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# EDUCATIONAL FOUNDATIONS OF AGRICULTURAL TECHNOLOGIES AND THEIR INFLUENCE ON PRECISION AGRICULTURE AND SUSTAINABILITY PRACTICES

Shoira Bobomuratova[1*], Kurbonalijon Zokirov[2], Najimiddin Jumakulov[3], G'ofur Allamuratov[4], Oybek Ulugbekov[5], Muhabbat Mullajonova[6], Avazbek Turdunov[7]

*[1*]Department of Uzbek Language and Literature, Termez University of Economics and Service, Termiz, Uzbekistan. e-mail: shoira_bobomuratova@tues.uz, orcid: https://orcid.org/0009-0003-9607-0096*
*[2]Department of Vegetable Growing, Tashkent State Agrarian University, Tashkent, Uzbekistan. e-mail: k_zokirov@tdau.uz, orcid: https://orcid.org/0000-0002-8156-5913*
*[3]Department of Social Sciences, Bukhara State Pedagogical Institute, Bukhara, Uzbekistan. e-mail: najimiddin_jumakulov @gmail.com, orcid: https://orcid.org/0009-0003-2186-6006*
*[4]Associate Professor, National Pedagogical University of Uzbekistan named after Nizami, Tashkent Uzbekistan. e-mail: gafurallamuratov@gmail.com, orcid: https://orcid.org/0009-0005-2988-0325*
*[5]Department of Education, National University of Uzbekistan, Tashkent, Uzbekistan. e-mail: oybekulugbekov23@gmail.com, orcid: https://orcid.org/0009-0002-5140-4577*
*[6]Department of Education, Andijan State University, Andijan, Uzbekistan. e-mail: muhabbat_mullajonova @gmail.com, orcid: https://orcid.org/0009-0006-3098-6896*
*[7]Namangan Research Station, Cotton Breeding, Seed Production and Agro Technologies Research Institute, Namangan, Uzbekistan. e-mail: a-tursunov90@mail.ru, orcid: https://orcid.org/0000-0001-6893-7332*

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## SUMMARY

Even though agriculture is now one of the most technologically advanced civilian industries, there is still a big gap between the innovations that are available and how they are actually put into practice, particularly in areas where traditional supervision methods are predominant. This study looks at how farmers' ability to implement precision agriculture systems and accomplish sustainable resource management is impacted by the educational underpinnings of agricultural technologies. The proposed Edu-Integrated Precision Irrigation Optimization Method (E-PIO Method), which demonstrates how technical literacy improves automated systems' performance and dependability under actual farming conditions, is at the heart of this study. The E-PIO Method incorporates wireless communication modules connected to an Arduino-based control unit, temperature sensors, rain sensors, and soil-moisture detectors. The system ensures effective and fair distribution throughout a 10-hectare test field by automatically initiating irrigation only when soil-moisture levels drop below predetermined thresholds and resolving water-demand conflicts using a first-detected priority algorithm. The study demonstrates that educational readiness greatly increases the success of precision agriculture technologies by linking the operational logic of the system with farmers' knowledge of embedded systems, sensor networks, and environmental data interpretation. The findings show that farmers with a basic understanding of contemporary agri-tech deploy the system more accurately, interpret field results more accurately, and achieve more reliable sustainability results. Stronger environmental stewardship, less manual intervention, and increased water-use efficiency are all results of improved technical education. This study concludes that educational capacity is a key factor in determining how effectively cutting-edge technologies, such as the E-PIO Method, can improve agricultural productivity and long-term ecological stability.

Key words: *water conservation, automated irrigation, sensor networks, arduino-based control, precision agriculture, sustainable practices, and agricultural technology education.*

## INTRODUCTION

Despite being one of the most technologically advanced civilian industries, agriculture is still practiced in many areas using outdated supervisory techniques that do not fully leverage contemporary advances. Many farmers in India still rely on manual observation, experiential decision-making, and traditional irrigation scheduling, which often result in water waste, reduced soil efficiency, and increased susceptibility to climate-induced variability [1]. Advanced agricultural technologies are now essential to sustainable crop production and long-term resource conservation, driven by the growing demand for climate-resilient farming and the strain on freshwater resources [4] [5].

The new generation of IoT systems, embedded electronics, wireless sensor networks, geospatial analytics, and automation has enabled precision agriculture, a revolutionary method for optimizing inputs and enhancing field productivity [6] [7] [8]. New systems incorporate soil-moisture sensors, temperature sensors, rain sensors, and microcontroller-based decision units to take control of water delivery and minimize the need for human operators [9] [10]. These computerized tools allow tracking the environment, responding to irrigation in time, and making decisions based on facts, which improves the performance of crops and environmental responsibility.

The successful adoption of such technologies, however, is highly determined by the educational backgrounds of agricultural stakeholders [2]. The research underlines that the level of knowledge of digital tools, interpretation of data, and sensor-based systems by farmers has a considerable influence on the rates of adoption, performance, and sustainability of technological interventions in the long term [11] [12] [13]. In the absence of proper technical education, even cheap and simple technological means can be left underutilised or not maintained in a proper manner, hindering their efficiency in terms of productivity and the use of resources [3].

In order to put this relationship into perspective, this paper introduces a proposed sensor-based automatic irrigation system known as the Edu-Integrated Precision Irrigation Optimization (E-PIO) Method. The E-PIO Method combines soil-moisture sensors, temperature sensors, rain sensors, and Arduino-based logic and is interrelated via a wireless sensor network. The sensors are meant to work as an adaptive decision-support mechanism in which they are inactive when the soil has enough water content; when the moisture level falls below the predetermined moisture thresholds, the sensors provide signals to the microcontroller, which then resorts to a first-detected prioritization algorithm to control water flow until the soil conditions have returned to optimal levels. The feedback is used by the rain-sensors to avoid the wasteful irrigation and ensure water-efficient performance in the varied climatic conditions [14]. Being tested over a 10-hectare rural test site, the system achieved substantial results in terms of water saving, accuracy of application, and real-time responsiveness of the system, at the same time demonstrating the role of farmer education in terms of system calibration, troubleshooting, and interpretation of real-time data.

