

Water smart irrigation technologies and management practices for ensuring food security

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Water use efficient techniques assume significance in agricultural sector of India in the background of diminishing surface and groundwater resources and climate induced natural disasters. Hence, we need to ensure favourable water regime in the rhizosphere zone of plants through precision water management. There is a need to implement water smart irrigation technologies like micro irrigation, solar enabled automated irrigation, etc. to utilize the available water resources in judicious manner thereby ensuring food security.

Keywords: Automated irrigation, Food security, Water smart irrigation

WATER is fundamental to agriculture and underpins global food security without it, crops and livestock cannot survive, and farming operations would grind to a halt. Yet, the rapidly rising demand for both food and animal feed spurred by population growth and shifts in diet is stretching this precious resource to its limits. Compounding the situation are climate change effects: Erratic rainfall, recurring droughts, and hotter conditions undermine both the supply and quality of water available for farming. These pressures threaten crop yields, push up production costs, exacerbate food insecurity, and jeopardize the livelihoods of many whose survival depends on agriculture. Without urgent change, the overuse of groundwater especially in areas lacking reliable surface water could erode the basis of sustainable agricultural systems globally.

At this critical stage, agriculture must embrace “water-smart” solutions that optimize how water is managed and applied. These approaches involve advanced technologies, resource-saving practices, and supportive policies that improve efficiency while safeguarding future supplies. We also need to focus on precision irrigation system which ensures the application of optimum amount of water to the plant at the right time and in the right manner. It also addresses the heterogeneity factor of land in terms of water stress through variable rate irrigation. With the advent of modern developments in information technology, machine learning, Geographic Position System (GPS), Geographic Information System (GIS), drone-based monitoring, and automation, the IoT enabled precision irrigation system has become more strengthened now.



Drip irrigation in cabbage



Drip fertigation system



Automated irrigation system

Precision irrigation, data-driven decision-making, rainwater harvesting, conservation tillage, and drought-tolerant crops are just a few examples. Alongside technical measures, building community awareness, ensuring institutional support, and strengthening farmer training are also essential. Taken together, these strategies will help farming systems adapt to climate change, conserve resources, and maintain food security for future generations.

Water-smart irrigation

Water-smart irrigation refers to the use of modern tools and data-driven methods to supply crops with exactly the right quantity of water at the right time. By aligning irrigation schedules with crop needs and environmental conditions, this approach improves plant growth, reduces water waste, and makes farming more resilient to water scarcity. Its key objectives are:

- **Conserving water:** Compared to traditional irrigation, smart systems can cut water use by 20–50% through accurate delivery and reduced runoff.
- **Enhancing crop performance:** Supplying water in precise amounts supports healthier plants and higher yields.
- **Protecting natural resources:** Using less water also means lower energy demand for pumping, reduced groundwater depletion, less fertilizer leaching, and a smaller carbon footprint overall.

Smart irrigation technologies

- **Drip irrigation:** Drip (or trickle) irrigation supplies water slowly and directly to the root zone through

a network of pipes and emitters. By reducing evaporation and runoff, it conserves water often cutting use by half or more compared with flood irrigation. Besides improving efficiency, drip system promotes uniform crop growth, healthier plants, and better yields. This also allows precise application of fertilizers (fertigation), reduce weed pressure, and can be automated to lower labour costs.

- **Sprinkler irrigation:** Sprinkler systems distribute water through nozzles that spray it over crops, creating an effect similar to natural rainfall. They provide even coverage, use less water than flood irrigation, and are suitable for uneven terrain. In addition, they help limit soil erosion, reduce nutrient losses, and save labour when automated.
- **Soil moisture sensors:** Soil moisture sensors measure the actual water content in the soil, giving farmers reliable data to guide irrigation. Common types include: Capacitance sensors detect moisture based on changes in the soil's dielectric constant; Time Domain Reflectometry (TDR), measures the speed of an electromagnetic pulse through the soil; and Tensiometers, record how much force plant roots must exert to extract water.
- **IoT based automatic irrigation systems:** Internet of Things (IoT) irrigation systems integrate real-time data from sensors, weather forecasts, and crop requirements. They use cloud platforms, smart valves, and mobile apps to automate water delivery, ensuring each crop gets just the right amount at the right time.



Automated surface irrigation system

The recent advances have facilitated the application of automation in both surface and groundwater irrigation which aid in achieving the target of maximum water use efficiency. Soil Moisture Sensor-Based Automatic Basin Irrigation System developed by Water Technology Centre, ICAR-IARI consists of three main units; a sensing unit, a communication unit, and a control unit. This system helps in water saving of 25% compared to the conventional manually controlled system in wheat.

- **Remote sensing and drones:** Remote sensing, especially with drones or satellites, helps monitor crop water status and detect stress early. Infrared imaging and indices like NDVI (Normalized Difference Vegetation Index) provide valuable insights into crop health. This information supports precise irrigation planning, reducing waste and improving yields.



