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Irrigation Status in Madhya Pradesh: Towards Sustainable and Efficient Irrigation Through AI Based Water Management System

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Agriculture is one of the oldest practices taking place worldwide to produce food and fodder. It is a continues demanding field whether in the present or future because agriculture forms the basis of human lives. The early domestication of plants and animals began around 10,000 years ago, marking the beginning of agriculture as an important part of human civilization. For all these activities, the foundation stone of agriculture is irrigation. In early days the irrigation practices were carried out through the indigenous knowledge and traditional practices but now the methods of irrigation have also evolved. What was once guided primarily by human knowledge and experience is now increasingly supported by Artificial Intelligence (AI). The method has changed, but the need remains the same.

Global Scenario of area under irrigation

The total land area in the world equipped for irrigation fluctuated during the period 2021-2024 shows significant changes. The total land area equipped for irrigation in the year 2021 was 354,971.59 thousand ha. In 2022 the area dropped by 862,910 ha. to 354,108.68 thousand ha. Then the year 2023 recorded a negligible increase of 35,330 ha bringing the total to 354,144.01 thousand ha. Then during the year 2024 irrigation infrastructure expanded again, gaining back 557,140 ha. And reached 354,701.15 thousand ha.

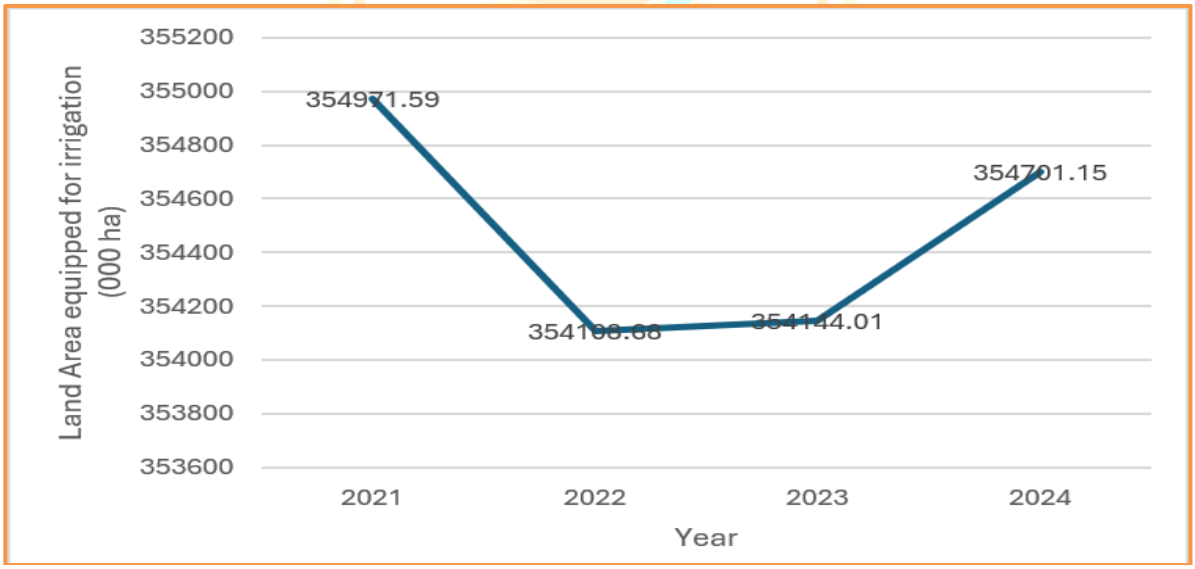


Fig 1: Land area equipped for irrigation (000 ha) *(Source: Food and Agricultural Organization, 2026 retrieved from www.fao.org/faostat)*

Fig. 2 shows the total average land area equipped for irrigation in the last five years (2021-2025) in the regions of Africa, America, Asia, Europe and Oceania. Out of the total equipped irrigated area of 354481.40 thousand ha, highest area was covered by Asian continent with 70.9 per cent, followed by Americas with a share of 5.5 per cent followed by Europe with a share of 7.9 per cent.