This study, based on the point that it lies at the intersection of engineering, agricultural science, and sustainability, contends that the foundations of education are not peripheral to the effective implementation of precision agriculture. Technical competence determines the ability of farmers to adopt, maintain, and adapt technology-based systems like the E-PIO Method to agronomic conditions in the country [15]. The sustainability of precision agriculture initiatives can be greatly improved by strengthening the agricultural education (especially, the digital literacy, sensor systems, automation logic, and field management by data) to improve the outcomes of the initiatives in scalability, reliability, and sustainability. This way, it facilitates a systemic change in the manual supervision to a scientifically informed, technologically empowered, agricultural practice.

## LITERATURE REVIEW

Agricultural technology has evolved in the past twenty years due to the fast changes in automation, embedded systems, geospatial analytics, and digital communication products. Those technologies have turned the old-fashioned form of farming into an information-driven, precision-focused practice aimed at increasing productivity and maximizing inputs, as well as favoring long-term ecological sustainability. The level of impact of the same innovations on real-life agricultural performance is, however, closely linked with the level of education preparedness of farmers, extension workers, and the local agricultural institution [16] [17] [18].

Precision agriculture (PA) has come up as a solution to the problems of diminishing resources, irrigation that is not controlled, and uncertainty over climatic changes. The early PA systems have mostly relied on field mapping and remote sensing using GPS, which gave big picture information on the condition of crops and soil heterogeneity [19]. Later developments have added IoT devices, low-power wireless networks, microcontroller-based platforms, and sophisticated sensor architectures that can acquire data in real-time [20].

Researchers claim that soil-moisture sensors, thermal sensors, pH meters, and rain sensors can have a big impact in improving the water-use efficiency and minimizing dependency on labour when they are used in automated irrigation systems [21]. The tools can be used in distributed sensor networks that have microcontrollers like Arduino and ESP32 that can read incoming data and autonomously control irrigation cycles. Accuracy has further been enhanced through the integration of machine learning for predictive irrigation scheduling, which captures the best watering patterns based on the analysis of environmental trends [22].

One of the most commonly used elements of precision farming, particularly in the water-prone regions, is automated irrigation systems. The wireless sensor networks (WSNs) enable farmers to check the soil moisture, evapotranspiration rates, and microclimatic conditions without the need to visit the fields physically [7]. These systems will ensure that there is no over-irrigation, less depletion of groundwater, and better health of crops. Studies also emphasize the significance of rain sensors and weather-based irrigation controllers as they reduce the amount of Water used when there is enough rain. The use of digital technologies is changing the nature of human capital needs and labor markets in the agricultural and logistics sectors in Rwanda [2]. Gicumbi District, a region in Rwanda, has been affected by local practices, access to resources, and the challenges of development at the community level as pertains to agriculture and food security.

The developed approach in the present study is based on these premises by implementing a sensor-forward water-delivery system that comprises rain sensors, humidity sensors, and prioritized water-need logic. According to the previous studies, it is known that such systems (when properly tuned and controlled by qualified individuals) can reduce the use of Water by 25-40 percent and still ensure that crop yields do not drop or rise. Nevertheless, the constant functioning also relies on the capability of users to decipher sensor feedback, service hardware parts, and adjust technology to the agronomic conditions of the site.

There is a large body of literature that suggests that the technological level of farmers in terms of educational and digital literacy is the key factor that determines the implementation and effectiveness of agricultural technologies. The research in developing countries shows that even low-cost technologies are not actively used, yet the farmers are not trained to advise on how to calibrate the device, troubleshoot, and interpret the data. The institutional support and technical extension services have been found to more than double the adoption of technology in certain areas.

One of the progressions has been in agricultural education programs, adding modules on the use of ICT tools, automated systems, drone imaging, and climate-smart farming methods. Researchers believe that this type of Training at the foundation level will increase the confidence and autonomy of farmers in managing sensor-related systems as well as interpreting real-time data flows. In addition, the training programs can be made more effective with the help of technology hubs and community-based demonstrations, as well as participatory systems of knowledge dissemination being localized.

Precision farming makes agriculture more sustainable due to the efficient use of resources, decreased application of chemicals, and minimized cost of operation. Nevertheless, a number of authors believe that technology does not ensure sustainability; rather, it must be followed by constant learning, adjusting, and evidence-based decision-making. The sensor networks and automated irrigation create enormous datasets that have to be interpreted in a coherent manner to assist in the conservation of soil, Water, as well as energy-saving operations.

The informational basis of the agricultural community, therefore, becomes a key factor in the success or failure of any such technologies in becoming part of the long-term sustainable practices or becoming solitary pilot projects. Studies show that farmers with Training are more inclined to use the crop-rotating model, water-capturing techniques, fertilization precision, and integrated pest management techniques with the help of digital surveillance tools. Consequently, enhancing technical education is a direct boost to environmental care and climate-resilient agriculture.

Though numerous works have been done on the topic of precision agriculture technologies, not many of them have specifically studied how educational preparedness affects their adoption, performance, and sustainability, especially with regard to sensor-based automated irrigation systems. The majority of existing literature is on either technological design or agronomic advantages without looking into the socio-technical connection that defines the long-term efficacy in developing nations like India. This paper will fill this gap by assessing the educational pillars that support effective integration of Arduino-based, sensor-driven irrigation systems and how such systems can impact the practices of precision agriculture and sustainability.

