial event—the 26th International Congress on Irrigation and Drainage and the 77th International Executive Council Meeting—from 12 to 17 October 2026 in the scenic and historic port city of Marseille, France. The event will be held under the theme "Water and Agricultural Resilience in the Face of Climate Change."

This prestigious global gathering will bring together experts, policymakers, researchers, practitioners, and stakeholders from across the world to exchange knowledge, share innovative solutions, and discuss strategies for strengthening water security and agricultural resilience in the face of climate change.

On this occasion, I warmly invite all ICID National Committees, partner organizations, academic and research institutions, and other stakeholders to contribute their valuable research papers, technical studies, case studies, and innovative practices to the Congress. I also encourage your active participation in large numbers to make this international event a vibrant platform for collaboration, knowledge exchange, and collective action towards sustainable irrigation, water management, and climate-resilient agriculture.

I look forward to meeting you all at this forthcoming fabulous event on the coast of the Mediterranean Sea, near the mouth of the Rhône river.

Warm Regards,



Dr. Marco Arcieri
President, ICID

Dr. R.K. Gupta *Secretary General, ICID*



Dear Colleagues, partners and friends,

Greetings from ICID Central Office, New Delhi

Irrigation sector is the largest consumer of freshwater resources, accounting for about 80% of usage in most developing countries. While it has driven economic growth and improved rural livelihoods, challenges like water scarcity, climate change, and environmental degradation threaten its sustainability. Thus, optimal utilisation of available water resources is of utmost importance. The past two decades have seen significant transformations in irrigation, with innovations like drip and sprinkler systems, precision agriculture, and community-based schemes enhancing crop yields and resource efficiency.

In today's world, where water scarcity and climate change are pressing concerns, optimizing irrigation practices is crucial for sustainable agriculture. Smart Irrigation Management offers a solution by leveraging advanced technologies to deliver the right amount of water at the right time, improving crop yields and reducing waste. Internet of Things (IoT), smartphone tools, and sensors are technologies that further enable farmers to know the exact status of their field, including soil temperature, amount of water required, weather conditions etc. The use of sensors is also important for farmers to better understand their crops, reduce the environmental impacts and conserve resources. Therefore, by the usage of SMART agriculture, farmers are given the opportunity to produce yields while using fewer resources, such as fertilizers, water, and seeds.

To commemorate its 76th Foundation Day, the International Commission on Irrigation and Drainage (ICID), under the patronage of the Department of Water Resources, River Development and Ganga Rejuvenation, Ministry of Jal Shakti, Government of India, organized the 2nd Indo-Global Irrigation Summit 2026 from 24 to 25 June 2026 at Dr. Ambedkar International Centre, New Delhi. The theme of the summit was "Smart Irrigation Management."

The summit covered a wide range of contemporary issues under the following sub-themes: Climate-Resilient Irrigation

Planning and Water Regulation; Application of Remote Sensing, Artificial Intelligence, and Machine Learning in Smart Irrigation; Digitalization and Automation of Irrigation Systems; Precision Irrigation and Green Energy Solutions for Sustainable Water Use; Smart Irrigation for Water Security; Optimizing Irrigation Water Use through Advanced Sensing and Monitoring Technologies; Integrated Modelling and Simulation Tools for Irrigation Planning and Decision-Making etc.

The summit was attended by more than 300 delegates representing Central Government organizations, State Water Resources Departments, Public Sector Undertakings diplomatic missions, present and former office bearers of ICID, National Committees on Irrigation and Drainage from Georgia, India, Japan, Malaysia, Nepal, Italy, Uzbekistan, Russia, Chile, Nigeria, and Sri Lanka, international organizations such as FAO, IAHS, ICARDA, IWMI, and the World Water Council (WWC), along with representatives from academia, industry, NGOs, and water resources experts from across the globe.

The international segment of the summit featured eminent experts and leaders, including Dr. Marco Arcieri, President, ICID (Italy); Mr. Loïc Fauchon, President, World Water Council (France); Dr. Vinay Nangia, Research Team Leader, ICARDA (Morocco); Dr. Salvatore Grimaldi, President, IAHS (Italy); Mr. Salman Maher, Senior Land and Water Officer, FAO; Prof. Chandra A. Madramootoo, President Hon. ICID (Canada) and Dr. Alok K. Sikka, former emeritus scientist, IWMI.

ICID expressed its sincere gratitude to the representatives of its National Committees whose active participation contributed significantly to the success of the summit.

The summit also provided an excellent platform for industrial partners to showcase innovative technologies through a dedicated exhibition on Smart Irrigation Management and other emerging solutions in water resources development. The exhibition displayed cutting-edge technologies, digital solutions, precision irrigation

From the Desk of Secretary General, ICID

systems, and sustainable practices aimed at improving water-use efficiency and agricultural productivity.

The 2nd Indo-Global Irrigation Summit 2026 served as a significant international platform for knowledge exchange, collaboration, and innovation in irrigation and water resources management. By bringing together policymakers, researchers, practitioners, industry leaders, and development partners, the summit reinforced the collective commitment to advancing smart irrigation technologies, promoting sustainable water management, strengthening climate resilience, and enhancing global food and water security.

To further enhance ICID's technical outreach and promote global knowledge exchange, a Webinar Series on "Smart Irrigation Management" was launched in October 2025. Since its commencement, the series has received an overwhelming response from irrigation professionals, researchers, academicians, and industry representatives from India and across the world. The webinar series highlights the growing significance of smart, data-driven irrigation management in addressing some of the most pressing challenges of our time, including climate change, increasing water scarcity, food security, and the need for sustainable agricultural practices.

The seventh webinar of the series, titled "Precision Water Resources Management: Irrigation Intelligent Sensing and Modelling," was organized on 22 May 2026. The session provided valuable insights into emerging approaches in precision water management, intelligent sensing technologies, and modelling tools that support improved irrigation planning and decision-making.

Continuing this knowledge-sharing initiative, the next webinar, titled "Satellite-Based Irrigation Monitoring to AI-Driven Irrigation Intelligence," is scheduled for 24 June 2026. The session will explore the potential of satellite-

based monitoring, remote sensing technologies, and artificial intelligence in transforming irrigation management and enabling more efficient, sustainable, and resilient water use.

Preparations are well underway for the 26th ICID Congress in Marseille, which will center around the critical theme of "Water and Agricultural Resilience in the Face of Climate Change." As a flagship mega-event, the Congress will focus on enhancing irrigation efficiency, driving agroecological transitions, and deploying innovative technologies to secure sustainable water systems. Special emphasis will be placed on exploring non-conventional water sources, such as wastewater reuse and desalination, alongside the development of supportive policy frameworks. By convening global researchers, policymakers, practitioners, and stakeholders, the event aims to facilitate the exchange of practical solutions for building climate-resilient agriculture, and all interested parties are strongly encouraged to participate.

I, on behalf of ICID, invite all the water and agricultural professionals and experts around the globe to participate in this flagship event of ICID.

Looking forward to seeing you all in the Marseille !



Dr. R.K Gupta
Secretary-General, ICID



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A Talk with ICID President Hon. Prof. Chandra A. Madramootoo



Prof. Chandra A. Madramootoo is a Professor of Agricultural and Bio-Systems Engineering in McGill University and Director of Brace Centre for Water Resources Management in McGill University, Montreal, Canada

1. Professor Chandra, could you reflect on the span of your association with the International Commission on Irrigation and Drainage (ICID) and share your thoughts on the important role ICID continues to play in irrigation, drainage, and flood management areas?

My association with ICID began with the 2nd Pan-American Regional Conference and 40th IEC, held in Ottawa, Canada in May 1989. I have remained an active member of both my national committee (CANCID) and ICID ever since. Obviously I am very committed to both CANCID and ICID because they are the only NGO voices that can articulate in an impartial and professional manner, improvements to irrigation, drainage and flood control policies, programs and practices, within a sound technical, social, economic and environmental framework.

Over the years, I served on several Working Groups and Task Forces in ICID, including as Chair of the Environmental Impacts WG, Member of the Drainage WG, Chair of the Permanent Finance Committee, Chair of the Task Force on the Aral Sea, elected Vice President in 1999, elected President in 2008, and a member of the organizing committee of the 18th Congress and IEC in Montreal in July 2002.

ICID is comprised of experts from National Committees with interdisciplinary backgrounds and extensive knowledge, who contribute to the work program of various work bodies and task forces. Representatives of National Committees are broad based bringing views from government decision makers, industry, academia, farmers, water users, to name a few. ICID has incorporated the views of women, and gender into its programming. We actively engage with young professionals, providing a forum, whereby they can help foster new knowledge and bring new ideas to the table. This encourages succession planning in the organization.

The diversity and inclusivity of views within ICID is a testimony to its strength, and ability to remain relevant, despite the many challenges around the world. ICID must build on these many attributes, as the world continues to grapple with the urgent challenges of meeting the food and water demands of a growing population.

Long held theories will no longer result in improvements to irrigation, drainage and flood control projects. We need to explore new ways of thinking, (as they say thinking outside the box), given the fiscal realities of countries, and cost of water projects.

2. In your view, what are the most pressing challenges confronting the irrigation and drainage sectors today, especially as we contend with rapid population growth, urbanization, and increasing climate variability?

There is no doubt that population growth, increased urbanization and climate variability are confronting the way we are planning for the immediate, medium, and long term future. We are being confronted also by water scarcity and drought. Time is not on our side. Valuable arable land is being lost to urbanization.

3. From your perspective, what innovative strategies, policy actions, or on-the-ground initiatives should policymakers, farmers, and development partners prioritize to build more resilient agri-food systems while safeguarding water resources for future generations?

I would begin with education and capacity building. This must occur at all levels – government planners, policy makers, academics, farmers, private sector, water users and students at TVETS and colleges. ICID must redouble its efforts in educational awareness. While webinars and

annual meetings serve a purpose, crucial messages are not getting down to the farmers and water users. They are after all, our largest stakeholders. ICID must find ways, working through its national committees, to get short videos in the local language, field days, and water user field schools, active in the member countries.

It is only through this on-the-ground educational effort that we will begin to see the emergence of resilient agri-food systems and water productivity improvements in member countries. Similar to the WATSAVE and other awards, ICID should offer an annual prize to the National Committee, who is putting on the best educational programs. This is also an area in which the Young Professionals can make a recognized contribution. Countries ought to call on the donors and private sector to support such educational programs. India has a good example of the WALMI's. Can this model be replicated in other countries?

4. Climate change and rapid population growth are placing enormous pressure on rainfall patterns, water availability, and crop yields, while also raising the risk of tensions between regions and countries, especially across Africa and Asia. In your view, what should be the primary focus areas, policies, and strategies for water resources management that can help humanity overcome poverty and hunger in a truly sustainable way?

We need to work with government agencies on land zoning and land use planning, to curtail loss of agricultural land, not just in the peri-urban areas, but also on forested and savannah lands. We need to introduce land reclamation programs, low cost water efficient technologies, and water conservation, reuse and recycling.

Governments and development agencies must see the need to invest in large-scale water projects, to benefit their citizens. In this regard, the sector must do more to tap into green funds to support climate change projects that mitigate impacts of floods and droughts.

5. As a global leader and mentor in the field, what priorities would you recommend for ICID's national committees and for the next generation of professionals working to advance sustainable agricultural water management?

Already addressed in #3 above.

6. Looking ahead, what strategic directions should ICID pursue to help realize its vision of a water-secure world free from poverty and hunger through sustainable rural development?

Already addressed in my responses above.

7. As Chair of the Technical Advisory Committee of FAO's Global Framework on Water Scarcity in Agriculture (WASAG), what is your overarching vision for addressing water scarcity in farming systems in the context of a changing climate?

I was honoured to be elected as Chair of the new Technical Advisory Committee (TAC), and I also sit ex-officio on the Steering Committee (SC).

FAO, in conjunction with its member countries, made a great leap by reforming WASAG in 2024, restructuring its operations. The TAC is comprised of elected representatives from various technical constituencies and representatives from the six FAO regions. WASAG therefore brings together experts from the regions, governments, international organizations, research institutions, NGOs, and the private sector. Its reach is therefore very broad. A 5 year strategy has been developed, which for the most part is guiding our activities.

8. How does the WASAG partnership platform enable effective collaboration among governments, international organizations like ICID, research institutions, and the private sector to develop practical, scalable solutions that strengthen food security in water-stressed regions?

The WASAG strategy has four pillars: i). Catalyzing policy development by countries to address water scarcity in an integrated way; ii). Driving scientific research, technological innovation and efficiency improvements for water-wise agricultural production; iii). Supporting knowledge management, capacity building, training and awareness-raising to address water scarcity at all levels from national to local levels; iv). Fostering increased finance for water infrastructure, resilience-building, disaster risk reduction and other investments to support farmers on the ground. Advocacy and gender cut across all the pillars.

WASAG is executing this new Strategy through various Work Groups and Task Forces. Several of these work bodies have already started to work on topics such as farmer-led

“Water is the most critical resource issue of our lifetime and our children's lifetime. The health of our waters is the principal measure of how we live on the land.”

– Luna Leopold, Hydrologist

irrigation, remote sensing, nutrition and gender, climate financing, neglected crops and orphan crops, livestock and water scarcity, to name a few. We should see the results of this work within the next two years at the latest. The good thing about having representatives of the regions on the TAC, and ICID involvement, is that we will be able to test and disseminate the knowledge products within ICID countries.

It is critical that ICID actively participate and contribute to FAO's Global Framework on Water Scarcity in Agriculture (WASAG). ICID is the largest NGO dedicated to water scarcity in agricultural given our geographical reach and mission.

WASAG is planning to host a side event at the upcoming ICID Congress in Marseilles. I hope several participants will be able to participate and contribute their ideas.

9. Professor, what key messages would you like to leave with our readers who are actively working to achieve water and food security around the world?

I will leave with two messages. Firstly Artificial Intelligence (AI) is with us. It is here to stay, for better or worse. The question is how ICID can make use of AI in a positive and constructive way to disseminate knowledge products, and collect and gather key information, data and statistics in the irrigation, drainage and flood control sector. ICID should take up this topic in a proactive way.

Secondly, ICID is only as strong as its member countries and national committees. We have been losing national committees for financial reasons and lack of interest. The geopolitical forces are becoming very challenging and are leading to uncertainty and instability around the world. These changes will create a ripple effect in ICID. Given these realities, a critical question is whether ICID should rethink its modus operandi, and what will a rebranded ICID look like, going forward?



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A river seems a magic thing. A magic moving living part of the very earth itself.

– Laura Gilpin

”



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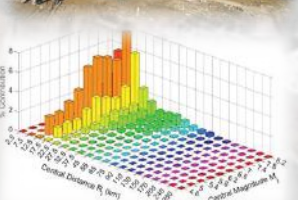
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ICID World Declaration



ICID • CIID



Best Irrigation Practices for Water and Food Security in the Context of Climate Change

PREAMBLE

The world is facing unprecedented challenges in ensuring water and food security for its growing population. Climate change is exacerbating these challenges, threatening various climate sensitive sectors such as water, agriculture, energy etc. The global population is projected to reach 9.8 billion by 2050 with most growth occurring in developing regions.

The global community needs to change the way things are being done now, for example, the agriculture sector needs to produce more food by using less water. Additionally, with improvement in living standards, there has been a significant shift in dietary pattern, the consumption of meat and dairy products has increased, even in emerging economies. This shift in dietary pattern, drove a corresponding rise in livestock support involving expanded infrastructure, feed production, and veterinary services to sustain larger animal populations.

Various estimates suggest that by 2050, about 70% of the population will live in urban areas, increasing pressure on Water, Food, & Energy nexus.

This declaration aims to promote best irrigation practices, sustainable water management, and to ensure water and food security for all.

The Challenges of providing Water and Food Security

The global freshwater demand is estimated at approximately 4,000 to 4,600 billion cubic meters (BCM) per year. **The global per capita water availability has been declining due to population growth, migration of people from rural to urban areas, land degradation and climate change.** In Sub-Saharan Africa and South Asia, where population growth rates are much higher than the global average, the per capita water availability has considerably gone down.

Global water demand for all uses—agriculture, industry, and domestic—is projected to rise by 20-30% from current levels by 2050.

- ❑ As a result of human population growth, change in dietary / consumption patterns, the global food demand is expected to be about 3 billion tons of cereals (up from ~2 billion tons in 2012) and 450-470 million tons of meat (up from ~300 million tons in 2012) annually.
- ❑ The availability and requirement of food varies significantly across different regions of the globe – maximum stress generally in poor / developing countries – causing further stress on already water stressed regions.
- ❑ Urbanisation and improvement in living standards has resulted into increase in the disposable incomes leading to change in consumption and dietary pattern towards processed and convenience foods which has resulted into increased water demands and also competition (and conflicts) across water using sectors.
- ❑ The livestock population also grew manifold, increasing the demand for fodder.
- ❑ Based on available estimates, global water demand for all uses—agriculture, industry, and domestic—is projected to rise by 20-30% from current levels by 2050.



- Generally, there are low water use efficiencies and low water & land productivity in agriculture, especially in developing countries.

Climate Change: A Threat Multiplier

Rising temperatures, changing precipitation patterns, and increased frequency of extreme weather events have been altering the availability and reliability of water resources. This, in turn, affects agricultural productivity, water and food security, and the livelihoods of millions of people.

□ Impact of Climate Change on Water Resources

- Water Resources Availability is, more or less, finite but intra and inter annual variability of water is expected to increase.
- With climate change, the pattern of precipitation has also been changing: number of rainy days are reducing and more intense rainfall events are being witnessed, leading to issues related to flood management and longer dry spells leading to prolonged droughts.
- While demand for water for various uses has been rising, the supply of water is getting more and more erratic and unpredictable. It is becoming increasingly difficult to meet the increased water demands from the erratic water supply.
- **It is estimated that with every 1°C of warming, global water demand is likely to increase by 2-3% due to higher crop irrigation needs and human consumption. If warming hits 3°C by 2100, there may be a 6-9% demand spike.**
- Since 1980s, global glacier mass has decreased by about 6% per decade.
- Himalayan glaciers - the source of water to about 1.9 billion people - are receding at 0.3–1 m per year. Estimates suggest that

by 2100, 30–90% of Himalayan glaciers may vanish under high-emission scenarios causing great water-related distress in the Indian sub-continent.

- The increased rate of melting of glaciers may initially result in increase in river flows. However, a substantial reduction in glacial mass over time will ultimately result in decreased river flows.
- **Central and South Asia (especially Himalayan and Pamirian glacier fed rivers) could see 20–40% less flow by 2100.**
- As glaciers shrink, the water supplies dwindle threatening water and food security.

□ Impact of Climate Change on meeting the food requirements:

- **Heat waves caused by climate change, in most cases, are reducing crop productivity, especially in tropical regions.**
- The crop yields have been generally falling in many regions under climate change impact:
 - ❖ **Maize:** Global yields may drop 24% by late century, with declines already evident in the U.S., Brazil, and Africa due to heat and drought.
 - ❖ **Wheat:** With increased temperatures, the yields could increase 17% globally due to CO₂ fertilization and longer seasons in temperate regions. However, tropical regions may have reduced yields.
 - ❖ **Rice:** Globally declining by 0.3% annually, with South Asia particularly vulnerable to erratic rainfall and frequent floods in rainy season.
 - ❖ **Other Crops:** Plantain production has fallen 43% over 20 years due to heat, and cocoa and coffee face challenges from erratic rainfall and pests.

With every 1°C of warming, global water demand is likely to increase by 2-3% due to higher crop irrigation needs and human consumption. If warming hits 3°C by 2100, there may be a 6-9% demand spike.

Principles of Sustainable Irrigation and Agricultural Practices

- **Sustainable Water Management:** Efficient Water Resources Management systems, water conservation, and protection of water sources.
- **Climate-Resilient Agriculture:** Climate-resilient agricultural practices, including drought-tolerant crops and climate-smart farming techniques.
- **Water-Food-Energy Nexus:** Recognising inter-connectedness of water, food, & energy security, and adopting integrated management approaches.

- ❑ **Equity and Inclusion:** Equal access to water and food for all, particularly vulnerable populations, and participatory decision-making processes.

Way Forward for Climate Resilience and sustainability of resources

- ❑ **Water Resources Infrastructure Development and Asset Management**
 - Enhancing water conservation and harnessing both surface water and groundwater;
 - **Creation of appropriately-sized water resources storage infrastructure and artificial recharge of groundwater;**
 - **Inter / Intra basin transfer of waters from the surplus to the deficit basins;**
 - Lining of canals to increase irrigation efficiency by reducing seepage losses in the conveyance systems.
 - Expansion of water resources infrastructure to meet the agricultural water requirements.
 - Maintenance of existing water resources infrastructure for enhanced efficiency to serve the humanity longer, including adopting Dam and Network Safety protocols.
 - **Adequate and sustained investment for developing water resources infrastructure, as well as, maintaining the existing infrastructure.**
- ❑ **Technological Development and Scientific Innovations**

The adoption of latest technology, modelling systems, and communication network will help in managing the growing water and food demands:

- **Promoting Micro-irrigation Systems (Drip and Sprinkler Systems)** to increase water-use efficiency in irrigation;
- Using **Pressurised Irrigation Network (PIN)** to reduce seepage and evaporation losses;
- Promoting **Smart and Digital Agriculture:** Encourage the use of precision agriculture technologies, such as precision irrigation and crop monitoring, to optimize water use and crop yields. Use of advanced technologies such as IOT sensors, drones, and data analytics to optimise crop-yields;
- Deployment of **Canal Automation** - coupled with AI&ML driven tools - to optimise water scheduling and reduce wastage
- **Seasonal Weather Forecasts** using process-based models or AI&ML based models for advance preparations and mobilisation;



- **Big data analytics** can be used to analyse large datasets on climate, soil, and crop yields, enabling farmers to make data-driven decisions about irrigation and crop management.
- Supporting **water productivity enhancement** (Use of High yielding variety seeds);
- Use of alternative **non-conventional resources for irrigation** and horticulture e.g. grey water, wastewater, desalinated water, etc.
- **Recycle, Reduce, and Reuse** of water;
- Sustainable **region-specific cropping pattern;**
- Promote the use of **drought-tolerant and climate-resilient crops** to reduce water requirements and enhance food security. Crop selection can help farmers adapt to changing climate conditions and reduce the risk of crop failure.;
- **Land preparation and soil health monitoring** using Satellite Remote Sensing (SRS) & drones. Promote soil/water conservation agriculture practices, such as mulching and cover cropping, to reduce soil erosion and enhance water retention. Conservation agriculture can improve soil health, reduce erosion, and increase water availability;
- **Use of renewable energy for sustainability of irrigation.**

❑ **Water Governance**

Institutional reforms for management of water resources with river basin as a hydrological unit. The reforms will include

- **Creation of River Basin Authorities**
- **Trans-boundary Water Cooperation,** Data, information, and knowledge sharing are critical for promoting best water resources management practices. Governments, international organizations, and civil society can:

- ❖ Establishment of reliable and scientific database related to water demand, usage, and forecast. Seamless sharing of data is necessary for ensuring transboundary cooperation among the co-basin states / countries
- ❖ Sharing Knowledge and Expertise on best water resources management practices, climate-resilient agriculture, and water management.
- ❖ Collaboration on Research and Development in best irrigation practices, climate-resilient agriculture, and water management.
- ❖ Technical and Financial Assistance to countries and farmers to adopt best irrigation practices and climate-resilient agriculture.
- Formation and promotion of **Water Users' Associations and Participatory Irrigation Management**
- **Incentives for adopting best practices** to farmers, such as, subsidies for drip irrigation systems, solar pumps, and precision agriculture technologies.
- **Auditing and Accounting of Water**
- **Gender responsive water policies and management**

❑ Policy Support

Develop, review, and implement policies that support the adoption of best irrigation practices, climate-resilient agriculture, and water conservation.

- **Alignment of appropriate water policies with UN Sustainable Development Goals relevant to water i.e. SDG 6.4.1 and SDG 6.4.2**
- Adopt **Integrated Water Resources Management (IWRM)** approach for sustainable development and optimal utilization of water resources
- Review the **Irrigation Water Pricing Policy** for sustaining the water resources infrastructure
- **Promoting risk management approaches** including crop insurance
- Alignment of water policy with policies of other sectors
- **Integrated irrigation and drainage management**
- Formulation of drought resilient and flood mitigation policies including proper O&M of water resources systems

- Formulation of Climate Change adaptation strategies
- **Maintaining balance between development and environment**

❑ Information, Knowledge, and Technology Transfer

The dissemination of best practices for optimal utilisation of water resources needs to be promoted by:

- Providing knowledge sharing platforms for water resources management, irrigation and drainage professionals
- Promoting regional cooperation
- Dissemination of data, information, tools, knowledge, and know-how among all stakeholders

❑ R&D, Capacity Building and adequate funding

- Stakeholder Engagement: Engage with stakeholders, including farmers, water managers, policymakers, and civil society organizations, to promote best irrigation practices and climate-resilient agriculture.
- Investing in R&D for irrigation not only addresses immediate agricultural challenges but also builds resilient systems for future global food demands.

Engage with stakeholders, including farmers, water managers, policymakers, and civil society organizations, to promote best irrigation practices and climate-resilient agriculture.

- Adequate funding mechanism required to ensure timely O&M of existing irrigation infrastructure.

SUMMING UP

Sustainable climate resilient best irrigation practices based on equity & inclusion, trans-boundary & regional cooperation, adoption of latest technology

ICID World Declaration

& scientific innovations, adequate funding support, robust governance, stakeholder & community participation are essential for ensuring water and food security in an environmentally sound manner.

We, therefore, call for joint efforts to achieve a "water secure world free of poverty and hunger" through sustainable water development and management

Water, food, and energy security are inter-linked, hence may be managed adopting a holistic approach and ensuring environmental sustainability.