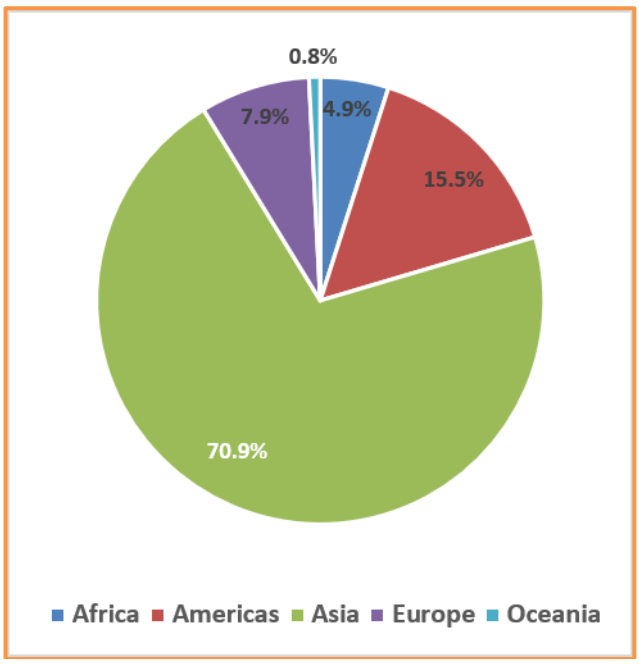
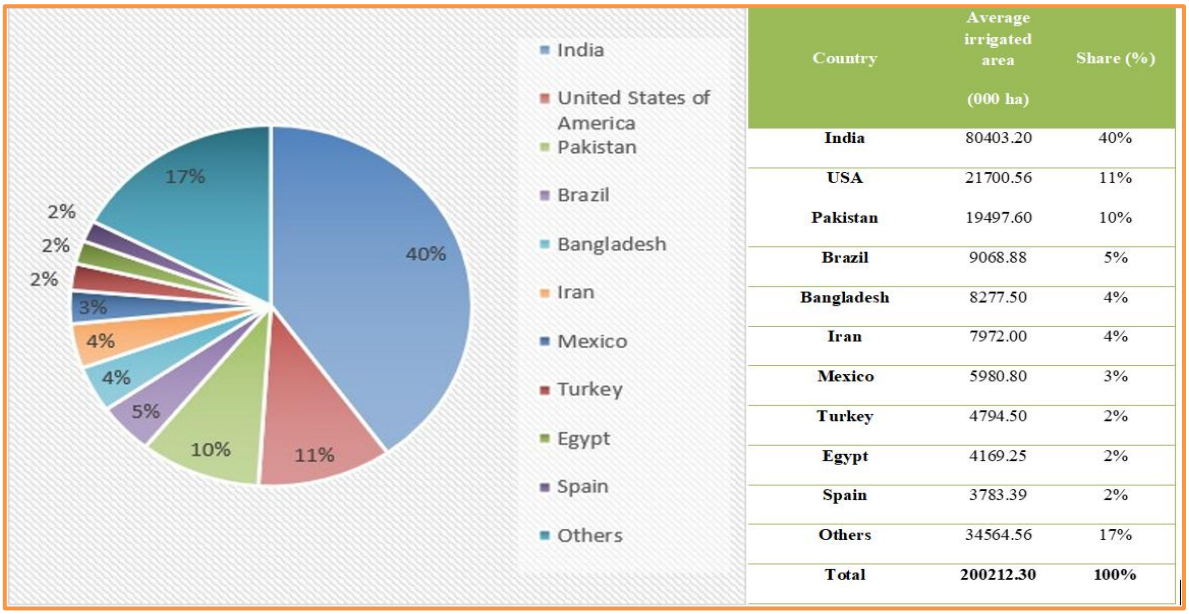


Fig 2: Continent wise irrigation equipped land area **(Source:** Food and Agriculture Organization of the United Nations (FAO), FAOSTAT (2026).

Fig. 3 and Table 1 denotes the average share (%) of irrigated land area by top 10 countries during the year 2020-2024. India ranks first among them with a share of 40 per cent (80403.21 thousand ha) followed by United States of America with 11 per cent (21700.56 thousand ha) and Pakistan ranking third with a share of 10 per cent (19497.60 thousand ha). Brazil, Bangladesh, Iran, Mexico, Turkey, Egypt and Spain are among the top 10 countries.



