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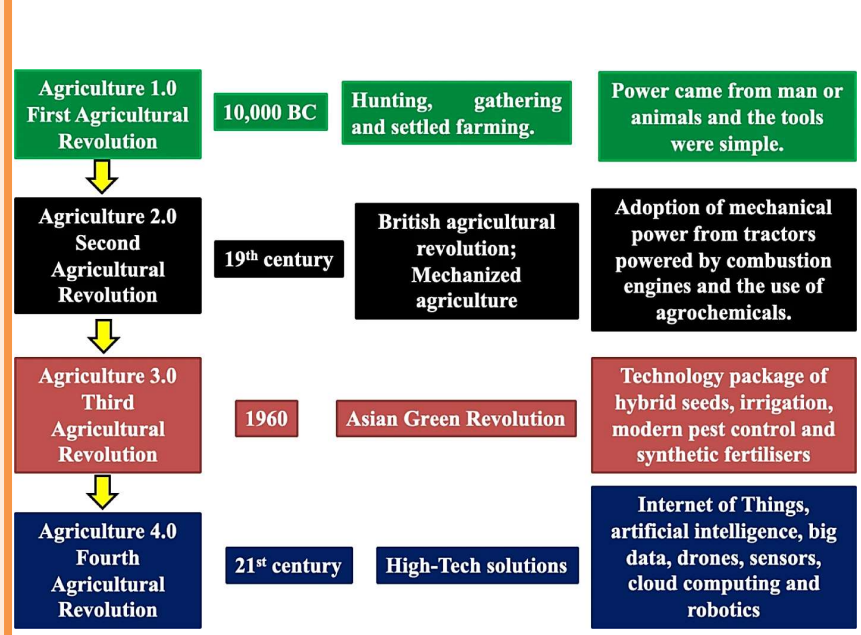
Use of IoT and Sensors in Agriculture – Opportunities & Challenges

Ravinder Kaur

Principal Scientist & Former Project Director -
Water Technology Centre, IARI
& Former Interim Director -
Indian Agricultural Research Institute (IARI), Delhi

An Invited Talk in PF4 Session on "Smart Irrigation Management" in 9th India International Water Week on Climate Resilient Water Management, September 23, 2026, Bharat Mandapam, New Delhi

Agriculture - one of humanity's first endeavours and Mainstay of our civilization



Ecological issues

- Environmental pollution
- Declining underground water table
- Ground water pollution
- Diverse weed flora
- New diseases and insect pests
- Reduced biodiversity

Agricultural issues

- Deteriorating soil health
- Large yield gaps
- Residue burning
- Labor shortage
- Declining crop response
- Extreme weather/climate change

Sustainable issues of agriculture 3.0

Social issues

- Population expansion
- Farmer's traditional mind-set
- Youth moving away from farming
- Smaller and fragmenting land holding

Technical issues

- Low mechanization
- Lack of appropriate seeders
- High cost of machinery
- Limited knowledge & skill

Has changed greatly over time to **Agriculture 4.0 (Smart Agriculture)** to fulfil the needs of an **expanding global population**, adjust to **shifting climatic circumstances**, and solve **sustainability related issues**

Goal of Smart Agriculture:

Precision-Profitability-Prudence based sustained agricultural production through Demand Coherence and Input Management

Conventionally relied on Sensing of Environmental Conditions

1. Soil Sensors/ Devices	Applications
a. Field Scouts	For tracking soil - water, salt and temperature
b. Soil moisture Transducers/ Tensiometers	For measuring point soil moisture tensions from 0 to 200 centibars.
c. Irrigation on/off sensors	For recording and analyzing relationships between irrigation periods and soil moisture contents.
d. Time domain Refrectrometers	For measuring soil moisture contents based on proven time-domain measurement technology

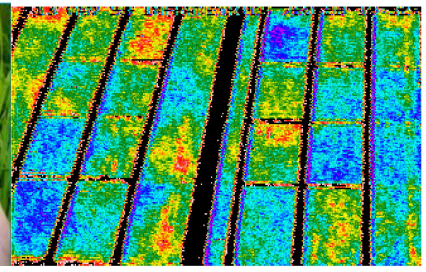
2. Plant Sensors/ Devices	Applications
a. Canopy analyzers	For measuring LAI of plant canopy and deriving canopy index-based plant growth & development
b. Infrared Sensors	For measuring plant temperature-based moisture stress
c. NDVI analyzers	For monitoring plant health, growth and development
d. CO_2 sensors	For measuring carbon-di-oxide levels in polyhouses
e. Porometers	For measuring plant transpiration rates
f. PS Systems	For measuring plant photosynthetic rates

3. Water Sensors/ Devices:	
	Applications:
a. Turbidity, colour, pH, EC, temperature, ORP, TSS, DO sensors	For measuring water quality
b. Pressure Transducers	For recording continuous water levels in open channels, wells, lakes, etc
c. Water meters	For measuring volume and flow rates of water