- cooperation among all stakeholders for the development and management of water resources
- Empowering women and youth in water management
- Increase in water storage and irrigation infrastructure and adopting dam safety protocols
- Promoting use of non-conventional water resources for irrigation and horticulture
- Adoption of latest technologies in irrigation

water management to improve water use efficiency and increase crop productivity

- Reviewing the policy for pricing of irrigation water to recover the O&M costs to ensure the sustainability and longevity of the irrigation infrastructure,
- Updated guidelines, and protocols may be aligned with UN SDGs and addressing the concerns related to climate change in an environmentally sustainable manner.
- Funding agencies to prioritise and support countries requiring development of water resources infrastructure

By adopting this declaration, we can work together to ensure water, food, and energy security for all, while promoting sustainable water management and climate-resilient agriculture practices.

The organisations supporting this declaration commit to collaborate with all partners and stakeholders that share this common vision.

Secretary General, ICID



New Delhi, 24 June 2025

President, ICID

Supported By:



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***Empowering farmlands through
engineered irrigation – Delivering
reliable and efficient irrigation
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Irrigation Service plays a crucial role in modern agriculture ensure timely supply of water to the crops.

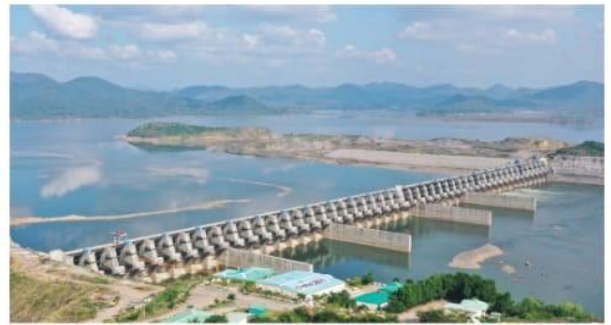
MEIL provide irrigation and lift scheme services involves planning, Design ,Installation and maintenance of the system that deliver water to agricultural lands all over the country.

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Impact of Smart Irrigation on Coconut and Mango Farming*

Abstract

This case study examines the implementation of smart irrigation systems at AKR Farms, Coimbatore, Tamil Nadu, and their transformative impact on mango and coconut farming. Traditional irrigation methods in both crops suffer from water inefficiency, inconsistent nutrient delivery, high labor dependency, and variable yields due to reliance on experience-based practices. By deploying sensor-based automated systems with real-time soil moisture monitoring, mobile control, and precision fertigation, the farm achieved substantial improvements in resource efficiency, crop uniformity, productivity, and profitability. In coconut farming, a controlled comparative study across identical 3-acre plots demonstrated a 53.1% reduction in water usage, a 59.1% average increase in yield per tree, and a 99% reduction in labor costs over six harvest cycles. Mango cultivation benefited from qualitative enhancements including uniform tree growth, improved fruit quality, and reduced operational variability. The findings highlight smart irrigation as a scalable, sustainable solution that balances economic gains with environmental stewardship in modern Indian horticulture.

Background

Mango and coconut farming are among India's most economically vital horticultural practices, particularly in regions like Coimbatore. For generations, irrigation decisions in mango orchards and coconut groves have relied on traditional observation—visual cues such as soil dryness, leaf condition, and weather patterns—along with seasonal intuition. While this approach embodies deep agricultural knowledge, it frequently results in uneven watering, over- or under-irrigation across different parts of the farm, inconsistent root development, and suboptimal nutrient uptake. Fertilizer application remains largely manual and bulk-based, leading to wastage, higher input costs, and potential soil degradation. Rising water scarcity, unpredictable climate patterns, and escalating labor costs further exacerbate these challenges, limiting overall farm efficiency despite substantial effort and investment.

Semi-automated irrigation systems introduced timers and basic controllers, enabling more consistent scheduling and reducing constant manual oversight. However, these systems still operate on fixed schedules and cannot adapt to real-time variations in soil moisture, weather, or crop-specific needs.



Smart irrigation systems mark a significant advancement by integrating soil moisture sensors, automated valves, controllers, and mobile-based monitoring platforms. Water and nutrients are delivered precisely according to actual field conditions rather than predetermined timetables. This dynamic, data-driven approach conserves water, enhances fertilizer efficiency through automated fertigation, and minimizes labor requirements. Farmers can monitor and control operations remotely via mobile applications. Solutions such as those developed by Mobitech Wireless Solution Private Limited (e.g., DCON Ag Air) are designed to be practical and user-friendly, bridging advanced technology with real-world farming needs.

Water usage (Liters per acres per day)

Day	Non-Automated Farm (Liters)	Automated Farm (Liters)	Water Saved (%)
1	20,800	9,750	53.1%
2	20,800	9,750	53.1%
3	20,800	9,750	53.1%
4	20,800	9,750	53.1%
5	20,800	9,750	53.1%
6	20,800	9,750	53.1%

At AKR Farms, smart irrigation was implemented across mango and coconut sections to address these longstanding limitations and promote precision agriculture. The technology enables a shift from reactive, experience-based practices to proactive, optimized management, supporting healthier crop growth, higher yields, and long-term sustainability.



*Mobitech Research Team < <https://mobitechwireless.in/> >

Impact of Smart Irrigation on Coconut & Mango Farming

Return of Investment (ROI) Analysis

Year	Investment (₹) per Acre	Annual Savings (₹)	Profit from Extra Yield (₹)	Total ROI (₹)
1	60,000 - 70,000	2,64,000	1,95,000	3,59,000 - 3,69,000
2	0	2,64,000	1,95,000	5,58,000 - 5,68,000
3	0	2,64,000	1,95,000	8,22,000 - 8,32,000

Methodology

The study was conducted at AKR Farms, Coimbatore, which has cultivated both mango and coconut for over a decade. For coconut farming, a rigorous comparative methodology was employed: two identical 3-acre sections of the farm were selected—one equipped with the smart irrigation system (automated drip irrigation with soil moisture sensors, controllers, and network connectivity) and the other continuing with traditional non-automated methods.

Data collection occurred over six harvest cycles (approximately 40-day intervals). Water consumption was measured daily using water flow meters (liters per acre per day). Yield was assessed by counting coconuts per tree per harvest cycle. Labor costs, maintenance expenses (including SIM recharge for the automated system), and coconut quality parameters (size uniformity, taste, and nutrient content of coconut water) were also recorded. Financial parameters, including return on investment (ROI), were tracked based on a one-time installation cost of ₹60,000–70,000 per acre.

For mango farming, the assessment was observational and implementation-based, drawing on before-and-after comparisons following deployment of the same smart irrigation technology. Parameters evaluated included irrigation consistency, fertilizer efficiency, labor requirements, crop uniformity (tree growth, flowering, fruit setting, size, and quality), and overall operational impacts. No separate quantitative control plot data were available for mango; benefits were derived from field observations and system performance metrics. Both crops utilized the same core smart irrigation framework, allowing cross-crop insights into precision agriculture.



Impact of Smart Irrigation on Coconut & Mango Farming

Results

Smart irrigation delivered clear advantages over traditional and semi-automated methods across both crops. The following comparative overview applies generally to the systems implemented at AKR Farms:



Comparative Overview of Irrigation Methods

Parameter	Traditional Method	Semi-Automated System	Smart Irrigation System
Irrigation Control	Manual, experience-based	Time-based scheduling	Sensor-based, real-time
Water Usage	High and inconsistent	Moderately controlled	Optimized and need-based
Fertilizer Application	Manual and uneven	Manual with planning	Automated precision dosing
Labor Requirement	High	Moderate	Low
Monitoring	Field presence required	Limited monitoring	Remote via mobile
Crop Growth	Uneven	Improved	Uniform and healthy

Operational Impact

Aspect	Traditional	Semi-Automated	Smart Irrigation
Water Efficiency	Low	Medium	High
Fertilizer Efficiency	Low	Medium	High
Human Error	High	Reduced	Minimal
Time Required	High	Moderate	Low
Productivity	Moderate	Good	High

Return on Investment (ROI) Snapshot

Cost Factor	Traditional	Semi-Automated	Smart Irrigation
Water Cost Impact	High	Medium	Low
Fertilizer Expense	High	Medium	Reduced
Labor Cost	High	Moderate	Significantly Low
Operational Efficiency	Low	Moderate	High
Overall Profitability	Limited	Improved	Strong Growth

Coconut-Specific Quantitative Results

1. Water Usage (Liters per Acre per Day) – Consistent across all six harvest cycles

Harvest Cycle	Non-Automated Farm	Automated Farm	Reduction (%)
1–6 (Average)	20,800	9,750	53.1

2. Yield Improvement (Coconuts per Tree per Harvest Cycle)

Harvest Cycle	Non-Automated Farm	Automated Farm	Increase (%)
1	28	44	57.1
2	26	42	61.5
3	30	46	53.3
4	27	45	66.6
5	29	43	48.2
6	25	42	68.0
Average	27.5	43.7	59.1

3. Impact on Coconut Quality and Market Value

Coconuts from the automated section showed superior taste and nutrient quality in coconut water due to consistent moisture levels. They were larger and more uniform in size, fetching a premium market price of approximately ₹5 more per coconut compared to those from the non-automated field.

4. Labor Cost Savings

Farm Type	Labor Requirement	Monthly Labor Cost (₹)	Additional Expenses (₹)	Total Monthly Cost (₹)
Non-Automated	2 laborers (weekly thrice)	18,000	4,000	22,000
Automated	None (except SIM recharge)	0	220	220

The smart irrigation system resulted in a 99% reduction in labor costs.

5. Return on Investment (ROI) Analysis

The one-time investment for the smart irrigation system was ₹60,000–70,000 per acre.

- ♦ **Year 1:** Full recovery within 12–16 months through labor savings (₹22,000/month), reduced water and fertilizer costs, and additional income from increased yield.
- ♦ **Year 2:** Pure profit phase with continued annual savings and extra yield income.
- ♦ **Year 3:** Cumulative financial gain exceeded ₹8 lakh per acre.

The investment proved highly profitable, delivering strong long-term returns.

In mango farming, results were observed qualitatively but followed the same efficiency pattern: uniform tree growth, better flowering and fruit setting, improved fruit size and quality, and greater yield predictability, along with significant labor and resource savings.



Conclusions

The implementation of smart irrigation at AKR Farms demonstrates a clear pathway toward modern, efficient, and sustainable horticulture for both mango and coconut crops. By moving beyond experience-based and schedule-driven methods to sensor-driven, real-time precision agriculture, the farm achieved substantial reductions in water and fertilizer use, near-elimination of labor-intensive tasks, and marked improvements in crop quality and yield—particularly evident in the 53.1% water savings and 59.1% yield boost in coconuts.

These outcomes translate directly into higher profitability (with rapid ROI) and reduced environmental impact through lower groundwater stress and minimized nutrient runoff. Smart irrigation empowers farmers with data-driven decision-making, scalability, and resilience to climate challenges.

Future scope includes further research on soil health improvements, integration with AI-based weather forecasting for even more adaptive scheduling, and expansion to additional crops. Overall, the AKR Farms case study confirms that smart irrigation is not merely a technological upgrade but a strategic investment essential for the long-term viability and competitiveness of Indian fruit farming. Wider adoption promises enhanced productivity, sustainability, and economic prosperity for farmers across the region.

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Application of Remote Sensing, AI & ML in Smart Irrigation

Madhuri Rampalli¹, and Nikhilesh Kumar²

Abstract

Smart irrigation systems harness an array of advanced technologies to deliver integrated decision support frameworks. These systems synergistically combine precision agriculture, remote sensing, artificial intelligence (AI), and machine learning (ML) to develop robust decision-support tools tailored for irrigation management. A flagship product in this domain, aquaIRRIGATION, optimizes water usage, enhances crop health, and bolsters climate resilience across canal-command regions and other irrigated landscapes. The advent of digital technologies has unlocked transformative opportunities in the water, agriculture, and irrigation sectors. By leveraging real-time data analytics, predictive modeling, and geospatial insights, smart irrigation addresses critical challenges such as water scarcity, inefficient resource allocation, and climate variability. Precision agriculture techniques enable site-specific crop management, while remote sensing provides high-resolution monitoring of soil moisture, vegetation indices (e.g., NDVI, NDWI), and evapotranspiration patterns. AI and ML algorithms further refine these inputs through data-driven forecasts, anomaly detection, and optimization of irrigation scheduling minimizing waste and maximizing yield potential. The primary objectives of this initiative are threefold: to elevate agricultural productivity, augment farmer incomes, and foster job creation alongside entrepreneurial opportunities. In canal-command areas, where traditional irrigation often suffers from over- or under-watering, aquaIRRIGATION integrates IoT sensors, satellite imagery, and hydrological models into a unified platform. This facilitates adaptive, demand-responsive irrigation, reducing water footprints and mitigating risks from erratic monsoons or droughts. On the other hand, fieldWISE enables scientific crop planning, verified farmer registries, satellite validated records, targeted scheme disbursement and evidence-based policy decision. Ultimately, such systems promote sustainable water resource management, aligning with global sustainability goals like the UN Sustainable Development Goals (SDGs 2, 6, and 13). By bridging technological innovation with on-ground implementation, smart irrigation paves the way for resilient agroecosystems, particularly in water-stressed regions like India.

Keywords: Remote Sensing, AI and ML, IoT, smart irrigation, aquaIRRIGATION, fieldWISE, SDG Goals

1. Introduction

The sectors of water, agriculture and environment face a major challenge. There exists continuous pressure for improvement of agricultural water productivity, the increase in growing population and meeting demands from other sectors. According to FAO 2021 the need for Agri- food systems is to be more resilient to shocks and stresses, with a focus on diversification to build resilience across relevant sectors and layers of government institutions. It is estimated that with an increase in global population the demand for food increases and this creates demographic and environmental pressures for the Agri food systems. It is also estimated that to cater to the need for food to such a population, to reach 9.7 billion in 2050, agriculture may need to produce 40-54% more food, fuel and feed than in the present year. This would create huge pressure on the earth's resources. Hence an efficient smart irrigation system is the need of the hour which comprises AI, remote sensing and machine learning.

In addition to this, the last milestone such as farmers' needs is to be integrated into markets so that they are financially secured, informed supply demand and timely quality inputs. These will help farmers' life prosperously, and it will also help in paying the water fees which maintains the infrastructure. Considering the life cycle of agriculture, irrigation and productivity, this paper focuses on smart irrigation which takes into consideration remote sensing, AI and Machine learning which will help in better crop productivity, good health and well-being of the people. These are the need of the hour as the use of technology will help farmers to become economically stable by which they can be in a position to implement the new technology and bring more productivity to the farms.

2. Literature Review

The smart irrigation system aims to take care of both under and over irrigation, the main purpose of which is to enhance agricultural productivity and reduce environmental impact of crops at the same time. There have been several

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Application of Remote Sensing, AI & ML in Smart Irrigation

researches which focused on agricultural production, agricultural development and generation. Based on these principles, technological development is required by using Remote sensing, GIS, AI and ML. Several studies are focused on these technologies. Manivasagam (2024) studied remote sensing of irrigation and found that irrigation has grown exponentially over the last two decades, indicating a growing interest in this field. Chavan et al. (2025) studied smart irrigation systems and found that recent systems integrate features such as soil moisture monitoring, automatic control mechanisms to optimize water distribution and improve agricultural productivity. Kaushik and Karan (2025) validated the potential of AI-driven systems to support resilient, and data informed agricultural practices that align broader goals of environmental sustainability and food security. There are several methods which focus on traditional irrigation which leads to wastage of water and uneven distribution (Vekariya et al. 2022; Patel et al., 2023a, Rank et al., 2023b; Vekariya et al., 2023). Hence the fields with smart sensor which monitor soil moisture, weather conditions and crop health transmits data through AI algorithms help in analyzing it in real - time, determines the precise water needs specific for a particular plant at a given moment (Patel and Rank, 2020; Vekariya et al., 2022; Rank et al., 2023b; Vekariya et al., 2023). AI helps in providing water in an optimum manner thereby ensuring every plant is receiving the optimum amount it needs. This type of irrigation helps with optimized resource utilization. Indian agriculture faces hurdles where limited access to technology, need for robust data infrastructure and high investment costs are some of the main challenges. To bridge this gap, AI powered irrigation helps in empowering farmers, food security and the thriving agricultural sector for India (Rank 2024). Younes et al. (2024) in his systematic literature reviewed in Smart Agricultural Technology and synthesized how machine learning techniques are used to optimize irrigation scheduling, water use efficiency, and crop yield in smart irrigation systems. It highlights common ML

models, identifies gaps such as data scarcity and limited generalizability, and calls for more interpretable, scalable, IoT-integrated models for real-time irrigation management. Takale et al.(2024) proposed a machine-learning-based smart irrigation system that uses sensor data to automate irrigation scheduling and improve water-use efficiency. The model dynamically adjusts irrigation according to soil moisture, weather, and crop needs, reducing water wastage. Their work demonstrates the feasibility of low-cost, ML-driven irrigation control for small-scale and precision agriculture. From the above studies it can be inferred that for a smart irrigation system, remote sensing, machine learning and artificial intelligence play a very significant role. The present study takes advantage of all three technologies into consideration with an efficient irrigation system. The methodology of the present study is discussed in the following sections:

3. Methodology

The methodology consists of amalgamation of remote sensing, AI and machine learning in smart irrigation (Figure 1):

- Providing remote sensing data in the form of satellite imagery which are time series and high-resolution imageries
- Integrating AI with the above imageries and climate data for preparation of hyperlocal weather models thereby helping with smart irrigation scheduling
- Providing ML models that learn from historical and real-time data to refine irrigation recommendations, thereby enabling automated irrigation management.
- Integrating remote sensing, AI/ML, IoT, and canal-command operations to enhance irrigation requirement estimation and automate water distribution management.

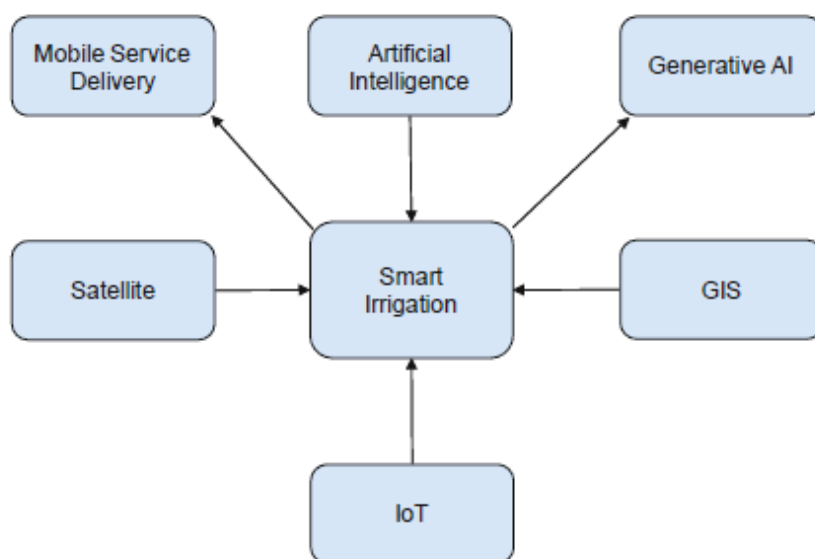


Figure 1 Smart Irrigation Flowchart

4. Methods

4.1. Role of Remote Sensing in AI-Driven Precision Irrigation

Remote sensing forms the cornerstone of aquaIRRIGATION and fieldWISE platform for climate-resilient water resource management, providing high-resolution, multi-temporal data on crops, soil moisture, and evapotranspiration (ET) across vast canal-command regions in India. By integrating satellite observations with physics-guided machine learning models, the present system aquaIRRIGATION enables real-time monitoring, predictive analytics, and equitable water allocation which is critical for optimizing reservoir operations and minimizing flood risks in monsoon-dependent agroecosystems.

4.1.1 Satellite-Based ET Estimation and Crop Stress Detection

Time-series optical data from Sentinel-2 and Landsat-9 are used to derive vegetation indices such as NDVI and NDWI, while thermal bands support evapotranspiration (ET) estimation. Furthermore, microwave backscatter

observations from Sentinel-1 provide all-weather monitoring capability by penetrating cloud cover and capturing vegetation structure and soil moisture information.

The aquaIRRIGATION platform utilizes hybrid AI/ML models to derive actual ET at plot-level granularity. This approach enables the detection of crop water stress zones and flags irrigation deficits in real time based on crop stage and crop coefficient (Kc) factors to estimate stage-wise water requirements for individual crops. The difference between crop water requirement with respect to the water available helps in water budgeting. For instance, pilot studies conducted in the Godavari Basin demonstrated that the aquaIRRIGATION platform reduced over-irrigation by identifying stress hotspots.

In addition, fieldWISE supports farm-level crop monitoring, including crop-sown area tracking and bund boundary detection (Figure 2). It also facilitates week-by-week comparison of satellite-derived observations with reported sown-area statistics (Figure 3). Multi-temporal analysis further enables season wise crop type identification for paddy, maize etc.

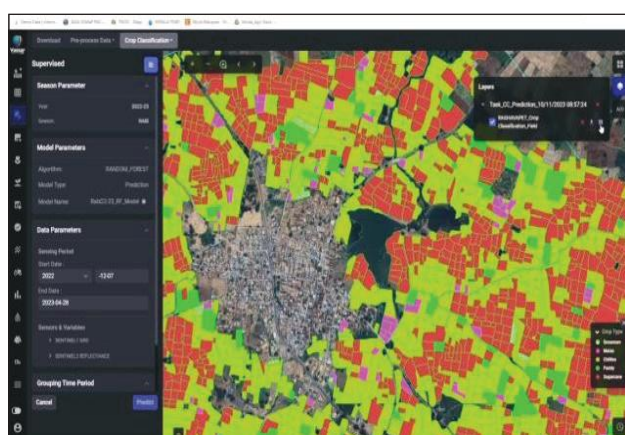


Figure 2. Crop classification



Figure 3. Bund boundary detection

4.1.2 Cropping Pattern Mapping

Using commercial high resolution and freely available satellite sources like Sentinel-1 and Sentinel-2, enables precise supervised classification using AI algorithms. These approaches achieve over 80-90% overall accuracy in delineating cropping patterns, validated through cross-validation with ground-truth data from field surveys.

Cropping intensity and rotation patterns are further extracted via temporal phenology analysis, which tracks vegetation indices (e.g., NDVI, NDWI, LSWI) across growth cycles to distinguish single-crop from double-crop parcels reliably. These spatially explicit insights underpin zonal water budgeting, where irrigated-to-rainfed area ratios guide equity-oriented irrigation scheduling, ensuring tail-end farmers receive proportional water supplies.

4.2. AI-Driven Predictive Irrigation Modeling

The aquaIRRIGATION platform systematically integrates multiple high-resolution data streams, including near-

real-time meteorological forecasts, satellite-derived evapotranspiration (ET) estimates, and comprehensive hydro-climatic observations, into advanced predictive irrigation modeling frameworks. Within these frameworks, hyperlocal weather and ET models employ sophisticated AI algorithms to seamlessly fuse short-term probabilistic forecasts of rainfall intensity, temperature fluctuations, and relative humidity levels with precise satellite-based ET measurements. This fusion process generates highly granular, field-specific irrigation schedules that are fully attuned to individual crop growth stages, explicitly detailing both the optimal timing for water application and the precise volumes required for each field. Consequently, these predictive models effectively anticipate future water availability scenarios while proactively identifying potential risks associated with over-irrigation practices and waterlogging conditions, thereby enabling significant reductions in overall water wastage across the irrigation network.

Application of Remote Sensing, AI & ML in Smart Irrigation

To ensure model reliability, the platform incorporates rigorous validation protocols, benchmarking AI-driven predictions against ground-truth data and historical irrigation records from diverse agro-climatic zones in India. Empirical results from pilot deployments in Telangana and other states demonstrate water savings alongside yield improvements. Furthermore, by leveraging cloud-based digital twin simulations, aquaIRRIGATION scales seamlessly to basin-level operations, integrating reservoir inflow forecasts with canal distribution networks to optimize conjunctive use of surface and groundwater resources. This holistic approach not only mitigates climate variability risks but also aligns with national priorities for sustainable agriculture under India's National Mission for Sustainable Agriculture (NMSA).

4.2.1 Surface Wetness and Crop Monitoring

aquaIRRIGATION and fieldWISE leverage satellite data to track these factors precisely.

Surface Wetness Monitoring

These platforms use open-source satellite data, including microwave and optical imagery, to assess surface wetness across canal command areas. This detects over-irrigation or under irrigation, waterlogging enabling targeted interventions to minimize wastage. Indices like LSWI help map moisture distribution in near real-time, supporting equitable water allocation.

Crop Monitoring Techniques

The systems monitor crop health via remote sensing indices such as NDVI and LSWI for growth. AI-driven crop classification identifies types and phenology, integrating with soil moisture sensors and weather forecasts. This generates advisories for irrigation timing based on crop water demand.

Irrigation Applications

In aquaIRRIGATION, surface wetness data combines with satellite data, IoT sensors for real-time canal monitoring and digital twins of networks. It optimizes schedules, predicts needs two weeks ahead, and assesses performance to boost yields while reducing waste. fieldWISE extends this to rainfed areas, estimating stress for precise advisories.

4.2.2 Water Demand Analysis and Scheduling

The platform's computational core calculates precise, crop-specific water demand profiles by integrating key variables such as dominant crop type, current phenological growth stage, and prevailing local weather conditions into sophisticated demand estimation models. Irrigation officers are empowered to configure customized water release cycles, typically spanning 10 to 15 days in duration, which are meticulously aligned with established cropping season timelines and corresponding crop growth phases. Interactive KPI-based dashboards further support decision-making by continuously tracking critical performance metrics, including actual water requirements versus released volumes, cumulative seasonal water supply dynamics,

and overall irrigation efficiency ratios, thereby informing evidence-based scheduling adjustments.

4.2.3 Performance Monitoring and Optimization

The integrated system maintains comprehensive, real-time monitoring of all irrigation activities, canal network operations, and broader water utilization patterns through an extensive suite of key performance indicators (KPIs), prominently featuring metrics such as crop yield outcomes and water use efficiency ratios. Field engineers leverage a comprehensive array of optimization tools designed specifically for proactive maintenance scheduling, real-time operational adjustments, and efficient grievance resolution workflows, ensuring sustained system performance and responsiveness to operational challenges.