Country	Average irrigated area (000 ha)	Share (%)
India	80403.20	40%
USA	21700.56	11%
Pakistan	19497.60	10%
Brazil	9068.88	5%
Bangladesh	8277.50	4%
Iran	7972.00	4%
Mexico	5980.80	3%
Turkey	4794.50	2%
Egypt	4169.25	2%
Spain	3783.39	2%
Others	34564.56	17%
Total	200212.30	100%

Fig 3: Average Share of Irrigated area by top 10 Countries (Year: 2020-2024)

Tab 1: Share of irrigated land

Country	Major source(s) of irrigation	Examples / explanation
India	Groundwater and surface water	Tube-wells, dug wells, rivers, canals and reservoirs. Groundwater is especially important in many intensively cultivated regions.
United States	Groundwater and surface water	Groundwater wells and surface-water delivery systems; the balance differs across states and river basins.
Pakistan	Surface water and groundwater	The Indus Basin Irrigation System, including barrages and canals, together with groundwater from aquifers.

Brazil	Surface water and groundwater	Rivers, reservoirs and groundwater; the relative contribution varies across agricultural regions.
Bangladesh	Groundwater and surface water	Tube-wells are important, alongside rivers, canals and other surface-water systems.
Iran	Groundwater and surface water	Wells and canal systems, along with rivers and reservoirs. Groundwater is particularly important in many arid agricultural areas.
Mexico	Groundwater and surface water	Wells, rivers and reservoirs support irrigated agriculture, with the mix varying by region.
Egypt	Surface water, predominantly Nile water	Nile River water distributed through irrigation canals; groundwater also contributes in some areas.

(Source: Food and Agriculture Organization of the United Nations (FAO), AQUASTAT database; U.S. Geological Survey (USGS). **)**

The top irrigated countries in the world were dominated by mostly canal, borewells and tanks. These countries have a wide scope of increase in efficiency of irrigation through AI automation system.

Irrigation Scenario in India

India has a wide diversity of irrigation sources and systems. The water requirement remained same but has evolved from traditional and experience-based practices toward technology supported system. India has adopted different policies toward improving irrigation and water efficiency like Pradhan Mantri Krishi Sinchayee Yojna (PMKSY) with a motive of Per Drop More Crop (PDMC) component to enhance water-use efficiency. Having access to irrigation water does not necessarily mean that the available water is being used efficiently. Earlier systems depended on traditional knowledge but with the emergence of sensors, data analytics, irrigation management can work through real time field conditions and predictive information. AI is being used in Indian irrigation system in areas such as irrigation scheduling, soil moisture monitoring, weather-based irrigation, crop water requirement, etc.

The total irrigated area in the country is non-uniformly distributed over the different states based upon various geographical and climatic conditions. Fig 4 and Table 2 shows the total irrigated area in India in the year 2023 was 82,416 thousand hectares. Out of the total irrigated area in the country, Uttar Pradesh ranks first with an irrigated area of 13656 thousand hectares covering around 16.57 per cent among the total irrigated area in the country. With 12747-thousand-hectare irrigated area (15.47 %), Madhya Pradesh ranks second. Rajasthan, Maharashtra, Gujarat, Karnataka, Punjab, West Bengal, Telangana and Bihar are among the top 10 irrigated states in the country. The major sources of irrigation in these states are Canal, Ponds, Wells and Borewells. There is still a vast scope for the application of Artificial Intelligence in these states.