4. Climate Sensors/ Devices:	
	Applications:
a. Hygrometer	For measuring atmospheric moisture contents
b. Dew cells	For measuring dew point of air
c. LUX Meters	For measuring intensity of light
d. Solarimeters	For measuring solar irradiance
e. UV sensors	For detecting the UV radiations
f. Anemometers	For measuring wind speed



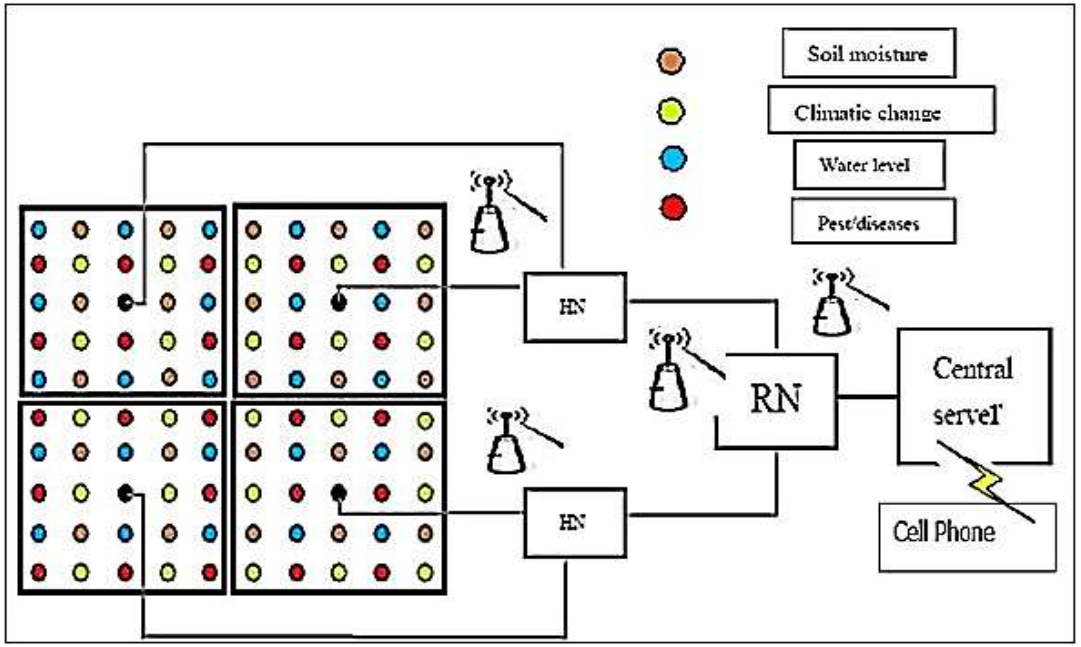




Contemporary Needs

Going beyond Sensing to Automatic application of inputs s.a. water, fertilizers and pesticides through "Smart Field Systems" with capability to:

- Sense agricultural parameters in real-time (**Detect**)
- At unique coordinates & temporal (e.g., morning, noon, afternoon and evening) domains at programmed "**sleep and awake**" battery cycles (**Locate**) and
- Transfer sensed data from crop field to control station thru a range of multi-hop **wireless transmission techniques & devices** for algorithm-based decision making (**Report & Apply**)



Automatic Solar Powered Drip Irrigation System for Orchards

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Sensor: TDR probe soil moisture placed at 5 & 10 cm depth

Power for sensor: solar-powered battery

Communication setup:

Sensor to Cloud – Telemetry (Sim based communication)

Cloud to Microcontroller/ App – Telemetry

Microcontroller to solenoid valve & pump – wired

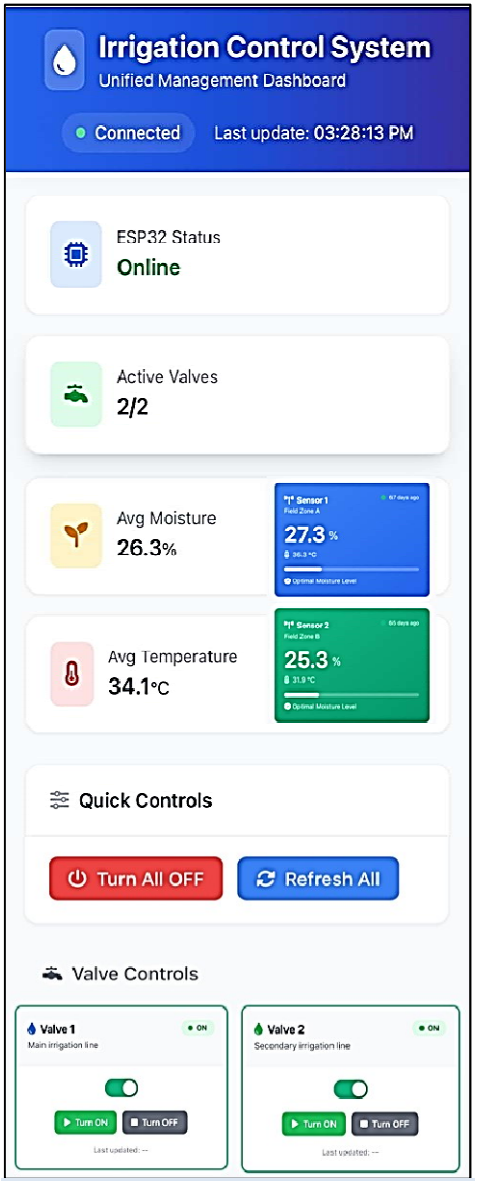
Pump & solenoid valves operation:

