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AUTOMATION OF IRRIGATION AND VENTILATION PROCESSES IN GREENHOUSES BASED ON SMART SENSOR SYSTEMS

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Sustainable agriculture increasingly depends on the ability to precisely manage environmental factors within protected cultivation systems. Greenhouses play a key role in meeting the growing demand for fresh vegetables and herbs while minimizing environmental impact. However, traditional control methods—based on manual irrigation and ventilation—are inefficient and depend heavily on human experience.

Automation of microclimate regulation through smart sensor systems and intelligent algorithms represents a promising direction for improving energy and water efficiency. Recent studies have demonstrated that integrating IoT technologies with climate control systems significantly enhances productivity and resource optimization in agriculture.

The proposed automation system follows a modular IoT architecture comprising three levels:

- Sensor layer — includes soil moisture sensors, air temperature and humidity sensors, CO_2 concentration meters, and light sensors.
- Control layer — based on a microcontroller (e.g., Arduino, ESP32, or Raspberry Pi) that collects data, analyzes it, and activates actuators (valves, fans, and pumps).
- Cloud and user interface layer — enables real-time data visualization, remote monitoring, and control via web or mobile applications.

Control logic is based on threshold algorithms and can be enhanced through adaptive and predictive models using machine learning. The system activates irrigation when soil moisture drops below the optimal range and adjusts ventilation speed according to temperature and CO_2 concentration.

Simulation and field testing of similar IoT-based greenhouse control systems show significant benefits:

– Water consumption reduction by up to 40–45% through precision irrigation;

– Energy savings of about 20% due to optimized ventilation and fan operation;

– More stable microclimate conditions, with temperature variation within ±1.5 °C;

– Yield increase of 12–18%, resulting from balanced humidity and temperature levels.

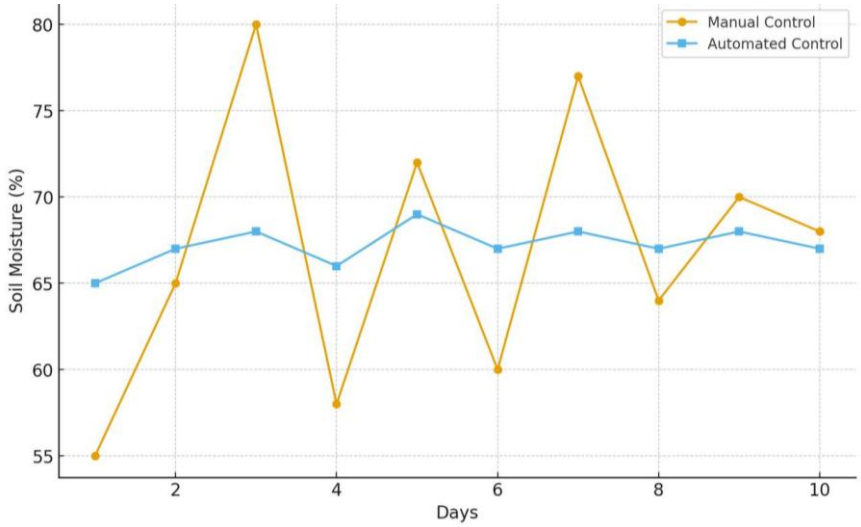

Figure 1 – Soil Moisture Dynamics Under Different Control Modes

Integration with artificial intelligence enables predictive control—anticipating environmental changes and adjusting system parameters in advance. Furthermore, the scalability of IoT networks allows such systems to be adapted for both small farms and industrial greenhouse complexes.

– The automation of irrigation and ventilation processes based on smart sensor systems is a key step toward sustainable and resource-efficient greenhouse production.

- The use of IoT and intelligent algorithms ensures precise microclimate management, minimizing human errors and resource waste.
- Implementing adaptive control systems contributes to increased crop productivity and reduced environmental impact.
- Future work should focus on integrating renewable energy sources and AI-based decision-support systems to develop fully autonomous greenhouses.

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