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Transforming Agriculture with Advanced Micro Irrigation: More Crop with Smart Drop

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ARTICLE ID: 17

Introduction:

As global concerns surrounding water scarcity and food security escalate, there will be more demand for micro-irrigation to meet growing food demands. Nearly 600 million people have been affected by the ongoing water crisis, which is projected to increase by 2050, and the country's population is expected to reach 1.6 billion. Micro irrigation has emerged as a promising trend that delivers water directly to the roots of plants, reducing all water losses and tackle conflicts over water resources management. The advent of advanced technologies such as the Internet of Things (IoT), artificial intelligence (AI), and data analytics has enabled the development of smart micro irrigation systems. These systems integrate sensors, actuators, and communication networks to optimize water application, reduce energy consumption, and improve crop yields. With the integration of smart irrigation technologies, farmers can significantly save from 20 to 50% amount of water compared to traditional micro irrigation methods and traditional micro irrigation systems often rely on manual operation and lack real-time monitoring and control capabilities.

Smart micro-irrigation systems have the potential to revolutionize the way we manage water resources in agriculture. By leveraging real-time data and advanced analytics, these systems can detect soil moisture levels, weather patterns, and crop water stress, enabling farmers to make data-driven decisions and optimize irrigation schedules.

Need for smart IoT and AI based irrigation:

Water scarcity is a leading concern throughout the world, and with depleting groundwater resources, reduced rainfall, and uneven water distribution, it became most dominant problem for farmers. With additional problems like field constraints, poor quality

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water, conveyance pipes, leakage, irregular and unplanned irrigation scheduling leading to water wastage, and affecting agricultural fields causing deterioration and resources wastage. In the current scenario many farmers are buying or borrowing additional water from nearby farmers to meet water needs, which is increasing overall farmers investment and burden to rely on searching for resources. But with integration of smart irrigation systems, farmers can obtain more yield with limited resources by optimizing scheduled irrigation with the motto right amount at the right place in the right time.

1. Smart irrigation sensors:

Smart irrigation sensors are devices that measure various environmental parameters to optimize irrigation scheduling, which reduces water wastage and improves crop health. Under plant-based sensors, leaf wetness sensors are used to detect moisture in plant leaves to prevent over irrigation and stem water potential sensors measure water stress to optimize irrigation. We have smart irrigation controllers, irrigation schedule adjustment based on real time weather data can be made by weather-based controllers and soil moisture sensor data by soil moisture-based controllers for optimization. Wireless sensor networks to enable real-time data transmission from sensors to irrigation controllers by IoT integration and cloud-based platforms for remote monitoring, data analysis, and irrigation scheduling adjustments.

Smart irrigation system solutions:

- **Raicho:** small irritation controller with weather data and all soil moisture sensors integration.
- **Sky drop:** uses weather data, soil moisture sensors, and flow meters to optimize irrigation.
- **Davis Instruments:** offers weather station data and soil moisture sensors for irrigation practices.
- **Aqua Spy:** agricultural and land scaping applications with soil moisture sensor development and irrigation management systems.

2. Automatic drip irrigation system:

A Smart drip irrigation system ensures precise application of irrigation and nutrification based on crop type, stage, and location by taking inputs from sensors, previous historic field data, satellite images and integrating machine learning algorithms. This irrigation

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system ensures efficient water, nutrient supply under automated operations, saving efforts and labor force. Farmers can monitor remotely for analyzing soil moisture content, crop growth and operate data driven irrigation systems. The system provides precise supply by optimizing water and nutrient use to counteract drought and climate change impacts on crops.

3. Smart sprinkler controller irrigation system:

Smart sprinkler control system is an advanced management system for irrigation optimization and reducing input waste with precise water application utilizing sensors, weather data, and machine learning algorithms. Farmers can incorporate smart timers to set and run irrigation scheduling directly from a smartphone. With irritation controller enables farmers to remote control sprinkles and can determine irrigation duration. The major advancement in sprinkler irrigation system is digitally mapped irrigation area and "prints" to plan irrigation water application precisely in required and stressed places only.

