ADVANCED IRRIGATION SYSTEM USING ARTIFICIAL INTELLIGENCE

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Abstract—*To make agriculture more sustainable by integrating different technologies to enhance its operation, regarding agricultural control based on land or crops in the modern agricultural system, networking technology has been crucial. Since farmers can control their activities more easily than before, it is possible to do so. Options are available even when farmers are not present. This also applies to water management in irrigation systems. The Internet of Things (IoT) tracks and analyzes real-time data for each agricultural crop collected through sensors and devices.*

Irrigation techniques and patterns are used in a country like India, where agriculture is mostly focused. The sector is unorganized and inefficient and often leads to unnecessary water wastage. A system that can provide an effective solution and, therefore, an implementable solution is needed. Using soil moisture data, we present this automated irrigation system. The studio can water the fields on its own. It is based on artificial intelligence (AI) and the Internet of Things (IoT). A system that selectively irrigates crop fields only when necessary, depending on climate and current soil moisture levels.

It is generated by the system's forecasting algorithms, which analyze historical weather data to determine and predict rainfall patterns and climate changes, with an accuracy rate of up to 80% during testing in a controlled environment.

Keywords— *Artificial Intelligence, Irrigation, Internet Of Things, Prediction Algorithms, Machine Learning, Water.*

I. INTRODUCTION

In modern agriculture, irrigation plays a pivotal role in ensuring crop productivity and sustainability, particularly in regions prone to water scarcity and unpredictable weather patterns. Traditional irrigation methods often rely on fixed schedules or rudimentary sensor-based systems, which can result in inefficient water usage and suboptimal crop yields. The incorporation of AI into irrigation systems represents a transforming approach to addressing these challenges by enabling smarter, data-driven decision-making processes.

Traditional irrigation practices typically involve uniform water distribution across fields based on predetermined schedules or manual observations. These techniques frequently overlook dynamic environmental factors like crop water requirements, weather, and soil moisture levels. As a result, water may be overused in some areas, leading to waterlogging and nutrient leaching, while other areas may experience insufficient irrigation, impacting crop growth and yield potential.

AI can analyze vast amounts of data and learn patterns from complex datasets, offering unprecedented opportunities to revolutionize agriculture, including irrigation management. AI algorithms, such as machine learning and neural networks, can process real-time data from sensors installed in fields, weather forecasts, and historical data to optimize irrigation schedules dynamically. Artificial intelligence (AI) can make sure that crops get the right amount of water at the correct moment, thereby optimizing yield potential while saving water resources. AI does this by constantly developing and adjusting to changing conditions.