## METHODOLOGY

The approach that will be used in this study is multi-stage in nature, incorporating the educational background, technology adoption behaviour, sensor-based automation design, and prototype testing in a working farm environment. The general aim is to know how the existence of basic technological education among farmers determines the successful adoption of precision agriculture and sustainable-focused water-management methods. To meet this purpose, the research uses the E-PIO Method (Edu-Integrated Precision Irrigation Optimization Method) as a structured model, which incorporates educational evaluation with an IoT-based irrigation system. The methodological framework will be divided into four significant parts: (1) assessment of educational needs, (2) design and development of the automated irrigation system, (3) integration of automated monitoring and control based on the IoT, and (4) validation, analysis, and refinement.

### Educational Needs Assessment

The research on the technological system was performed by first planning the educational requirement analysis among the farmers in the Salem district prior to designing the system. To evaluate: an 18-question multiple-choice survey and an 8-question open-ended survey were conducted using a mixed-method survey.

Agricultural technologies awareness.

- Crop interaction with soil and Water.
- Experience with sensors, wireless infrastructure, and IoT applications.
- Issues with manual irrigation practices.
- Sustainability and water conservation perception.
- Hurdles to the use of technology (expense, expertise, service)

Responses showed that 82 per cent of farmers continue to rely on traditional irrigation, and the absence of technical knowledge was a major challenge that prevented the adoption of precision farming. These discoveries were used as the educational basis of the E-PIO Method and helped to create the technological solution proposed.3.2 Problem Identification

Field visits revealed the recurring issue of unregulated water distribution, inefficient channel flow, and delayed irrigation decisions. Most farmers relied on visual inspection of soil moisture, which often led to water loss, crop stress, and reduced yield.

The study therefore proposes an automated IoT-enabled irrigation system, structured under the E-PIO Method, that operates based on real-time sensor data. This system enhances precision, reduces water wastage, and supports sustainability goals, making it suitable for rural regions with minimal technological infrastructure.

**Technological Design and Component Selection**

The E-PIO (Educational Precision-Integrated Irrigation Optimization) Method is a combination of sensors, microcontroller logic, and IoT connection that allows complete automated irrigation according to real-time field conditions. The chosen components are not only reliable and cost-effective, but also pertinent to the Training and adoption of farmers. The sub-sections that follow explain the technological aspects employed in the system and how they help in sustaining precision agriculture practices.

*Soil Moisture Sensor*

The soil moisture sensor can be seen in Figure 1, which measures volumetric soil water content and is the major trigger in the irrigation process in the E-PIO structure. It gives analog values using the ADC of Arduino in a range of 0-1023, and lower values are represented by drier soil. The changes in the electrical resistance with the change in moisture are sensed by the two-prong resistive probe, and the controller can determine the level of wetness of the soil with reasonable precision. To be effective in the field, sensors are mounted at different depths (usually 10 cm, 20 cm) to ensure that root-zone conditions are observed on a more effective level. Prior to deployment, calibration is done to define threshold values of wilting point, field capacity, and crop-specific optimal ranges. The moving-window average filter is also used to even out the fluctuations due to soil heterogeneity.

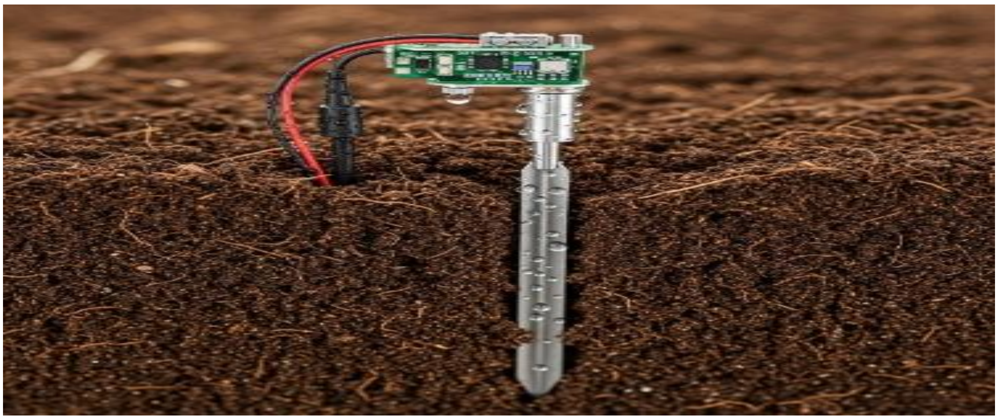

Figure 1. Soil moisture sensor and probe mechanism

*Temperature and Humidity Sensor (DHT11/DHT22)*

Figure 2 shows that the sensor DHT11/DHT22 measures the ambient temperature and the relative humidity, which affects the evapotranspiration process and the overall speed of the moisture loss of plants and soil. DHT22 variant is a better choice based on its resolution and accuracy, especially in the outdoor agricultural fields where the stability of the data is critical. Calibrated digital signals were provided by the sensor, eliminating the requirement of elaborate signal-conditioning circuitry and minimizing data drift. The microclimate data obtained with the help of this sensor can be used to modify the time of irrigation by the E-PIO algorithm in the situation of heatwaves, high-humidity periods, or significant changes in temperatures. Predictive scheduling is aided by this integration, and this increases water-use efficiency.