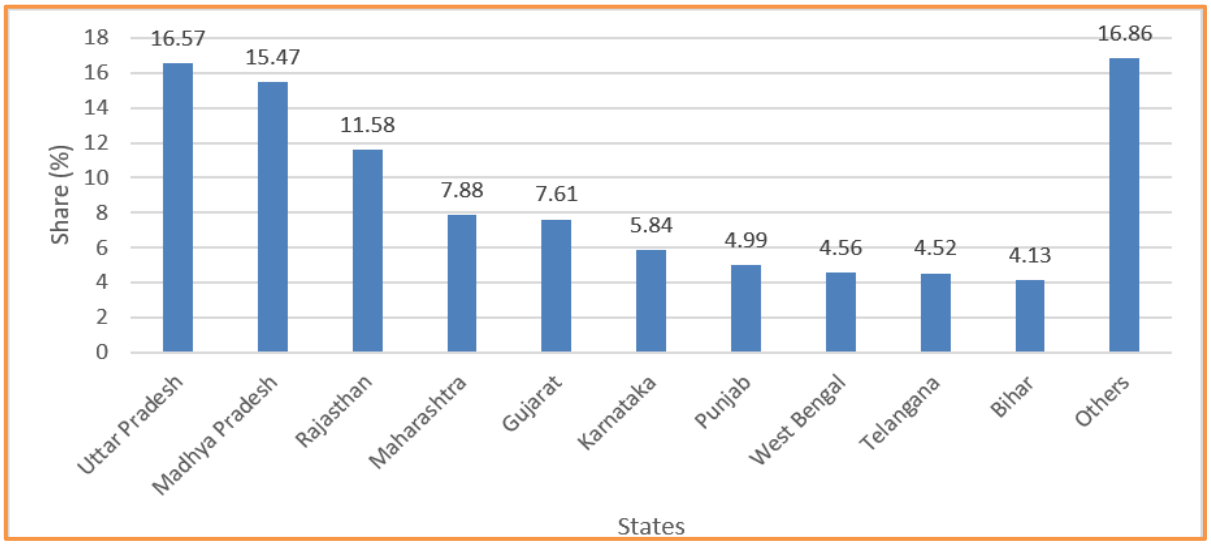


Fig 4: Share (%) of top 10 states based on net irrigated area in the year 2023.

Table 2: State wise share of net irrigated area in India

Rank	State	Net irrigated area (000 ha)	Share of India's net irrigated area (%)
1	Uttar Pradesh	13,656	16.57
2	Madhya Pradesh	12,747	15.47
3	Rajasthan	9,547	11.58
4	Maharashtra	6,496	7.88
5	Gujarat	6,273	7.61
6	Karnataka	4,809	5.84
7	Punjab	4,109	4.99
8	West Bengal	3,757	4.56
9	Telangana	3,728	4.52
10	Bihar	3,401	4.13
	Others	13,893	16.85
—	All India	82,416	100.00

*(**Source:** Directorate of Economics and Statistics (DES), Department of Agriculture and Farmers Welfare, Government of India. Net irrigated area, 2023–24.)*

Irrigation Scenario in Madhya Pradesh

Madhya Pradesh ranks 2nd in terms of the total irrigated area in the year 2023 with an area of 12747 thousand hectares which is around 15.47 percent. According to state environmental plan (2024) Out of the total geographical area 308.252 lakh hectares of the State, only about 151.91 lakh hectares are arable. The crop density of the State is 165.70 percent (State environmental Plan Madhya Pradesh, 2024, mppcb.mp.gov.in). The total irrigated area in the State is about 110.97 lakh hectares. Rivers are the main source of surface water in the state and its dependence on river water for irrigation. Since Madhya Pradesh has a diverse cropping pattern, a uniform irrigation schedule cannot be equally suitable for all crops. Fig. 5 shows the net irrigated area in the top 10 districts of Madhya Pradesh (2020-21). Out of the total net irrigated area in Madhya Pradesh the highest area is covered by the Vidisha district with 5,12,547 ha area followed by the district Sagar with 4,92,325 ha area and Ujjain with a share of 4,77,538 ha area, Shivpuri, Rajgarh, Dhar, Sehore, Chhindwara, Satna and Dewas ranks among top 10 districts.