4. Centre pivot irrigation system:

Centre pivot irrigation is a modern and the most efficient method of irrigation for agricultural fields in large areas. In centre pivot irrigation method, a circular rotating arm is used to sprinkle water over the cross in a circular pattern. The pivot is mounted on wheeled towers with a central water supply and a network of pipes and sprinkle's extending radially. When the center pivot moves around the field, water is sprayed evenly, providing crops with uniform distribution with controlled water supply in a continuous manner.

The center pivot system is almost automated, reducing labor requirements to minimal and basic supervision. This system can be adapted to various field typographic variations of different sizes and shapes. The integration of Internet of Things technologies and remote sensing enables farmers to monitor and control center pivot system from their smartphones. The center pivot system can be powered by solar energy, ensuring reduced carbon footprints and operational costs additionally.

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5. Solar-powered irrigation system:

Solar-powered irrigation systems provide farmers innovative and sustainable solutions, reducing their reliance on fossil fuels and decreasing carbon footprints. It contains solar panels to convert sunlight into electricity and charge controllers to regulate flow of energy to battery storage for later use even at night. The energy stored is utilized for pumping water and irrigation controller for automatic irrigation scheduling. Drip irrigation, sprinkler irrigation, center pivot irrigation can be integrated with solar-powered systems.

Startups offering solar-powered irrigation systems:

- **Das Energy:** solar-powered irrigation systems, including on-grid, hybrid, and off-grid solutions.
- **International Water Management Institute (IWMI):** develops and promotes sustainable water management practices in India.
- **CGIAR:** support the development and adaptation of solar-powered irrigation setups.

Indian government initiatives: PM-KUSUM to promote adoption of solar-powered irrigation systems for farmers and provide them with subsidies and incentives.

6. Advanced smart irrigation systems in vertical farming:

Advanced irrigation methods include Nutrient Film Techniques (NFT), where plants are grown in controlled media in narrow channels with a continuous flow of nutrient-rich water. Ebb and flow (flood and drain) method in which plants are grown in a tray or bed that is periodically flooded and drained with water. Mist irrigation is used for spraying fine mist of water into plants, and aeroponics are plants grown in air while their roots are suspended in a fine mist of water and nutrients.

In these advanced irrigation systems, farmers can integrate precision irrigation controllers for optimization of irrigation scheduling using sensors and algorithms. Automated

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dosing systems are used for adequate nutrient application with reduced wastage. With vertical farming software, farmers can integrate data from sensors and ML systems for optimal irrigation, nutrient application, and climate control. Farmers can remotely monitor and control irrigation using wireless sensors and cloud-based platforms.

Examples:

- **Bright Agrotechs ZipGrow:** A vertical farming system that uses a combination of drip irrigation and NFT with advantageous plant growth.
- **Green Sense Farms vertical farming** system with collaboration of drip irrigation and LED lighting to optimize water usage and promote plant growth.
- **Bowery Farming's smart irrigation system:** it integrates machine learning algorithms and IoT sensors to optimize irrigation.

7. Robotic fleets:

Robotic fleets, also known as autonomous farming fleets or precision agriculture fleets, are transforming the precision irrigation technologies for efficient application and minimal wastage of water. Farmers have an autonomous drip irrigation system by robotic fleets to automate drip irrigation, precision sprinkler systems to optimize irrigation by adjusting its application based on different influential attributes on crops, and robotic irrigation management system integrating sensors, GPS, and weather data to optimize scheduling and water application.

Examples:

- John Deere's See and Spray with an autonomous irrigation system uses computer vision and machine learning to detect and spray.
- Netafim's NetBeat, which uses AI and ML to analyze sensor data and optimize irrigation scheduling.

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8. Advanced water pumps:

Water pumps are integrated with technologies that vary pressure, speed, and drive, which ensures more efficient water distribution. These advanced pumps adjust their speed and pressure based on data collected in real time from integrated Internet of Things sensors. Intelligent systems optimize water pump performance, significantly reducing water loss.

9. Actuators:

Actuators are used for controlling the physical action of irrigation infrastructure. Operating values, pumps, and other irrigation equipment based on commands received from controllers. The data collected by sensors of soil moisture triggers the actuators if moisture levels reach below a predefined threshold to open water valves. Automation enhances performance efficiency and reduces the need for manual intervention.