4.2.4 Digital Twin of Command Areas

The aquaIRRIGATION platform comprises comprehensive digital twins of canal command regions through systematic fusion of multi-modal data sources, comprising high-resolution satellite imagery, real-time canal release measurements, and observations from distributed sensor networks across the irrigation infrastructure. These digital twins provide dynamic, virtual representations that accurately mirror the physical characteristics, hydrological processes, and operational dynamics of entire command areas, extending from headworks to tail-end fields.

This digital twin framework enables simulation-based optimization of water release cycles by modeling intricate water flow dynamics, infiltration patterns, and distribution inequities across diverse operational and environmental scenarios. Specifically, predictive simulations optimize release timing, volumetric allocations, and flow routing to enhance tail-end water equity, thereby ensuring more equitable distribution of irrigation resources to downstream fields that frequently experience shortages due to upstream withdrawals.

The embedded monitoring capabilities within the digital twin facilitate continuous, granular visualization and analysis of water flow progression throughout the canal command area. This encompasses tracking of volumetric flow rates at critical control structures, detection of conveyance bottlenecks or leakages, quantification of seepage losses along canal segments, and spatiotemporal mapping of moisture propagation from main canals through distributaries to field outlets. Such detailed monitoring helps in equipping irrigation managers with actionable insights to support proactive interventions, adaptive release adjustments, and equitable water governance within heterogeneous command landscapes.

4.3 Machine Learning for Irrigation Control

Machine learning (ML) has emerged as a powerful tool for improving irrigation decision-making by integrating historical observations with near real-time environmental and crop data. In precision agriculture, these models support dynamic irrigation recommendations and, in advanced implementations, by automated control of

irrigation systems. By doing so, ML-based approaches can substantially improve water use efficiency, reduce unnecessary applications, and enhance crop productivity under variable climatic and soil conditions.

4.3.1 Soil Moisture and Crop Water Demand Models

ML-based soil moisture and crop water-demand integrate multiple data streams to estimate current water deficits and project future irrigation needs. These inputs generally include in-situ soil moisture sensor readings, satellite-derived vegetation and water-stress indices crop growth-stage information, meteorological variables, evapotranspiration estimates, and soil physical properties. By learning from these heterogeneous datasets, the models generate reliable forecasts of crop water demand across timescales, while crop health is also monitored.

These models are especially useful for capturing spatial and temporal variability in irrigation requirements within individual fields or across larger agricultural landscapes. When combining weather forecasts and crop phenology data, they give dynamic irrigation schedules. This facilitates precise water application, reduces over-irrigation, and supports adaptive irrigation management under fluctuating climatic and hydrological conditions.

4.3.2 Anomaly Detection and Stress Identification Models

In addition to estimating irrigation demand, machine learning (ML) techniques are increasingly being applied to detect anomalies associated with crop stress and irrigation inefficiencies. Researchers and farmers alike rely on these methods to monitor fields more effectively. The algorithms used excel at analyzing temporal patterns derived from various data sources. For instance, they process time-series data from soil moisture sensors, weather stations, and remote sensing imageries (both optical and microwave/SAR). By doing so, they identify early signs of irrigation requirement with high precision.

Early detection empowers irrigation systems to respond adaptively in real time. Systems can automatically adjust application timing, volume, or frequency based on the observed stress signals from ML models. Farmers no longer need to wait for manual inspections or crop failure indicators. In this way, ML-enabled anomaly detection contributes significantly not only to improved water management but also to overall risk reduction and yield stabilization across seasons. Such advancements are increasingly relevant for sustainable agriculture today. In regions facing water scarcity, timely intervention becomes essential for maintaining crop health. At the same time, they help conserve limited water resources by minimizing waste from over or under irrigation. This work helps in developing scalable solutions for global farming challenges.

4.4. Integration with IoT and Canal-Command Operations

This integrated platform exemplifies a tightly coupled architecture that synergistically fuses remote sensing-derived data with artificial intelligence/machine learning

(AI/ML) algorithms and Internet of Things (IoT) infrastructure to optimize canal-command operations. This multi-layered approach addresses longstanding challenges in irrigation efficiency, such as spatial heterogeneity in water demand and temporal mismatches in supply scheduling.

At the core of this integration lies the bidirectional data fusion between field-level IoT sensors and satellite observations. In-situ sensors, including soil moisture probes, automated weather stations measuring evapotranspiration (ET) rates, and canal flow meters, provide high-frequency, ground-truth data. These are seamlessly ingested into the platform via edge computing nodes and fused with multi-spectral satellite imagery using advanced data assimilation techniques, such as physics-guided neural networks. This fusion not only calibrates irrigation demand models reducing root-zone soil moisture estimation errors from but also validates predictive models for crop water stress indices. Consequently, the system dynamically refines hydraulic routing models across canal networks, enabling precise forecasting of seepage and evaporation losses.

Complementing this, the platform's AI/ML engine drives canal-release optimization at granular levels: distributary, minor, and sub-minor canals. Real-time visualizations rendered via interactive GIS dashboards display current water levels, flow velocities, and gate statuses, derived from SCADA (Supervisory Control and Data Acquisition) integrations. Machine learning models, trained in historical discharge data, crop phenology, and demand forecasts, generate prescriptive recommendations for optimal release volumes and timings. For instance, optimized gate operations to minimize conveyance losses while ensuring equitable distribution to tail-end farms, mitigating inequities rooted in rotational scheduling. This results in enhanced last-mile equity, with reported reductions in water theft and over-irrigation.

4.5 Practical Impacts on Vassar Labs' Operational Systems: Integration of Irrigation with agriculture for better yield and productivity

In real-world deployments across Indian canal-command regions such as those managed by the Andhra Pradesh and Telangana irrigation departments this technology stack has demonstrated transformative outcomes, including substantial water conservation and efficient water use. These impacts stem from transitioning from rigid, calendar-based irrigation regimes to adaptive, data-driven precision watering protocols.

Quantitatively, operational pilots have achieved 20–35% reductions in total water withdrawals compared to conventional flood irrigation baselines, without compromising crop yields. The system's stakeholder-centric design amplifies adoption: government water-resource managers access enterprise-grade dashboards for network-wide monitoring and scenario planning (e.g., drought-response simulations); Agri-enterprises leverage API integrations for supply-chain optimization; and smallholder farmers receive hyper-local mobile advisories via SMS or vernacular apps, and alerts. This democratizes precision

agriculture, fostering resilience in climate-vulnerable regions and scalable pathways for Integrated Water Resources Management (IWRM).

In addition to this, Farmers receive regular irrigation advisories throughout the season, along with fortnightly crop health updates that include fertilization recommendations. They also get farm-specific pest forewarnings up to two weeks in advance. An AI-powered disease detection system provides remedial advisories as needed. Additionally, farmers enjoy exclusive access to live market prices, a buyer connection platform via an e-marketplace, streamlined applications for relevant government schemes, and options to rent farm machinery.

5. Conclusion

This paper demonstrates significant advancements in precision agriculture and water management. These technologies integrate satellite data, predictive modeling, and IoT to optimize irrigation scheduling, reduce water wastage by 15-35%, and enhancing crop yields in Indian canal-command areas. The key contributions include remote sensing, which provides high-resolution vegetation indices (NDVI, NDWI) and ET estimates, fused with AI-driven hyperlocal weather models for real-time crop stress detection and equitable water allocation. ML models enable anomaly detection, digital twins of canal networks, and adaptive scheduling, addressing challenges like over-irrigation and tail-end inequities in regions such as Godavari and Narmada basins. Practical Impacts can be seen in the pilots in Telangana and other states which achieve water savings, while empowering farmers via mobile advisories and dashboards. Integration with SCADA and fieldWISE platforms supports policy goals like NMSA and SDGs 2, 6, 13 for sustainable agriculture.

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Quantification of Irrigation Over Non- Paddy Crops through the Combined Analysis of Observed Hydrologic Variables and Water Balance Model Simulations

Ms. Anni Maria Issac¹

Abstract

Irrigated agriculture accounts for 80–90% of water withdrawals in developing countries like India, making it the dominant anthropogenic influence on the terrestrial water cycle. Contemporary earth observation satellites enable high-frequency retrieval of hydrologic variables such as evapotranspiration and soil moisture. Integrating these datasets with soil water balance models enables the quantification of irrigation inputs in data-scarce regions. This study presents a methodology to quantify irrigation-driven irrigation over non-paddy crops by integrating observed hydrologic variables with soil water balance modelling. Irrigation events were detected using time series analysis of soil moisture and rainfall. The irrigation is quantified by inverting the water balance equation, which relates changes in root-zone soil moisture to rainfall, runoff, evapotranspiration, and percolation. Runoff was estimated using a modified SCS-CN method incorporating antecedent soil moisture, evapotranspiration from observations, and percolation as soil moisture exceeding field capacity. The soil parameters in the model were calibrated to minimise the root mean square error (RMSE) between observed and simulated soil moisture, achieving an RMSE of approximately 0.01. Implementation of the approach using data from multiple flux towers showed irrigation estimates deviating by only ± 5 –10% from field-recorded values, depending on crop and soil type. Such retrieval of irrigation estimates is vital for evaluating efficiency, supporting sustainability-driven irrigation planning and water resource optimization.

1. Introduction

Quantifying the amount of water used for irrigation is generally more challenging than mapping the extent of irrigated areas alone. The ability to observe land surface

temperature from remote sensing has enabled the estimation of actual evapotranspiration (ET_{actual}), as demonstrated in studies (Mu et al., 2007; Mallick et al., 2007; Bezerra et al., 2015). Studies have employed the surface energy balance algorithm for land for mapping ET_{actual} , which is split into ET_{actual} induced by precipitation and ET_{actual} induced by irrigation (van Ekelen et al., 2015; Senay et al., 2016; Msigwa et al., 2021). The irrigation withdrawals were quantified as ET_{actual} induced by irrigation, after accounting for the irrigation system's conveyance and application efficiencies. Multiple studies have compared estimated ET_{actual} from Land Surface Models (LSMs) that do not incorporate irrigation with remotely sensed ET_{actual} . The excess ET_{actual} was quantified as irrigation (Hain et al., 2015; Pena Arancibia et al., 2016).

The quantification of irrigation from remote sensing-based soil moisture data involves inverting the soil water balance equation to estimate the amount of water entering the soil using soil moisture information as input. The estimated amount of water entering the soil in excess of the rainfall was quantified as irrigation. This approach was implemented on soil moisture data at multiple resolutions (Brocca et al., 2018; Jalilvand et al., 2019; Dari et al., 2020). An alternative method uses soil moisture predictions from land surface models that do not account for irrigated water, whereas satellite soil moisture retrievals do. The aggregated discrepancy between the satellite-observed soil moisture and the model predictions is quantified as the amount of irrigation water withdrawn (Zaussinger et al., 2019; Zohaib & Choi, 2019).

This study proposes a methodology for detecting and quantifying irrigation using a water balance approach was initially tested with point-scale data from flux tower observations. Flux towers provide high-frequency measurements of key hydrological variables such as



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evapotranspiration, soil moisture, and precipitation, enabling a detailed assessment of the water balance at a localized scale. By analyzing these observed data, the methodology was evaluated for its ability to capture irrigation signals and accurately quantify the applied water.

2. Materials and Methods

2.1 Data Used in the Study

An open-path eddy covariance (OPEC) flux tower system was installed at the Central Institute of Agricultural Engineering (CIAE) in Bhopal to monitor land-atmosphere interactions in a soybean-wheat cropping system. This site represents a typical rainfed agro-ecosystem in central India, characterized by black soil with a clayey texture, which influences water retention and surface energy fluxes.

The flux tower is equipped with an extended open-path eddy covariance system that includes an Integrated CO₂ and H₂O Open-Path Gas Analyzer and a 3-D Sonic Anemometer (IRGASON) to measure carbon fluxes and turbulence. Additionally, the setup comprises a net radiometer to monitor incoming and outgoing radiation, soil moisture and soil heat flux sensors to assess subsurface energy balance, and relative humidity and ambient air temperature sensors to capture microclimatic variations. The sonic anemometer provides high-frequency wind velocity data, essential for computing turbulent fluxes. This comprehensive instrumentation enables continuous monitoring of energy, water, and carbon exchanges between the land surface and the atmosphere, facilitating research on crop water use, evapotranspiration dynamics, and carbon fluxes in irrigated and rainfed agricultural systems.

The flux tower installation was designed to collect high-resolution observations of key land-atmosphere interactions, including evapotranspiration, CO₂ flux, net radiation, rainfall, wind velocity at three heights, soil moisture, and soil temperature at multiple depths (10 cm, 30 cm, and 60 cm), as well as soil heat flux, as illustrated in Figure 1. Data are recorded at 30-minute intervals, enabling the derivation of daily aggregated values that capture diurnal and seasonal variability effectively.

For this study, rainfall, surface soil moisture, and evapotranspiration data from the flux tower were utilized to analyze water balance dynamics over two distinct cropping seasons: the Kharif season (10th July – 15th October 2023) and the Rabi season (1st November 2022 – 21st March 2023). These datasets provide crucial insights into seasonal variations in soil water availability and crop water use, which are essential for understanding irrigation demands and optimizing water resource management in the region.

2.2 Methodology

Detecting irrigation activities using remotely sensed soil moisture data requires a clear separation of irrigation events from rainfall events. Following a rainfall event, the soil becomes wet and therefore the soil moisture increases. Similarly, during an irrigation event, the soil moisture will increase but with no or a decrease in rainfall. The

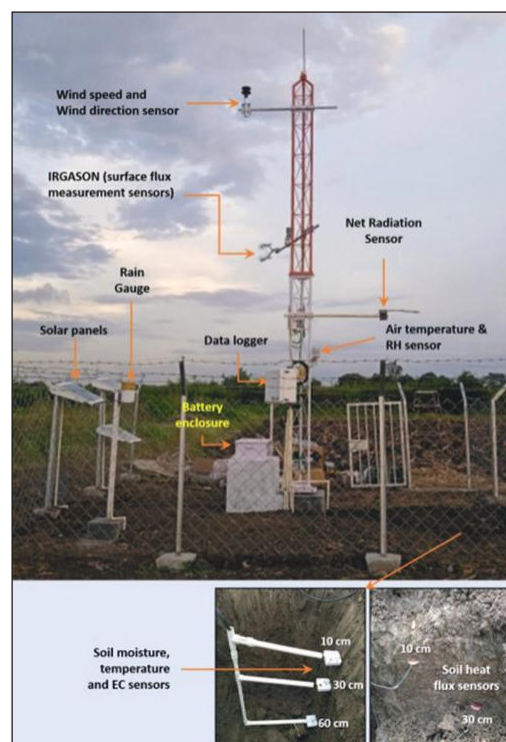


Figure 1. The OPEC flux tower with various sensors

quantification of irrigation for a non-paddy crop proposed in this study is based on water balance. Assuming a surface irrigation application, soil moisture is simulated using the water balance model. The change in soil moisture is simulated and estimated from the Water Balance Model (WBM) as rainfall in excess of runoff, percolation, and actual evapotranspiration. The runoff is estimated using the modified SCS curve number method, in which the curve number is adjusted for soil moisture conditions. Standard CN was modified to account for the moisture condition of the top soil layer using two dimensionless parameters (Hayashi et al., 2012). As seen in Figure 2, the WBM is executed for the non-irrigation weeks and the model parameters such as Curve Number, Field Capacity and Permanent Wilting Point are calibrated with observed soil moisture. Thereafter, the model is executed for the irrigation weeks using the calibrated parameters, with irrigation added as a forcing along with rainfall. The irrigation quantity is estimated iteratively until the root mean square error (RMSE) between observed and simulated soil moisture is less than 0.01.

3. Results and Discussion

Rabi season spanning from 1st November 2022 to 21st March 2023, is considered in this study. The season is divided into weeks.

Through similarity analysis of the soil moisture and rainfall time series, three distinct irrigation events were identified in the field using observed flux tower data. These irrigation occurrences were detected based on deviations in soil moisture trends that could not be attributed to natural rainfall patterns as seen in Figure 3. The identified irrigation periods are as follows:

Quantification of Irrigation Over Non-Paddy Crops

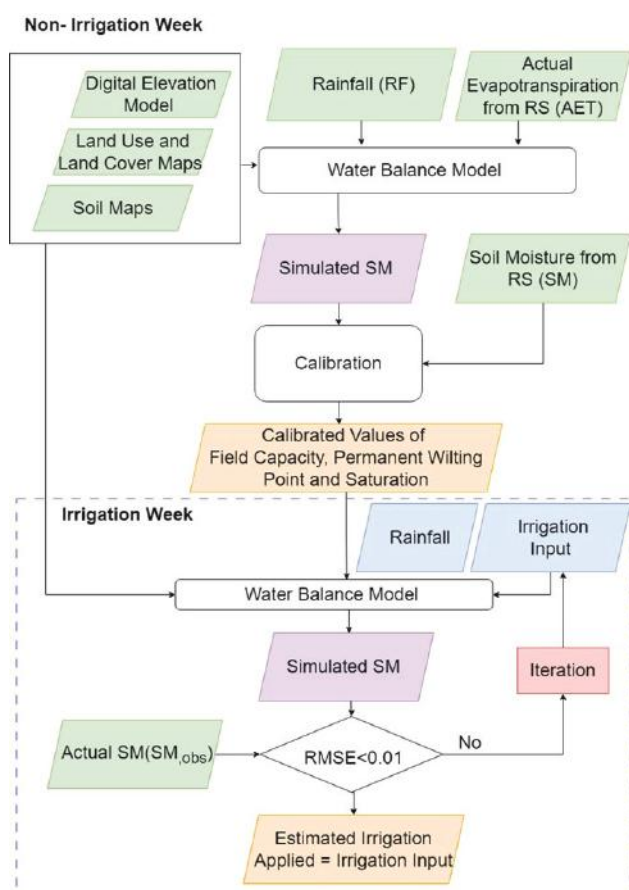


Figure 2. Calibration of the water balance model and estimation of the irrigation applied

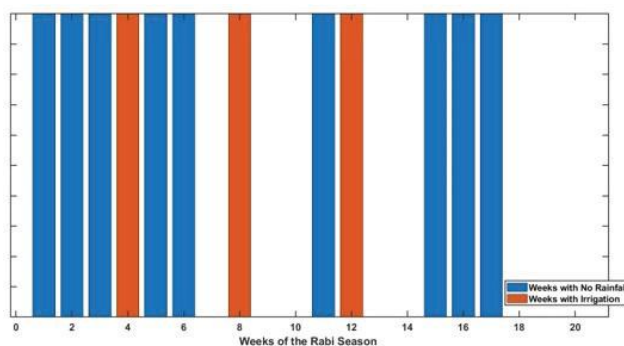


Figure 3. Weeks of irrigation identified during Rabi season from evapotranspiration, soil moisture and rainfall observations

- Week 4: 22nd November 2022 – 28th November 2022
- Week 8: 20th December 2022 – 26th December 2022
- Week 12: 17th January 2023 – 23rd January 2023

During these periods, soil moisture increased abruptly, not corresponding to recorded precipitation, confirming the application of irrigation. These findings provide critical insights into irrigation scheduling and water management practices in the study area, highlighting the role of supplementary irrigation during key growth stages of the Rabi season. Further analysis could refine the detection methodology by integrating additional

hydrological variables, such as evapotranspiration trends and groundwater fluctuations, to improve the accuracy of irrigation quantification.

The irrigation applied was estimated iteratively using the methodology described in Section 2.2. The model was self-calibrated, adjusting soil parameters and irrigation amounts for the identified irrigation weeks to achieve an optimal root-mean-square error (RMSE) of 0.01 between observed and simulated soil moisture values. This calibration ensured that the estimated irrigation closely matched actual field conditions.

The final estimated irrigation amounts, along with field-recorded irrigation data, are summarized in Table 1. The comparison provides insights into the accuracy of the estimation approach and highlights potential discrepancies arising from variations in soil infiltration characteristics, irrigation efficiency, or measurement uncertainties. This iterative approach enhances the reliability of irrigation quantification, which is essential for improving water resource management and hydrological modeling in agricultural systems.

The estimated irrigation amounts derived from the model show a close agreement with the actual irrigation applied in the field, demonstrating the reliability of the estimation methodology. Figures 4 illustrate the comparison between observed and simulated soil moisture with irrigation. The simulated data effectively capture the same patterns of variation as the observed data, reinforcing the effectiveness of the model calibration process. These findings confirm that accounting for irrigation significantly improves soil moisture simulations, which is crucial for accurate water balance assessments and irrigation management in agricultural landscapes.

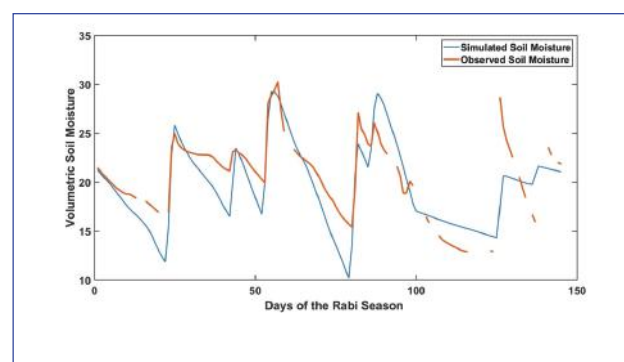


Figure 4. Model simulated soil moisture with irrigation for Rabi season

Conclusion and Way Forward

The methodology developed was initially validated using flux tower site observations to serve as a proof-of-concept study. Flux towers provide high-temporal-resolution measurements of land-atmosphere exchanges, making them ideal for testing the accuracy and reliability of the proposed approach under controlled conditions. Following this initial validation, the methodology shall be extended

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Table 1. Details of estimated irrigation supplied and actual irrigation supplied during the Rabi season

Irrigation event	Information retrieved from observations		Field Data of Irrigation	
	Date identified from observations	Estimated Irrigation Supplied (mm)	Dates of irrigation	Irrigation Supplied (mm)
1	22/11/2022-28/11/2022	159.22	25/11/2022- 27/11/2022	150
2	20/12/2022-26/12/2022	114.30	No Records	No Records
2	17/01/2023-23/01/2023	138.52	21/02/2023-23/01/2023	135

to additional flux tower sites that cover diverse climatic and land-use conditions. This step is crucial for assessing the robustness and generalizability of the approach across different environmental settings.

Advances in remote sensing and geospatial technologies have enabled routine access to spatially explicit datasets of precipitation, evapotranspiration, and soil moisture at increasingly finer resolutions. Leveraging these capabilities, the modeling framework developed in this study offers a viable pathway for estimating water supplied in irrigation systems where irrigation deliveries are unrecorded or poorly documented.

By generating spatially distributed estimates of irrigation supply, the approach provides critical diagnostic information for evaluating the performance and operational efficiency of irrigation systems. Such insights are essential for supporting data-driven decision-making and promoting the sustainable management of agricultural water resources under increasing water scarcity.

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Chongyi Shangbao Terraces

Name	Chongyi Shangbao Terraces
Location	Jiangxi Province, China
Latitude	N 25°24'~25°55'
Longitude	E 113°55'~114°38'
Category of Structure	Terrace
Year of commissioning	12th to 13th Century
River Basin	Zhangjiang River Basin under the Gangjiang River System, Yangtze River tributary
Irrigated/Drained Area	More than 3,400 ha



History

According to the Classic of Mountains and Seas and other historical documents, the development of the Shangbao Terraces dates back to the pre-Qin period before 221 BC. Later in the Qin and Han dynasties, the terraces had gradually taken shape. After regular repairs and expansions in the later dynasties of Tang, Song, Yuan, Ming and Qing, the terraces eventually obtained their present magnificence. The remains of the stone dog preserved at the Chishui Village of Shangbao Township are proof of the terraces' early history.

Chongyi Shangbao Terraces began to form a full-scale in the Southern Song Dynasty more than 800 years ago. However, agricultural development in the region dates far back to the Qin and Han Dynasties. After China was unified in 221 BC, people from the north began to migrate to this region. A prefectural government was then established, and Chongyi County was within its jurisdiction. Later in the Tang Dynasty (618-907), the local ethnic minorities and migrants from the north (the Hakka people) gradually integrated, and the large scale development of terraces started. This process continued into the Song Dynasty (960-1279). At that time, the locals built terraces on gentler mountain slopes to expand arable land and constructed systems of mountain ponds, canals, ditches and bamboo pipes to utilize the abundant water resources and achieve gravity irrigation.

In the later half of the Song Dynasty or the Southern Song Dynasty, the Terraces had reached a relatively large scale, which ensured local grain output and supported population growth. In the later Dynasties of Yuan (1271-1368) and Ming (1368-1644), the migration continued, and the following ballooning demand for food made it necessary to build more terraces. As a result, isolated terraces gradually became contiguous, spanning mountain after mountain. By 1552, 60 weirs had been built, irrigating more than 530 ha of land. At the early stage of the Qing Dynasty (1636-1912), the government adopted a series of policies to encourage migration and agricultural production. For instance, financial subsidies were offered for land reclamation. As a result, more and more people were driven to relocate to Chongyi County, leading to a surge in population and further expansion of terraces. It was during this period that Chongyi Shangbao Terraces attained its current scale. Also during this period, even more attention was given to the conservation of water and soil resources. By 1893, 77 weirs had been built, irrigating more than 780 ha of farmland.

After the foundation of the People's Republic of China in 1949, both the scale (3,400 ha) and the grain yield of the Terraces further expanded thanks to the construction and rehabilitation of infrastructures such as canals and weirs. In addition, the protection of the local ecosystem and cultural heritages has been gaining weight. In 2012,

Chongyi Shangbao Terraces

it was given the title “the largest Hakka Terrace in the World” by the Guinness Book of Records. In April 2018, it was listed as a “Globally Important Agricultural Heritage System” by FAO.

Description

Between the Luoxiao Mountains and the Zhuguang Mountains, at the source of the Zhangjiang River, a tributary of the Ganjiang River in the Yangtze River basin, there is a settlement of the Hakka people where the local mountains have been transformed into terraces. This is the Chongyi Shangbao Terraces, a marvel of the Hakka farming culture.