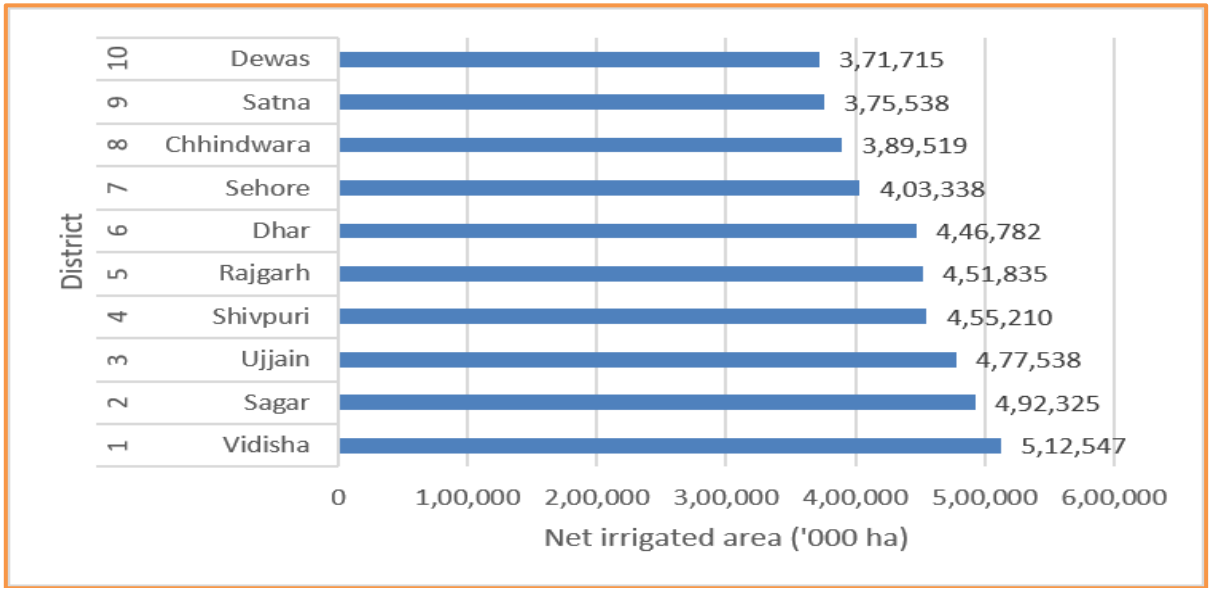


Fig. 5: Top 10 district wise irrigated area in Madhya Pradesh

*(**Source:** Directorate of Economics and Statistics, Ministry of Agriculture & Farmers Welfare (2020-21).)*

Conventional Irrigation in Madhya Pradesh

Before the widespread use of AI, there were traditional methods of irrigation which were based on manually operated pumps, fixed irrigation schedules, and farmers' experience.

Major conventional irrigation methods are Flood irrigation, Furrow irrigation, well based irrigation, Canal Irrigation, Traditional water lifting methods. These practices vary by region and crop.

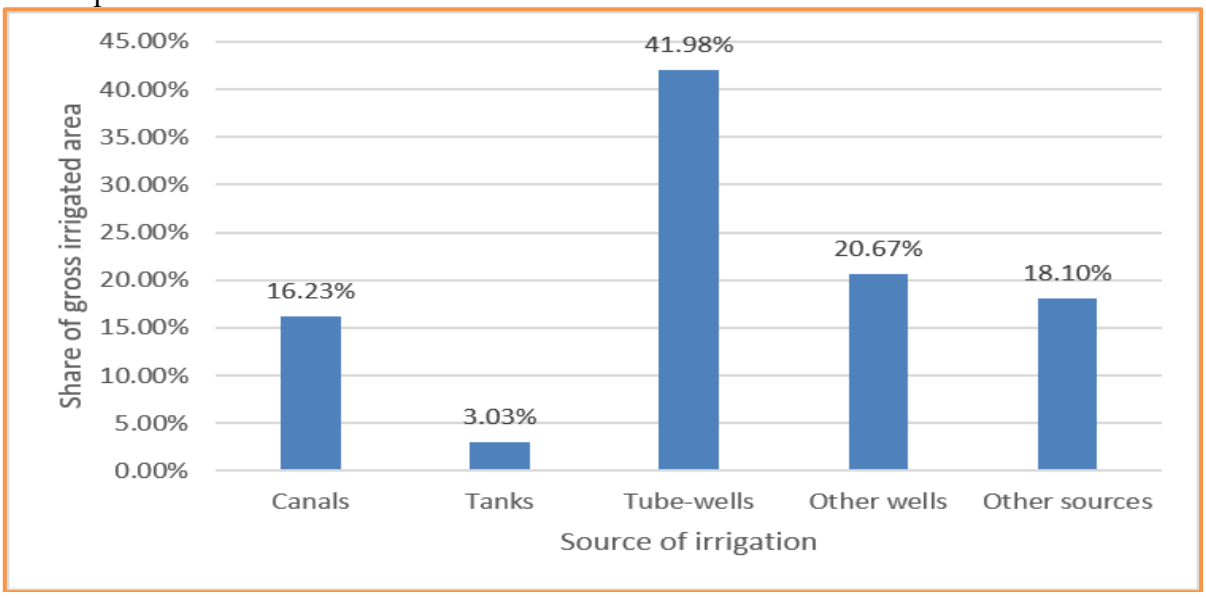


Fig. 6: Share of gross irrigated area in Madhya Pradesh

*(**Source:** Directorate of Economics and Statistics, Ministry of Agriculture and Farmers Welfare, Government of India,2023)*