Smart Micro Irrigation Management Softwares:

- **Software FERGON**: Fertigation is a complex process and requires estimation of irrigation water requirements, drip system capacity, required nitrogen, potassium, and phosphorus nutrients and their concentration, capacity of tank and injection rate.
- FERGON was developed for user-friendly, interactive fertigation system management and planning for orchard crops as well as closely spaced field crops. FERGON also calibrates fertigation duration and nutrient concentration in irrigation water.
- **Software MICROS:** Software MICROS was developed using Visual BASIC 6.0 for the design and evaluation of micro sprinkler systems. It considers effective area irrigated by each micro sprinkler and its water spread, plan spacing in the field. The software guides and gives warning or messages at suitable steps of computation and ensures accurate and reliable results for design and evaluation.
- **IFSHED:** a decision support system for scheduling irrigation and fertigation in drip irrigated crops. IFSHED was developed to prepare irrigation and fertigation schedule of crops by closely simulating crop water and nutrient needs on daily basis. The decision support system calibrates the crop water management and nutrient requirement estimated from interpolated daily evapotranspiration values. Based on drip system capacities and estimated water requirement, the irrigation system is scheduled using

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DSS on daily, alternate day or once-a-week as per the farmers choice. The DSS requires very little data input from farmers and prepares irrigation and fertigation scheduling for the entire crop duration.

- **IRRI:** The International Rice Research Institute continuously explores, develops, and promotes sustainable water management approaches and recommends the best options or combinations of technologies for farmers, advanced adoption techniques by providing field design, land gradient leveling, and irrigation scheduling using safe alternate wetting and drying micro irrigation management.
- **Software DRIPD**: User-friendly and interactive software was developed in Visual Basic to design the drip system. It helps farmers to estimate irrigation water requirements, capacity of drip main line, number of drippers and lateral pipes, diameter of main and submain pipes and size of pumping unit. After loading the software, if the user wishes to design the system, then simply click the yes button and proceed further for designing the system.

Smart irrigation technologies and systems offer numerous benefits, yet there are also some disadvantages and limitations to consider:

1. **High Initial Cost:** Smart irrigation systems can be expensive to purchase and install, making them less accessible to small-scale farmers or homeowners with limited budgets.
2. **Complexity:** Smart irrigation systems often require technical expertise to install, program, and maintain, which can be a barrier for users without technical knowledge.
3. **Dependence on Technology:** Smart irrigation systems rely on sensors, software, and other technologies that can malfunction or be affected by environmental factors, such as extreme temperatures or electromagnetic interference.
4. **Data Security Concerns:** Smart irrigation systems often rely on cloud-based data storage and transmission, which can raise concerns about data security and privacy.
5. **Limited Compatibility:** Smart irrigation systems may not be compatible with all types of irrigation systems or equipment, which can limit their adoption.

Future directions:

1. **Improve affordability and accessibility:** Develop more affordable, user-friendly smart irrigation systems with technical support and training sessions for farmers to install, perform, and maintain systems.

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2. **Develop more robust and reliable technologies:** Improving the durability and reliability of smart irrigation system components with robust data security protection for farmers.
3. **Improve compatibility and scalability:** Developing smart irrigation systems that are compatible with a wider range of irrigation systems and equipment, and can be scaled up or down depending on user needs.

Conclusion:

Smart irrigation systems with IoT based automation offer a wide array of benefits that significantly enhance water management in agriculture. Integrating advanced technologies like sensors, data analytics, and automation ensures efficient water usage with improved yield and resource conservation. Farmers can monitor over soil moisture, temperature, and weather conditions in real time for irrigation optimization to provide precise irrigation and prevent overflooding. Data driven decision-making IoT technologies help farmers to make informed management practices. Customization and scalability can be tailored to meet the specific needs of individual farms, cater to different crop types and soil conditions. These sustainable agriculture practices help reduce environmental impact. Smart irrigation systems can be scaled to accommodate increased demand, making them a flexible solution for both small and large agricultural enterprises.