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NOSOIL: SMART INDOOR SOILLESS GARDENING SYSTEM

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Abstract : In the current fast-paced urbanization era, conventional soil farming is increasingly threatened by the lack of space, unpredictable climatic conditions, and high resource consumption. This study proposes the NoSoil system, an intelligent soilless indoor farming solution that aims to facilitate sustainable plant growth through the effective application of web technologies. The proposed system combines the principles of hydroculture, incorporating IoT sensors, AI-powered plant suggestions, and an intelligent monitoring interface to provide optimized water conservation, environmental monitoring, and simplified plant maintenance. Developed using the MERN Stack technology framework (MongoDB, Express.js, React.js, and Node.js), the NoSoil system ensures the provision of real-time plant status monitoring, user authentication, and proactive notification systems.

***Index Terms* — Hydroponics, Smart Gardening, IoT, MERN Stack, Soilless Cultivation, Sustainable Agriculture..**

I. INTRODUCTION

A. Background

Contemporary urban areas are challenged by limitations in agricultural production because of a lack of space, soil contamination, and increasing needs for eco-friendly sources of food. Indoor hydroponic farming has recently been recognized as a promising substitute, allowing plants to grow without soil by utilizing nutrient-rich water. This method makes it possible to control environmental factors and prevent water waste. The NoSoil system is based on this innovative solution and uses AI, IoT sensors, and full-stack web development to provide smart gardening solutions for everyone, from private households to offices and hospitals.

B. Problem Statement

Traditional indoor gardening can be hampered by manual watering, irregular growth observation, and pest problems. Soil causes mess, allergies, and suboptimal resource use. Moreover, existing hydroponic solutions are either costly or too technical, thus hindering their use by urban consumers. There is a need for a cost-effective, smart platform that integrates automation, analysis, and engagement for soilless plant cultivation.

C. Objectives

1. Develop a **smart hydroculture system** using MERN stack technology for soilless plant growth.
2. Implement **IoT-based water and temperature sensors** for real-time monitoring.
3. Create an **AI-assisted recommendation module** for plant selection.
4. Enable **automated irrigation alerts** and minimal maintenance gardening.
5. Design a **user-friendly interface** suitable for residential, commercial, and institutional spaces.

II. PURPOSE AND PROBLEM DEFINITION

A. Operational Pain Points:

Conventional gardening techniques involve the use of soil and manual maintenance. In a densely populated urban setting, this is not feasible. Some of the key challenges involved are:

- Overwatering or underwatering based on manual estimates.
- Lack of knowledge about plant health and environmental conditions.
- Pests accumulating and soil becoming contaminated.
- High water usage and absence of automation.

B. System Purpose

The NoSoil system is an automated and soilless platform that allows users to track water levels, temperature, and plant status in real-time through the seamless integration of various technologies. The system has sensor modules for constant environmental monitoring, an AI-powered chatbot that provides users with tailored plant suggestions and advice, and a dynamic dashboard that displays performance analytics for easy tracking. Through the integration of intelligent automation and sustainability, the NoSoil system aims to make plant maintenance easy, resource-saving, and more eco-friendly for users in both residential and commercial settings.

III. SCOPE

A. Functional Scope

- **Dashboard:** Displays real-time data of plant water levels and temperature.
- **AI Chatbot:** Guides users in plant selection and care.
- **Alerts Module:** Notifies when refilling or maintenance is required.
- **Hydroculture Control:** Maintains nutrient and water balance.
- **Authentication System**: Secure login and personalized user dashboard.

B. Technical Scope

Frontend: React.js 18 (Vite), Tailwind CSS, Recharts.
Backend: Node.js, Express.js.
Database: MongoDB Atlas (Cloud).
IoT Components: Water level and temperature sensors.
External APIs: AI recommendation engine and plant data APIs..

C. Limitations

The first prototype of the NoSoil system relies on mocked sensor data to simulate real-time monitoring, with future plans to incorporate live IoT devices for increased accuracy and functionality. The system is designed to work specifically in an indoor setting, with a focus on delivering an efficient and controlled gardening experience in a home, office, or other enclosed space. The system also needs a stable power supply and network connectivity to function properly.

IV. EXISTING SYSTEM / LITERATURE REVIEW A. Soilless Cultivation Techniques

Hydroponics and aeroponics have proven to be more efficient in water and nutrient utilization compared to conventional farming. The results have been 90% less water usage and 25% faster growth rate compared to soil-based farming.

B. IoT in Smart Farming

IoT technology allows for smart farming by tracking real-time data and automating the irrigation process. Microcontroller-based systems like Arduino Uno or Raspberry Pi increase accuracy and minimize human errors.