Precision irrigation system in protected cultivation

Water-smart management practices

- **Irrigation scheduling:** Irrigation scheduling is the practice of deciding when and how much to irrigate so crops receive adequate water without waste. Decisions are based on crop type and stage of growth, weather conditions, and soil moisture.
- **Crop needs:** Different plants demand water at varying stages. For example, flowering and fruiting are critical periods. Pan evaporation measures evaporation from a standard pan to estimate crop water needs. Crop Water Stress Index (CWSI) compares canopy and air temperatures to detect plant stress.
- **Weather:** Temperature, humidity, and rainfall forecasts affect evaporation rates and must be factored in. Crop calendars gives long-term schedules suggesting irrigation timing, adjusted with real-time data.
- **Soil moisture:** Monitoring root-zone moisture ensures irrigation is applied only when necessary.
- **Mulching:** Mulching covers soil with organic or synthetic materials to conserve moisture, suppress weeds, and improve soil health. Plastic mulch retains moisture and warms soil but can pose disposal challenges. Organic mulch (straw, compost, leaves) decomposes, adding nutrients and improving soil structure. Biodegradable mulches (BDMs), made from starch or cellulose, provide similar benefits while naturally decomposing, though they can be more costly.
- **Laser land leveling:** This technology uses laser-guided equipment to smooth field surfaces, ensuring water spreads evenly. The practice improves crop germination, reduces erosion, enhances fertilizer use, and lowers fuel and labour requirements. By eliminating uneven patches, it also suppresses weeds and increases the cultivable area.
- **Rainwater harvesting:** Rainwater harvesting collects and stores runoff for future agricultural use. Methods include: Groundwater recharge through pits, trenches, or wells; direct irrigation from ponds or tanks, often linked to drip systems; livestock watering and aquaculture in farm ponds; and domestic use when properly filtered.
- **Conservation agriculture:** Conservation agriculture emphasizes minimum soil disturbance, permanent soil cover, and diverse crop rotations. Zero tillage allows crops to be sown without plowing, preserving soil structure and reducing evaporation and residue retention leaves plant material on the soil surface, protecting against erosion, conserving moisture, and enriching the soil over time.

Government initiatives for water-smart agriculture

To encourage efficient water use in farming, the Government of India and allied institutions have introduced several schemes and programmes. Two of the most significant are Pradhan Mantri Krishi Sinchayee Yojana (PMKSY-Per Drop More Crop) and initiatives

supported by the National Bank for Agriculture and Rural Development (NABARD).

PMKSY (Per Drop More Crop): This flagship programme promotes micro-irrigation techniques such as drip and sprinkler systems, aiming to increase water-use efficiency and improve farm productivity. Its goals are to expand micro-irrigation coverage, reduce water consumption in water-intensive crops, and raise farmer incomes through precise irrigation. Through this *yojana*, farmers receive subsidies covering a major share of installation costs with higher assistance for small and marginal farmers. Funding is shared between the central and state governments, with special provisions for north eastern states, Himalayan regions, and Union Territories. Some states also provide extra subsidies to ease the farmer's share.

NABARD: NABARD contributes to water-smart agriculture by financing and supporting climate-resilient practices.

- **Micro Irrigation Fund (MIF):** Established with an initial ₹5000 crore to help states expand micro-irrigation.
- **Climate-smart projects:** Support for initiatives such as solar-powered pumps and efficient irrigation systems.
- **Capacity building:** Training and awareness programmes to familiarize farmers with modern irrigation and precision farming techniques.
- **Research and pilot projects:** Funding for innovations

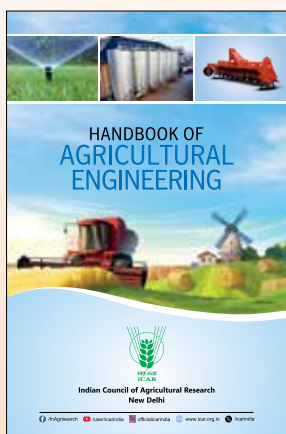
such as sensor-based irrigation systems to test and scale up new technologies.

SUMMARY

Water is the elixir of life and this precious natural resource needs to be preserved for ensuring safer environment. Owing to the climate change, the water resources are declining at significant rate which must be addressed urgently for ensuring sustainable development. In this context, we need to strengthen the sustainable water resource development and management through promotion and adoption of "water smart" agricultural practices. Integrated use of innovative techniques like drip irrigation, sprinkler systems, soil moisture sensors, automatic IoT-based irrigation systems, remote sensing and drones, optimized irrigation scheduling, mulching, laser land leveling, rainwater harvesting, and conservation agriculture will aid in paradigm shift towards efficient and sustainable water management in agriculture. Furthermore, it serves dual purpose of ensuring economic prosperity of Indian farmers and mitigating environmental degradation by conserving groundwater, reducing energy consumption for pumping, and minimizing the runoff of fertilizers and pesticides.

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