Located in the northwest of the mountainous Chongyi County of Jiangxi Province of China, the Terraces cover an area of about 3,400 ha distributed in 26 villages of the three townships of Shangbao, Fengzhou and Sishun. With a maximum altitude of 1,260 m and a minimum of 280 m, the terraces have a vertical drop as large as 1000 m, and the largest terrace has as many as 62 levels of ridges.

Shaped by the mountainous terrain, the Chongyi Shangbao Terraces flourish because of the water. The densely forested mountains help store abundant water resources; the granite mountain structure constitutes an impermeable reservoir so that rainwater harvested on the mountaintop can only seep out from the hillside slopes, creating a natural underground distribution and drainage network with reliable water supply to the terraces.

For thousands of years, local people have respected the laws of nature and built terraces with a water distribution system tailored to the local conditions. Connected to this irrigation network, each ridge serves as a small

reservoir and soil preservation bed, preventing and controlling land erosion. This is indeed a good example of irrigation engineering created and perfected by the ancient Chinese people.

In general, the Chongyi Shangbao Terraces adopt gravity irrigation, and various irrigation methods are applied in different water demand scenarios such as isolated hills and seasonal and meteorological changes. The irrigation system of the terraces can be divided into three categories, namely the water storage structures, the canal network, and water flow regulation facilities. There are three ways of water storage: water directly seeping out of the mountain slopes, man-made water storage and distribution structures, and man-made filter and sedimentation facilities. Under the category of the canal network, there are several sub-categories: diverting water with weirs, delivering water through inverted siphons, using the small plots of farmland as canals, delivering water with aqueducts and bamboo tubes, and lifting water with waterwheels. For water flow regulation, water-distributing stones and pipeline valves are installed.

Today, the structure and layout of this gravity irrigation system are still intact. As a product of the sweat and wisdom of the ancient Chinese people, it has become an important part of the local agricultural economy. Combined with the development concept of modern agriculture, it is helping realize the value and functional potential of the terraces.

With the simplest engineering facilities and minimal maintenance, the Chongyi Shangbao Terraces have achieved sustainable and efficient gravity irrigation and thus strongly boosted land reclamation and agricultural production. Currently, the average grain yield has exceeded 7,500 kg/ha. Meanwhile, the ecological concepts and experience in construction and management accumulated over the past millennia could serve as a valuable reference for modern terrace management and soil and water conservation.

The Longsheng Terraces of Guangxi, the Yuanyang Terraces of Yunnan, and the Chongyi Shangbao Terraces are the three most scenic terrace systems in China. The Chongyi Shangbao Terraces also called the heavenly stairs, are spectacular throughout the year. In spring, the irrigated paddy fields are like strings of silver chains hanging in the mountains; in summer, the lush crops are like green waves pouring from the sky; the autumn is the season of gold, featuring the joy of harvest; in winter, the terraces are covered with pure snow, auguring another fruitful year.

Water Heritage

The building of the Terraces has improved irrigation conditions and thus enlarged the area of the paddy field. According to the Chronicles of Chongyi County, back in 1522, Chongyi County had about 4181 ha of arable land; in 1706, it grew to about 5235 ha; then, in 1765, it further increased to 5384 ha; by 1937, the arable land had expanded to around 9772 ha; after the foundation of the People's Republic of China in 1949, the figure was



Chongyi Shangbao Terraces

10491 ha, of which 10280 ha were paddy field, and the growing trend has continued.

The development of the Terraces has also driven the formation of the local paddy-based agricultural structure. Within the long history of the Terraces, people have bred various strains of rice tailored to local water and soil conditions, including varieties of indica rice, japonica rice, early season rice and late rice, and formulated different cropping systems respectively. Irrigation and drainage facilities of the Terraces have greatly boosted local grain yield. According to the Chronicles of Chongyi County, by 1942, the grain yield per hectare had reached 3240 kg; currently, the figure is more than 7500 kg/ha. It is the sound irrigation and drainage system of the Terraces that has transformed the wild mountains into a land of fertility and prosperity.

The construction of the Terraces is a process of mountain development and population growth. The irrigation and drainage system, by bolstering land reclamation and agricultural production, has also helped the expansion of human settlements and population growth, which in turn further enhanced local economic and social development.

Currently, the Terraces supply 76.5% of food crops, various oil-bearing crops, vegetables and fruits for the local people. In 2015, the economic revenue of the proposed site was 1.357 billion yuan. The income from farming/agriculture contributed 87.8% to the total income of the rural households, while that from agriculture and forestry contributed 78.7%.

When building the terraces, the locals had fully considered the natural conditions of the mountains: the forest on the mountain top was preserved for water conservation; below the mountain top, villages were built; and below the villages lay the terraces. The canopy and soil of the forest above the terraces can greatly conserve water and effectively regulate the spatial and temporal distribution of rainwater. On rainy days, the forest ecosystem on the top part of the mountain can retain part of the rainwater, which will decrease the surface runoff and weaken the flood peak of rivers.

Meanwhile, in the dry season, the water conserved by the forest will infiltrate gradually into the terraces to meet the water demand of terrace crops. The soil of terraces can also conserve water to some extent and guarantee the water demand of varieties of plants in the ecosystem. Soil retention is also an important ecosystem function of these terraces. Covered by dense forests, terraces are rich in a variety of plants. Soil fixation character of vegetation roots is realized by the organic matter secreted by plants, which can therefore cement the soil and make them strong enough to resist soil erosion. The canopy of tall trees intercepts raindrops to undermine the erosion force of rain splashing directly on the soil, while the regulation of the ground vegetation and the litter layer on precipitation and runoff eliminates the erosion forces of rainfall from the top and runoff on the surface of the soil. Therefore, the terraces can help achieve better soil conservation, which is reflected in avoiding the waste of land, reducing sediment deposition and preventing the loss of soil nutrients. In this way, the elements of forests,



villages and terraces are transformed into an integrated and eco-friendly agricultural system.

The building materials of the Terraces and the local farming practices have also reflected the respect and protection of nature. Built with locally produced soil, bamboo pipes and stones, the terraces fit perfectly into their surroundings, minimizing the impact on the local ecosystem. In addition, only organic fertilizers such as animal waste and plant-based compost are applied.

Besides, the design and scale of the terraces are based on the carrying capacity of local water resources. In ancient times, people drew insights and lessons from past experiences and formulated reclamation plans annually. If the hydrothermal condition was good, the plan would be more ambitious; if a drought was likely, they would reduce or even stop the work of reclamation. This principle of measured development has helped prevent the waste of human and material resources and the drastic change in the local ecosystem.

The Terraces are models of sustainable management of land and water resources in mountainous and hilly areas, providing important experiences for coping with global ecological problems like land degradation, extreme droughts and floods caused by climate change.

The history of Chongyi Shangbao Terraces dates back to the 12th-13th centuries. The Terraces are constituted by water storage structures, water diversion structures, canal systems, waterwheels and drainage structures. Its engineering form remains unchanged today. The gravity irrigation system of Chongyi Shangbao Terraces is an embodiment of the ancient Chinese philosophy of harmony between man and water, and man is an integral part of nature. In addition to the use of locally available building materials, the layout, engineering design and construction of weirs, water intakes and canals are all based on local terrain and resource availability, aiming at minimizing the possible impact on the local ecosystem.

Besides, the Terraces are home to various heritages of agricultural culture, including proverbs and calendars assisting farming and rituals and customs such as bull dance. In April 2018, the Terraces, under the name of "Jiangxi Chongyi Hakka Terraces", were listed as a "Globally Important Agricultural Heritage System" by FAO as part of "Rice Terraces in Southern Mountainous and Hilly areas, China".



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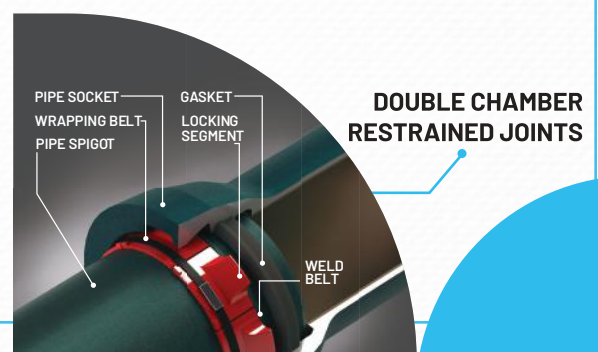
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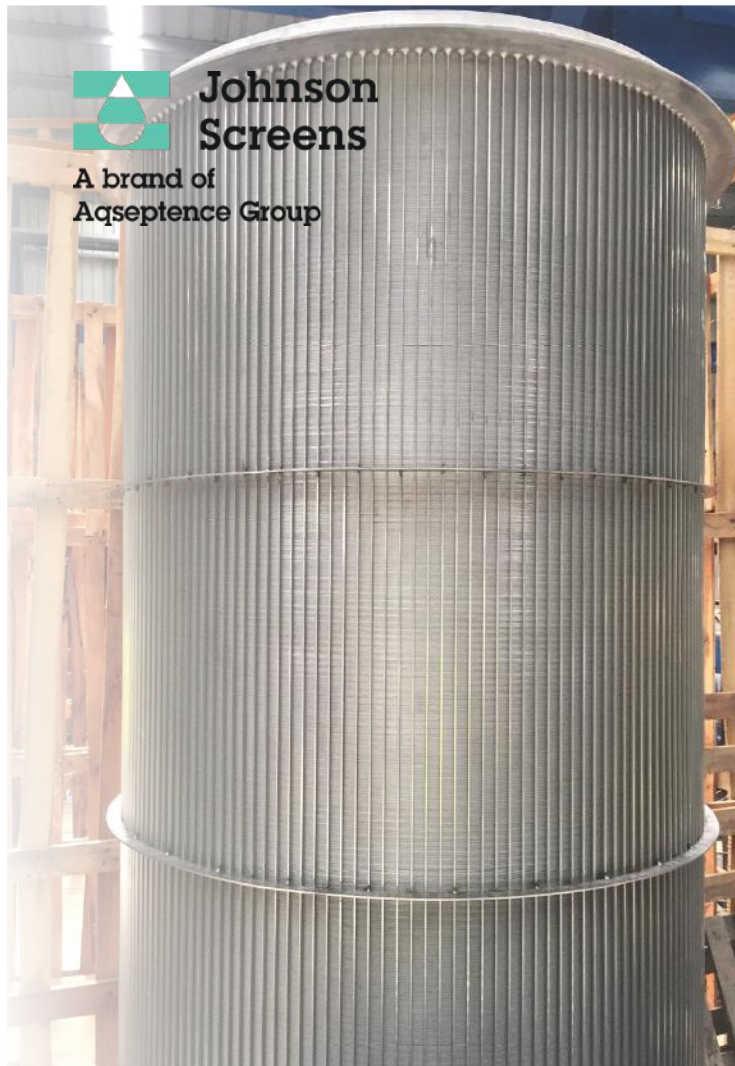
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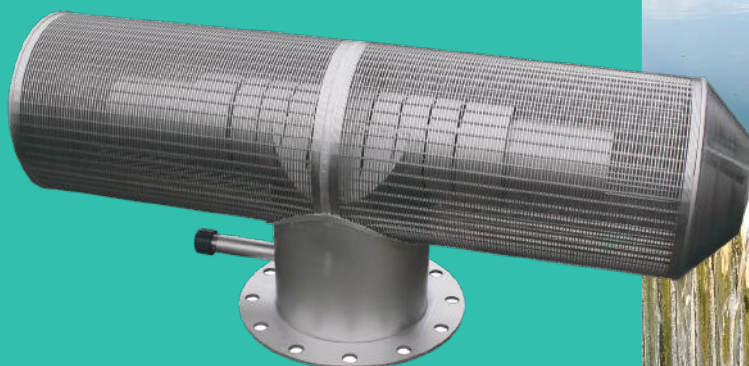
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Republic of Korea: Irrigation and Drainage Profile

Geo. Area
10.045 Mha
(2024)



Population
51.8 M
(2024)



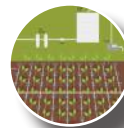
Average
rainfall 1,252
mm (2020)



Arable Area
1.505 Mha
(2024)



Irrigated Area
in Paddy 0.651
Mha (2024)



Farmer
population
2.0M (2024)



Paddy Field
Area 0.761 Mha
(2024)



Upland Area
0.744 Mha
(2024)



Geography

The Republic of Korea is a peninsula located between the People's Republic of China and Japan. It lies between the latitudes 33° 6' N and 38° 31' N and has many islands along the west and south coastlines. The total territorial area of Korea is 10.045 Mha (2024). Korea is a mountainous country and high mountains are located along the eastern part of the peninsula. Most plains and hilly areas are scattered in the western and southern parts of the country. The eastern coast of the Korean Peninsula has steep slopes, simple shorelines and deep-water depth. But there are many islands and irregular shorelines in the western and

southern coasts. Tidal range of the western coast is very high and tidal flats are well developed. Many tidal land reclamation works were implemented in the past and a good potential for tidal land reclamation widely prevails.

Population and land use

The population of Korea was 51.8 million in 2024. Korea is one of the most populated countries showing the population density of 515 persons/Km² in 2024. The population engaged in agriculture in 2024 was 2,004 thousand persons or 3.9% of the total population. Due to the fast industrialization and rapid expansion of urban

Republic of Korea: Irrigation and Drainage Profile

areas, the percentage of population in the agricultural sector has sharply decreased during last several decades. The average size of farm holding has been steadily increased from 0.97 ha in 1977 to 1.55 ha in 2024 mainly due to decrease in farm households and with the Government's continuous efforts. In 2020, Forest area is 6.298 Mha or 62.7% of the total area. Rivers, roads, residential area, industrial sites, and others occupy the rest. Out of total land area, the cultivated land covered 1.505 Mha; paddy fields (0.761 Mha) and upland (0.744 Mha) in 2024.

Climate and rainfall

Korea lies within the temperate zone between the People's Republic of China and the Pacific Ocean. Summer is hot and humid, while winter is cold and dry. The climates of spring and autumn are moderate and dry. A long drought from winter to spring or a severe spring drought often threatens transplanting of rice which is carried out in May or June. The monthly average temperature is higher than 30°C during the summer months from June to September and it falls below freezing point during the winter months from December to February. Temperature also varies with the location, showing high in the southern part and low in the northern part. The southeast wind prevails in summer and the northwest wind in winter. Annual average precipitation is 1,252 mm. More than two third of the annual precipitation occurs during the summer months from June to September. Typhoons originating from the Pacific Ocean pass the peninsula mainly in August and September.

Food and agriculture

Agriculture is mainly developed in the south-western part of the country. While 1.504 Mha or 15.0% of the total area in 2024 are arable, the area under grain production, except rice, is continuously decreasing as they have low profitability. On the contrary, the area of land used for growing vegetables and fruits and for greenhouse farming, which can yield more profit is increasing. The main crops grown in the irrigated uplands are economically profitable orchards, vegetables, and other horticultural plants. The vegetables are now normally cultivated in the irrigated uplands to increase production. Food crops grown in addition to rice are barley, soybeans, red bean, green bean, sweet potato, potato, maize, millet and sorghum.



There is very little wheat cultivation because of the lack of competitiveness and therefore it is largely imported.

Irrigation and drainage

It was known that rice culture in the Korean Peninsula began in the fourth or third century BC. From the beginning, most irrigation water was obtained from rivers and streams by constructing small reservoirs, diversion weirs or feeder canals. Many irrigations and flood protection facilities such as small dams, diversion weirs, canals, river embankments, etc. were continuously constructed by the central governments, local governments, or farmers for many centuries up to 20th century. In 2024, out of a total irrigated area of 0.651 Mha was served by surface water of which 65% was fed by 17 thousand reservoirs, 26% by 9 thousand pumping stations, and 9% by 18 thousand weirs. The amount of water served by groundwater accounted for 14%. In 2024, total irrigated area was 0.651 Mha. It was reduced gradually, since some land has been diverted to other purposes such as construction of public facilities, houses, and factories. Surface drainage systems with gravitational drainage are provided to remove excess water from paddy fields in the flooding season. Where gravitational drainage was not possible, pump drainage was used. To reduce inundation area in the paddy, Drainage system in the paddy was fed by 1.2 thousand drainage pumping stations, 70 thousand KM drainage canal In 2024. It was increased drastically drainage pumping stations since high value crop was cultivated by green-house in the paddy field.

Water resources management

Divides of watersheds of the major rivers are in the eastern part of the peninsula. So major rivers flow long distance from east to west or from north to south through low valleys and plains and become good irrigation water sources. The average annual precipitation in Korea is 1,252 mm and it indicates 126.4 Bm³ of water in volume (2021). The average annual runoff is 73.1 Bm³ (59%) and the annual volume lost by evaporation or others is about 51.6 Bm³ (41%). More than two-third of the annual runoff occurs during the flood season from June to September and so a great amount of the water becomes unusable. Total available surface and ground water is estimated at 36.6 Bm³ which includes 12.2 Bm³ of river flows during the non-flood season, 20.4 Bm³ of stored water in multipurpose dams and agricultural reservoirs and 2.9 Bm³ of ground water. Yearly water use amounts to about 24.4 Bm³; 15.4 Bm³ (63%) for irrigation, 1.6 Bm³ (7%) for industrial water, 7.4 Bm³ (30%) for water. In Korea, groundwater is not a major source of irrigation water and it covers less than 14% of irrigated usage. Groundwater is often used as supplementary irrigation water during drought periods.

Water policies

Since 2018, The main institutions involved in Water resources management is the Ministry of Environment (MOE), which was changed the Ministry of Climate,



Energy and Environment (MCEE) in 2025. However, in case of Irrigation and drainage management, it was still controlled by the Ministry for Agriculture, Food and Rural Affairs (MAFRA).

As state-owned company belong in MAFRA, KRC (Korea Rural community corporation) was established in 1908. It was covered Irrigation and drainage management by Farmland Improvement Associations (FLIA) which formed by farmers (WUG). Otherwise, RDC (Rural Development Corporation) was carried out the planning, survey and design, construction. It was separated three institutions, RDC, 103 FLIAs, the Federation of Farmland Improvement Association (FFIA) until 1999. In 2000, It was merged KRC as integrated institution.

In 2024, It was covered Irrigation area by KRC, account for 71%. Others was covered by local government, account for 29%. KRC was implemented Irrigation and drainage management as governmental company. KRC has a technical capacity and excellent experts to develop Irrigation sector. KCID was established by KRC in 1992. KRC has supported for KCID activities and operated secretary of KCID until now.

ICID and National Committee

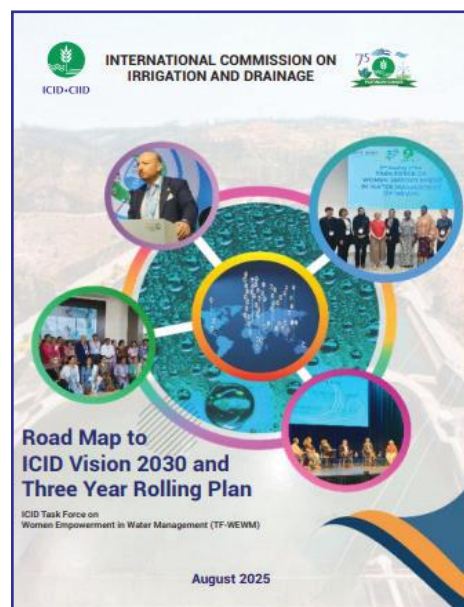
The Republic of Korea became ICID's member in 1969 and established the Korean National Committee on Irrigation and drainage (KCID) in 1992. KCID gave six Vice Presidents to ICID: Mr. Yu, Kuen-Hak (1993-1996); Prof. Soon-kuk Kwun, (2000-2003); Dr. YooMan HUH, (2004-2007); Prof. Kim, Tai-Cheol, (2011-2014); Mr. Bong Hoon Lee (2014-2017), and Prof. Choi, Jin-Yong (2020-2023). The 1st Asian Regional Conference and 52nd International Executive Council Meeting (IEC) was organized during 16-21 September 2001 at Seoul, South Korea. The KCID was also organized the 22nd International Congress on Irrigation and drainage and 65th International Executive Council Meeting (IEC) during 14-20 September 2014 at Gwangju, Republic of Korea. The details regarding Korean National Committee on Irrigation and Drainage (KCID) can be accessed from: https://icid-ciid.org/member/country_profile1/51_A



Road Map to ICID Vision 2030 and Three Year Rolling Plan

On The water crisis, one of the most complex challenges of the 21st century, stems from a multitude of factors such as climate change, rapid population growth, inefficient consumption patterns, increasing demand, and mounting pressure on limited water resources. These issues have made a fundamental revision of water management and governance approaches inevitable. Global estimates indicate that by 2050, over two-thirds of the world's population will face water stress. This alarming projection underscores the necessity for adopting innovative approaches, comprehensive and inclusive strategies, and participatory management practices in water governance.

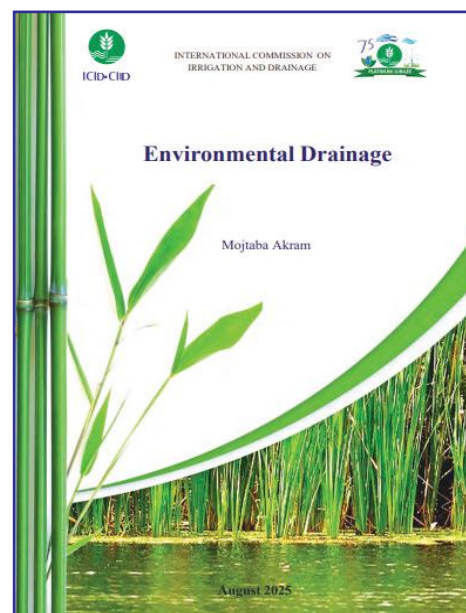
This report presents a roadmap that highlights the importance of women's empowerment in water management. Through the ICID Task Force on Women Empowerment in Water Management (TF-WEWM), we aim to create the conditions for women to become key decision-makers in water governance, ensuring that their perspectives are integrated into policies, programs, and strategies at all levels. This roadmap aligns with our Vision 2030, which aims to foster a more inclusive, integrated, and resilient water governance framework, focusing on sustainable water use and the equitable participation of all stakeholders. Women bring unique insights and innovative approaches to water management, particularly in addressing the interconnected challenges of water, food, and energy security. Their active participation will not only strengthen our water management systems but also contribute to achieving the broader Sustainable Development Goals (SDGs). Empowering women in water management is not a mere aspiration—it is a strategic necessity. As we continue to navigate complex global challenges, ICID is dedicated to creating a future where women can lead with their knowledge, creativity, and commitment to building resilient water systems. https://icid-ciid.org/icid_data_web/RoadMaptoVision2030-2025.pdf



Environmental Drainage

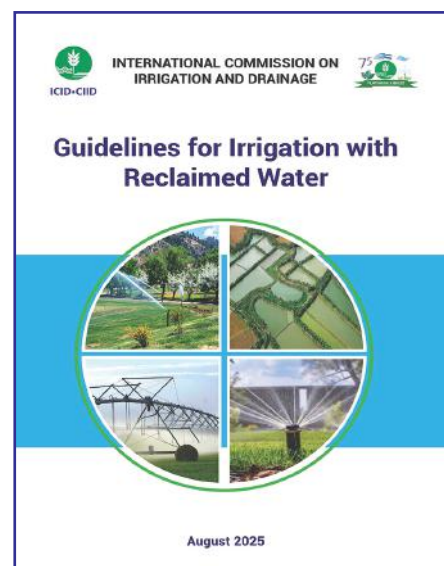
This book begins by discussing general environmental issues. It then delves into the pollutants found in drainage water, with a particular focus on soil and water salinity, especially in arid and semi-arid regions. The residues of chemical fertilizers and animal manure, particularly nitrogen and phosphorus, are major environmental pollutants. Heavy metals, though less understood, are also significant contaminants. The use of wastewater from urban treatment plants introduces pollutants into the soil and plants, posing risks to animal and human health. Therefore, the topic of wastewater irrigation is thoroughly examined.

In the final part of this book, solutions to reduce drainage water pollution are discussed, with specific improvement strategies for each major pollutant. For instance, reducing the depth of drains can help lower the load of salt pollution and fertilizer residues. Constructing wetlands can mitigate nitrates and, to some extent, phosphorus. Phytoremediation is explored for areas contaminated with heavy metals. Additionally, edge-of-the-field solutions such as bioreactors, buffer strips, and saturated buffers are discussed, despite their limited current adoption. It is hoped that in the future, more farmers will embrace these methods to reduce environmental pollution. https://icid-ciid.org/icid_data_web/EnvironmentalDrainage2025.pdf



Guidelines for Irrigation with Reclaimed Water

Using wastewater or poor-quality water for irrigation is one of the eight technical strategies proposed in the roadmap to 2030 ICID Vision “A water-secure world free of poverty and hunger through sustainable rural development”. Reclaimed water is considered a stable alternative water source for irrigation which is increasingly used worldwide. These guidelines produced by Working Group on Use of Non-Conventional Water Resources for Irrigation (WG-NCWRI), ICID, is the technical approaches for the safe reuse of reclaimed water. These Guidelines are in direct support of SDG 2’s call to “end hunger and promote sustainable agriculture”, as well as SDG 6’s mandate to “ensure sustainable water management.” By integrating reclaimed water into irrigation systems, we do not only safeguard crop yields but also reduce dependence on overexploited freshwater sources. This is especially vital for smallholder farmers and communities in arid regions, where water variability poses a constant threat to livelihoods. Simultaneously, the safe reuse of wastewater advances SDG 6 by curbing environmental degradation and protecting groundwater from contamination. https://icid-ciid.org/icid_data_web/GuidelinesforReclaimedWater2025.pdf

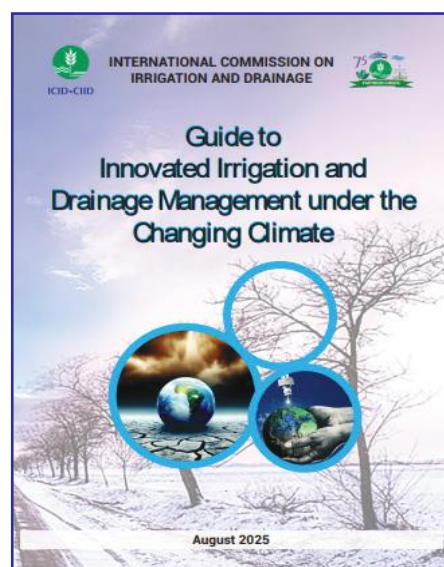


Guide to Innovated Irrigation and Drainage Management under the Changing Climate

Climate change and variability are well-documented through global climate records since the 19th century. To address the challenges needs effective adaptation and mitigation strategies, especially through sustainable water resources management. This chapter covers various topics related to optimizing and productively water resources for agriculture irrigation and drainage, focusing on adaptation and mitigation efforts. Adaptation strategies focus on decreasing risks related to climate change, such as improving soil and water management, growing biodiversity, and adopting integrated pest management. There are several methods such as value-engineering, the Water-Energy-Food (WEF) nexus, and life cycle analysis as mitigation strategies that aim to decrease greenhouse gas emissions such as decreasing fossil fuel use, shifting to sustainable dietary habits, and promoting greener cities are discussed concerning their impact on agriculture and water management

This publication “Guide to Innovated Irrigation and Drainage Management under the Changing Climate”, as an output of the Working Group on Climate Change and Agricultural Water Management (WG-CLIMATE), aims to share information about the prediction of the global and regional climate change and climate variability; to explore and analyze the implications of climate change and climate variability for agricultural water management including irrigation, drainage, and flood control; to promote archiving useful information and case studies on climate change for practical use in improved impact assessment and adaptation development; to enhance discussion on climate change and water management at national and regional scales among the stakeholders including academician, practitioners, decision makers, media as well as farmers and water users in a region; and to join the international dialogue on Climate change and water management.