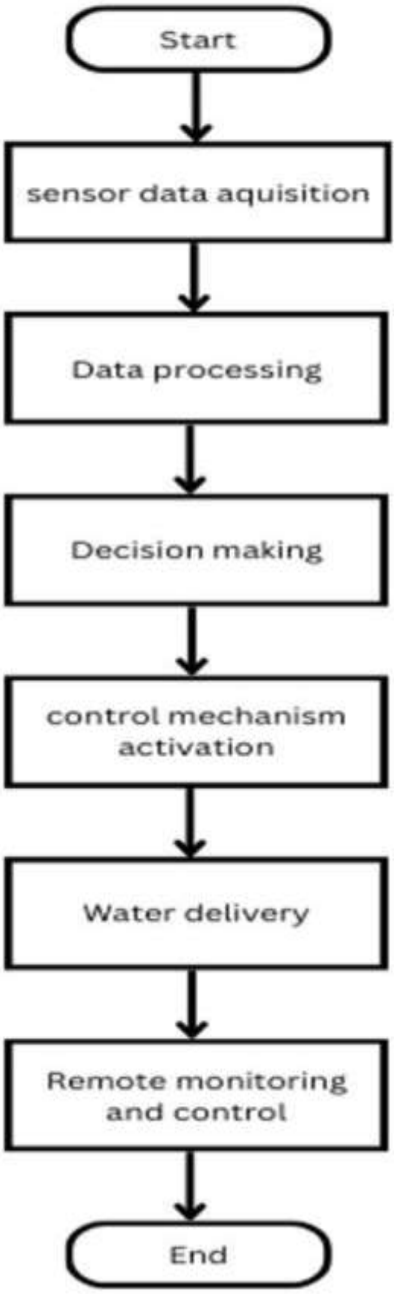
II. BACKGROUND

In [1], this paper by Ennouri et al. investigates how fake insights (AI) and inaccessible detection are revolutionizing farming. AI-based apparatuses, rambles, and inaccessible detecting are changing trim generation, verifying, and information collection. These innovations address challenges like climate change, soil well-being, and plant assurance. AI in farming can foresee climate, screen edit well-being, control pests, and analyze soil. This can improve efficiency, minimize natural effects, and maximize asset utilization. Inaccessible detecting permits for assessing arrivals without coordinated contact, empowering inaccessible perceptions and information investigation. Distinctive finders analyze vegetation characteristics, surveying components like abdicate and soil dampness. The article investigates other advanced innovations in farming. AI can indeed foresee nourishment patterns and optimize pesticide utilization. AI-powered arrangements can handle natural concerns, screen soil and crops, and optimize water systems. This leads to maintainable cultivating hones. By and large, the article highlights how AI and inaccessible detection can revolutionize horticulture. These advances improve yields, address the basic perspectives of cultivate administration, and reduce natural challenges. They hold monstrous potential for the future of farming. In [2], the archive "Survey of Machine Learning(ML) Demonstration Applications in Exactness Farming" examines the critical headways in advanced farming due to the integration of ML and fake insights. The creators emphasize the application of ML models in different perspectives of accuracy in agribusiness, including edit abdicate expectation, infection discovery, weed discovery, edit acknowledgement, trim quality evaluation, dribble water system, water quality administration, soil properties examination, climate determining, creature welfare, animal generation, collecting methods, and fertilizer suggestion. The article highlights the use of machine learning calculations such as back vector machines (SVMs), convolutional neural systems (CNN), irregular timberland (RF), K-nearest neighbour (KNN), K-means clustering, and XGBoost in these agrarian applications. The archive also presents the challenges regarding information security, eradication, and testing, as well as the potential future scope for creating strong suggestion frameworks and robotizing pre-harvesting and post-harvesting practices utilizing machine learning procedures. The comprehensive diagram given in the report sheds light on the transformative potential of machine learning in revolutionizing accuracy in agribusiness to improve efficiency and sustainability. In [3], Akash Saha Priyanka Sarkar Das et al. proposed “Smart Green House for Controlling and Checking Temperature, Soil, and Stickiness Utilizing IOT” IEEE-2022. Agricultural financial matters play a crucial role in the financial matters segment of improvement since a huge part of a country’s populace depends on the farming segment. An increase in agrarian efficiency also boosts provincial population wages, which in turn increases demand for mechanical yield. Approximately 70% of India's population is employed in agriculture. In many developing countries, agrarian progress constitutes a fundamental prerequisite for overall financial development. Farmers' demands for non-farm goods, as well as agricultural inputs and administrations, increase along with their income. Expanded rural generation also leads to expanded requests for handling offices. There are various components that modify this improvement. So Keen cultivating is an administration concept utilizing advanced innovation to increase the amount and quality of agrarian items. The use of contemporary innovations like robots, temperature and moisture sensors, aerial photography, and GPS technology is commonplace in horticulture today. Businesses are now able to operate more efficiently, safely, and hospitably thanks to these cutting-edge devices and precision in mechanical and agricultural frameworks.

III. PROPOSED METHODOLOGY

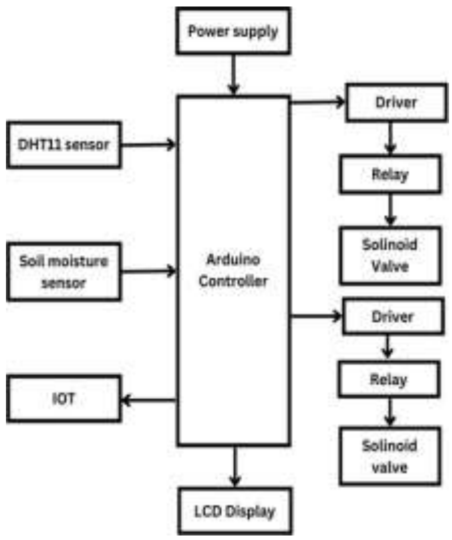
The proposed advanced irrigation system marks a pivotal shift in modern agricultural practices, holding in a new era of efficiency and sustainability through the fusion of artificial intelligence (AI) with IoT.