On: below the threshold value of soil moisture

Off: FC-based calculation







System being tested on coffee plantation & flowering plants

Courtesy: Dr Vijay Prajapati,
Sr. Scientist, WTC, IARI
(prajapati114@gmail.com)

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AUTOMATIC SOLAR POWERED BASIN IRRIGATION SYSTEM

Key Technical Features

- Automatic opening/closing of basin gates
- Real-time soil moisture–based irrigation
- Wireless communication among field units
- Solar-powered, low maintenance design
- User dashboard with alert system

Benefits to End Users

- 30–40% water saving
- Reduced labor and field monitoring
- Improved irrigation timeliness
- Better crop health & higher yield
- Scalable across crops and basin geometries



Savings

- 70–90% labor reduction
- 30–50% water savings
- Saves electricity

Contact for Demonstration

Dr Monalisha Pramanik, Water Technology Centre
ICAR–Indian Agricultural Research Institute, New Delhi
zonaltech@gmail.com

System successfully tested in rice-wheat cropping system: Saved ~ 30% water

Low-Cost Polymer based Sensors/ Sensing Devices

In the world of sensor technology, miniaturization has been a driver of innovation leading to the development of **micro-electromechanical systems** (**MEMS**) and **nano-electromechanical systems** (**NEMS**).

These are polymer based technologies & **integrate mechanical elements and electronics at micro and nano scales**.

Nutrients	Polymers
Nitrogen (in gaseous form)	2-Acrylamido-2-methyl propane sulfonate modified with tetraethyl orthosilicate, iron oxide–polypyrrole nanocomposite
Nitrate	Plasticizer-free polysiloxane/ trifluoropropyl-functionalized polymer
Nitrite	(i) PANI, polyaniline and acetic acid mixed film PANI-polystyrene sulfonic acid composite film
	(ii) PVC (structure is shown in Figure 3)
Ammonia	Polyaniline (emeraldine base) (structure is shown in Figure 4)
Potassium	(i) Polyurethane-based photocurable polymer (structure is shown in Figure 5)
	(ii) Plasticizer-free polysiloxane/ trifluoropropyl-functionalized polymer
	(iii) Photocurable polymers
Phosphorus	Phosphate-selective molecularly imprinted polymer (structure is shown in Figure 6)

1. Sensitivity and Accuracy Limitations

Have **lower sensitivity and accuracy** compared to high-end metal or ceramic-based sensors leading to less precise measurements to impact crop yields.

2. Environmental Degradation

Polymers can degrade over time due to **UV exposure, temperature fluctuations, and humidity** thereby leading to shorten lifespan and more frequent replacements of sensors.

3. Calibration and Drift Issues

Polymer-based sensors may experience **signal drift** over time, requiring regular calibration : Challenging in remote agricultural fields where maintenance is infrequent.

4. Limited Chemical Resistance

Some polymer materials are not resistant to **fertilizers, pesticides, or soil chemicals**, thereby causing sensor malfunction or inaccurate readings.

5. Power and Connectivity Constraints

In IoT applications, low-cost sensors often have **limited power efficiency** and may not support long-range wireless communication, making them less effective in large-scale farms without additional infrastructure.

6. Manufacturing Variability

Low-cost production methods can lead to **inconsistent quality** between batches, affecting reliability and performance.