This publication will be quite helpful in understanding the complex relationship between climate change and water resource management, especially in agriculture, emphasizing the need for sustainable adaptation and mitigation strategies. It highlights global trends, including reductions in rainfall and groundwater recharge, rising temperatures, and increased demand posing challenges to water availability and quality. https://icid-ciid.org/icid_data_web/ClimateChangeGuideBook2025.pdf



ICID 75th Commemorative Publication Book

The ICID 75th Commemorative Publication Book is a landmark publication celebrating seventy-five years of the remarkable journey, achievements, and global contributions of the International Commission on Irrigation and Drainage (ICID). The publication highlights the organization's enduring commitment to advancing irrigation, drainage, flood management, and sustainable water resources development across the world.

The commemorative book documents the evolution of ICID since its establishment in 1950, showcasing major milestones, international collaborations, technical innovations, policy contributions, and capacity-building initiatives undertaken over the decades. It reflects on the

organization's role in promoting food security, climate resilience, agricultural sustainability, and efficient water management practices in both developed and developing countries.

The publication also features messages from distinguished leaders, contributions from National Committees, historical archives, photographs, case studies, and success stories that illustrate ICID's impact on global irrigation and water management communities. Special emphasis is placed on emerging challenges such as climate change, water scarcity, digital agriculture, smart irrigation technologies, and community-led water governance.

Designed as both a historical record and a forward-looking document, the ICID 75th Commemorative Publication Book serves as a tribute to the dedication of water professionals, researchers, policymakers, and partner organizations who have contributed to ICID's mission over the past seven and a half decades. The publication also outlines ICID's vision for the future, emphasizing innovation, international cooperation, and sustainable water solutions for generations to come. https://icid-ciid.org/inner_page/265



ICID FIRST CONGRESS ON IRRIGATION AND DRAINAGE, 1951

FIRST CONGRESS ON IRRIGATION AND DRAINAGE

Representatives of 16 countries participated in the First Congress on Irrigation and Drainage held in Delhi from January 11-16, 1951. Observers from 14 other countries and ECAFE also attended the Congress. The total number of delegates was 350 of whom a large number was from India.

JOINT INAUGURAL SESSION

Since two other international engineering conferences—The International Commission on Large Dams and Sectional Meeting of the World Power Conference—were being held in New Delhi at the same time, the Inaugural



Joint Inaugural Session

It was indeed significant that India, who sponsored the establishment of the International Commission on Irrigation and Drainage should be the host country for the First Congress. A personal invitation from Shri Jawahar Lal Nehru, the Prime Minister of India, on behalf of his Government, was the highlight of the First Session.

Session was held jointly with them at 10-30 A.M. on January 11, 1951 in the Constituent Assembly Hall of Parliament House, New Delhi.

Mr. B.K. Gokhale, I.C.S., Secretary to the Government of India, Ministry of Works, Mines and Power welcomed the delegates on behalf of the Government.

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and the people of India. He then read out the following message from the President of the Indian Republic:

"It gives me immense pleasure to welcome to our country, and to this capital, the representatives of so many nations of the world who have assembled here to advance the cause of science. I understand they are attending a Sectional Meeting of the World Power Conference, the Fourth Congress on Large Dams and the First Congress

into creative channels so as to ensure plenty and prosperity to the people. The present state of scarcity and want in many regions of the world, in the face of potential resources, was a challenge to the creative and constructive genius of engineers and the people were looking up to them to meet this challenge nobly and with success.

Mr. A.N. Khosla, President of the Indian National Committee, said that dams and canals were known in India long before the dawn of history. He dwelt upon the water and land resources of India and the potentialities to exploit them for the benefit of the people. He pointed out that the engineers would achieve their biggest objective if through the medium of these international engineering organisations, it was possible to stimulate the native genius of less developed areas in fruitful action through self-help. Mr. Khosla concluded:

"Let us then pool our specialised knowledge, technical know-how and realism in enterprise and share in the common endeavour for the uplift of backward humanity. Let us approach the problem, not in a spirit of patronage or exploitation, but in a spirit of service and understanding so that those who have lagged behind may now be encouraged to approach and join in the common march of humanity towards world peace and prosperity. Let these meetings mark the beginning of a happy union between the East and the West, the spiritual and the material and between man and machine so that with a balanced fusion of the cultures and techniques of the East and the West we may succeed in evolving a social order in which the spectres of suspicion, fear and suicidal wars will stand ostracized."

Sir Vincent de Ferranti, Chairman of the International Executive Council, World Power Conference; Mr. A. Croyre, President, International Commission on Large Dams and Prof. Dr. S.H.A. Begemann, Vice-President, International Commission on Irrigation and Drainage then delivered their presidential addresses.

Shri Rajagopalachari, Minister for Home Affairs, Government of India welcomed the guests. In his inaugural address Shri Rajagopalachari said:



Shri Rajagopalachari delivering his inaugural address

"The qualifications for achieving success in engineering are intellectual and moral honesty, courage, independence of thought, fairness, good sense, sound judgment,



Delegates at the President's reception



Joint Inaugural Session

on Irrigation and Canals, which will be dealing with highly specialised scientific subjects. Such meetings provide the best opportunity of collecting the findings and pooling the experience of all participating countries for the greater benefit of humanity. Indeed such international collaboration in the matter of advancement in scientific technique and knowledge is bound to unite the various nations with ties of goodwill and understanding and help to establish an easing influence on the International political field.

"I feel sure that the personal contacts that will be established at this Meeting will leave a lasting impression on the representative scientists for the benefit of our respective countries. I hope our visitors from abroad will find their stay in India interesting and instructive and they will carry with them happy memories of their visit to this country."

Mr. Gokhale described how the rivers in India were looked upon as 'Mothers'. These mothers, he said, were anxious to be increasingly harnessed in the service of humanity and were looking up to the engineers for the diversion of the pent up store of energy, which they carried,

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perseverance, resourcefulness, ingenuity, orderliness, application, accuracy and endurance. An engineer should have ability to observe, deduce, to correlate cause and effect, and to apply the principles discovered.

"Dealing with men, he should have the ability to co-operate, to organise, to analyse situations and conditions, to formulate problems, and to direct the efforts of others. He should know how to inform, convince and win confidence by skilful and right use of facts. He should be alert, ready to learn, open-minded but not credulous. He must be able to assemble facts, to investigate thoroughly, to discriminate clearly between assumption and proven knowledge.

"He should be a man of faith, one who perceives both difficulties and ways to surmount them. He should not only know mathematics and mechanics, but should be trained in methods of thought based on these fundamental branches of learning. He should have extensive knowledge of the sciences and other branches of learning besides knowing intensively those things which concern his specialities. He must be a student throughout his career and keep abreast of human progress."

Concluding his remarks he added: "Well, if we could only get engineers of this type in India, there could be no difficulty in giving them not only all the public works of the country to be done, but the whole Government of India, lock stock and barrel."

Dr. Shen Yi (ECAFE); Mr. Gail Hathaway (U.S.A.); Mr. Voznesensky (U.S.S.R.); Mr. Benassini (Mexico); Mr. Mohsin Ali (Pakistan); Mr. Westenberg (Sweden) and Mr. Henry Gicet (Switzerland) also spoke on the occasion.

Social functions included a banquet by the Indian National Committees at the Imperial Hotel on January



Banquet at the Imperial Hotel, New Delhi.

12, 1951, reception at the Government House by the President, on January 13, 1951, and a reception by the

Institution of Engineers (India) at the Red Fort on January 11, 1951. Other engagements included visits to Red Fort, Qutab Minar, Birla Mandir and National Physical Laboratories. On Sunday, January 14, 1951, one special train took the delegates to Agra for seeing the Fort, the Taj and Fatehpur Sikri. There was a special sight-seeing programme for ladies accompanying the delegates.



The Taj

TECHNICAL DISCUSSIONS

The questions selected for discussion at the Congress were:

1. National Review of Irrigation Development and Practice.
2. Present-day problems in Irrigation & Drainage.

Five national reports were presented for discussion under Question No. 1. The two reports from Netherlands described the technique adopted in that country for the drainage and reclamation of low lying lands (polders). The report from India traced the history of irrigation development and practice in India from ancient times. It was, however, mainly during the last one hundred years that extensive irrigation works had been constructed. The total area irrigated annually was 49 million acres. India had successfully tackled the problems of river training by means of pitched islands, repelling and attracting spurs. Khosla's theory of the design of hydraulic structures on permeable foundations had enabled construction of such works with precision and economy. Notable advance had been made in perfecting the designs of irrigation outlets or turnouts. The report from Japan detailed in chronological order various measures taken by the Government to develop areas under irrigation and to reclaim land by drainage. The total area cultivated in Japan is 10 million acres out of which 7.5 millions are under irrigation. The report from Italy described the formation and development of irrigation works which were started as far back as 1100-1200 A.D. and traced the evolution of irrigation, its principles and the most important plants. The area irrigated in Italy had risen from 1.5 million hectares to 2.1 million hectares in 1939.

The delegates from other countries which could not submit their Reports gave brief reviews of the development of irrigation in their countries. Mr. I.A. Sharov (U.S.S.R.) stated that his country had by now reconstructed all the dams and primitive systems of irrigation and had also brought under irrigation vast areas of land by construction of new irrigation canals. Mr. R.A. Hordall (Australia) said that compared with India, North America and Europe, the water resources of Australia were scanty and it had been estimated that with full development, the limit of area under irrigation would have to be set at about five million acres, only one-quarter of one per cent of the total area of the Continent. The area under irrigation at present is 1.4 million acres out of which 1.3 million acres is in the valleys of the river Murray and its numerous tributaries. Dr. M.A. Selim (Egypt) described the basin irrigation which is being practised in Egypt from the time of Pharaohs. Multipurpose projects were now under construction on the Nile to harness the flood waters. The total area under irrigation at present is seven million acres which would increase to 10 million acres shortly. Mr. H.A. Morris (Sudan) revealed that a peculiar feature of the method of irrigation used on the Gezira Scheme was that the crops were not watered during night. The 14-inch pipes were closed about sunset, but the water continued to enter the heads of the minor canals at the same rate as before. At the end of each reach on the minor canals there was a flat-topped brick weir, pierced by a steel pipe that was always shut at night. As water poured into the first reach of such a canal, its level rose until the discharge over the weir was equal to the inflow at the head. The process was then repeated successively in all the other reaches until by sun-rise the canal had been converted into a series of pools. The water was then drawn off approximately twice as fast as it was flowing in through the head. By sunset, therefore, the water level had dropped down below the eills of the

brick weir and the cycle was repeated.

Under Question No. 2, 19 papers were contributed dealing with the various problems met with in irrigation and drainage and the attempts that had been or being made to solve them. These related to silt, weed clearance, distribution and control of supplies, yields in irrigation projects, design of levees on rivers and lining of canals.

Mr. Seino (Japan) pointed out that the increase in food production depended not only on the dams, barrages, canals and drains but also on soil dressing, the drainage system and cultivated land adjustments and such small works were important in Japan. Further the temperature of irrigation water in certain parts of Japan was very low and harmful for rice growing. A number of small reservoirs, having a capacity of about 10,000 cubic metres, had been constructed where the water was warmed by the solar radiation. The delegate from Ceylon stated that cost of providing irrigation facilities in Ceylon was very high and he hoped that the forum of these Congresses would give them some general ideas of the methods to secure economy. Dr. Selim (Egypt) dwelling on the problem of malaria mentioned that in Egypt rice was not flooded all the time. It was irrigated and drained every eight days, i.e., a rotation of four days water and four days no water. It had been discovered by entomologists that if the ground could be kept dry for four or five days, all the malarial insects would be killed. Experiments for the development of a new variety of rice to suit such dry conditions were still going on and had met with success.

There was a special session in which the Soviet delegation answered various queries from other delegates regarding the system of irrigation, methods of erosion control and financial aspects of irrigation works etc. in U.S.S.R.



Model tests in connection with the Bhakra-Nangal Project at the Hydraulic Research Station, Malikpur. The facilities available at the station enable the construction of large scale river models.



Handworks at Hardwar—Built in the middle of the nineteenth century and remodelled in 1917-20. The Ganga Canal taking off has a capacity of 8,400 cusec and irrigates 1.6 million acres annually.



STUDY TOUR

A study tour of river valley projects, under operation and construction, industrial centres and historical and cultural places had been arranged. About 278 delegates participated in this tour.

The party left Delhi on January 16, 1951 and after visiting Surajpur Cement Factory, Hydraulic Research Station, Mallikpur, Amritsar, Bhakra-Nangal Projects, Bahadrapur Hydraulic Research Station, Harwar, Benaras, D.V.C. Projects, Calcutta, Tatnagar, Hirakud, Khaperkheda Power House (Nagpur), Ajanta Caves, Khadakvasala Research Station and India Meteorological Department Office (Poona), Tungabhadra Project, Mettur Dam; Bangalore and Jog Falls, reached Mysore



A close view of volute siphons for the automatic release of surplus flood supplies at the Havtkegar Dam.



An interior view of one of the caves at Ajanta. Built between 200 B.C. and 500 A.D., the Ajanta caves house 24 monasteries and five temples and were formerly a great centre of Buddhist worship.



Jog Falls—Lovely drop of 800 feet in Mysore. Night illuminations and fire works were arranged at the Falls in honour of the delegates.

on February 1, 1951 for the closing session.

CLOSING SESSION

The Joint Closing Session of the Conferences was held

in the Crawford Hall at Mysore on the forenoon of Thursday, February 1, 1951. His Highness the Maharaja of Mysore addressed the closing session and welcomed the assembly of eminent engineers of the world to his State.

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Joint Closing Session

Resolutions of thanks etc. were moved by Mr. C.H. Gray, Secretary, International Executive Council of the World Power Conference and seconded by Lord Cetrine (Great Britain), Mr. Vozensky (U.S.S.R.), Mr. Bowman (USA), Mr. Gicot (Switzerland), and Mr. Hupner (France). Shri A.N. Khosla on behalf of the Indian National Committee thanked the delegates for the invaluable contribution made by them to the successful conclusion of the Conferences.

The Secretary-General, Shri N.D. Gulhati, read out the following conclusions arrived at as a result of discussions at the first Congress:

CONCLUSIONS OF THE FIRST CONGRESS ON IRRIGATION AND DRAINAGE

Having received National Reports on irrigation and drainage from member-countries and having taken note

of and discussed many present-day problems relating to irrigation and drainage, the First Congress on Irrigation and Drainage consider it of the first importance that detailed information about the practices, methods and techniques employed by different countries of the world in connection with irrigation and drainage be collected and assembled in full detail and made known to all member-countries, and with this end in view,

Recommend that the Central Office of the Commission be instructed to take steps to prepare and issue to all countries a Questionnaire on the related practices, methods and techniques including those concerning the administrative and financial aspects of irrigation and drainage projects, and compile and publish for general information an authentic Treatise based on data to be received in reply to the Questionnaire.

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Study Tours

With a view to enabling the delegates to see actually the existing river valley projects in India, the major schemes on which India has embarked, and to have an insight of her ancient culture traceable in old monuments, both religious and archaeological, the Indian National Committee conducted a study tour after the Conferences at Delhi commencing on January 16 night from Delhi and finishing at Mysore on February 1, 1951, where the joint closing session of the Conferences was held.

Two special trains carried the delegates to the places of visit and were fully equipped with catering and other facilities. There were 145 people in Train No. 1 and 133 in Train No. 2. The mileage covered by each train was over 4,500 miles. In addition over 800 miles were performed by the participants on buses when visiting works.



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FAO African Conference on Sustainable Agricultural Mechanization, 3-6 February 2026



The conference Organized by the Food and Agriculture Organization of the United Nations in collaboration with the Government of Tanzania. The conference served as a major continental platform to promote sustainable agricultural mechanization (SAM) as a driver for transforming Africa's agrifood systems.

The conference brought together policymakers, researchers, farmers' organizations, private sector representatives, development agencies, youth groups, and mechanization experts from across Africa and beyond. Discussions focused on improving agricultural productivity, strengthening food security, reducing labor-intensive farming practices, and building climate-resilient agricultural systems through modern mechanization technologies.

Key thematic areas included:

- Sustainable and precision agriculture
- Research, innovation, and digital transformation
- Mechanization supply chains and financing
- Capacity development and institutional strengthening
- Youth entrepreneurship and mechanization hire services
- Conservation agriculture and climate-smart farming practices

The conference emphasized the implementation of the Framework for Sustainable Agricultural Mechanization



in Africa (F-SAMA), launched jointly by FAO and the African Union. Participants highlighted the importance of regional cooperation, investment in mechanization services, local manufacturing, and digital technologies to support smallholder farmers and rural development.

The 500 in-person delegates and over 1,000 online participants representing African governments and agriculture stakeholders came up with a ten-point action plan that reflects a clear shift from dialogue to delivery and is aimed at accelerating technology-led farming that is inclusive, practical and adapted to African realities.

Among others, these actions include expanding tailored financing and investment mechanisms, strengthening mechanisation service provision ecosystems; promoting viable, service-based and shared-use mechanisation business models; accelerating digital transformation; mainstreaming youth and women's access to mechanisation services; and advancing demand-driven and context-adapted research and innovation.

"These ten actions are not aspirational," said FAO Policy Officer Mark Fynn during the conference's closing ceremony. "They reflect shared direction and practical readiness to act."

The conference highlighted innovations such as GPS-guided drones, autonomous feeding systems that use sensors, artificial intelligence-supported advisory services and big data platforms to support decision-making. Together, these solutions can raise productivity, reduce losses, cut drudgery and create new jobs across Africa's agri-food systems.

The Coalition for African Rice Development (CARD) reported that the rising consumption of rice on the continent is constrained by both supply and demand faults. FAO recently cited that limited access to farm machinery is

one of the major causes of yield gaps on the continent. Promoting mechanization in rice farming can help close yield gaps by significantly reducing labor and capital, while boosting production and income.

The outcomes of the conference, which was running under the theme, “Innovate, Transform, Sustain,” will also help shape FAO’s Global Conference on Smart Farming to be held in Rome in July.

The 2026 Global Report on Food Crises

The 2026 GRFC features the lowest number of countries and territories with acute food insecurity data meeting GRFC technical requirements in ten years. Specifically, in 2025, 18 countries and territories selected for the GRFC did not have acute food insecurity data, or did not have data meeting the GRFC’s technical requirements, including the requirement on consensus-based estimates. Five of these countries – Burkina Faso, the Republic of the Congo, Ethiopia, and displaced populations in Algeria and Ecuador – had data available in the GRFC 2025, representing more than 27 million people facing high levels of acute food insecurity in 2024. However, no updated estimates were available for 2025. Data gaps emerged mainly due to a combination of factors, including challenges to obtain authorization to collect or share data, limited funding and a lack of priority for data collection. Limited funding led to data gaps for example in the Republic of the Congo, for migrants in Peru, and for refugees in Benin, Côte d’Ivoire and Togo. The broader decline in humanitarian financing has further restricted resources for assessments. While this most visibly results in some countries producing no acute food insecurity estimates, more frequently it leads to reduced frequency of data collection, lower population coverage, and less disaggregation for displaced populations. This trend was already evident in 2025: WFP, one of the principal data providers for IPC analyses, conducted 800 000 survey interviews, representing a 30 percent decrease from 1.1 million the previous year. A further reduction is expected for 2026.³ Similarly, FAO Data in Emergencies reduced its household survey interviews by around 31

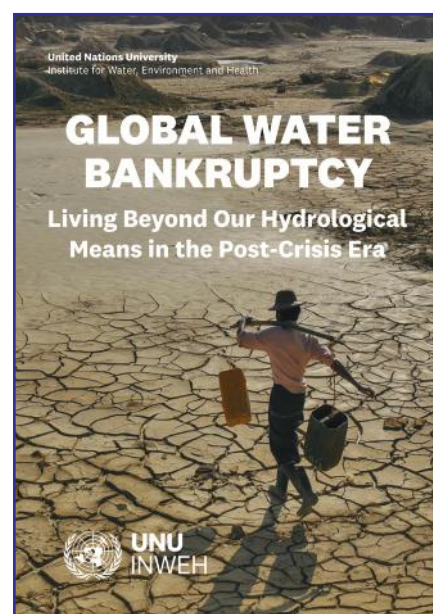


percent – from around 170 000 in 2024 to 118 000 in 2025.⁴ CH analyses shifted from biannual to annual in some countries (for instance, the Gambia and Guinea-Bissau). Population coverage of IPC/CH analyses declined by about 40 percent in Zambia between 2025 and 2026, 17 percent in Malawi, 14 percent in Guinea and, despite increased geographical coverage in past few years, 10 percent in Nigeria, limiting comparability and biasing trends. In 2026, no data is available for refugees in Chad, and no disaggregation is available for returnees in South Sudan, reducing visibility on these vulnerable groups. As a result, the integrity of the data systems underpinning the GRFC is increasingly at risk. Protecting and investing in food security and nutrition information systems is critical to safeguard evidence based decision-making.

Global Water Bankruptcy UN: Living Beyond Our Hydrological Means in the Post-Crisis Era

Published on the occasion of UNU-INWEH’s 30th anniversary, and ahead of the 2026 UN Water Conference, this flagship report, *Global Water Bankruptcy: Living Beyond Our Hydrological Means in the Post-Crisis Era*, argues that the world has entered a new stage: more and more river basins and aquifers are losing the ability to return to their historical “normal.” Droughts, shortages, and pollution episodes that once looked like temporary shocks are becoming chronic in many places, signalling a post-crisis condition the report calls water bankruptcy.

The report makes the case for a fundamental shift in the global water agenda—from repeatedly reacting to emergencies to “bankruptcy management.” That means confronting overshoot with transparent water accounting, enforceable limits, and protection of the water-related natural capital that produces and



stores water—aquifers, wetlands, soils, rivers, and glaciers—while ensuring transitions are explicitly equity-oriented and protect vulnerable communities and livelihoods.

Crucially, the report frames water not only as a growing source of risk, but also as a strategic opportunity in a fragmented world. It argues that serious investment in water can unlock progress across climate, biodiversity, land, food,

and health, and serve as a practical platform for cooperation within and between societies. Acting early, before stress hardens into irreversible loss, can reduce shared risks, strengthen resilience, and rebuild trust through tangible results. For full report please visit the link: <https://unu.edu/inweh/collection/global-water-bankruptcy>

Trends defining water innovation in 2025 and what they mean for the global water agenda in 2026

The year 2025 has emerged as a defining period for global water innovation, shaped by economic uncertainty, geopolitical tensions, climate challenges, and the rapid expansion of artificial intelligence (AI). Water is no longer viewed solely as an environmental or infrastructure issue; it has become a central component of business resilience, industrial competitiveness, climate adaptation, and sustainable development strategies worldwide.

A significant trend in 2025 is the growing recognition of water resilience as a core business priority. Traditionally, sectors such as food and beverages led corporate water stewardship efforts, but increasing water stress and supply-chain disruptions are now compelling technology companies and industrial sectors to address their water footprint. The rapid growth of AI and cloud computing has intensified concerns regarding the energy and water demands of data centres. Major technology firms have responded by introducing water management programmes, investing in water reuse systems, and adopting sustainability strategies aimed at reducing operational risks associated with freshwater scarcity. At the same time, AI itself is becoming an important tool for improving water management through predictive analytics, smart sensors, leak detection systems, and intelligent planning technologies.

Public sector regulation and investment have also become major drivers of innovation in the water sector. Governments and regulatory agencies across the United States and Europe are strengthening policies related to contamination control, water quality, and infrastructure modernization. Particular attention is being given to PFAS or “forever chemicals,” leading to increased demand for advanced detection and treatment technologies. These policy measures are creating opportunities for startups and technology providers focused on water treatment, monitoring, and environmental remediation. In addition, research institutions and universities are playing a greater role in advancing water resilience initiatives through interdisciplinary projects combining technology, policy, and community engagement.

Another defining development in 2025 is the rapid consolidation of the global water technology market.



Large corporations and utilities are increasingly pursuing mergers and acquisitions to strengthen their capabilities in desalination, industrial treatment, digital water systems, and infrastructure management. Rising operational costs, ageing infrastructure, labour shortages, and growing regulatory complexity are encouraging utilities and private companies to adopt larger and more integrated operating models. While this consolidation may improve efficiency and scalability, it also raises concerns regarding competition and long-term innovation capacity within the sector.

Despite rising investor confidence and the establishment of new water-focused venture funds, financing remains a major challenge. Global investment needs for water infrastructure are estimated to reach trillions of dollars over the coming decades, significantly exceeding current public funding commitments. Additionally, many regions continue to face difficulties in effectively deploying available funds due to institutional and technical limitations.