FLOW CHART



Fundamentally, the system makes use of a variety of sensors to gather data in real-time on important factors like temperature, moisture content of the soil, and ambient conditions. This basic information serves as the foundation for informed decision-making, empowering farmers with insights vital for maximizing irrigation techniques. Through the implementation of advanced AI algorithms, including sophisticated machine learning models, the system processes this data to craft customized irrigation schedules tailored to the unique needs of specific crops and prevailing environmental states. The integration of these optimized schedules is facilitated through automated control mechanisms superimposed into the irrigation equipment. Here, the heart of the system, the Arduino Uno controller, orchestrates the operation, working in tandem with solenoid valves to ensure precise water delivery to distinct areas of the field. These valves, triggered by inputs from the AI section, dynamically customize water flow rates based on real-time requirements, thereby reducing wastage and improving efficiency in irrigation practices. Furthermore, the system's remote monitoring and control capabilities, facilitated by the Blynk application and the Internet of Things (IoT) connectivity, offer farmers unprecedented levels of oversight and management. Through intuitive interfaces accessible via Android devices, farmers can remotely monitor sensor data, modify irrigation schedules, and respond to changing conditions in real time. This level of accessibility not only streamlines operational processes but also enables farmers to conserve water resources, enhance crop yields, and reduce overall operational costs. In essence, the proposed advanced irrigation system represents a holistic approach to agricultural management, harnessing cutting-edge technology to drive productivity, efficiency, and environmental stewardship. By seamlessly integrating. As the agricultural sector suffers from the challenges of feeding a growing global population amidst escalating environmental concerns, initiatives such as this offer a beacon of hope, showcasing the transformative potential of technology in shaping the future of agriculture.

IV. BLOCK DIAGRAM



EXPLANATION

First, information is gathered by the system from the sensors buried in the ground. The Arduino Uno board receives data from the soil moisture sensor, which gauges the amount of moisture in the soil. A well-liked and frequently used sensor for determining humidity and temperature is the DHT11. After processing the sensor data, the Arduino Uno board determines whether to operate the water pump by turning it on or off. To irrigate the plants, the Arduino Uno board triggers the relay attached to the water pump when the soil moisture content falls below a set threshold. Until the soil moisture content reaches the target level, the water pump keeps running. The Arduino Uno board turns off the water pump and deactivates the relay when the appropriate moisture level is reached. This lessens the chance of overwatering the plants and saves water. An essential part of the suggested system is the soil moisture sensor, which allows the system to automatically modify the irrigation schedule according to the current weather. In order to identify whether there are any animals in the farm area, it also has an ultrasonic sensor. When an animal approaches the garden, the ultrasonic sensor is positioned at the right height and angle to detect it. The device sounds a buzzer to frighten animals away if the ultrasonic sensor finds them. This keeps the garden and the plants safe and healthy by preventing animals from harming the plants. The system shows the sensor data on the LCD screen in addition to managing the water pump. The temperature, humidity, and current soil moisture content are all displayed on the LCD screen. Farmers can use this information to monitor crop health and make necessary system settings adjustments. A NodeMCU module is also part of the system, which is used to upload sensor data to the cloud and connect the system to the internet. The NodeMCU module stores the data in a database and uses Wi-Fi to send it to the cloud. Farmers can use a computer or a mobile device to access the data remotely. Real-time sensor data display via an intuitive interface is offered by the cloud platform. This encourages effective water use and empowers farmers to make well-informed decisions about their irrigation systems. All things considered, the advanced irrigation system with artificial intelligence that is being proposed combines a several technologies to offer an automated and optimal irrigation system for gardens, farms, and other places where plants are grown. With the system, plant enthusiasts, farmers, and gardeners can maximize the effectiveness of their irrigation systems, leading to healthier plants and more economical use of resources. The following is a separate explanation of each block's function:

A. Arduino Uno Controller

The Arduino Uno is among the most popular microcontroller boards used for prototyping and educational purposes. It is part of the Arduino family, which provides an open-source platform for electronics and software development. Here is an in-depth look at the Arduino Uno:

1. Overview

- **Microcontroller**: Atmega328P.
- **Architecture**: 8-bit AVR.
- **Clock Speed**: 16MHz.
- **Input Voltage (Recommended)**: 7-12V.
- **Operating Voltage**: 5V.
- **Digital I/O Pins**: 14 (of which 6 could be utilized as PWM outputs).
- **Analog Input Pins**: 6.
- **UART**: 1 (Serial communication).
- **I2C**: 1.
- **SPI**: 1.
- **Flash Memory**: 32KB (of which 0.5KB has been utilized by the bootloader).
- **SRAM**: 2KB.
- **EEPROM**: 1KB.
- **Dimensions**: Approximately 68.6mm x 53.4mm (2.7in x 2.1in).

2. Board Layout

- **Power Jack**: For external power supply.
- **USB Connector**: For programming and power via a computer.
- **Digital Pins**: Pins 0-13 have been utilized for digital input and output.
- **Analog Pins**: Pins A0-A5 for analog input.
- **PWM Pins**: Pins 3, 5, 6, 9, 10, and 11 for Pulse Width Modulation output.
- **Power Pins**: Includes 5V, 3.3V, GND, and VIN.
- **Reset Button**: Resets the microcontroller.
- **LED Indicator**: Built-in LED on pin 13 used for debugging and status indication.

3. Features

- **IDE Compatibility**: Compatible with the Arduino IDE (Integrated Development Environment) that has been utilized for writing and uploading code.
- **USB Communication**: Uses an FTDI FT232RL or ATmega16U2 USB-to-serial converter for communication with the computer.
- **Bootloader**: Pre-installed bootloader allows programming via USB without needing an external programmer.

4. Programming

- **Language**: The Arduino IDE utilizes a simplified version of C/C++.
- **Libraries**: Numerous libraries are available to simplify coding for various components like sensors, motors, displays, etc.

B. DHT11 Sensor

The DHT11 is a popular and widely used sensor for measuring temperature and humidity. It is often employed in various projects and applications, especially in hobbyist electronics and IoT systems. Here is a detailed overview of the DHT11 sensor:

1. Overview

- **Function**: Measures temperature and relative humidity.
- **Output**: Digital signal.
- **Interface**: Single-wire communication protocol.

2. Key Specifications

- **Temperature Range**: 0 - 50°C with a ±2°C accuracy.
- **Humidity Range**: 20% to 80% relative humidity with a ±5% RH accuracy.
- **Resolution**:
  - **Temperature**: 1°C.
  - **Humidity**: 1% RH.
- **Operating Voltage**: Typically, 3.3V to 5V.
- **Power Consumption**: Low; typically, around 0.3mA when operating, and less than 60µA in sleep mode.
- **Response Time**: Typically, 1 second.

3. Pin Configuration

The DHT11 sensor usually has four pins:

1. **VCC**: Power supply (3.3V - 5V).
2. **GND**: Ground.
3. **Data**: Digital output pin used to read temperature and humidity data.
4. **NC**: No Connection (often left unconnected).

4. Working Principle

- **Sensing Mechanism**: The DHT11 sensor measures humidity and temperature utilizing a thermistor and a capacitive humidity sensor. These measurements are transformed into a digital signal by the sensor.
- **Data Communication**: The sensor communicates via a single-wire protocol. It sends a signal that contains temperature and humidity data in a specific format.

5. Data Format

The DHT11 sends data in a 40-bit format:

- **Humidity Data**: 16 bits (high and low byte).
- **Temperature Data**: 16 bits (high and low byte).
- **Checksum**: 8 bits for data integrity verification.

6. Interfacing with Microcontrollers

Libraries: Many microcontroller platforms like Arduino, Raspberry Pi, and ESP8266/ESP32 have libraries to facilitate easy communication with the DHT11 sensor. For Arduino, the DHT library by Adafruit is commonly used

C. Soil moisture sensors

Soil moisture sensors are crucial tools for monitoring the moisture levels in the soil, helping to optimize irrigation and manage water resources effectively. They are widely used in agriculture, gardening, and environmental monitoring.