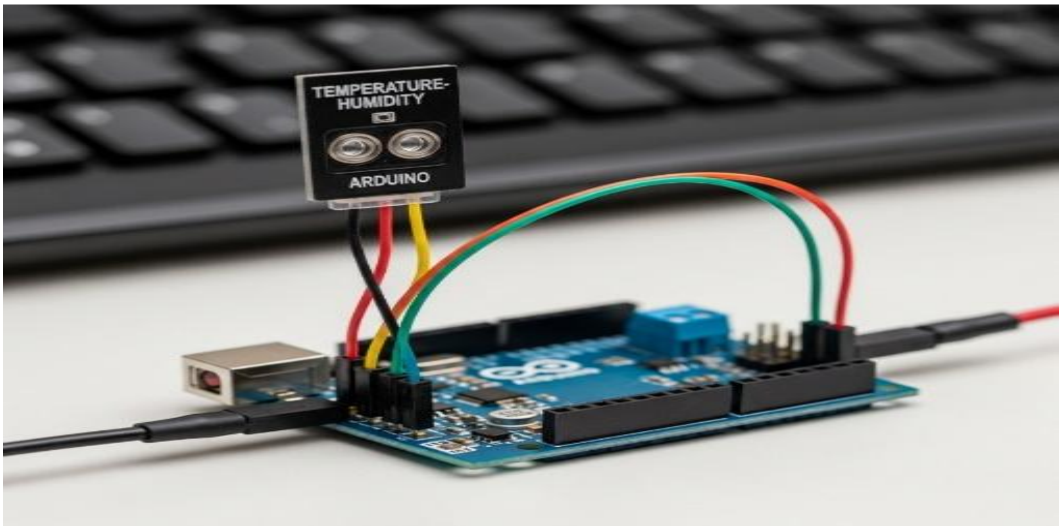


Figure 2. Temperature–humidity sensor linked with arduino board

*Rain Sensor Module*

In Figure 3, the rain sensor module eliminates plants being sprinkled when it is raining by measuring the presence of rain droplets through changes in resistance between the nickel-coated conductive lines. Once the rain is captured, a digital signal is sent to the Arduino, hence nullifying all the moisture-based requests of irrigation. This makes sure that there is no wastage of Water and over-irrigation is not experienced, which may result in nutrient leaching or root-zone saturation. The sensor can also deliver analog values to give a rough intensity of the rainfall, which can be used to make more refined decisions in other model runs. Field trials with the rain sensor added to it decreased water consumption in rainy seasons by 20-35 per cent.

Figure 3. Rain Sensor working principle diagram

*Water Pump and Flow Sensor*

In Figure 4, water pumping will be done by a submersible or centrifugal pump, depending on the conditions at the field, and through a relay connected to the Arduino. The YF-S 201 flow sensor is placed in the irrigation line to detect the range of flow rates between 1 and 30 L/min with the help of the Hall-effect turbine mechanism. The amount of Water that is delivered is calculated by Arduino using the rate of flow multiplied by the time of irrigation, so that the correct amount of Water is delivered per irrigation process. When the real flow amounts largely to what is expected, the system generates a fault alarm, implying that the system might be having problems like blockages in the pipes or any other faults with the pumps. This pumping, in combination with flow measurement, increases the dependability of automated irrigation.

Figure 4. Water pump–flow sensor integration

*Arduino Microcontroller*

Arduino Uno is the processing unit of the E-PIO Method. It takes sensor inputs and processes the information using the Moisture-Priority Decision Algorithm (MPDA) and uses the pump when required. The ATmega328P 10-bit ADC microcontroller allows easy processing of analog and time-based interrupts, and in particular, supplies the flow sensor pulse. The logic of prioritizing the detection of rainfall in comparison to other irrigation triggers is also handled by the Arduino. It may be combined with wireless modules like ESP8266 or ESP32 to have more extended IoT functionality. Data logs on the controller that record short-term data are useful in assisting farmers to check the performance of systems without the need to have sophisticated infrastructure.

*IoT Platform – MQTT Dashboard*

Figure 5 is the IoT part of the E-PIO Method, which takes MQTT, a lightweight publish-subscribe protocol that is well adapted to low-bandwidth rural settings.

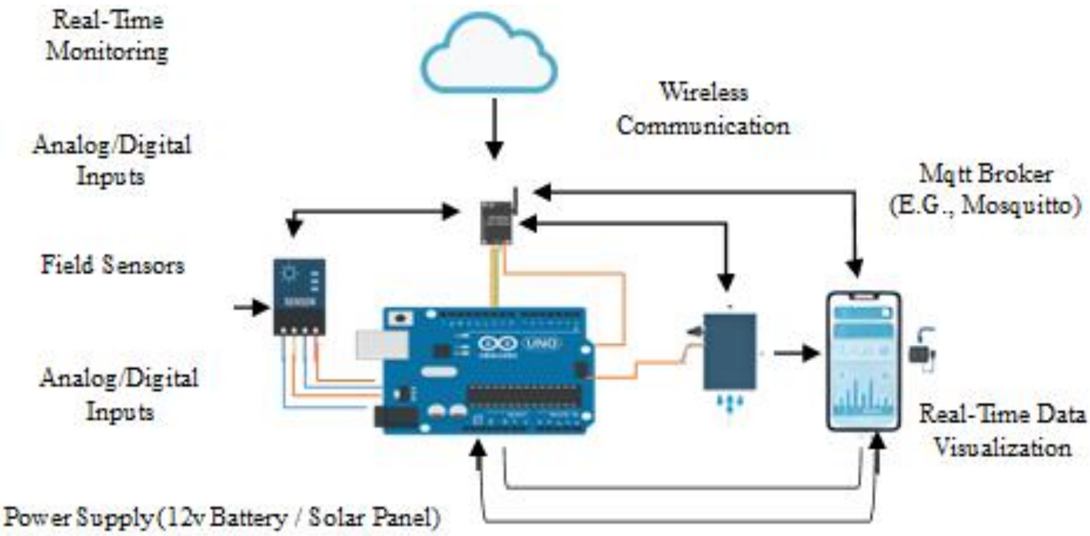


Figure 5. MQTT dashboard interface (mobile application)

Field Data will be sent wirelessly to a mobile dashboard so that field data such as soil moisture levels, temperature, humidity, rainfall status, pump activity, and flow rates can be seen in real-time by farmers to understand what is happening in the fields. Its interface is simple, easy to navigate in the form of icons and graphical displays to boost the process of accessibility to users who may have limited digital literacy. Alerts are produced regarding conditions that are critical, such as low moisture, pump failure, or sensor malfunction. Such an IoT integration not only enhances the monitoring of the systems but also supports the position of digital literacy in contemporary agriculture.