Overall, 2025 marks a transition from awareness to action in global water management. Water innovation is increasingly connected with climate resilience, industrial sustainability, digital transformation, and economic security. Looking ahead, 2026 is expected to focus on implementing practical solutions and strengthening international cooperation. The upcoming year is anticipated to serve as a major platform for aligning global finance, technology, and policy efforts toward achieving long-term water resilience and sustainability goals. <https://www.weforum.org/stories/2025/12/trends-defining-water-innovation-2025-what-they-mean-global-water-agenda-in-2026/>

South Asia is expected to receive below average monsoon rainfall: WMO

A few parts of the north-western, north-eastern and southern region are likely to receive normal to above normal rainfall between the May-September monsoon period, according to the South Asian Climate Outlook Forum.

Temperatures – both maximum daytime and minimum overnight ones – are expected to be above normal.

Advance information about the likely performance of the monsoon underpins planning in climate-sensitive sectors such as agriculture and renewable energy (hydropower). It also informs risk management and public health strategies – including heat-health action plans - in the world's most populous region.

Seasonal climate outlooks are one of a suite of products from the World Meteorological Organization community which protect lives and livelihoods, and are worth billions to the international economy. They exemplify the cooperation and data-sharing fostered by WMO to support community and global well-being.

Developing El Niño

The forum, held in Malé, Maldives, brought together nine National Meteorological and Hydrological Services in South Asia, namely Afghanistan, Bangladesh, Bhutan, India, Maldives, Myanmar, Nepal, Pakistan and Sri Lanka.

The forecast is based on an analysis of global climate conditions. There is strong consensus among experts that El conditions are likely to develop during the 2026 monsoon season. In parallel, the Indian Ocean Dipole – which is another key climate driver in the region – is expected to move from a neutral to positive phase.

Although the current spring predictability barrier means that forecasts at this time of year have less certainty, National Meteorological and Hydrological Services will provide nationally-tailored updates to inform decision-making.

From June through September, the Southwest Monsoon dominates life in much of South Asia. Accounting for 75-90 per cent of the annual rainfall in most parts of the region (excepting Sri Lanka and south-eastern India), replenishing water resources like rivers, lakes, and groundwater, which are vital for irrigation and drinking water supplies.



It is the lifeblood of national economies, agricultural production and food security. Below-average monsoon rainfall can trigger food insecurity among vulnerable populations, whilst heavy monsoon-related rainfall and flooding also causes many casualties each year.

WMO Action

WMO is supporting the expansion of multi-hazard early warnings, including flash flood forecasts and drought and water management tools.

The WMO is also working with the World Health Organization and partners to strengthen collaboration between meteorological and health authorities. The new South Asia Heat and Health Hub will serve as the region's central platform for collaboration, knowledge exchange, and policy innovation on heat-related health risks.

In addition, there is a new South Asia Climate-Health Desk, established as part of the WHO-WMO Climate and Health Joint Programme and implemented with the Indian Institute of Tropical Meteorology (IITM), India Meteorological Department (IMD), and other partners.

The WMO Coordination Mechanism (WCM) delivers a Global HydroMet Weekly Scan and the Global Seasonal Climate Outlook Briefing, to support UN and humanitarian agencies in preparedness and early action. These products are even more relevant given the likely development of El Niño.

ICBA and IWMI to strengthen global collaboration on water security and climate-resilient agriculture

The International Center for Biosaline Agriculture (ICBA) and the International Water Management Institute (IWMI) have signed a strategic Memorandum of Understanding (MoU) to advance scientific collaboration in sustainable water management and climate-resilient agriculture. The

agreement between the two research centers comes at a time when global water scarcity and food security challenges are intensifying. The MoU was signed by Tarifa A. Al Zaabi, Director General of ICBA and Mark Smith, Director General of IWMI, during an official



delegation visit to ICBA's headquarters in Dubai. The agreement establishes a three-year cooperation framework focused on joint research, knowledge exchange, capacity development and integrated solutions to strengthen the resilience of water and food systems in regions highly exposed to climate risks.

"This partnership comes at a time when more than two billion people live in countries experiencing high water stress, and climate-related disruptions to food systems are becoming more frequent and severe," Al Zaabi said. "By combining ICBA's applied research strengths with IWMI's global leadership in water management, we aim to accelerate the development of solutions that support countries navigating these converging pressures. This collaboration is not only timely it is essential for building a more secure and climate-resilient future."

"ICBA and IWMI bring capabilities that are critical for future food security and water security in the driest regions of Africa, MENA and Central Asia, where vulnerability to climate change is highest," Smith said. "Both organizations

are driven by applying science and innovation to sustainable development. This MoU reflects our shared recognition that by working together, we will be more successful in meeting the expectations of our partners and stakeholders."

The collaboration builds on mutual priorities at a moment when the Middle East and North Africa region is warming at nearly twice the global average, with 2024 identified by the World Meteorological Organization as the region's hottest year on record — a trend that continues to exacerbate water scarcity and pressure on food systems. According to the Food and Agriculture Organization of the United Nations (FAO), agriculture accounts for roughly 70% of all freshwater withdrawals worldwide, underscoring the urgency of improving water efficiency and advancing climate-resilient production systems.

As part of the official visit, the IWMI delegation headed by Smith and Rachael McDonnell, Deputy Director General toured ICBA's research facilities, gaining insight into ongoing work in digital agriculture, saline water irrigation systems, climate-resilient crop research and soil health innovations. Both teams also discussed strategic water initiatives for the United Arab Emirates and globally, including opportunities for digital water analytics, drought preparedness planning and data-driven decision-support tools for national water and food security programs.

The partnership positions ICBA and IWMI to jointly mobilize expertise, resources and scientific evidence to support countries facing tightening water budgets, rising temperatures and complex food system vulnerabilities. It also creates new pathways for collaborative innovation, policy engagement and research investments designed to generate meaningful, scalable impact over the coming decade.

UN sounds alarm over rising demands on water resources as scarcity increases

It provides an update on renewable water availability, which refers to the amount of freshwater that is replenished each year in rivers and aquifers through precipitation.

Renewable water availability per person has declined by seven per cent over the past decade – from 5,326 to 5,719 cubic metres (m³), according to the 2025 AQUASTAT Water Data Snapshot.

Regions such as Northern Africa, Southern Asia and Western Asia have the lowest freshwater resources per capita, with Kuwait, the United Arab Emirates, Qatar and Yemen ranking among top countries with lowest total renewable water.

Increase in freshwater withdrawal

Several regions have also seen an increase in freshwater withdrawals in recent years, which is adding to the strain on already stressed river basins and aquifers.



"Northern Africa saw the largest increase, with freshwater withdrawals rising by 16 per cent," the report said.

International News

Most withdrawals globally, nearly 70 per cent, were from surface water sources, while 23 per cent came from groundwater.

Water for agriculture

Agriculture remains the largest water-using sector, accounting for some 72 per cent of freshwater withdrawals globally. The industrial and service sectors followed at 15 per cent and 13 per cent, respectively.

Sixty-six countries allocated more than 75 per cent of their total freshwater withdrawal to agriculture.

For Afghanistan, the Lao People's Democratic Republic, Mali, Nepal, Somalia and Sudan the figure was 95 per cent.

Shift in availability and demand

The report also shows how water availability and demand are shifting across regions.

This includes North Africa, where freshwater availability per head remains among the lowest globally, while withdrawals have increased by 16 percent over the past 10 years.

In Western Asia - which for the report includes most Middle Eastern countries - rapid demographic growth and agricultural demand are contributing to increased pressure on limited supplies.

Irrigation and efficiency

The report also highlights wide disparities in irrigation and water-use efficiency in cultivated land.

"In parts of Latin America and Asia, irrigation supports a large share of crop production, whereas in sub-Saharan Africa irrigated cropland represents only a small fraction of total cultivated land, reflecting persistent gaps in access to water infrastructure," FAO said.

At the national level, Bahrain, Egypt, Saudi Arabia, Suriname, and Uzbekistan reported the highest irrigation coverage. Over 90 per cent of cultivated land in these countries is equipped with irrigation infrastructure.

In contrast, some 35 countries – mainly in sub-Saharan Africa – had less than one per cent of cultivated land under irrigation.

African Development Bank convenes stakeholder workshop to scale youth-owned climate solutions



The African Development Bank Group has concluded a stakeholder consultative workshop, bringing together business leaders, policymakers and development partners to advance youth-owned adaptation solutions supported by the Bank's YouthADAPT programme in its new phase.

Held from 24–25 February 2026, the consultation reviewed delivery experience from YouthADAPT's first three cycles, examined key lessons emerging from implementation, and explored design options for the programme's fourth Cycle. Discussions highlighted the need to move beyond stand-alone grant funding, strengthen post-award support, improve

market and investor linkages, and build a more sustainable financing model for early-stage climate enterprises.

YouthADAPT is a flagship initiative implemented by the African Development Bank to support youth-owned enterprises delivering innovative climate adaptation solutions across Africa, funded by the Bank's Youth Entrepreneurship Multi-Donor Trust Fund (YEI MDTF) and the Africa Climate Change Fund (ACCF). In its first three cycles (2021–2025), the programme supported 39 enterprises across 20 African countries and helped generate approximately 11,000 direct and indirect jobs.

International News

Women-owned businesses accounted for 63 percent of the portfolio, underscoring the programme's contribution to inclusive climate entrepreneurship.

Opening the workshop, Al-Hamndou Dorsouma, Manager for Climate and Green Growth at the African Development Bank Group, underscored the strategic importance of youth-led innovation in strengthening climate resilience across Africa.

"Africa is the world's youngest continent, yet it is also the most climate-vulnerable. Innovation is the bridge between these two realities," Dorsouma said. "It is how young Africans are building solutions in water, food systems, energy access, the circular economy, and climate-smart services—solutions that are faster to deploy at scale with greater impact."

Edith Ofwona Adera, YouthADAPT Coordinator at the African Development Bank Group, noted that the programme had reached an important point of reflection and evolution, stressing the need to use lessons learned to build a more resilient and lasting framework that empowers young African innovators to expand their climate adaptation efforts.

Emphasising on partnership and learning, Mary Kashangiki, Manager for Early-Stage Finance at Financial Sector Deepening Africa noted that the consultation process would help integrate lessons from YouthADAPT with broader efforts to strengthen climate innovation financing across the continent.

Participants agreed that the fourth cycle of YouthADAPT should place entrepreneurs at the centre of the programme

design, ensuring that support responds directly to their financing, capacity-building and market-access needs. They also stressed that enterprise growth depends on stronger ecosystem around founders — including earlier investor engagement, enhanced venture-builder support, stronger local partnerships, and clearer pathways from catalytic grant funding to sustainable follow-on finance.

Facilitators also revisited findings from the pre-workshop survey, which identified key risks to programme effectiveness. These included weak transitions to private finance after programme completion, designs that insufficiently reflect local market realities, and overreliance on single delivery partners.

A recurring recommendation was the introduction of a clearer capital transition pathway within the programme. This could combine catalytic grants with milestone-linked tranches, returnable or revenue-based instruments where feasible, and investor advisory mechanisms to de-risk follow-on finance. The aim is to reduce long-term grant dependency while helping enterprises become bankable and investment-ready without exposing them to inappropriate financing terms.

The workshop concluded with agreement on next steps, including consolidating findings into a design-ready package, conducting targeted follow-up consultations, and working with implementation partners to shape a scalable, partnership-driven and outcomes-focused delivery model for the programme's fourth cycle. <https://www.afdb.org/en/news-and-events/african-development-bank-convenes-stakeholder-workshop-scale-youth-owned-climate-solutions-91596>

Eco-Friendly Solutions to Combat Cactus Cochineal in Morocco and beyond



On 12 December 2025, ICARDA hosted the Launch of the Eco-Friendly Cochineal Management Project in Morocco in Rabat. The workshop brought together 20 participants from different institutions, including research organizations,

extension services, cooperatives and NGOs partners, underscoring the strong multi-stakeholder commitment to protecting cactus production systems.

Cactus is a key commodity for Rural Resilience in dry areas

Cactus plays a strategic role in Morocco and other countries with dryland agriculture, supporting rural livelihoods, livestock feed, climate resilience, and ecosystem services. However, the invasive cactus cochineal (*Dactylopius opuntiae*) continues to pose a serious threat, particularly in marginal and arid areas where alternative crops are limited. The workshop aimed to align stakeholders around science-based, eco-friendly, and scalable solutions, while strengthening cooperation between Moroccan institutions, ICARDA, and the Spanish Embassy/ Spanish Agency for International Development Cooperation (AECID).

Stakeholder Commitments

Opening remarks underscored the importance of collaboration and innovation in addressing shared agricultural challenges. ICARDA highlighted the need for integrated approaches that link research, development, and extension to ensure solutions reach farmers effectively. AECID reaffirmed Spain's commitment to supporting sustainable agricultural practices and strengthening Moroccan-Spanish scientific cooperation. L'Office National du Conseil Agricole (ONCA) emphasized its national mandate to support farmers, promote sustainable cactus cultivation, and implement national agricultural strategies, while also acknowledging the operational challenges posed by the rapid spread of cochineal.

From Research to Field-Level Solutions

Technical sessions showcased promising eco-friendly management options, including essential oils, entomopathogenic fungi, plant extracts, and the effective use of black soap under field conditions. Participants emphasized that no single solution is sufficient, and that Integrated Pest Management (IPM) combining resistant varieties, biological control, cultural practices, and limited chemical use where necessary—is essential.

Experiences shared by the Dar Si Hmad Foundation demonstrated the value of community-based, pesticide-free approaches, particularly in areas such as Sidi Ifni, where cactus supports both farmer incomes (up to 60%) and agriculture. Cactus cooperatives highlighted the cultural and



economic importance of local varieties and the challenges they face in adopting sustainable practices.

Knowledge Sharing and Innovation

Platforms such as the “Universidad Itinerante” WhatsApp group illustrated how digital tools can enhance knowledge exchange among farmers, researchers, and practitioners across regions where cactus is an important crop. These networks emerge as powerful mechanisms for disseminating practical solutions and lessons learned.

Breeding for the Future

ICARDA's cactus breeding program presented advances in developing cochineal-resistant varieties, while addressing the complexity of cactus genetics. The integration of cactus improvement into ICARDA's 2023 Research-for-Development Strategy reflects a long-term commitment to sustainable dryland agriculture.

The workshop concluded with a shared commitment to continue collaboration beyond the meeting, leveraging the strengths of ICARDA, AECID, national institutions, and local partners to protect cactus production systems and the livelihoods that depend on them.

By fostering science-based partnerships and eco-friendly innovation, the project marks an important step toward resilient, sustainable cactus production in Morocco and similar dryland regions.

Crop protection can no longer keep pace with nature. How do we catch up?

Crop protection is facing greater challenges from climate change, pest resistance and intensifying regulation. The traditional R&D system, often taking over a decade to deliver new products, is no longer aligned with the pace of biological change. Adaptive R&D systems are emerging as a practical way to improve capital efficiency

by focusing resources on higher-probability molecules earlier in development.

Crop protection is fundamental to global food security, yet it remains underappreciated outside agriculture. Each year, pests destroy an estimated 20-40% of global crop



production, contributing to higher food prices, supply instability and economic strain. These pressures are increasing as climate change accelerates pest evolution and creates more volatile growing conditions.

The urgency is amplified by rising global food demand, biodiversity loss and increasing expectations for sustainability. Biodiversity loss alone represents an estimated \$10 trillion annual impact when accounting for healthcare and agricultural effects. At the same time, roughly one-third of all food produced for human consumption is lost or wasted globally.

Against this backdrop, the industry's ability to innovate is under pressure. The removal of older chemistries has increased reliance on fewer, highly effective products, accelerating resistance. Field evaluation remains constrained by seasonal cycles, while climate variability adds further complexity. At the same time, global regulatory requirements continue to expand, increasing cost, timelines and uncertainty.

Over the past 50 years, R&D models have produced new crop protection products at an average of 12.3 years, at costs exceeding \$300 million per active ingredient. This pace is no longer aligned with the challenges agriculture faces. The industry must rethink how innovation is delivered.

The limits of traditional R&D

For decades, innovation followed a linear path from discovery through to commercialization. This model delivered results, but it was built for a different era. Today, it is misaligned with the pace of biological and environmental change. Development timelines exceed a decade, while resistance can emerge in just a few years. The gap is widening.

Constraints that define the system are unlikely to change quickly. Products must be validated across multiple crop cycles. Safety assessments continue to rely on animal testing. Regulatory frameworks are expanding globally. These are necessary, but they limit where speed can be gained.

Where adaptive R&D can deliver

Adaptive R&D is not simply about moving faster across the entire pipeline. It is about concentrating innovation where it is most feasible today: early discovery.

At this stage, constraints from field seasons, regulatory requirements and large-scale validation are significantly reduced. This allows for rapid, iterative experimentation, where integrated computational tools and high-throughput validation can compress cycle times from several years to one to two.

AI-enhanced discovery plays a central role in this shift. By identifying patterns, prioritizing novel modes of action and filtering candidate pools before synthesis, it enables organizations to eliminate low-probability options earlier. Leading programmes are already reducing candidate pools by more than 90% prior to synthesis while improving early success rates.

This fundamentally reframes the problem. Rather than attempting to accelerate the entire pipeline – much of which is structurally constrained – adaptive R&D improves how capital is allocated at the earliest stages. Resources are directed toward higher-probability candidates, reducing downstream attrition and increasing the likelihood that successful products emerge.

Failures in this system are not sunk costs, but inputs into continuous learning cycles. The result is a more capital-efficient model that expands the innovation space while improving decision quality.

Impact will come from focusing on what can change within meaningful time frames. Regulatory standards will remain rigorous. Field validation will continue to depend on seasonal cycles. Safety requirements will not fundamentally shift in the near term.

The opportunity is to act where constraints are lowest: early discovery. By concentrating innovation efforts here, the industry can improve speed and efficiency today, without relying on longer-term changes to regulatory frameworks or testing paradigms. This is where adaptive R&D can deliver immediate, measurable impact.

Why resiliency still matters

Speed and efficiency must be paired with resiliency. This requires diversified pipelines, multiple modes of action, and validation across geographies and crops. Sustainability considerations must also be integrated early in the discovery process.

Agriculture operates under constant biological evolution, climate volatility and geopolitical pressure. Organizations that adopt adaptive R&D with discipline can improve capital efficiency, accelerate discovery, and increase the likelihood that new solutions reach farmers in a relevant timeframe.

The question is no longer whether the industry can move faster. It is whether it can redesign how innovation happens – focusing capital, learning and decision-making where they can have the greatest impact now. Those that do not will fall further behind. <https://www.weforum.org/stories/2026/04/crop-protection-agriculture-innovation/>

Nature-based infrastructure is vital to avert Asia's looming water crisis: Asian Development Bank (ADB)

The Asia-Pacific has made remarkable progress in water and sanitation over the past decade. Hundreds of millions more people now have access to clean and reliable water and sanitation, improving public health, productivity and dignity across the region.

But beneath the progress lies a growing vulnerability. The natural systems that are the basis for water security—wetlands, rivers, and aquifers—are deteriorating rapidly. This is evident in the more than 80% slump in the global populations of freshwater species since 1970. If the decline in water systems continues, it could unravel decades of hard-won gains and expose economies and communities to escalating risks.

The Asia-Pacific is home to 60% of the world's population and some of its most fragile ecosystems. Rapid urbanization and industrialization, groundwater depletion, river pollution, deforestation, and the loss of coral reefs and mangroves are straining water systems to breaking point. The changing climate is intensifying these pressures, bringing longer droughts, heavier rainfall and more destructive floods.

Just over a decade ago, the region's most urgent water challenge was basic access to water and sanitation, particularly in rural areas. Massive investments into supply systems, sewers and wastewater treatment, as well as better access to toilets and improved hygiene, have transformed that picture. In Nepal, for example, the near-total elimination of open defecation has delivered major benefits in public-health and reduced waterborne diseases.

Since 2007, the Asian Development Bank (ADB) has been tracking water security in the Asia-Pacific. Across 50 economies surveyed by the latest Asian Water Development Outlook, our analysis shows that since 2013 most countries have improved in rural, urban and economic water security. To put that into perspective, around 2.7 billion people, equivalent to about 60% of the region's population, have been lifted from the most extreme forms of water insecurity.

But one indicator stands out for the wrong reason: environmental water security—how well countries protect the ecosystems that supply and regulate clean water. In 30 economies, performance either stagnated or declined. Even among the 10 strongest overall improvers, the average gain on environmental protection was negligible.

Nature has become the weakest link in the region's water chain. Environmental water security is a core concern—it is a foundation on which all other water investments depend.



Healthy catchments filter and store water, regulate flow and buffer communities against floods and droughts. Once these systems are degraded, even the most sophisticated pipes, pumps and treatment plants cannot fully compensate.

The costs of neglect are rising fast. Despite better access to water and sanitation, around 4 billion people still face risks including poor water quality, degraded ecosystems and disasters.

The data is stark. Between 2013 and 2023, the Asia-Pacific experienced 244 major floods—41% of the global total—alongside 104 droughts and over 100 severe storms. Deforested hillsides turn rainfall into flash floods and landslides. Polluted rivers spread disease. Drained wetlands remove natural storm buffers.

Small island nations in the Pacific, urban areas and coastal megacities are especially vulnerable. Rising seas, saltwater intrusion, urban land subsidence and storm surges threaten freshwater supplies and infrastructure. While many island ecosystems remain relatively intact, weak governance—including urban planning, land management and poor enforcement of environmental safeguards—puts these natural defenses at risk.

International News

Disasters force governments to spend billions on repairs and reconstruction. Yet prevention and risk reduction—especially through nature-based solutions—remain underfunded.

The path forward is clear. Gray infrastructure and green systems must work together. Pipes, pumps and concrete drains are essential, but they are not enough on their own to manage more frequent and extreme storm events. Landscapes such as marshes, mangroves and floodplains, as well as nature-based infrastructure such as green roofs, parks, and retention ponds can retain stormwater and absorb shocks, ideally when systemically integrated with engineered gray drainage systems.

In Viet Nam, ADB helped cities become more resilient by combining green with conventional gray infrastructure and strengthening urban planning for flood impacts. This approach effectively demonstrated how a shift from concrete to nature-based solutions can deliver sustainable urban growth and enhanced water security.

Water decisions must also be inclusive, especially at a local level, to benefit groups that are most exposed. A community-led project in Mongolia shows what can be done: through training in forest planning, including practices to protect riparian zones, local people were able to improve forest health, protect river flows and boost environmental water security.

The Asia-Pacific will need an estimated \$4 trillion in water, sanitation and hygiene investment by 2040. Current

public spending covers only about 40%. Closing this investment gap is essential. But how money is spent is just as important as how much is spent. Funding new infrastructure matters; so too do budgets for maintenance and improvements.

Nepal's experience illustrates the point. While 94% of rural households have access to basic water supplies, only 55% have a piped connection and just 14% receive water free from contamination. Infrastructure without adequate maintenance, governance and ecosystem protection delivers diminishing returns.

Innovative financing—blending public, private and concessional funds such as loans at preferential rates, grants and development aid—can ease pressure while scaling up nature-based solutions.

Our data shows that trust, participation, and the effectiveness of governments and other public institutions determine whether investments succeed. Multilateral banks and development partners have a critical role to play, developing solutions in partnership with governments, communities and the private sector.

Healthy ecosystems are the first line of defense against water stresses and shocks. If we invest in them wisely, they will deliver water security, resilience and sustainable growth for decades to come. <https://www.adb.org/news/features/nature-based-infrastructure-vital-avert-asias-looming-water-crisis>





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First Indo-Global Irrigation Summit, 24-25 June 2025, Dr. Ambedkar International Center, New Delhi

As part of its Platinum Jubilee celebration, the International Commission on Irrigation and Drainage (ICID), under the aegis of the Ministry of Jal Shakti, Department of Water Resources, River Development and Ganga Rejuvenation, Government of India, organized the Indo-Global Irrigation Summit (IGIS) 2025. The summit was held from 24-25 June 2025 at Dr. Ambedkar International Centre, New Delhi, India. Themed "Best Irrigation Practices for Water and Food Security," the summit brought together over 300 global water professionals, including irrigation experts, engineers, policymakers, international and national financing agencies, and government representatives. The event highlighted critical global challenges such as climate change, water scarcity, and food security, and explored innovative solutions in irrigation and sustainable water management.

The summit was inaugurated by Ms. Debashree Mukherjee, IAS, Secretary, Ministry of Jal Shakti, Government of India. The ICID-75 Platinum Jubilee and Indo-Global Irrigation Summit (IGIS) were also marked by the presence of representatives from long-standing associates and new partners, including representatives from the World Bank (WB), the International Water Management Institute (IWMI), the Food and Agriculture Organization (FAO), the Ministry of Water Resources of Tajikistan, the Central Water Commission, WAPCOS, and the Water Resources Departments of Maharashtra, Bihar, Gujarat, Kerala, Tamil Nadu, Haryana, Punjab, and Rajasthan, along with several industrial manufacturers.

From the ICID community, the summit welcomed Dr. Marco Arcieri, President, ICID, Dr. R.K. Gupta, Secretary General, ICID, President Hon. Eng. Felix Reinders, President Hon. Prof. Dr. Chandra Madramootoo, and Prof. El-Houssine Bartali, Vice President, ANAFIDE. Diplomatic representatives included H.E. Mr. Dharamkumar Seeraj, High Commissioner of Guyana; Mr. Kayshav Tewari, Second Secretary at the High Commission of Guyana; and Mr. Nazar Mirjan Mohammed, Charge d'Affaires, Embassy of Iraq.