1. Components and Working Principle

- **Sensing Element**: The part of the sensor that interacts with the soil (e.g., metal probes, capacitive plates).
- **Signal Processing**: Converts the raw measurement into a readable output (analog or digital).
- **Output**:
    - **Analog Output**: Voltage or resistance that varies with moisture levels.
    - **Digital Output**: Processed data sent via communication protocols (e.g., I2C, SPI).

2. Interfacing with Microcontrollers

Soil moisture sensors are typically interfaced with microcontrollers like Raspberry Pi, Arduino, or ESP8266/ESP32.

D. IoT

The Internet of Things, or IoT, is a game-changing technology which enables different physical objects to be connected to the Internet so they can gather, share, and use data. This is a detailed examination of IoT:

1. Overview of IoT

- **Definition**: The term "Internet of Things" (IoT) explains a network of linked devices which could communicate online with one another and with centralized systems. Sensors, software, and other technologies are integrated into these devices to gather and share data.
- **Components**: Typically includes sensors, actuators, connectivity modules, cloud platforms, and data analytics systems.

2. Key Components

- **Sensors and Actuators**:
  - **Sensors**: Gather information from the surroundings, such as temperature, humidity, and motion.
  - **Actuators**: Perform actions based on data (e.g., turning on lights, adjusting thermostats).
- **Connectivity**:
  - **Protocols**: Various communication protocols are used, including MQTT, CoAP, HTTP, and WebSocket.
  - **Networks**: Includes Wi-Fi, Bluetooth, Zigbee, LoRa, cellular networks, and more.
- **Data Processing**:
  - **Edge Computing**: To cut down on latency and bandwidth consumption, data is processed locally on the device or at the network edge.
  - **Cloud Computing**: Centralized processing, storage, and analytics in cloud platforms (e.g., Google Cloud IoT, AWS IoT, Azure IoT).
- **User Interface**:
  - **Applications**: IoT device control and interaction are facilitated by mobile apps, web dashboards, and other interfaces.

3. How IoT Works

1. **Data Collection**: Sensors gather data from the physical environment.
2. **Data Transmission**: Data is sent to other devices or a central system over the internet.
3. **Data Processing**: Data is processed and analyzed to derive insights.
4. **Action**: Based on the analysis, automated actions are taken or users are alerted.

4. Applications of IoT

- **Smart Homes**: Automation of household devices like lights, thermostats, and security systems.
- **Healthcare**: Remote monitoring of patient health, wearable devices, and smart medical equipment.
- **Agriculture**: Precision farming, soil moisture monitoring, and livestock tracking.
- **Industrial IoT (IIoT)**: Equipment monitoring, predictive maintenance, and process optimization in manufacturing.
- **Smart Cities**: Traffic management, waste management, and energy efficiency.
- **Transportation**: Fleet management, vehicle tracking, and autonomous vehicles.

5. Benefits

- **Efficiency**: Automation and data-driven decisions lead to increased operational efficiency.
- **Cost Savings**: Reduces operational costs through predictive maintenance and optimized resource management.

- **Improved Quality of Life**: Enhances convenience, safety, and health through smart devices and systems.
- **Data Insights**: Provides valuable insights through data analytics for better decision-making.

E. Solenoid Valve

An electromechanical device called a solenoid valve has been utilized in many different applications to regulate the flow of gases or fluids. It operates using a solenoid, which is an electromagnetic coil that, when energized, moves a plunger to open or close the valve.

1. Overview

- **Function**: Controls the flow of liquids or gases by opening or closing the valve based on electrical signals.
- **Types**: Can be classified based on their construction, operation, and application.

2. Working Principle

1. **Electromagnetic Coil**: A magnetic field which has been produced by the solenoid coil when an electrical current is applied to it.
2. **Plunger Movement**: The magnetic field attracts or repels a plunger or armature within the valve, moving it to open or close the valve.
3. **Fluid Control**: As the plunger moves, it either opens or closes the valve seat, regulating the flow of the fluid or gas.

3. Components

- **Solenoid Coil**: The electromagnetic component that generates the magnetic field.
- **Plunger/Armature**: The moving part that interacts with the valve seat.
- **Valve Seat**: The surface that the plunger presses against to control the flow.
- **Spring**: Often used to return the plunger to its default position when the solenoid is de-energized.
- **Body**: The main housing of the valve, is typically made of brass, stainless steel, or plastic.