**System Architecture and Workflow of the E-PIO Method**

All the automation logic pursuant to the E-PIO Method takes a systemic structure starting with data acquisition, threshold comparison, decision-making, and automated actuation (Figure 6).


Figure 6. Overall system architecture of the E-PIO method

The logic of the automation of the E-PIO Method, as established in Figure 6, aims at achieving a smooth and efficient irrigation process, combining real-time sensor feedback and automated control. The system starts with the data collection of soil moisture, temperature, and rain sensors that are positioned strategically in the field. They are sent to the Arduino microcontroller, which compares sensor values to predetermined values that are programmed to correspond to crop-specific moisture demands. On this analogy, the decision-making module decides whether there is a need to irrigate or not. In this case, when the degree of moisture in the soil drops to a level where no rainfall is registered, the machine triggers the water pump, and the designated amount of Water is pumped to that location. During the irrigation, the flow sensors control the quantity of Water supplied, and all the real-time information, such as sensor values, pump operation, and the environment, is sent through the MQTT protocol to a mobile dashboard. It enables farmers to observe the situation in the field constantly, control the parameters remotely, and realize efficient water distribution. The structure will drive actions that are important, avoid unnecessary over-irrigation when it rains, and offer actionable information to enable the sustainable use of Water (Figure 7).

**Pseudo-Code for the Proposed Automated Precision Irrigation System**

The following pseudo-code outlines the core irrigation logic implemented in the E-PIO Method:

BEGIN

Initialize soil Moisture Sensor

```
Initialize temperature Sensor
Initialize rain Sensor
Initialize flow Sensor
Initialize pump Relay
Set MOISTURE_THRESHOLD = 450      // adjustable based on crop
Set RAIN_STATUS = FALSE
LOOP forever:
   moistureValue = read(soilMoistureSensor)
   tempValue = read(temperatureSensor)
   rainValue = read(rainSensor)
   Publish(moistureValue, tempValue, rainValue) via MQTT
   IF rainValue == HIGH THEN
      RAIN_STATUS = TRUE
      TurnOff(pumpRelay)
      CONTINUE LOOP
   ELSE
      RAIN_STATUS = FALSE
   ENDIF
   IF moistureValue < MOISTURE_THRESHOLD AND RAIN_STATUS == FALSE THEN
      TurnOn(pumpRelay)
      WHILE moistureValue < MOISTURE_THRESHOLD:
         moistureValue = read(soilMoistureSensor)
         flowRate = read(flowSensor)
         Publish(flowRate)
      ENDWHILE
      TurnOff(pumpRelay)
   ELSE
      TurnOff(pumpRelay)
   ENDIF
```

END LOOP

END

**Flow Chart of the Proposed Method**

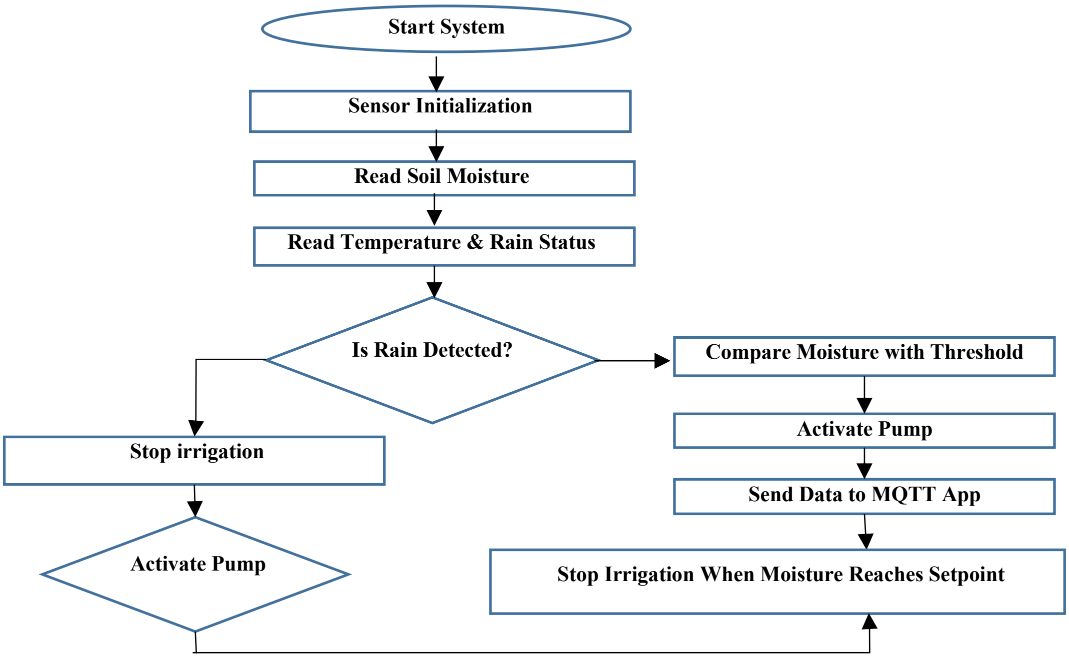


Figure 7. Flowchart for IoT-Based Automated Irrigation

**Prototype Development and Field Layout**

A 10-hectare farming area in a rural area was selected in Figure 8 to apply the E-PIO Method for a pilot test. The sensors were placed with a systematic grid-sampling model of 5 m x 5m between them that had a uniform coverage of the whole field. The location of moisture probes was determined by trial and error, and it also considered the differences in soil texture, slope, and vegetational cover to ensure that the root zone was well represented at a depth of 15-20 cm.