Glimpses of ICID in 2025



Glimpses of ICID in 2025



The Originator of Water Conservancy Culture, Dujiangyan, China



Integrating High-Resolution DTM and HEC-RAS for Canal Performance Assessment: Case Study of Left Bank Main Canal (LBMC), Panchmahal District*

1. Introduction

Irrigation canals are vital to agriculture, but their conveyance capacity often declines due to siltation, vegetation growth, bank erosion, and unrecorded field alterations. These changes modify channel geometry, increase hydraulic roughness and head losses, and can create overtopping risks and uneven water distribution. Sediment deposition reduces operational efficiency and demands regular desilting and structural maintenance (Lund et al., 2023). Modern canal assessment increasingly uses DGPS, GNSS control, and UAV photogrammetry, as UAV-derived terrain data provide higher topographic accuracy than conventional surveys (Acharya et al., 2021). When integrated into HEC-RAS, these datasets support more reliable hydraulic simulations essential for effective operational planning (Serede et al., 2014).

This study integrates DGPS- and UAV-based topographic data to generate a high-resolution DTM/DSM and 30-m interval cross-sections for one-dimensional steady-flow modelling in HEC-RAS under the design discharge of 600 cusecs. The approach is built on (a) detailed geometry to minimize uncertainty, (b) the proven capability of HEC-RAS for canal and structure modelling, and (c) design-flow evaluation to identify overtopping-prone and constricted reaches requiring corrective action.

The Left Bank Main Canal (LBMC) of the Panam High-Level Canal (PHLC) system serves a large command area in Panchmahal district, Gujarat. Field observations and preliminary surveys indicate rising bed levels and localized siltation that may be restricting conveyance. With changing operational demands and monsoon variability, an updated hydraulic assessment is required to evaluate safe discharge, overtopping and erosion risks, and the performance of existing syphon structures. Such analysis supports Gujarat's ongoing canal modernization and data-driven maintenance initiatives.

2. Objectives of the study

The primary objective of this study is to assess the hydraulic performance of a 26 km stretch of LBMC using high-resolution survey data and hydraulic modelling. The specific objectives are to:

- Develop accurate canal geometry inputs by extracting and validating cross-sections from DGPS and UAV-based surveys.
- Simulate hydraulic behavior at the design discharge of 600 cusecs to analyze water surface profile, flow depth, and conveyance efficiency.
- Identify sections vulnerable to overtopping by comparing modelled WSE with embankment elevations.
- Evaluate the hydraulic adequacy of 13 syphons, focusing on discharge capacity, head losses, and velocity variations.
- Provide data-supported recommendations for flow regulation, maintenance, and structural improvement.

3. Study area

The study covers a 26 km stretch of the Left Bank Main Canal (LBMC), a major conveyance component of the Panam High Level Canal (PHLC) system in the Panchmahal district of Gujarat, India. The canal reach, shown in Figure 1, deliver irrigation water from the headworks to downstream command areas. The alignment passes through semi-undulating terrain with predominantly agricultural land use and minor settlements. A total of 13 syphon structures lie along this 26 km canal stretch.

4. Methodology

The methodology integrates advanced survey techniques, terrain data processing, one-dimensional hydraulic modelling, and structural assessment into a unified

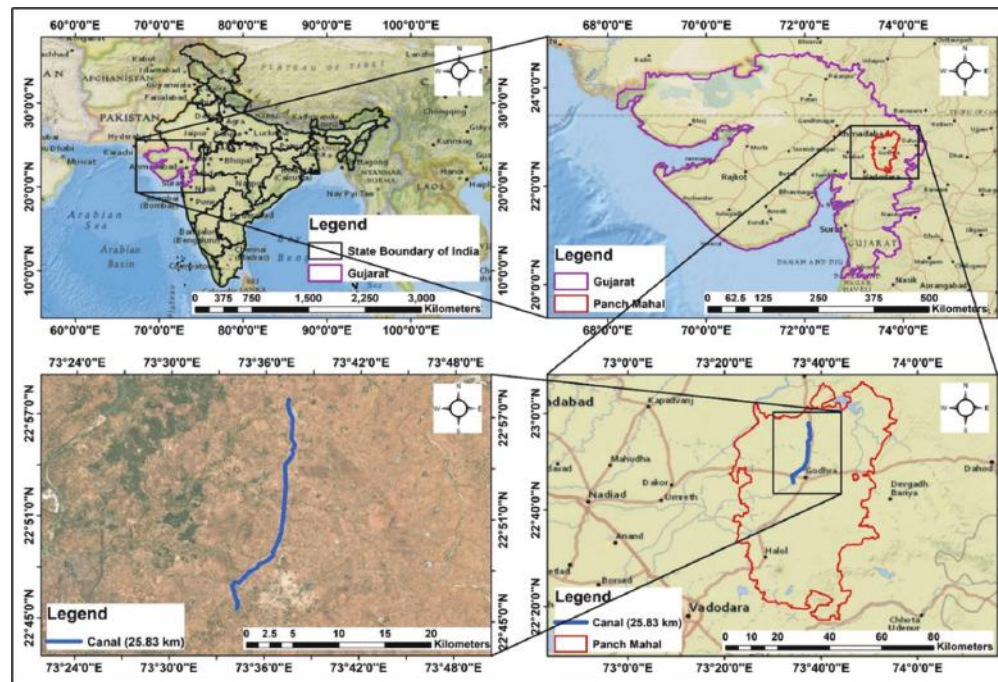


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Figure 1.
Location of the
study area.

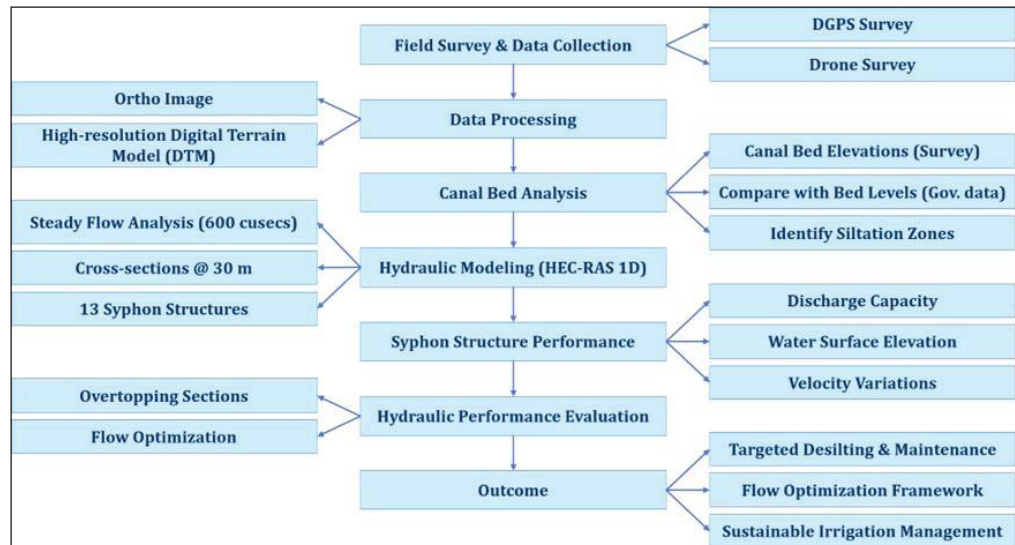


workflow, progressing from field data acquisition to hydraulic performance evaluation (Figure 2).

A detailed field survey was carried out to obtain accurate canal geometry and positional data. Photographs from the site visit are presented in Figure 3. DGPS was used to establish ground control points (GCPs) and capture the canal alignment with high positional accuracy. Complementing

this, drone-based ortho-image acquisition produced high-resolution ortho-mosaics for mapping canal geometry, bank conditions, and surrounding terrain. UAV-based photogrammetry is increasingly used in hydraulic and irrigation channel studies due to its ability to capture fine-scale topography and structural details with centimeter-level precision (Nex & Remondino, 2014).

Figure 2.
Methodology
Flowchart



Survey points, drone imagery, and elevation data were processed to generate ortho image and high-resolution DTM representing the canal bed and adjacent features. Cross-sections extracted from the DTM were validated against field observations to ensure consistency in bed levels, side slopes, and bank elevations. The dataset was further analyzed to detect siltation, elevation changes, and other geometric constraints influencing conveyance capacity.

A one-dimensional steady-flow hydraulic model was developed in HEC-RAS to evaluate the hydraulic behavior of the canal under the design discharge. The calibrated

geometry, derived from the processed survey data, was used to represent the canal's longitudinal profile. The model generated water-surface profiles, flow depths, and velocity distributions to identify overtopping-prone reaches and hydraulic inefficiencies. Within the 26 km stretch, 13 syphon structures were assessed using model-derived parameters to quantify head losses, turbulence effects, and flow-through capacity. The combined results from hydraulic simulation and syphon evaluation were synthesized to determine overall conveyance performance and to identify sections requiring desilting, structural adjustments, or flow optimization.

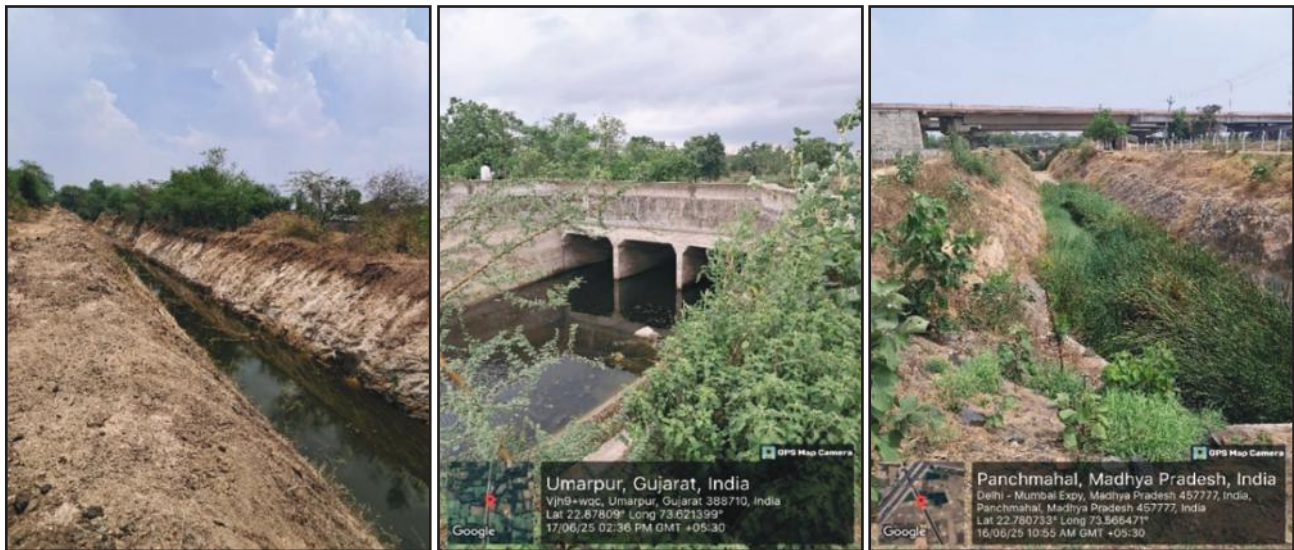


Figure 3. Site photographs

5. Results

The 26 km canal geometry was reconstructed using DGPS data and drone-derived datasets, allowing accurate extraction of cross-sections for hydraulic analysis. Bed levels, side slopes, and embankment elevations were refined where field conditions indicated discrepancies, resulting in a reliable geometric dataset for steady-flow simulation.

Steady-flow simulation for the design discharge of 600 cusecs generated the water surface profile used to assess hydraulic behavior under peak flow. While the canal reach safely conveyed the discharge, multiple sections displayed elevated water levels approaching or exceeding embankment crests, particularly where channel constriction or siltation has occurred. These overtopping-prone locations require structural or maintenance intervention. The WSE profile is shown in Figure 4.

The hydraulic response of the 13 syphon structures under the 600-cusec discharge was evaluated using model-derived flow parameters. Most syphons were operating at or near

full hydraulic capacity, and several exhibited increased downstream velocities, indicating localized acceleration, turbulence, and potential erosive risks. Minor backwater effects were observed upstream of some structures due to geometric narrowing or reduced clear-flow width.

Under the design discharge of 600 cusecs, a number of cross-sections located in the vicinity of syphon structures were found to be sensitive to hydraulic adjustments induced by flow constriction. The complete list of these cross-sections for the 600-cusec simulation is compiled in Table 1.

Overall, the validated canal geometry enabled reliable simulation outputs, showing that several sections of the reach exceed safe conveyance limits under the 600-cusec design discharge. Multiple cross-sections experience water levels at or above embankment elevation, and syphons contribute to additional head losses and turbulence. These results highlight the need for flow regulation, maintenance, and potential structural strengthening to ensure safe operation at peak discharge.

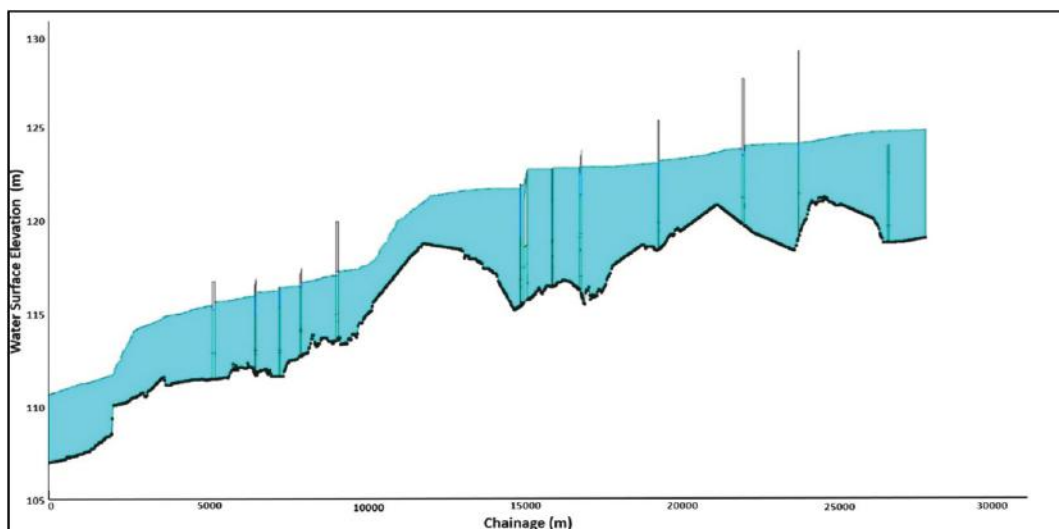


Figure 4. Water surface elevation profile (600 cusec flow)

Table 1. Affected cross-sections corresponding to syphon structure (600 cusecs)

No	Cross-Section No	Chainage (m)	Syphon No	Chainage (m)
1	25680 - 24837	600 - 1450	25194.35	1020
2	24719	1570		
3	22554 - 22410	3750 - 3900	22543.52	3660
4	22204 - 22115	4110 - 4200		
5	21465	4860		
6	20993 - 20936	5330 - 5400		
			20926	5370
7	18360	7920		
			18339	7890
8	16613 - 13504	9610 - 12720	15924	10185
			15106	11150
			14353	11830
			14160	12010
9	8808 - 8779	17430 - 17490		
			8762.75	16950
10	7749 - 7453	18530 - 18830	7709.55	18060
11	7199 - 6879	19080 - 19410	7082.56	18690
12	6373 - 6366	19920 - 19930		
			6346	19170
13	5291 - 5168	20970 - 21090		
14	5124 - 5107	21120 - 21180		
			5053	20640
15	3996 - 3966	22280 - 22310		
16	1218 - 860	25020 - 25400		
17	143 - 24	26100 - 26220		

*The blue-highlighted cells indicate the syphons operating at full capacity under the design discharge.

6. Conclusion

The present study reconstructed the canal geometry and assessed its hydraulic performance at the design discharge of 600 cusecs. DGPS surveying combined with drone-based high-resolution mapping enabled accurate capture and validation of the canal alignment, embankments, cross-sections, and structures for modelling. The integration of DGPS elevation control with drone-derived ortho-mosaics and DTM provided a detailed spatial representation of channel conditions, flow paths, and micro-topographic variations.

Hydraulic simulation results show that several parts of the canal reach experience elevated water surface levels, in some sections approaching or exceeding the embankment crest, indicating overtopping risk under peak operation. The syphon performance analysis indicates that most units function at or near full hydraulic capacity at 600 cusecs, increasing the likelihood of erosive forces and long-term structural stress. These findings highlight the need for targeted interventions such as desiltation, structural strengthening, and flow regulation. Overall, the combined DGPS and drone-based approach proved

effective for hydraulic assessment, and the generated outputs (validated elevations, cross-sections, WSE profiles, and summary tables) provide a strong technical basis for future decision-making.

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Gravity-Piped Irrigation Network (G-PIN) from a High-Altitude Canal Sourced from a Low-Altitude Reservoir by Lifting Water: A Success Story of Upper Indravati Lift Canal System

Siva Prasad Patnala*

Introduction

Conventional gravity irrigation systems in India predominantly rely on open canal networks fed by dam or barrage reservoirs. These systems demand extensive land acquisition from farmers, local bodies, and forest departments, while also disrupting natural drainage patterns and cutting across existing road and rail infrastructure. Such networks necessitate a range of civil structures — both along the main canal and within the distribution network — including road-crossing bridges, canal syphons or aqueducts for stream and river crossings, drainage syphons, and flow-regulating structures. The viability and extent of irrigation under this system is entirely contingent on the hydraulic head available at the source; coverage is therefore limited to the command area that this head can serve.

In recent years, a hybrid irrigation model has gained traction across India — one that involves lifting water from lower-altitude reservoirs through a dedicated pump house, storing it temporarily in single or multiple service reservoirs constructed at higher altitudes, and then distributing it through an underground Gravity-Piped Irrigation Network (G-PIN), also widely referred to as Underground Gravity Pipelines (UGPL) in several Indian states. These service reservoirs — designed for a defined detention period — may take the form of elevated RCC water tanks or ground-level artificial reservoirs, with water supplied to them through continuous pumping before being released into the distribution network under gravity. This approach has been successfully implemented in Odisha

under the Lift Canal System framework, and has similarly been adopted in states such as Gujarat, Madhya Pradesh, Maharashtra, and Jharkhand.

This paper presents the success story of the Upper Indravati Lift Canal System, which incorporates a gravity-piped distribution network to irrigate 26,248 hectares of upland command area in the Kalahandi district of Odisha — a region that had depended entirely on rain-fed agriculture during the monsoon season until the end of 2020.

History

Kalahandi district, located in the southwestern part of Odisha, has long been synonymous with drought and deprivation — conditions that have historically driven poverty and distress among its population. Agriculture in the district is predominantly rain-fed and rice-centric, with maize and chili emerging as significant crops in recent years. However, the sector has consistently faced structural challenges including inadequate irrigation infrastructure, limited market access, and a weak agro-processing ecosystem — despite the district's considerable agricultural potential.

To address the chronic drought conditions in Kalahandi, the Water Resources Department (WRD), Government of Odisha — the sole Project Implementing Unit (PIU) for Command Area Development (CAD) in the state — launched the Upper Indravati Irrigation Project (UIIP) in 1978, with the twin objectives of providing assured irrigation to drought-prone areas and improving the socio-economic conditions of the farming community.



Siva Prasad Patnala, Head (Civil) – LWS, III SBG, WET IC at L&T, is a seasoned leader with 20+ years of expertise in infrastructure and irrigation projects. He spearheaded the landmark UIIP Canal Project in Odisha, delivering ahead of schedule and earning recognition as the state's fastest irrigation project. Under his leadership, multiple lift irrigation schemes across India were successfully engineered, covering intake structures, pump houses, and distribution networks. His strategic contributions extend to high-value bidding and execution excellence. Prior roles include managing World Bank-funded rural road projects and leading major highway and canal initiatives with GKC Projects.

GRAVITY-PIPED IRRIGATION NETWORK (G-PIN)

The project is anchored by a large reservoir formed by a dam across the River Indravati, with a gross storage capacity of 2,300 MCM and a live storage of 1,435.5 MCM. An integrated water conductor system conveys water through a 165-meter head race channel and a 4.32-km long, 7-meter diameter head race tunnel — designed to carry a discharge of 210 cumecs — into a surge shaft. From the surge shaft, two 330-meter long, 5.25-meter diameter pressure shafts carry the flow to a bifurcation near the valve house, which feeds four surface penstocks, each 790 meter long and 3.5 m in diameter. These penstocks supply water to a powerhouse equipped with four 150 MW generating units operating under an average gross head of 371 meters. The first unit was commissioned in 1999, with the remaining three units progressively brought online thereafter.

Following power generation, the water is discharged through a 9-km tail race channel into the Hati River, from where it reaches the Mangalpur Barrage — a 12.01-meter high, 117-meter-long weir constructed across the Hati River with a live storage capacity of 603.57 hectare-meter. Two main canals originate from the Mangalpur Reservoir: a 48.5-km Left Bank Canal serving a Culturable Command Area (CCA) of 59,309 hectares, and a 70.4-km Right Bank Canal covering 42,455 hectares. Together, these canals serve a total CCA of 1,01,764 hectares through an open gravity canal network in the Hati River basin. The WRD/PIU has been operating and maintaining the Left Canal irrigation distribution system since 1999 and the Right Canal system since 2005.

No.	Name of the Canal System	CCA in Ha
1	Left Canal System up to River Tel	49,085
2	Right Canal System up to River Sagada	27,195
3	Left Canal Extension beyond River Tel	10,224
4	Right Canal Extension beyond River Sagada	15,260
5	Kokasara Mega Lift (Lift Canal System) (L&T Scope of work)	26,248
	Total	1,28,012

The PIU encountered significant challenges during construction, the foremost being land acquisition for the main and distribution canals — an inherently time-consuming process further compounded by local resistance. Communities were apprehensive about losing agricultural land, their primary livelihood, and largely unaware of the project's long-term benefits. Being gravity canals, the alignment also required numerous crossings of roads and natural drainage courses, necessitating the construction of road bridges, canal syphons, drainage syphons, and aqueducts. Additionally, repair and maintenance of this open canal system has remained operationally demanding, adversely affecting overall irrigation efficiency.

In view of these challenges, the WRD held extensive deliberations with its stakeholders and arrived at an underground Gravity-Piped Irrigation Network (G-PIN) as the preferred solution — designed to minimize land

acquisition cost and time, evapotranspiration losses, and maintenance costs, while improving irrigation efficiency and meeting environmental water needs. To realize this concept, the WRD proposed a high-altitude open gravity canal to irrigate uplands and make water available to villagers for domestic use, livestock, and nearby plantations, orchids and forest areas, by pumping water from the Mangalpur Reservoir.

WRD has identified 26248 Ha of Uplands CCA of Kalahandi district to implement G-PIN as a pilot project.

Scope of work

- ❖ This project envisages lifting of 30 m³/sec of water up to a total head of 32m including losses, from the Reservoir of existing Hatti Barrage near village Mangalpur in Jaipatna tehsil of Kalahandi District of Odisha.
 - ❖ Construction of forebay and Pump House located on the left bank of the Reservoir with 8 vertical turbine pumps and 8 rows of M.S. pipes with each pump having a capacity of 13500 m³/hr.
 - ❖ Power System connectivity through Electrical distribution Sub-Station by connection to the nearest 220/132kV grid station.
 - ❖ 15.3km transmission line from existing 220/132kV Grid Substation located at Baner ensuring reliable power connectivity and efficient energy distribution to the project.
 - ❖ Construction of 132/6.6kV Switchyard in the pump house complex to feed the power to Pump motors and other utilities.
 - ❖ Rising Main: 4.65km length, 8 rows of 1600mm diameter Mild Steel pipes laid underground with a total discharge of 30 m³/sec delivering into a convergent Delivery chamber, end of which is the starting point of the open canal i.e., Gravity Flow. A structure with energy transition from residual head to atmospheric head is achieved in a curved shape structure - Delivery Chamber (Pic-1) transiting turbulent flow into a laminar flow.
 - ❖ A 43.260 km long CC lined contour canal to carry discharge of 30m³/sec with 22 nos. of off-taking structures (Head Regulators) and with an underground closed conduits distribution system up to a 4-ha block chak (UGPL) to provide irrigation to a command area of 25,275 ha.
- This canal is constructed over land of 320Ha through Land Acquisition by WRD, Govt. of Odisha.**
- ❖ The end of the canal at 43.260km is proposed with a Tail End structure allowing excess unused water, if any by chance, to fall into the River Behera, which is a tributary of Tel River.



Pic-1. Delivery Chamber

This enabled inter-basin diversion of water from the Godavari basin (Indravathi) to the Mahanadi basin (river Behera) by this Lift Canal System.

- ❖ Additionally, a command area of 1000 Ha. on the higher elevation in the deep cutting reach of the canal is irrigated through a pressurized underground pipeline distributary system (P-PIN) by constructing a Pump House on the right bank of the canal at RD19.8km.
- ❖ Underground Pipeline Distribution Network (UGPL / PIN) consists of 1,142km closed conduit, utilizing Prestressed Concrete (PSC), High-Density Polyethylene (HDPE), and Polyvinyl Chloride (PVC) pipes covering a total command area of 26,275Ha under this project.

Pump house

Water is lifted from the Mangalpur Barrage through a pump house (Pic-2) housing 8 vertical turbine (VT) pumps, each delivering 13,500 m³/hr, via 8 rows of MS rising main pipelines of 1.6 m diameter over a length of 4.5 km and discharged into a delivery channel (Pic. 1) from which the open canal extends for 43.26 km before terminating at the Behera River. Water drawn from the reservoir at El. 260.000 m is lifted and delivered into the delivery chamber to achieve the required Full Supply Level (FSL) of 282.090 m at RD 0.0 km.

The pumps are operated through an integrated PLC–SCADA. The control architecture is based on an integrated PLC–SCADA platform supported by Instrumentation Control Panels (ICP) for real-time monitoring, control, and protection of all Electro-mechanical equipment.

The Programmable Logic Controller (PLC) system employs 1:1 hot-redundant CPUs to ensure high availability and fail-safe operation. PLCs continuously acquire key process parameters such as flow, level, pressure, and temperature from field instruments and MCC panels. Based on predefined logic and safety interlocks, the PLC executes sequential and combinational control for pumps, soft starters, and

motorized valves. Under abnormal process conditions, the PLC retains overriding authority and automatically trips the equipment to prevent damage and ensure system safety.