An inventive and clever remedy for the inefficiencies of conventional irrigation systems is the suggested artificial intelligence-based Advanced irrigation system. The system makes sure that water is used effectively and efficiently, encouraging healthier plants and a more sustainable approach to agriculture using sensors, microcontrollers, IoT, and other components. With the system's real-time temperature, humidity, and soil moisture monitoring, farmers can better manage their crops and make educated decisions regarding their irrigation systems. Farmers can remotely access sensor data and modify system settings with the aid of the remote access platform. A rain sensor and an ultrasonic sensor are two more features included in the suggested system that guard against overwatering and animal damage to plants. These characteristics improve the system's efficacy and efficiency while encouraging the best possible plant growth and yield.

In modern agriculture, irrigation plays a pivotal role in ensuring crop productivity and sustainability, particularly in regions prone to water scarcity and unpredictable weather patterns. Traditional irrigation methods often rely on fixed schedules or rudimentary sensor-based systems, which can result in inefficient water usage and suboptimal crop yields. The integration of AI into irrigation systems represents a transformative approach to addressing these challenges by enabling smarter, data-driven decision-making processes.

Traditional irrigation practices typically involve uniform water distribution across fields based on predetermined schedules or manual observations. These methods often fail to account for dynamic environmental factors which includes weather conditions, levels of soil moisture, and crop water requirements. As a result, water may be overused in some areas, leading to waterlogging and nutrient leaching, while other areas may experience insufficient irrigation, impacting crop growth and yield potential.

Artificial Intelligence, with its capability to analyse vast amounts of data and learn patterns from complex datasets, offers unprecedented opportunities to revolutionize agriculture, including irrigation management. AI algorithms, like ML and neural networks, can process real-time data from sensors installed in fields, weather forecasts, and historical data to optimize irrigation schedules dynamically. AI can make sure that crops receive the right amount of water at the right time, optimizing yield potential while conserving water resources. AI does this by continuously learning and adapting to changing conditions

This technology monitors the soil moisture content continually. The solenoid valve is activated by the system to supply water to the plants when the moisture level drops below a marked threshold that is programmed into the microcontroller. The microcontroller may use the data from the DHT11 sensor to customize watering according to the surroundings. The soil moisture content and other environmental factors are shown visually on the LCD display of the monitor.

V. PROPOSED ALGORITHM

MACHINE LEARNING

ML is a branch of AI & computer science focusing on using data and computations to replicate how humans learn, albeit with ever-increasing accuracy. Machine learning is a key component of the rapidly developing field of information science. Factual strategies are used to prepare calculations for forecasting or classification, exposing important details within information mining endeavours. In an ideal world, these bits of information along these lines influence important development metrics and drive decision-making inside applications and businesses. As information grows and develops, information researchers will be needed to identify the major trading questions and the data to answer them.

DECISION TREE ALGORITHM

Although it can be used for classifying and relapse problems, decision trees are directed learning processes most often used for classification. It is a tree-structured classifier in which each leaf hub indicates the result, branches indicate the choice rules and inside hubs indicate the highlights of a dataset. Choice trees have two hubs: choice and leaf. Choice hubs make choices and have multiple branches, while leaf hubs are the outcome of those choices and have no advanced branches. The test or the choices are based on the highlights of the accessible dataset. A graphical tool for finding all possible solutions to an issue or choice under certain conditions. The root hub spreads outward on developed branches resulting in a tree-like structure, making it a choice tree.

Choice Tree Terminologies

1. **Root Hub:** The hub where the choice tree starts is called the Root hub. It provides information to the entire dataset, which is split up into two or more homogeneous sets.

2. **Leaf Hub:** After obtaining a leaf node, the tree cannot be isolated because it is the final yield hub.

3. Part: It is the handle for dividing the root hub/choice node into smaller nodes based on the specified parameters.

4. Branch/Sub Tree: It is a tree shaped by part of the tree.

5. Pruning: It involves removing unwanted tree branches.

6. Parent/Child Hub: The parent hub is the tree's root hub, and the other hubs are child nodes.

Advantages:

1. Optimized Water Utilization: By accurately observing soil dampness and other natural components, the appropriate water system framework guarantees that crops get the required amount of water at the right time, reducing water wastage and optimizing water usage.