Fig. 6 shows the share of gross irrigated area in Madhya Pradesh during the year 2023. The major source of irrigation is Tube well with a share of 41.98 per cent followed by Other wells with a share of 20.67 per cent and other sources ranks third with a share of 18.10 per cent, canals (16.23%) and Tanks (3.03%) are the top 5 sources of irrigation in Madhya Pradesh.

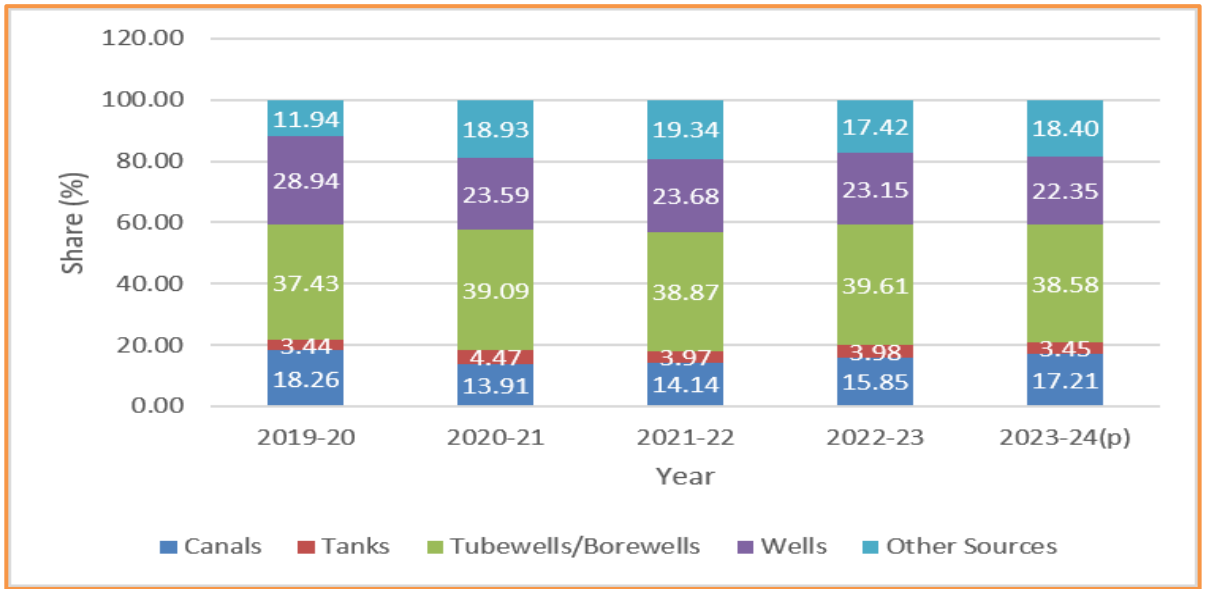


Fig. 7: Source wise net irrigated area in Madhya Pradesh

(Source: Directorate of Economics, Statistics and Evaluation (ESE), Ministry of Agriculture and Farmers Welfare, Government of India (2025). **)**

Fig. 7 shows the source wise share of net irrigated area in Madhya Pradesh from 2019-20 to 2023-24. Tube wells are the major source of irrigation followed by Wells. Tubewells constitute more than 35 per cent and Wells constitute more than 20 per cent in each year. Canals are the least preferred source of irrigation in the state.

Districts in which AI based irrigation are currently implemented in Madhya Pradesh.