C. AI and Data Analytics in Agriculture

AI-based technologies such as computer vision and predictive modeling help in analyzing plant health and optimizing growth factors. The addition of AI chatbots increases user engagement and knowledge, particularly for beginners.

D. Gap Identified

Current hydroponic technology is hardware-centric and does not have any digital interface or user analysis. NoSoil fills this gap by providing a comprehensive web platform for automation, user education, and AI analysis.

V. SYSTEM DESIGN AND ARCHITECTURE A. Architecture Overview

The **NoSoil architecture** follows a **decoupled MERN stack model**:

1. **Presentation Layer (Client):** Interactive user interface for dashboards, alerts, and AI chatbot.
2. **Application Layer (Backend):** Processes requests, handles authentication, and communicates with IoT sensors.
3. **Data Layer (Database):** Stores user profiles, plant data, and sensor readings.
4. **AI Integration Layer:** Facilitates AI and sensor API connectivity.

B. Key Modules

Sensor Monitoring Module: Collects and logs environmental parameters.
Data Processing Engine: Applies threshold-based logic for alerts.
OCR Service: Extracts coupon details from images automatically.
AI Recommendation Engine: Suggests suitable plants based on conditions.
User Interface Module: Displays plant health metrics and care tips.

VI. METHODOLOGY & ALGORITHMS A. Sensor Data Acquisition

The system captures water level and temperature readings at specific time intervals. If the water level (WL) is below 30%, a water alert is triggered; if the water level is 30% or higher, no alert is generated.

B. AI Recommendation Algorithm

The AI recommendation algorithm analyzes environmental factors such as light, available space, and required care level to filter and suggest suitable plants. Based on these parameters, each plant is assigned a score, and the top-rated plants are displayed to the user for selection.

C. Security Algorithms

- **JWT Authentication** for user sessions.
- **AES Encryption** for stored data.
- **Input Validation** to prevent injection attacks.

VII. IMPLEMENTATION DETAILS

A. Tech Stack

Frontend: React 18, Tailwind CSS + Vite + Axios.
Backend: Node.js v18, Express.js.
Database: MongoDB Atlas.
Security: JWT, bcrypt password hashing.

B. Implementation Approach

- **Sensor Simulation:** Mock data for water and temperature.
- **Authentication Flow:** JWT-secured routes for personalized dashboards.
- **Alert Systems:** Auto-generated care reminders via backend logic.
- **Dashboard:** Aggregates stats including “Healthy”, “Needs Water”, and “Average Temperature”.

VIII. RESULTS AND DISCUSSION

A. Observations

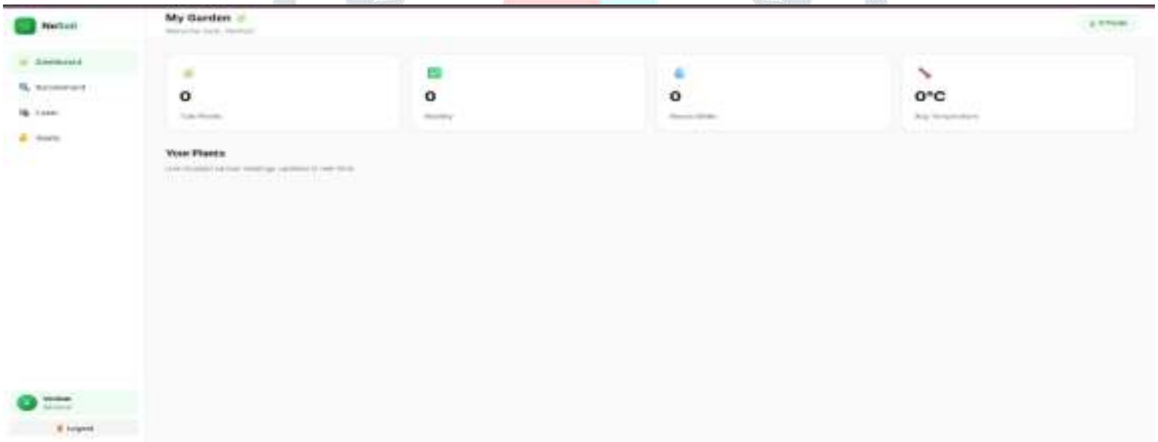
- All core modules, including authentication, notifications, recommendations, and data visualization, were successful.
- Average API response time: 100-300ms.
- Frontend load time: less than 1 second.
- Security verification using hashed credentials and secure routes was successful.