2. Expanded Trim Yields: Modifiable water system plans based on real-time information and AI analysis can lead to improved overall well-being and higher yields as crops get ideal water levels and conditions for growth.

3. Asset Proficiency: Mechanization and optimization highlights diminish the need for manual mediation and minimize asset wastage, counting water, vitality, and labour, resulting in more proficient cultivating practices.

4. Taken a toll Diminishment: By moderating water assets, optimizing inputs, and lessening operational wasteful aspects, the shrewd water system framework makes a difference in helping ranchers cut down on operational costs over time, contributing to increased profitability.

5. Natural Supportability: By advancing effective water administration and diminishing natural effects through exact water system hones, the framework underpins maintainable cultivating hones and makes a difference in relieving the negative impacts of agribusiness on the environment.

Applications:

1. Agricultural Farming: The primary application of the advanced irrigation system is in agricultural farming, where it can be deployed in various crop types and cultivation methods, including field crops, orchards, vineyards, greenhouse farming, etc.

2. Horticulture and Landscaping: This system can also be used in horticulture and landscaping applications to maintain optimal soil moisture levels for ornamental plants, gardens, parks, and urban green spaces.

3. Commercial Farming Operations: Large-scale commercial farming operations can benefit from the efficiency and productivity gains offered by smart irrigation systems, helping them manage vast agricultural lands more effectively.

4. Urban Agriculture: In urban and peri-urban areas, where land is limited and water resources are often scarce, advanced irrigation systems can enable efficient and sustainable urban agriculture initiatives, such as rooftop gardens and community gardens.

5. Research and Development: Advanced irrigation systems can serve as precious tools for agricultural research institutions, universities, and research organizations to study crop-water interactions, optimize irrigation techniques, and develop innovative farming practices for the future.

VI. RESULTS AND DISCUSSION

The results and discussion section of a study or project on an advanced irrigation system using AI and IoT deals with several key aspects and implications of its implementation. Firstly, the data reveals a significant positive impact on water conservation and efficiency compared to conventional irrigation systems. This is attributed to the system's ability to precisely tailor irrigation schedules based on real-time data, leading to minimizing water wastage and improving resource utility. Furthermore, the implementation of the advanced irrigation system demonstrates tangible benefits in terms of crop yield and quality. By ensuring appropriate moisture levels and reducing plant stress, the system contributes to quality crops with increased yields and improved nutritional content. Additionally, the automated control of irrigation equipment results in energy savings and cost efficiency, benefiting farmers economically while also promoting sustainable practices. The discussion also extends to the environmental impact of the system, highlighting its role in mitigating water scarcity, minimizing runoff and soil erosion, and fostering overall environmental sustainability in agriculture. However, challenges such as sensor accuracy, data integration complexities, and initial setup costs are acknowledged, suggesting avenues for future research and development to enhance system performance. Scalability and adaptability are also key points of discussion, emphasizing the system's flexibility to integrate with existing infrastructure and accommodate diverse field sizes and crop types.

VII. CONCLUSION

In conclusion, the integration of AI with IoT in the development of Advanced irrigation systems represents a significant advancement in modern agriculture. The results and discussions from various studies and projects consistently highlight the positive impact of these systems on water conservation, crop yield optimization, cost efficiency, and environmental sustainability. By leveraging real-time data, advanced algorithms, and automated control mechanisms, advanced irrigation systems effectively address challenges such as water scarcity, inefficient resource utilization, and environmental degradation. The evidence gathered underscores the potential of advanced irrigation systems to revolutionize agricultural practices, promote resilience against climate change, and contribute to global food security. However, it is essential to acknowledge and address challenges such as sensor accuracy, data integration complexities, initial setup costs, and user adoption barriers. Future research and development efforts should focus on enhancing system reliability, scalability, user-friendliness, and affordability to maximize their benefits for farmers and stakeholders across diverse agricultural landscapes. Overall, the widespread adoption and continuous improvement of advanced irrigation systems hold promise for sustainable agriculture, efficient resource management, and the long-term viability of food production systems worldwide. Collaboration among researchers, policymakers, industry stakeholders, and farmers will be crucial in harnessing the full potential of these innovative technologies to address the complex challenges facing the agricultural sector in the upcoming era.