The SCADA system provides a centralized operator interface for monitoring and controlling the pumping station. It enables mode selection, command issuance, alarm management, trend analysis, and historical data storage. Communication between PLCs and SCADA workstations is achieved through a high-speed Ethernet network, ensuring reliable real-time data exchange.

The pumping stations are designed to operate under Remote, Auto, Manual, and Local modes, providing operational flexibility. Auto mode enables fully automated operation with all safety interlocks active, while Manual and Local modes facilitate controlled intervention during maintenance or special operational requirements. Electrical and logical interlocks remain operative across all applicable modes.

Delivery Chamber

A delivery chamber of size 65mx20m has been constructed at RD 0.0 km of the canal and a converging 90 degrees bend delivering into canal. An RCC structure is proposed to support eight rows of pipe with flap shutters to control the reverse flow of the water.

Design Methodology of Gravity Canal

A preliminary canal alignment has been identified covering a GCA of 33000 Ha on the left side of existing left main canal. A topographical survey has been conducted between this preliminary alignment and existing left main canal from Mangalapur reservoir through a surveying agency.

A contour map of 0.5m contour interval has been prepared, and the canal alignment fine-tuned reach wise to balance earth work cut and fill quantities. Planning the location of offtake structure is a challenging task, as each structure must cover the maximum possible command area. The

GRAVITY-PIPED IRRIGATION NETWORK (G-PIN)



Pic-2. Pumping Station

entire command area is examined critically based on its contours and divided into 22 zones (Table-1) keeping in mind major streams and rivers crossing the canal alignment. The canal is accordingly designed into 8 reaches with telescopic reduction in cross section area. All the 22 Head regulating structures (Pic-3) are proposed with manually operated gates, as no Power Source is available nearby. Each zone is designed as a G-PIN system.

The Main Canal is a contour canal with a total length of 43.260km, falling within Survey of India toposheets 65 I/9 SE, 65 I/10 NE, 65 I/10 SE, 65 I/11 NE, and 65 I/15 NW and is designed to carry a discharge of 30cumecs.

The Upper Indravati Lift Canal is divided into eight reaches (Table-2) based on the discharge requirements of the distributaries in each zone. Eight cross-regulating structures (Pic-4), cross-drainage structures (Pic-5), and

Table 1. Canal Distributaries Statement

Sl. No.	Chainage (m)	Off take	Discharge for each offtake (cumecs)	CCA (Ha)	Reqd Discharge in Canal at the head of Chainage (Cumulative) (cumecs)	Canal Reaches (m)	Reqd Discharge in Canal at the head of Chainage (cumecs)	Discharge provided in the canal (Cumecs)
1	20	DM-1	0.571	543.00	28.386	0-4060	28.386	29.584
2	760	DM-1A	0.466	438.00	27.798			
3	2160	DM-1B	0.454	426.00	27.316			
4	4560	DM-2	0.506	472.00	26.837			
5	6040	DM-3	0.632	590.00	26.318	4060-10910	26.318	27.208
6	7500	DM-3A	1.103	1028.00	25.674			
7	10860	DM-4	0.376	357.00	24.543	10910-14920	24.147	25.090
8	12360	DM-5	0.549	558.40	24.147			
9	13680	DM-6	0.746	722.10	23.539			
10	14860	DM-7	0.635	581.50	22.756	14920-22200	22.102	22.164
11	18400	DM-8	1.062	1199.10	22.102			
12	22120	DM-9	1.193	1117.80	20.788	22200-26700	19.570	19.733
13	25060	DM-10	1.747	1636.90	19.568			
14	26640	DM-11	2.566	2403.90	17.808	26700-35135	15.221	15.256
15	29020	DM-12	0.640	599.60	15.221			
16	31640	DM-13	0.765	716.50	14.561			
17	34230	DM-13A	1.044	978.40	13.776			
18	35120	BRANCH	5.591	5238.10	12.725	35135-32980	7.120	7.349
19	36860	DM-14	1.689	1582.80	7.120			
20	39240	DM-15	0.985	922.30	5.417	39280-43260	4.413	4.531
21	42900	DM-16	1.508	1412.20	4.413			
22	43260	DM-17	2.903	2719.80	2.903			

GRAVITY-PIPED IRRIGATION NETWORK (G-PIN)



Pic-3. Head Regulating Structure



Pic-4. Cross Regulating Structure

Table 2. Canal Section Design Statement

Canal Designs for Lift Canal of UIIP										
Sl. No.	Reach Name	Units	REACH I	REACH II	REACH III	REACH IV	REACH V	REACH VI	REACH VII	REACH VIII
	Reach From	km	0	4.6	10.91	14.92	22.2	26.7	35.135	39.28
	To	km	4.6	10.91	14.92	22.2	26.7	35.135	39.28	43.26
1	Ayacut	Acres	65018.58	60364.13	55471.89	50859.55	45120.39	33625.71	16452.81	10246.72
		Hectares	26248.00	24369.00	22394.00	20532.00	18215.10	13574.70	6642.00	4136.60
2	Discharge Required (Q _r)	Cumecs	28.39	26.32	24.15	22.10	19.57	15.22	7.12	4.41
3	Bed Width (B)	m	8.50	8.10	8.10	7.40	7.00	6.10	3.40	2.75
4	Bed Fall (S)	1 in	6000	5600	5600	5200	5000	5000	5000	5000
5	Rugosity Coefficient (n)	n	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
6	Full Supply Depth (FSD)	m	2.40	2.30	2.20	2.10	2.00	1.85	1.60	1.35
7	Free Board	m	0.75	0.75	0.75	0.75	0.75	0.75	0.60	0.60
8	Side Slopes (s)	1 in	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
9	Wetted Area (A)	Sq.m.	29.04	26.57	25.08	22.16	20.00	16.42	9.28	6.45
10	Wetted Perimeter (P)	m.	17.15	16.39	16.03	14.97	14.21	12.77	9.17	7.62
11	R=A/P	m.	1.69	1.62	1.56	1.48	1.41	1.29	1.01	0.85
12	R ^{2/3}		1.42	1.38	1.35	1.30	1.26	1.18	1.01	0.89
13	Velocity (V)=(1/n)*r ^{2/3} *sqrt(1/S)	m/s	1.02	1.02	1.00	1.00	0.99	0.93	0.79	0.70
14	Design Discharge (Q _d)	cumecs	29.584	27.208	25.090	22.164	19.733	15.252	7.349	4.531
15	Critical velocity (V _o)=V _c = c*d ^{0.52}	m/s	0.84	0.82	0.80	0.78	0.76	0.73	0.68	0.62
16	C=Constant=0.53									
17	V/V _o		1.22	1.25	1.25	1.28	1.30	1.27	1.17	1.13
18	B/D ratio		3.54	3.52	3.68	3.52	3.50	3.30	2.13	2.04
19	Lining Thickness	m	0.075	0.075	0.075	0.075	0.075			

village road bridges (Pic-6) have been provided as per site requirements, with the head loss at each structure duly accounted for in the hydraulic design and longitudinal section of the main canal along its full length.

Three canal escape regulators (Pic-7) have been provided for canal maintenance. Their locations have been strategically selected in proximity to major river crossings — namely Gaidhar Nadi (RD 14.7 km), Kamal Nadi (RD 22.2 km), and Behera Nadi (RD 40.02 km) — and sufficiently upstream of

aqueduct approach sections to avoid canal banking reaches. Escape regulating structures are constructed on one bank of the canal to facilitate smooth discharge into natural streams or rivers during emergencies or maintenance. An escape channel has also been designed and constructed parallel to the main canal, incorporating suitable canal drop structures for energy dissipation.

In response to requests from the local community for cross-canal access, a walkway bridge (Pic-8) was constructed to

GRAVITY-PIPED IRRIGATION NETWORK (G-PIN)



Pic-5. Cross Drainage Structure



Pic-6. Village Road Bridge



Pic-7. Escape Regulator



Pic-8. Walkway Bridge

serve cattle movement and pedestrian use. The structure has no central pier and is supported on pile foundations on the canal banks. This footpath bridge is provided in addition to the mandatory road-crossing bridges constructed at several locations along the canal.

The canal alignment crosses eight major rivers, at each of which an aqueduct has been provided (Pic-9). Head losses — including eddy, entry, exit, and friction losses

— at all structure locations were computed during the preliminary design stage. During detailed engineering of these structures, it was ensured that actual head losses did not exceed those assumed in the preliminary design. Consequently, the canal hydraulic design remained unaltered through the detailed hydraulic and structural design stages. This ensured that the head available for the G-PIN of each zone was preserved, thereby safeguarding the intended command area.



Pic-9. Aqueduct

GRAVITY-PIPED IRRIGATION NETWORK (G-PIN)

Design of Piped Irrigation Network (PIN)

Water is drawn from main canal into 22 Distributary Mains. The distribution hierarchy systematically routes water to the highest elevations of designated 32-hectare blocks, which are subsequently subdivided into eight 4-hectare chak. At these 4-hectare sub-chak outlets, local Water Users Associations-Pani Panchayats-assume responsibility for equitably distributing the water to individual farmers and fields.

Hydraulically, the network is engineered for a design discharge (Duty) of 1.067 litres per second per hectare maintaining a crucial minimum residual head of 1m above ground level at the 4-hectare outlets (Pic-10), where orifice

controls ensure the exact, designed discharge is delivered. Operation and maintenance are actively supported by a network of butterfly, flush-out and air valves throughout the pipeline. Furthermore, the entire distribution network has the control systems to continuously monitor and control canal gates of both head and cross regulators.

Had this UG-PIN system been planned as open Gravity distributary canals, approximately 320Ha of land would have been required for acquisition. Moreover, all road and drainage crossings would have required Road Bridges and Cross Drainage structures in addition to Canal Drops or Canal Falls to negotiate terrain fall. This option would have taken more time for land acquisition and construction and there by delaying the commissioning.



Pic-10. Outlet Arrangement at 4 Ha Chak

Uchhala Pandaripakhan Lift Irrigation Scheme

Following canal realignment, a command area of 1,000 Ha at higher elevation is irrigated through a pressurized underground piped irrigation system (P-PIN), served by a pump house (Pic. 11) constructed on the canal bank at RD 19.8 km — where the cutting depth is approximately 20 m — and an overhead distribution tank of requisite capacity. This scheme is designated the Uchhala Pandaripakhan Lift Irrigation Scheme, named after the adjoining village.

This project has become a model initiative within WRD Odisha, demonstrating that deep-cutting canal sections can also serve adjoining high-altitude command areas through pumping — something not achievable through a conventional gravity distribution system.

Several similar pumping schemes with P-PIN are now being implemented across Odisha — including command areas of the Rengali Left Bank Canal and Rengali Right Bank Canal, originally planned under open canal distributary systems — with many more in the pipeline along existing canals. The Odisha Mega Lift Irrigation Projects SPV,



Pic-11. Pump house of Uchhala Pandaripakhan Lift Irrigation Scheme

under the Government of Odisha, is the nodal agency implementing these P-PIN based pumping schemes.

Benefits of this Project

The system has significantly enhanced water-use efficiency, minimized conveyance losses through underground pipelines and ensured equitable and reliable water supply down to the 4-hectare chak level. Timely execution, advanced design automation and innovative engineering solutions—such as pressurized irrigation for elevated command areas—have led to a fourfold increase in crop yields and tangible socio-economic upliftment of nearly 3 lakh farmers.

Overall, the project stands as a replicable, sustainable irrigation solution for undulating and water-scarce regions, demonstrating how integrated planning, modern technology, and community participation can turn chronic drought into long-term agricultural resilience.

Gist of benefits are

- ❖ Minimal land acquisition is required — confined to the high-altitude gravity canal corridor and the pump house complex near the source.
- ❖ The canal water is easily accessible by nearby villagers for their domestic needs, watering the nearby plantation and for their livestock as steps are provided next to road bridges and cattle ramps to reach water.
- ❖ Where water is available at lower elevations, higher-altitude command areas can be served through a P-PIN system.
- ❖ Evapotranspiration, seepage losses, and water theft are substantially reduced in PIN systems, whereas conventional canal distribution networks must be designed with 30% additional capacity to account for such losses.
- ❖ Farmers benefit as only barren lands are acquired for the high-altitude open canal, leaving irrigable farmlands undisturbed.
- ❖ Unobstructed farming across command areas results in greater irrigated coverage.
- ❖ Road and drainage crossings for UGPL are eliminated except at unavoidable locations.
- ❖ PIN construction is faster than open canal distributary networks, given the minimal requirement for crossing structures.
- ❖ PIN systems are resilient against storms, summer heat, and contamination by people or cattle.
- ❖ In pumping schemes, drip and sprinkler irrigation can be integrated with SCADA, enabling greater crop yield per unit of water.
- ❖ Orifice meters at chak heads facilitate precise flow regulation as per end-user requirements.

Way forward to Piped Irrigation System (PIN) & SCADA

The pilot project was commissioned in December 2020, following which the WRD, Odisha has extended same concept of G-PIN to serve the command areas adjoining the existing canal systems of Odisha viz.,

- (i) Phase I and Phase II of the Rengali Right Irrigation Project covering a command area of 46,000 hectares,
- (ii) Salandi Left Main canal under Anandpur Barrage Project covering a command area of 40,000 hectares,
- (iii) And many more similar projects are coming up in Odisha and other Indian States.

The SCADA system, currently operational at the pump house level, may be progressively extended to enable monitoring and control at the chak outlet level. Such expansion would facilitate real-time regulation of water distribution, improve scheduling accuracy, enhance operational transparency, and ensure equitable delivery to end users. Decentralized control of this nature would also support data-driven decision-making, reduce manual interventions, and improve overall irrigation efficiency. This approach has already been implemented successfully in Madhya Pradesh — notably the Kundaliya Irrigation Project (KIP) irrigating approximately 1,30,000 Ha CCA across both banks of the River Kalisindh, the Kalisindh Lift Irrigation Scheme covering 2,00,000 Ha CCA, and the Parwathi Lift Irrigation Scheme covering 2,00,000 Ha sourced from the Indira Sagar Project reservoir on the Narmada — with numerous similar schemes being executed for Narmada Valley Development Authority (NVDA)/WRD Madhya Pradesh by various construction agencies. This model is progressively being adopted pan-India by respective state WRD and irrigation authorities.

Conclusion

The Lift Canal System of the Upper Indravati Irrigation Project is a pioneering example of a hybrid lift-gravity irrigation model (Gravity-PIN) that has successfully transformed drought-prone Kalahandi district into a region with assured irrigation and improved agricultural productivity. By efficiently utilizing powerhouse tail-race water and combining pumped lift with gravity flow and underground pipeline distribution, the project has extended irrigation to higher elevation command area which had only rain fed irrigation till this project was commissioned.

Several similar projects are now being implemented across Indian states, with potential for replication nationwide. With SCADA and advancing digital technologies, each chak head can be controlled remotely from a centralized station covering the intended command area — an advancement that will meaningfully improve national irrigation efficiency, enhance food security through higher crop yields, and contribute to sustainable development and GDP growth.

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Submerged Inlined Flood Proof Pumpset (AILFP) Submerged Centrifugal Flood Proof Pumpset (ARFP)

Q (m³/hr) : upto 9,500
H (m) : upto 85
Motor Rating (kW) : upto 2,500



Submerged Elbow Pumpset (AES)

Q (m³/hr) : upto 3,500
H (m) : upto 20
Motor Rating (kW) : upto 110



Non Clog Flood Proof Submersible Pumpset (ANFP) Aqua Slurry Flood Proof Submersible Pumpset (ASFP)

Q (m³/hr) : upto 9,500
H (m) : upto 85
Motor Rating (kW) : upto 2,500



Submersible Dredging / Slurry Pumpset (ADSJ)

Q (m³/hr) : upto 400
H (m) : upto 40
Motor Rating (kW) : upto 90

Submerged Centrifugal Double Suction Pumpset (ARSDS)

Q (m³/hr) : upto 9,000
H (m) : upto 400
Motor Rating (kW) : upto 2,500



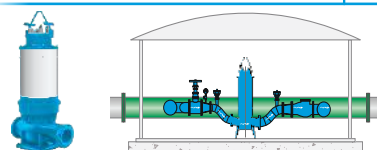
Submerged Tubular Column Pumpset (ATBx)

Q (m³/hr) : upto 25,500
H (m) : upto 40
Motor Rating (kW) : upto 2,500



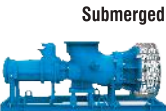
Portable, Electric; Dewatering pumpsets (PD)

Q (m³/hr) : upto 180
H (m) : upto 55
Motor Rating (kW) : upto 18.3



Submerged Inlined Flood Proof Pumpset (AILFP)

Q (m³/hr) : upto 462
H (m) : upto 45
Motor Rating (kW) : upto 75



Non Clog Submersible Sewage Pumpset (ANS)

Q (m³/hr) : upto 9,000
H (m) : upto 90
Motor Rating (kW) : upto 2,500



Submersible Slurry Pumpset (ASS) Submersible Slurry Hydro Electric Pumpset (ASSHE)

Q (m³/hr) : upto 2,500
H (m) : upto 100
Motor Rating (kW) : upto 355



Submerged Mine Dewatering Pumpset (AMS)

Q (m³/hr) : upto 2,000
H (m) : upto 450
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4-5, August 2026

7th International Conference on Agriculture, Kuala – Lumpur, Malaysia

Agro Food is organizing the conference on the theme “Focused on addressing food security, climate-smart agriculture, and sustainable food systems”. For more details: <https://agrofoodconference.com/>

23-27 August 2026

World Water Week 2026, Stockholm, Sweden

Stockholm International Water Institute is organizing the conference on the theme “Water for People and Progress”. For more details: <https://worldwaterweek.org/programme/theme>

26 August 2026

Special Technical Meeting of THAICID, Pak Kret, Thailand

Thai National Committee on Irrigation and Drainage (THAICID) is organizing the meeting. For more details: <https://www.rid.go.th/Thaacid/>

26 August 2026

THAICID Annual Meeting 2026, Samsen, Thailand

Thai National Committee on Irrigation and Drainage (THAICID) is organizing the annual meeting. For more details: <https://www.rid.go.th/Thaacid/>

Co-hosting the Thailand STEM Project Competition, Chonprathan Wittaya School, Thailand. Thai National Committee on Irrigation and Drainage (THAICID) is organizing the workshop. For more details: <https://www.rid.go.th/Thaacid/>

31 August 2026 - 4 September 2026 Africa Food Systems Forum 2026

Kigali Conference Center (KCC), Rwanda
<https://agrif-inperson.com/>

1-4 September, 2026

South African Hydrological Conference (SAHS) 2026, Johannesburg, South Africa

<https://sahs.conference.org.za/>

8–22 September 2026, New York City, United States of America

81st Session of the UN General Assembly (UNGA 81) Opening and General Debate

<https://sdg.iisd.org/events/81st-session-of-the-un-general-assembly-unga-81/>

14-16, September 2026

6th Edition of the Global Conference on Agriculture and Horticulture (AGRI-2026), Rome, Italy

Magnus Group is organizing the conference on the theme “Frontiers and Advances in Agriculture and Horticultural Science”. For more details: <https://agriculturemeetings.wordpress.com/>

21-23 September, 2026

Global Symposium on Soil Compaction, Aarhus, Denmark (Hybrid)

<https://www.fao.org/events/detail/global-symposium-on-soil-compaction/en>

22-26, September 2026

9th India International Water Week 2026, New Delhi, India

Ministry of Jal Shakti, Government of India is organizing the conference on the theme “Climate Resilient Water Management”. For more details: <https://www.indiawaterweek.in/Default.aspx>

Events Calendar

4-8, October 2026

IWA World Water Congress & Exhibition, Glasgow, UK

The International Water Association (IWA) is organizing the conference on the theme “Water action – the path to resilience and prosperity”. For more details: <https://worldwatercongress.org/>

12-16 October, 2026

Rome Water Dialogue 2026 Rome, Italy (Hybrid)

Organized by the FAO, this event showcases innovative water solutions for food security and agriculture. <https://www.fao.org/events/detail/rome-water-dialogue-2026/en>

12-17, October 2026

26th ICID International Congress on Irrigation and Drainage & 77th International Executive Council Meeting, Marseille, France

ICID is organizing the conference on the theme “Water and agricultural resilience in the face of climate change”. For more details: <https://icidcongress2026.org/>

19-30 October 2026, Yerevan, Armenia

2026 UN Biodiversity Conference (COP 17)

<https://www.iwmi.org/events/2026-un-biodiversity-conference-cop-17/>

2-4, December 2026

2026 UN Water Conference, United Arab Emirates (UAE)

United Nation along with Senegal and the UAE is organizing the conference on the theme “Accelerate the Implementation of Sustainable Development Goal 6: Ensure availability and sustainable management of water and sanitation for all”. For more details: <https://www.unwater.org/news/2026-un-water-conference>

22-28, March 2027

11th World Water Forum, Riyadh, Saudi Arabia

World Water Council (WWC) is organizing the conference on the theme “Action for a Better Future”. For more details: <https://www.worldwatercouncil.org/en/11th-world-water-forum-saudi-arabia-and-riyadh-host-11th-world-water-forum-2027>



Invitation to Join ICID *As* Direct Member



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Invitation to Join!

The International Commission on Irrigation and Drainage (ICID) is a leading scientific, technical, and professional not-for-profit international organization established in 1950 with headquarters in New Delhi, India; working in the field of irrigation, drainage, and flood management to promote and achieve 'sustainable agriculture water management' through its vision "A water secure world free of poverty and hunger through sustainable rural development".

ICID's Membership is open to **Private Companies, Institutions, and Individuals** involved in agriculture water management to join as a 'Direct Member'. By joining ICID as a "DIRECT MEMEBR", companies, institutions, and individuals working or dealing with irrigation, drainage, flood-related issues, and other allied fields would be part of an international network that offers opportunities to exchange knowledge and experience, establish partnerships; stay informed on recent irrigation, drainage and flood management news and events through Commission's publications; make their voice heard and contribute to improved understanding among stakeholders, enabling new ideas on water policy; benefit from worldwide exposure of their organization's activities by using the Commission's communication tools and by participating in the Commission's activities;

and influence policymakers to develop sound irrigation-related policies and give it higher priority in the political agenda.

ICID organizes triennial International Congress on Irrigation and Drainage – addressing specific questions; World Irrigation Forum, Regional Conferences, International Drainage Workshops, International Micro Irrigation Conferences, etc. regularly. The Commission brings together experts from different parts of the world to share their experiences and knowledge on specific issues through the ICID technical workbodies. The workbodies bring out manuals, guidelines, and special publications from time-to-time.

For more information related to Direct Membership, please visit: https://icid-ciid.org/member/direct_member

Apply Online for Direct Membership: https://icid-ciid.org/member/dm_membership_form

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Please send your feedback through email at icid@icid.org.

Your feedback means a world to us!

26th ICID International Congress and 77th IEC Meeting

12-17 October 2026, Marseille, France



Theme: Water and agricultural resilience in the face of climate change



Question 66

In the face of climate change, how can irrigation and drainage contribute to the agro-ecological transition?

[More information](#)



Question 67

Innovative technology and practices for increasing water use efficiency, Irrigation management and services, remote sensing, irrigation equipment... where do we stand?

[More information](#)



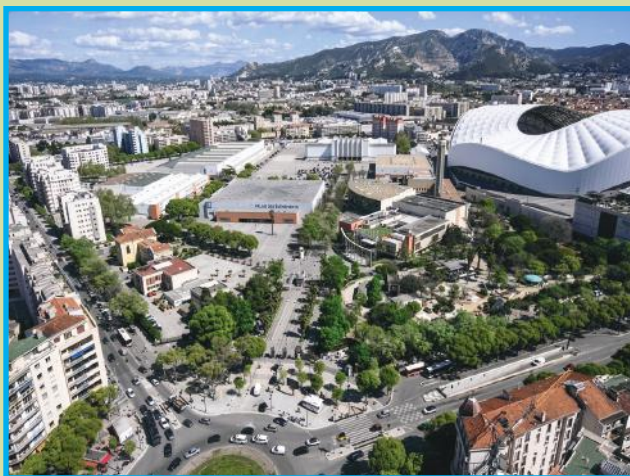
Question 68

Non-conventional water (REUSE, desalination): can we really loosen the grip on the resource and for what uses?

[More information](#)

Contact: For more information, please visit: <https://icidcongress2026.org/>

Marseille, one of the first five pilot cities, was certified as an **“Innovative Sustainable Destination”** by Bureau Veritas in 2022, in collaboration with Marseille Chanot – Palais des Congrès and Parc des Expositions (114 Rdpt du Prado in Marseille)



Call for Articles for ICID Digest

ICID Digest aims to provide valuable insights and updates in the field of water resources and irrigation.

Each issue of the ICID Digest will feature technical articles on topics such as water conservation, irrigation and drainage management, water-food-energy nexus, integrated water resources management (IWRM), reservoir operations, basin planning, remote sensing applications, advanced technologies (e.g., AI, machine learning, canal automation, hydrology, micro-irrigation, smart irrigation, IoT, and sensors), flood and drought management, dam safety, water recycling and reuse, treated wastewater for irrigation, environmental management, and case studies. Contributions from distinguished experts, international organizations, and leading industries highlighting the latest advancements, including case studies and practical examples will also be covered.

It will include our regular features like World Heritage Irrigation Structures, International News and Updates on initiatives and activities undertaken by National Committees of ICID.

Considering the vast experience in industrial sector related to water resources management, irrigation, drainage, latest technological advancements, etc ICID invites all National Committees, experts and professionals and industries associated in the field of agricultural water management to contribute articles and share experiences on the topics

listed above or any other relevant subject within the broader water sector.

The format of Articles is given below:

- (a) MS-Word file
- (b) 6-8 pages (A-4 size)
- (c) Title of the paper: Bold Font-Calibri, font size-16
- (d) Para headings: Bold Font-Calibri, font size-14
- (e) Text: Justify, Font Times New Roman, font size 12, 1.2 line spacing
- (f) All margins: 1 inch
- (g) Brief Profile of author (about 100 words)
- (h) Photo of author: .jpg file

ICID greatly appreciates your time and valuable contribution to the ICID Digest. Your expertise will enrich this publication and foster knowledge-sharing within our global community.

Please send your contribution to **icid@icid.org**.



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