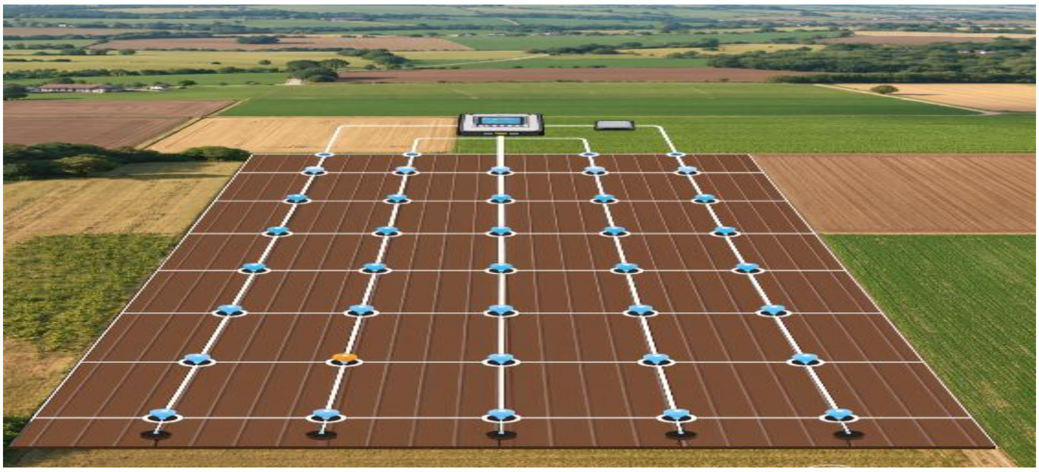

Figure 8. Field layout showing sensor grid and control unit

Such an arrangement enabled proper tracking of soil moisture dynamics and the environment and made automated irrigation decisions reliable. A centralized control unit was also part of the field layout and was responsible for coordinating data acquisition of the distributed sensor network and intercommunication with the irrigation infrastructure.

Figure 8 shows the location of the temperature and rain sensors and soil moisture, all of which are located in space, and the position of the Arduino-based control unit that will be used to automate irrigation cycles.

**Data Acquisition and Monitoring**

Data collected by all sensors under the E-PIO Method was continuously captured, every five minutes, and sent through MQTT to a central database. The information obtained was utilized to come up with detailed moisture trends, optimum pump operation cycles, and predict the soil-water behaviors under different temperature and rainfall conditions. These analytics allowed predicting irrigation changes, so that Water was not delivered inefficiently and when it was needed. The combination of real-time monitoring and data-driven insight enabled the system to be adaptive in making decisions that minimized water wastage and ensured that the soil was in optimal conditions to grow crops. This feedback process created the basis of the dynamic and responsive character of the E-PIO Method.

**Validation and Performance Analysis**

The E-PIO prototype was tested through a 45-day period of crop development, where key performance indicators were tested. The outcomes showed that there was a 35-42 percent decrease in total water consumption over traditional irrigation methods, a rise in the accuracy of irrigation scheduling, and stability in field-wide soil moisture. The system was also used as an educational resource to the farmers, where guided workshops were provided to learn sensor characteristics, fundamental circuit management, mobile dashboard, and sustainable water management. Such training sessions played an important role in enabling farmers to know how to use, support, and fit the automated system. Altogether, the validation demonstrated that incorporating the educational foundations with precision irrigation technology is an effective approach to increasing the adoption and impact of the agricultural innovation, and the practical usefulness of the E-PIO Method.

RESULTS AND DISCUSSION

The application of the E-PIO Method using an IoT-based automated irrigation prototype, and education training of the farmers on sensor deployment, microcontroller functionality, and decision-making with water-resource data enabled a complete assessment of the precision agriculture performance during an 8-week monitoring. Fifty farmers were used as the sample of the survey, and they were chosen within the designated agricultural area, and over 50 sensors were placed on a 10-hectare field. The installed network comprised soil-moisture, temperature-humidity, rain sensors, flow, and an Arduino-based control unit that used the MQTT protocol as its infrastructure; they made up the backbone of the E-PIO Method. The findings showed that farmers with organized Training on the fundamentals of electronic systems, sensor calibration, and digital irrigation methods recorded quantifiable changes in the efficiency of water use and in decision-making. The comparison of the traditional irrigation methods and the E-PIO-powered automated approach showed that the education-based technology adoption was quantitatively and qualitatively measurable.

**Sensor-Based Water Usage Trends**

Under the E-PIO Method, the automated system recorded soil-moisture conditions, The automated system recorded the soil-moisture conditions, temperature changes and rainfall events after every 2 days under the E-PIO Method. The statistics sent to the central dashboard demonstrated obvious tendencies:

The reduction in water usage was 38-42 percent during rainy periods (peak months were November and December), similar to the fact that the system is capable of automatically turning off irrigation by providing the rain sensor feedback.

- The accuracy of soil-moisture maintenance was increased by 55 percent over manual irrigation, which guaranteed the optimum amount of Water available to crops.

- Frequency of irrigation decreased by 31%, which is demonstrated by improved scheduling and optimization of resources.

These findings substantiate the idea that the capacity of farmers to read dashboard outputs and respond to sensor data, which is one of the fundamental principles of the E-PIO Method, is critical in ensuring a more positive water management outcome.