REFERENCES

[1] Karim Ennouri, Slim Smaoui, Yaakoub Gharbi, Manel Cheffi, Olfa Ben Braiek, Monia Ennouri and Mohamed Ali Triki (2021). A review of the use of remote sensing and artificial intelligence in agriculture. Computers and Electronics in Agriculture, https://doi.org/10.1155/2021/6242288

[2] Patil Sagar Baburao (B), R. B. Kulkarni, Pramod A. Kharade, and Suchita S. Patil A. (2021). Machine learning in precision agriculture: A review of supervised learning approaches for crop yield prediction. Biosystems Engineering, 209, 106-122.

[3] Akash Saha, PriyankaSarkar Daset all proposed “Smart Green House for Controlling & Monitoring Temperature, Soil & Humidity Using IOT” IEEE-2022

[4]F. Adenugba, S. Misra, R. Maskeliūnas, R. Damaševičius, E. Kazanavičius- Smart Irrigation system for environmental sustainability in Africa: an Internet of Everything (IoE) approach - Math. Biosci. Eng., 16 (5) (2019), pp. 5490-5503.

[5] Butler, D., Ward, S., Sweet apple, C., Astaraie-Imani, M., Diao, K., Farmani, R., et al. (2017). Reliable, resilient and sustainable water management: the Safe & SuRe approach. Glob. Challenges 1, 63–77. doi: 10.1002/gch2.1010.

[6] Chartzoulakis, K., and Bertaki, M. (2015). Sustainable water management in agriculture under climate change. Agric. Agric. Sci. Procedia 4, 88–98. doi: 10.1016/j.aaspro.2015.03.011.

[7] Doorenbos, J., and Pruitt, W. O. (1977). Guidelines for Predicting Crop Water Requirements. FAO Irrigation and Drainage Paper 24. FAO. [8] Juwana, I., Muttil, N., and Perera, B. J. C. (2012). Indicator-based water sustainability assessment — a review. Sci. Total Environ. 438,357–371.doi: 10.1016/j.scitotenv.2012.08.093.

[9] Khan, S., Tariq, R., Yuanlai, C., and Blackwell, J. (2006). Can irrigation be sustainable? Agric. Water Manag. 80, 87–99. doi: 10.1016/j.agwat.2005.07.006.

[10] Alcamo, J., Döll, P., Henrichs, T., Kaspar, F., Lehner, B., Rösch, T., et al. (2003). Global estimates of water withdrawals and availability under current and future "business-as-usual" conditions. Hydrol. Sci.J. 48, 339–348. doi: 10.1623/hysj.48.3.339.45278.

[11] Balaei, B., Wilkinson, S., Potangaroa, R., Hassani, N., and Alavi-Shoshtari, M. (2018). Developing a framework for measuring water supply resilience. Nat. Hazards Rev. 19:04018013. doi: 10.1061/(ASCE)NH.1527-6996.0000292. [12] Rosa, L., Rulli, M. C., Davis, K. F., Chiarelli, D. D., Passera, C., and D'Odorico, P. (2018). Closing the yield gap while ensuring water sustainability. Environ. Res. Lett. 13:104002. doi: 10.1088/1748-9326/aadeef.

[13]Vanham, D., Hoekstra, A. Y., Wada, Y., Bouraoui, F., de Roo, A., Mekonnen, M. M., et al. (2018). Physical water scarcity metrics for monitoring progress towards SDG target 6.4: an evaluation of indicator 6.4.2 "Level of water stress". Sci. Total Environ.613–614,218–232.doi: 10.1016/j.scitotenv.2017.09.056

[14]Sandoval-Solis, S., McKinney, D. C., and Loucks, D. P. (2011). Sustainability index for water resources planning and management. Water Resour. Plan. Manag.137, 381–390. doi: 10.1061/(ASCE)WR.1943- 5452.0000134.

[15]Pfeiffer, L., and Lin, C. Y. C. (2010). The effect of irrigation technology on groundwater use. Choices 25, 1–6. doi: 10.22004/ag.econ.980