Table 3: AI based irrigation in various districts of M.P

District	Documented technology	Relevance to irrigation	Evidence status
Khargone	IoT-based precision-farming sensors and GeoAgro-iKrishi advisory platform using AI/ML	Real-time advisories help farmers fine-tune irrigation and other farm inputs	Documented initiative
Sehore	IoT-based precision-farming sensors and GeoAgro-iKrishi advisory platform using AI/ML	Real-time advisories help farmers fine-tune irrigation and other farm inputs	Documented initiative

*(**Source:** ICARDA's 2023 report on precision-farming advisories.)*

Dependency of crops on irrigation

Madhya Pradesh cultivates a diverse range of crops, including soybean, gram, urad, linseed, maize, and sesame, among others. In the year 2023, the major crops grown were Paddy (478.28 lakh ha), Wheat (318.33 lakh ha), Oilseeds (301.92 lakh ha), Pulses (275.05 lakh ha), Soybean (249.38 lakh ha), Cotton (126.88 lakh ha), and Sugarcane (57.40 lakh ha). Kharif crops in Madhya Pradesh rely substantially on monsoon rainfall to meet their water requirements. Soybean and urad are largely rain-fed crops, whereas sesame is relatively drought-tolerant, although prolonged moisture deficiency can adversely affect its yield. Given the state's diverse cropping systems, a single, uniform irrigation schedule may not adequately meet the water requirements of all crops. Differences in crop duration, seasonal conditions, and growth patterns result in varying irrigation needs. Rabi crops such as gram, masoor, and linseed depend considerably on the moisture stored in the soil; therefore, supplementary irrigation may be necessary when available soil moisture is insufficient. Crop water requirements vary according to several interrelated factors, including crop species, variety, growth stage, rainfall, temperature, soil type, and soil-moisture availability. Consequently, irrigation planning should be adapted to the specific requirements of each crop and the prevailing agroclimatic conditions.

Role of AI in irrigation

- **Irrigation scheduling:** AI can help in determining when irrigation should be applied and can be self-automated, reducing the labor cost.
- **Estimation of crop-water requirement:** AI can analyze the water requirements based on historical data and real time data to estimate crop water requirement. The quantity of water that needs to be supplied can reduce the risk of over-irrigation.
- **Soil moisture monitoring:** It can help determine whether the irrigation is required or not. Soil sensors can measure the moisture present in the soil. This can support more timely irrigation decisions and help avoid unnecessary application of water.
- **Weather based irrigation:** Rainfall, temperature, humidity, wind speed and solar radiation can affect the crops. Weather can be predicted earlier and based upon the data received if enough rainfall is expected, the irrigation can be postponed.
- **Precision irrigation:** It refers to applying water at the right time at the right location according to the field requirement.

Efficiency of AI based irrigation techniques

Table 4: Efficiency Outcomes of various AI based irrigation techniques.

Technology	Reported efficiency outcome
IoT-enabled soil-moisture sensing for irrigation scheduling	10–15% water saving compared with traditional irrigation scheduling
Automated alternate wetting and drying (AWD) for transplanted rice	Approximately 17% water saving
Sensor-based micro-irrigation scheduling for drip-irrigated banana	20% water saving and 15% higher yield

Subsurface drip irrigation for maize-based cropping systems	16% water saving, 12% higher yield, and 34% higher water productivity compared with surface drip irrigation

*(**Source:** Indian Council of Agricultural Research, Landmark Technologies.)*

Efficiency of conventional and AI based irrigation techniques

Table 5: Comparison between conventional and AI enabled irrigation

Efficiency indicator	Conventional flood irrigation	AI-enabled / sensor-based irrigation	Evidence
Water-use efficiency	Approximately 30–50%	Depends on the irrigation system and control method; sensor-based systems have demonstrated water savings	ICAR; Ministry of Agriculture
Water consumption	Can involve excess application if irrigation is poorly scheduled	Soil-moisture and weather data help apply water when needed	ICAR
Irrigation scheduling	Often based on fixed schedules or farmer experience	Use real-time sensor readings and AI-generated advisories	ICARDA
Water savings	Baseline for comparison	An ICAR-IARI automatic basin irrigation system saved approximately 25% water in wheat compared with manual irrigation	ICAR
Crop yield	Depends on crop, soil, climate, and management	May improve when irrigation timing and quantity better match crop requirements; gains are not guaranteed	ICAR
Initial cost	Generally lower for basic surface irrigation	Higher potential investment in sensors, controllers, connectivity, and maintenance	Technology-dependent