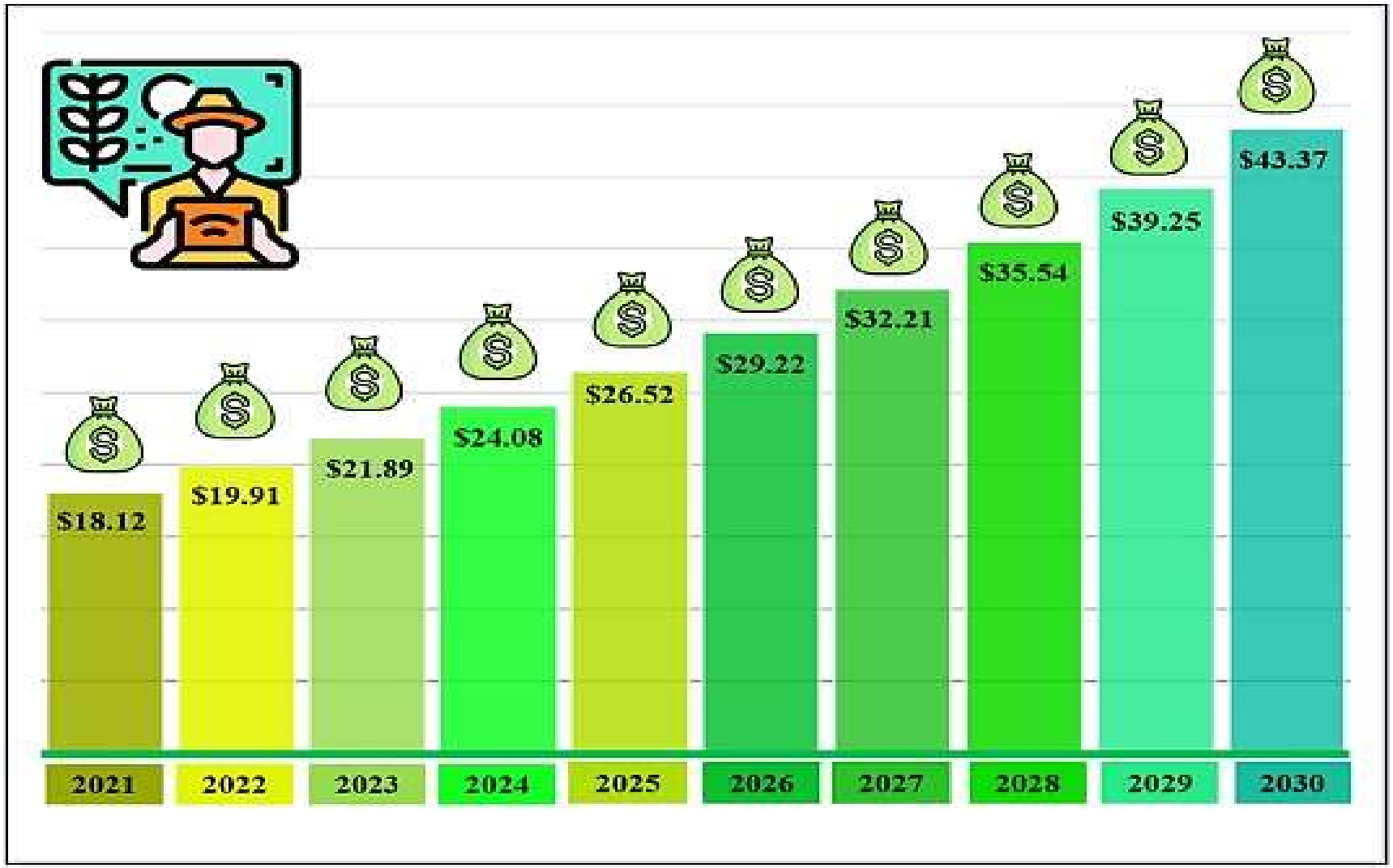
7. Data Reliability and Integration

Inconsistent readings from low-cost sensors can make **data integration with IoT platforms** more complex, requiring additional filtering and error correction algorithms.

However, their mechanism of exposure, stability, soil compatibility and complete mechanical system designing are yet to be standardized

Global Market Size For Smart Agriculture:

As per "Precedence Research", smart agriculture market has grown considerably over time & is expected to increase @ Compound Annual Growth Rate (CAGR) of 10.2% between 2022 and 2030



Limitations & Needs for Sensor Technology under Indian Scenario

Despite its potential, the adoption of Agriculture 4.0 remains slow and uneven, particularly in developing nations due to:

- **SMALL LAND HOLDINGS**
- **Low capital**
- **Multiple crops/ cropping systems**
- **Irregular electricity supply**
- **Mechanical failure of the sophisticated devices** under harsh environmental conds.
- **Digital literacy issues**
- **Lack of precisely validated zone-specific integrated simulation models**
- **Data security threats**

Investments in rural infrastructure (high speed & low cost internet/ data transmission , solar powered multipurpose robots/ UAVs, locally manufactured sensors, intelligent batteries/ algorithms & indigenous mobile applications for real time analytics),

Public-Private partnerships,

Farmer training programs (digital literacy & nation wide drone training & certification), **and**

Policy interventions including subsidies, tax incentives, custom hiring/ rental services & regulatory frameworks **to ensure implementation of smart farming on a large scale.**


Thank You.