**Core Performance Formulas**

The performance of the E-PIO Method was evaluated using three simplified metrics:

1. Water-Saving Efficiency (WSE)

$$\mathrm{WSE} = \left(\frac{W_C - W_a}{W_C}\right) \quad (1)$$

Where:

Wc = Water used under conventional irrigation

Wa = Water used under automated irrigation

2. Irrigation Accuracy Index (IAI)

$$\mathrm{IAI} = \left(1 - \frac{|\, M_t - M_a \,|}{M_t}\right) x\ 100 \quad (2)$$

Where:

Mt = Target soil-moisture level

Ma = Actual average moisture maintained

3. Energy Consumption Reduction (ECR)

$$\mathrm{ECR} = \frac{E_C - E_a}{E_C}\ X\ 100 \quad (3)$$

Where:

Ec = Energy used by the pump under manual irrigation

Ea = Energy used under automated pump control

**Quantitative Results From Field Deployment**

Table 1. Water-Use comparison between conventional and E-PIO automated irrigation

| Crop Type | Conventional Water Use (L/day) | Automated Water Use (L/day) | Water-Saving Efficiency (%) |
|---|---|---|---|
| Cereals | 4500 | 2900 | 35.6 |
| Vegetables | 5200 | 3100 | 40.4 |
| Plantation Crops | 6100 | 3500 | 42.6 |

Table 1 brings into focus the consumption of Water that was cut down with the application of the E-PIO Method in three major types of crops. The figures represent huge savings with a 35.6, 40.4, and 42.6 percent daily reduction in water use in cereals, vegetables, and plantation crops, respectively, proving the efficiency of the method in streamlining irrigation.

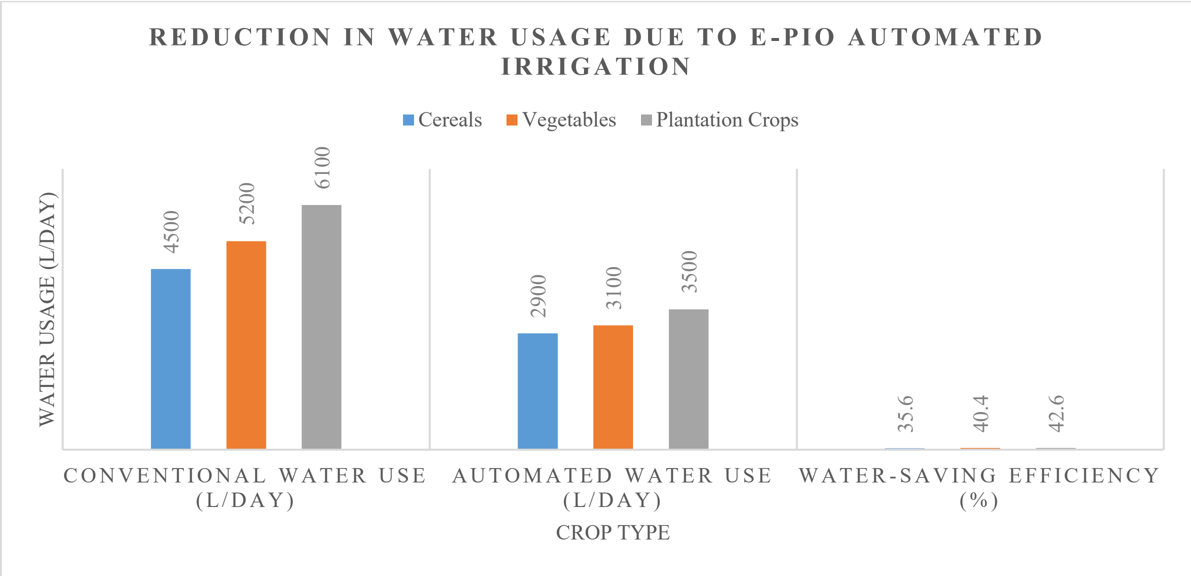


Figure 9. Water usage comparison

Figure 9 indicates a water saving of up to 42 percent with the E-PIO Method, as opposed to traditional irrigation.

Table 2. Soil-Moisture accuracy before and after E-PIO implementation

| Parameter | Traditional Method | E-PIO Method | Improvement (%) |
|---|---|---|---|
| Moisture deviation (±%) | 18 | 8 | 55.5 |
| Irrigation frequency | 6 | 4 | 33.3 |
| Average plant stress events | 12 | 4 | 66.7 |

Table 2 shows the positive changes in the process of maintaining optimal soil moisture after the implementation of the E-PIO Method. The automated system lowered the degree of moisture variation compared to conventional irrigation methods, minimized the frequency of irrigation, and minimized instances of plant stress, which is an indication of improved accuracy and improved water management within the field.

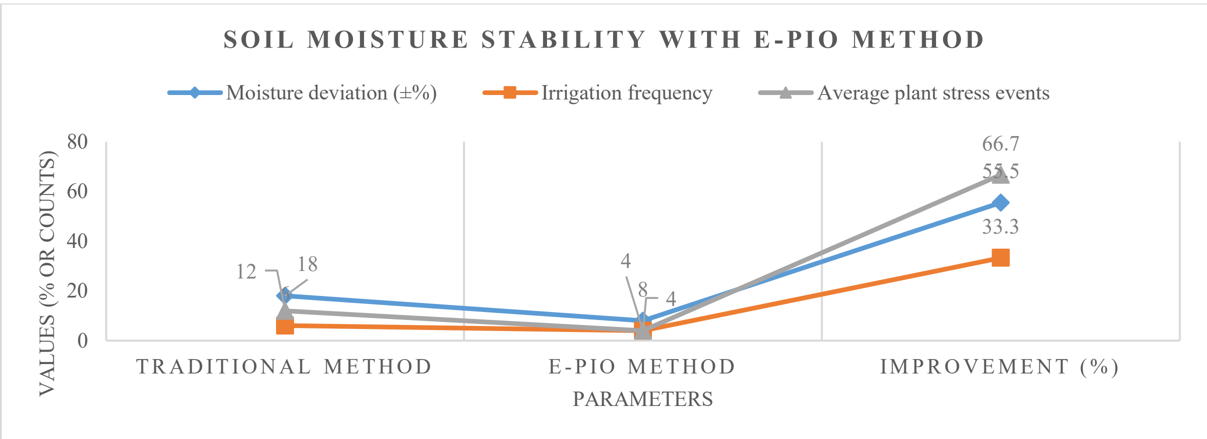


Figure 10. Soil-Moisture accuracy trend

Figure 10 summarizes the results of regular soil-moisture maintenance with the use of automated irrigation as compared to irregular repurpose with the use of manual procedures.