*(**Sources:** ICAR, Landmark Technologies; Press Information Bureau (2019); ICARDA (2023)*

It is an emerging approach to agricultural water management in which it analyses soil-moisture data, weather conditions, irrigation scheduling, leak /fault detection, and crop water requirements to support irrigation decisions. AI can predict weather by identifying patterns and farmers can adjust sowing, irrigation and harvesting. It can analyze water stress, nutrient deficiencies, disease symptoms, pest damage, and poor plant growth by monitoring the image. It can help in reducing unnecessary pesticide application, automated irrigation.

Challenges and Limitations from AI based irrigation techniques

Despite AI can be used for a better strategy, there are certain challenges. These challenges are grouped into three overarching dimensions: technical, economic, and social barriers.

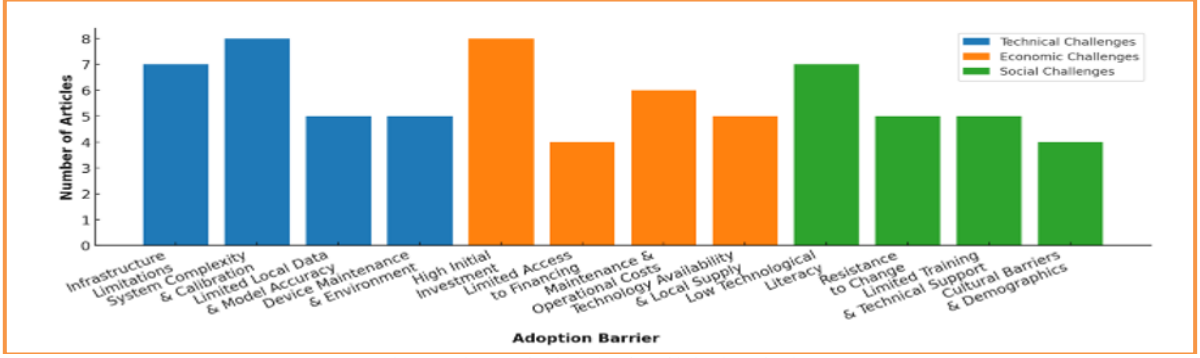


Fig. 8 Barriers to adoption of AI based irrigation adoption

(Source: Nurmalitasari et al. (2025), Artificial intelligence-driven solar smart irrigation for sustainable agriculture: Trends, challenges, and SDG implications)

In Technical challenges the major issue is about the calibrations and complexity of AI algorithms as it requires precise, site-specific data. Furthermore, a scarcity of localized agriculture datasets undermines model accuracy in new regions. The further limitation is infrastructure, where unreliable internet, poor cellular coverage, and power instability restrict real time sensor communication. In the Economic challenge, the major issue which prevents farmers from upgrading to AI based irrigations system is "High initial investment" required for automated valves, Iot sensors, and AI software installation. In social challenge "Low technological literacy" is the primary social barrier as many farmers lack the digital skills and "limited training and technical support" is the reason behind "resistance to change" leading to cultural barriers & Demographics.

AI can be considered a decision-support technology rather than an independent replacement for farmers' knowledge.

Future Prospects

AI can potentially contribute to the following areas:

1. **Sensors and IoT for environmental monitoring:** Sensors and IoT platforms play a significant role in AI-based smart irrigation. They can measure soil moisture, temperature and crop water requirements in real time.
2. **Crop-specific irrigation scheduling:** AI can help apply the right amount of water to each field according to the crop's needs, saving both time and manpower.
3. **Weather-based irrigation recommendations:** Irrigation timing can be adjusted according to weather forecasts. This helps prevent crop losses caused by waterlogging before harvest and avoids unnecessary irrigation.
4. **Groundwater-use monitoring:** AI can track groundwater depletion. If the water table keeps falling, it will cause serious problems in the future, so early monitoring supports timely action.
5. **Automated pumps and valves:** Irrigation timing can be controlled remotely, so farmers do not need to visit the field every time.
6. **Water demand forecasting:** AI can predict the amount of water a crop will need at each growth stage, almost as if the plant were communicating its own requirements. This can lead to better yields.

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