B. User Feedback

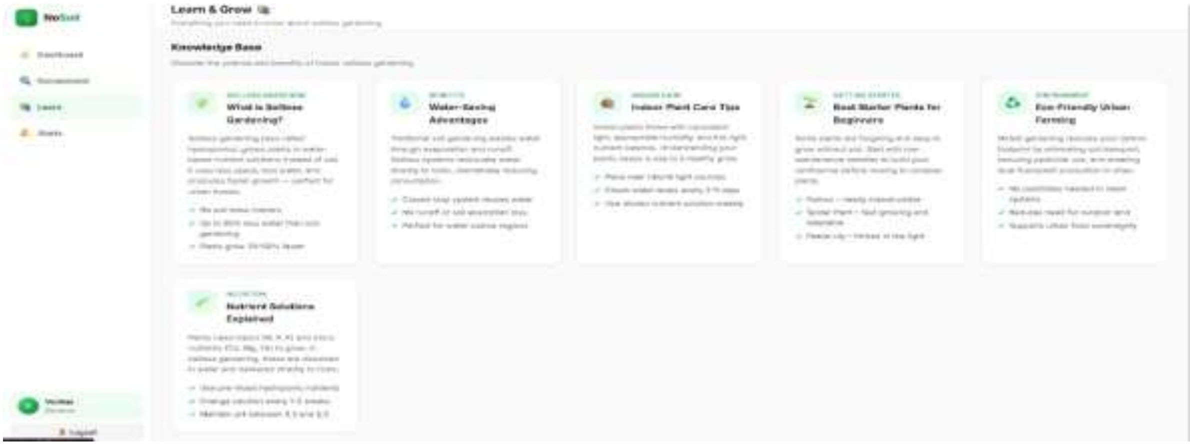
- Simple dashboard design and plant health visuals.
- Intuitive AI recommendations.
- Quick system responses and minimal technical complexity.

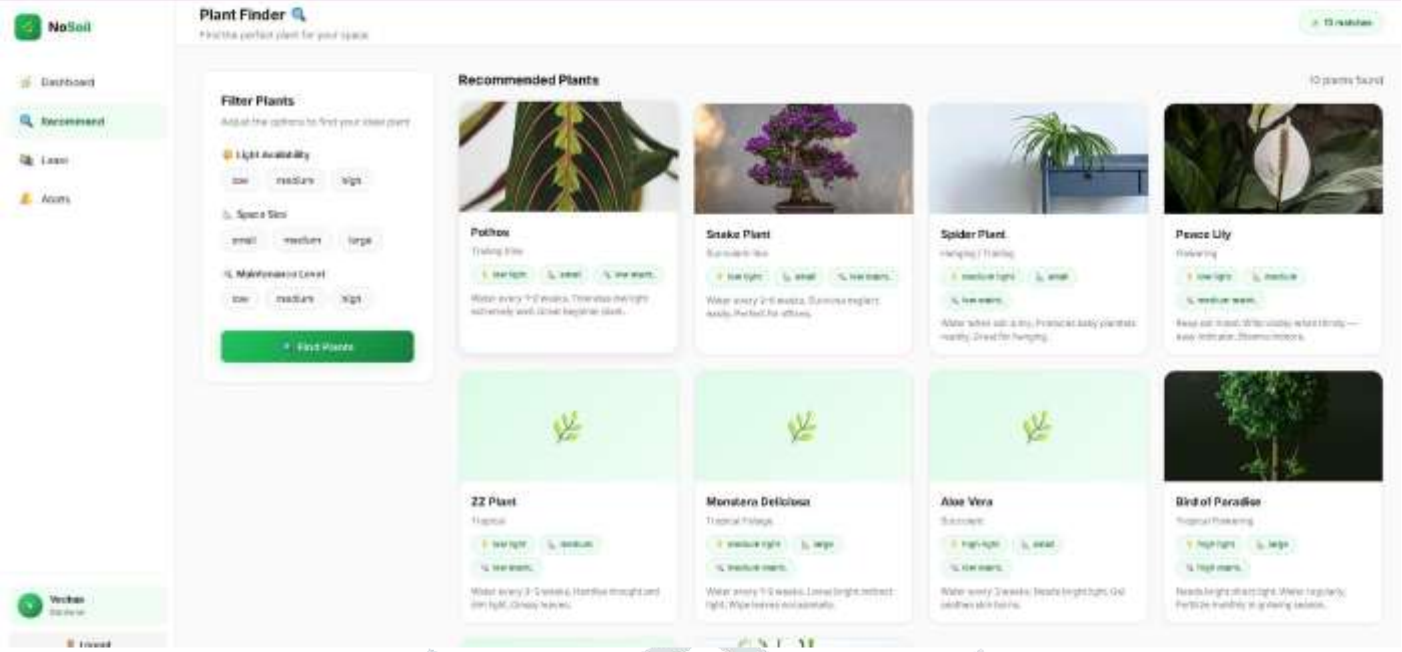
Adding Trade details

Fig. VIII.1



AI Trade Analysis





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