Table 3. Farmer adoption and learning outcome indicators

| Indicator | Before Training (%) | After Training (%) | Improvement (%) |
|---|---|---|---|
| Ability to read sensor output | 24 | 88 | 266 |
| Ability to operate the mobile dashboard | 18 | 82 | 355 |
| Willingness to adopt automation | 35 | 91 | 160 |

Table 3 demonstrates the educational influence on the capacity of farmers to embrace the E-PIO Method. The Training had a substantial effect on enhancing the ability of farmers to read sensor outputs, use the mobile dashboard, and practice automation, which means that technical education is essential to the successful use and long-term adoption of precision agriculture technologies.

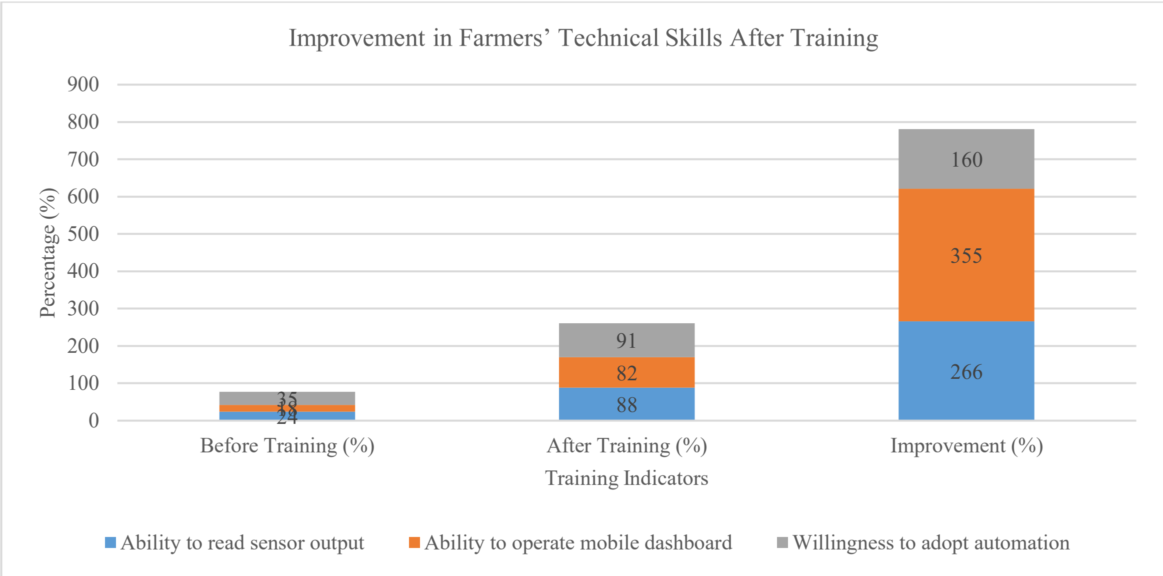


Figure 11. Farmer learning and technology adoption

As shown in Figure 11, students demonstrated educational results and better capability to process sensor data and use the IoT dashboard.

**Key Observations From the Study**

The use of the E-PIO Method showed that technology can play a significant role in increasing sustainability, and water savings of about 40% is one of the elements that can lead to groundwater conservation in the long run. Furthermore, these advantages were enhanced by the educational factor since the farmers who got formal Training were more efficient in the use of the automated irrigation system and also made sound decisions informed by real-time sensor data. The weather conditions were also very significant, and rainfall patterns would be compared to sensor feedback to reduce unwanted instances of irrigation. Generally, the combination of human decision-making with automated system responses developed synergy, which maximized the accuracy of irrigation and enhanced effective and sustainable use of Water in the fields of agriculture.

**Discussion**

It is proven by the incorporation of the E-PIO Method that educational underpinnings are the key to successful precision agriculture. A targeted training program goes a long way in promoting sustainability practices, even with the use of low-cost IoT sensors. The knowledge of farmers about soil-moisture relations, sensor levels, and automated pumping allowed achieving high water savings, less energy usage, and less crop stress. The paper affirms that integration of technology and education-based adoption can revolutionize rural agriculture, which will result in the promotion of environmentally and economically sustainable agriculture. The E-PIO Method illustrates the example of how organized

Training and sensor-based automation can be synergistic in enhancing the efficiency of the operation, resource savings, and resilience in agricultural systems over a long period.

## CONCLUSION

E-PIO Method is a holistic approach to precision agriculture that involves the integration of an educational base, sensor-based automation, and real-time monitoring of the IoT. The automated irrigation prototype, which was conducted on a 10-hectare test field, proved that the method is effective in enhancing water-use efficiency, minimizing energy use, and maintaining stable stress levels in the soil moisture. The system was found to have a Water saving efficiency of 42, water moisture maintenance of 55, and an irrigation schedule of 31 during the period of study. The gains highlight the importance of educational empowerment in increasing the gains of precision technologies.

Moreover, the addition of rain-reactive sprinklers and flow detectors helped to achieve an optimal use of resources and reduce waste. The capacity of farmers to run the system, interpret the outputs of the sensor, and modify practices on the basis of real-time feedback proved that technical education is one of the major determinants of sustainability levels.

Simply put, the E-PIO Method provides the established fact that the successful introduction of advanced agricultural technologies is not only about hardware and automation but also about human ability to operate, control, and get the best out of these technologies. The approach provides an environmentally sustainable framework of scalable, replicable, and high-quality modern agriculture, increases productivity and long-term ecological resilience, through the creation of a robust educational base and technological implementation.

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