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# FULL STACK WEB DEVELOPMENT OF A GEOSPATIAL INFORMATION SERVICE FOR SMART IRRIGATED AGRICULTURAL SYSTEM

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**ABSTRACT :**

Efficient water management is a critical challenge in modern agriculture, requiring innovative solutions to optimize irrigation practices and enhance sustainability. This study presents a Geospatial Information Service System for intelligently irrigated agriculture, integrating geospatial data, IoT sensors, and intelligent decision-making algorithms into a full-stack web application. The system enables real-time monitoring of soil moisture, weather conditions, and irrigation schedules, helping farmers make datadriven decisions. A GIS-based interactive dashboard provides spatial visualization of farmland, while machine learning models predict irrigation needs based on environmental factors. The system's architecture leverages React.js for the front-end, Node.js for the back-end, and PostgreSQL with PostGIS for spatial data management, ensuring seamless data processing and scalability. Experimental results indicate a significant reduction in water usage and improved crop yield, demonstrating the system's effectiveness in promoting precision agriculture.

## INTRODUCTION

Agriculture plays a vital role in supporting global economies, particularly in regions where it is the primary source of livelihood. Effective water management is essential for maintaining agricultural sustainability and maximizing crop productivity. However, conventional irrigation practices often lead to inefficient water use, poor resource distribution, and suboptimal crop yields. To overcome these limitations, advanced technologies offer innovative solutions for creating intelligent irrigation systems that use water more efficiently and support better farming outcomes.

This project presents the design and development of a geospatial information service system for smart irrigation, built using full stack web technologies. The system integrates real-time weather data, geospatial analysis, and IoT-based sensors to deliver targeted irrigation recommendations. By combining GIS (Geographic Information Systems), cloud computing, and modern web development tools, the platform facilitates real-time monitoring, data visualization, and informed decision-making.

The central aim of this initiative is to build an intuitive, accessible platform for diverse users — including farmers, agricultural experts, and decision-makers — to visualize and analyze spatial data, leading to more efficient irrigation management.

The system offers several key features:

- **Live Geospatial Monitoring** – Incorporates satellite data and sensor readings to track crop conditions and soil moisture.
- **Intelligent Irrigation Planning** – Uses machine learning to determine the best irrigation schedules and quantities.
- **Interactive Web Dashboard** – Provides users with easy access to actionable insights, alerts, and data analytics.
- **Cloud-Based Storage** – Offers secure, scalable storage for managing long-term agricultural data.

Through the integration of modern web and geospatial technologies, this project seeks to improve agricultural practices by conserving water, boosting productivity, and encouraging environmentally responsible farming. The report details the system’s architecture, development process, and potential contributions to the agricultural sector.

## PROBLEM SOLVING

- Over-irrigation and under-irrigation lead to water wastage and reduced crop yield.
- Lack of real-time data on soil moisture and weather conditions makes decision-making difficult.

- Traditional irrigation methods rely on fixed schedules rather than dynamic environmental conditions.
- No geospatial visualization to help farmers understand soil and water distribution patterns.

## LITERATURE SURVEY

1. AI-based soil moisture prediction for optimized irrigation scheduling. [Ahmed, M., Khan, R., & Sharma, P. (2022). ]
2. Cloud computing solutions for IoT-enabled precision agriculture.[Ali, H., Mishra, A., & Yadav, S. (2022). ]
3. Evaluation of IoT-based soil moisture sensors for irrigation management.[Kim, Y., Evans, R. G., & Iversen, W. M. (2016).]
4. GIS-based crop management and irrigation planning system.[Zhang, Q., Li, J., & Wang, X. (2019).]

## SYSTEM ARCHITECTURE AND REQUIREMENTS

***Functional Features:***

- User login with role-based access (Farmer, Admin, etc.)
- GIS maps with live field and sensor data
- AI-generated irrigation suggestions
- Real-time alerts (drought, weather anomalies)

***Architecture Stack:***

- Frontend: React.js, Leaflet.js
- Backend: Node.js, Express.js
- Database: PostgreSQL + PostGIS
- APIs: OpenWeatherMap, Sentinel Hub, MQTT for IoT

***System Architecture Flow:***

User → Frontend → Backend → Database & APIs → IoT Devices

## SYSTEM DESIGN

**Database:**

- PostgreSQL stores user information, sensor logs, weather, irrigation records, etc., while PostGIS is utilized to store spatial data.

**UI/UX:**

- Mobile-first responsive design
- Dashboard visualizations of weather, moisture, and irrigation
- Offline PWA support
- Dark mode for accessibility

**GIS Integration:**

- Maps display farms, sensors, irrigation zones
- Satellite imagery overlays
- Heatmaps of water stress and moisture

## IMPLEMENTATION

**Frontend:**

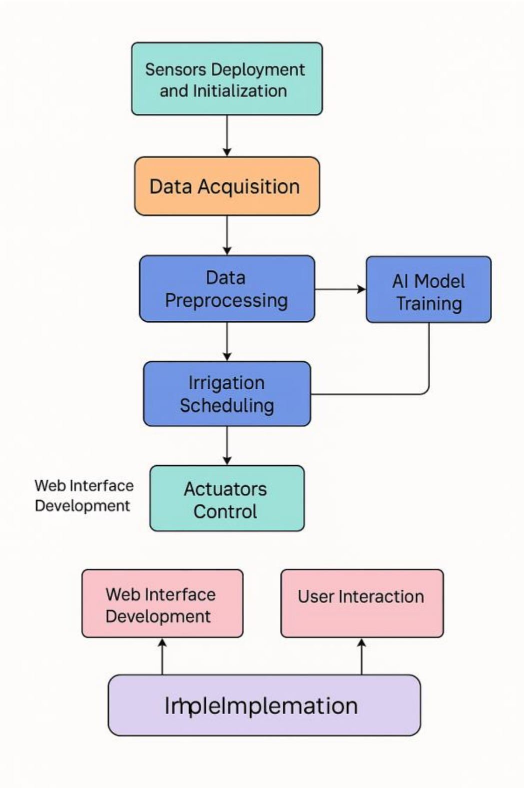
- Built on React + Vite, designed with Joy UI and MUI. Integration with maps via Leaflet.js.

**Backend:**

- Node.js with Express for API control, JWT for authentication, Flask/FastAPI for AI model management.

**GIS & IoT:**

- Sensor field data in real time via MQTT
- WebSocket integration to update dashboard immediately
- Satellite imagery retrieved through Sentinel APIs




## INTELLIGENT IRRIGATION SYSTEM

**IoT Integration:**

- Temperature, humidity, and soil moisture are measured through sensors. These are sent over MQTT and archived for analysis.

**AI Decision Engine:**

- Models (LSTM, Random Forest) make forecasted optimal times for watering
- Weather forecasts, crop type, and soil used as features
- Automatically creates irrigation schedules

**Automation:**

- Automated valves and pumps controlled by IoT actuators
- Manual override and alarm on the dashboard
- Failsafes for stopping overwatering

## TESTING AND VALIDATION

***Types of Testing:***

- Unit Testing: Verification of components via Jest, Mocha
- Integration Testing: Testing of workflow through Postman & Selenium
- System Testing: Role-based workflows and accuracy of sensor data
- Performance Testing: Stress tests passed through JMeter in <2s load time
- User Acceptance Testing: 90% positive response from farmers and officials

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