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Aeroponic Smart Farming System for Water Efficiency & High Value Crop Production Using Micro-Controller

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Abstract: This project is about a new way of farming called **Aeroponics**, where plants grow without soil. Instead, they get nutrients from a fine mist that is sprayed directly on their roots. This method saves a lot of water than normal farming. The system uses special sensors and a small computer to keep track of things like air moisture, temperature, and pH levels to make sure plants grow the best they can. Aeroponics is great for places with little water or poor soil, and it helps grow plants faster and in less space. By growing plants in tall stacks, it makes farming possible in cities where there isn't much land. The project shows how this method can change farming for the better, making it more sustainable and efficient.

IndexTerms **- Aeroponics, Soilless Farming, Smart Farming, Sustainable Agriculture, Precision Agriculture**

INTRODUCTION

Aeroponic farming is an advanced agricultural technique where plants are grown without soil, using air to suspend the roots and mist them with a nutrient-rich solution. The system is water-efficient, space-saving, and well-suited for high-value crops like herbs and leafy greens. The technology is ideal for urban farming and areas where water and arable land are scarce, and it can significantly reduce resource usage while increasing crop yield. In terms of space, aeroponic systems are highly scalable and can be arranged vertically in multi-tier structures. This vertical farming aspect allows for the cultivation of a large number of plants in a much smaller footprint, making aeroponics particularly suited to urban environments where land is at a premium. Aeroponics also stands out for its ability to support high-value crops with rapid growth cycles. Plants like herbs, leafy greens, and strawberries flourish in aeroponic systems, and the year-round production capability ensures a steady and reliable supply to markets. This not only provides farmers with a competitive edge but also enhances food security by enabling consistent production irrespective of external climate or environmental challenges. With its numerous advantages, aeroponic farming offers a sustainable, efficient, and future-ready solution for global agricultural demands. Furthermore, aeroponic farming aligns with global sustainability goals by reducing the environmental footprint of agriculture. Traditional farming often leads to soil degradation, excessive water consumption, and chemical runoff that pollutes water bodies.

NEED OF THE STUDY.

The need for this study arises from the growing demand for sustainable and efficient farming solutions, especially in regions facing water scarcity, limited arable land, and rapid urbanization. Traditional farming methods consume excessive water, rely heavily on soil quality, and are labor-intensive, making them less viable in modern contexts. Aeroponic farming, with its soil-free, mist-based nutrient delivery system, presents a compelling alternative by drastically reducing water and nutrient usage while increasing crop yield and growth speed. Despite existing research on aeroponics, there has been limited development of systems that incorporate real-time monitoring and automation using microcontrollers. This study aims to bridge that gap by designing a smart aeroponic system with sensor integration and automated controls to optimize growing conditions for high-value crops, making farming more sustainable, precise, and scalable.

3.1Population and Sample

KSE-100 index is an index of 100 companies selected from 580 companies on the basis of sector leading and market capitalization. It represents almost 80% weight of the total market capitalization of KSE. It reflects different sector company's performance and productivity. It is the performance indicator or benchmark of all listed companies of KSE. So it can be regarded as universe of the study. Non-financial firms listed at KSE-100 Index (74 companies according to the page of KSE visited on 20.5.2015) are treated as universe of the study and the study have selected sample from these companies.

The study comprised of non-financial companies listed at KSE-100 Index and 30 actively traded companies are selected on the bases of market capitalization and 2015 is taken as base year for KSE-100 index.

3.2 Data and Sources of Data

For this study secondary data has been collected. From the website of KSE the monthly stock prices for the sample firms are obtained from Jan 2010 to Dec 2014. And from the website of SBP the data for the macroeconomic variables are collected for the period of five years. The time series monthly data is collected on stock prices for sample firmsand relative macroeconomic variables for the period of 5 years. The data collection period is ranging from January 2010 to Dec 2014. Monthly prices of KSE -100 Index is taken from yahoo finance.

3.3 Theoretical framework

Variables of the study contains dependent and independent variable. The study used pre-specified method for the selection ofvariables. The study used the Stock returns are as dependent variable. From the share price of the firm the Stock returns are calculated. Rate of a stock salable at stock market is known as stock price.

I. METHODOLOGY

System Design:
Creation of a modular, vertical aeroponic structure to maximize space and deliver nutrient mist efficiently. The smart aeroponics system is structured as a modular, vertical farming setup to maximize space utilization, particularly in urban or limited-space environments. This design involves stacking multiple levels of plant holders, each equipped with nutrient delivery nozzles to create a mist environment for the plants' roots. The modular approach allows flexibility in scaling the system to suit small-scale home gardening or larger commercial farming operations.

Fig: 3.1 Aeroponic Tower

Efficient delivery of nutrient mist ensures even distribution to all plants, reducing wastage and promoting uniform growth. The structure is built using durable and lightweight materials, ensuring portability and ease of maintenance.

Sensor Integration:
Use of humidity, pH, and light sensors connected to a microcontroller to monitor and control environmental factors. To monitor and control the essential environmental parameters, the system integrates advanced sensors, including humidity, pH, and light sensors. These sensors are connected to a microcontroller, which acts as the system's brain. The microcontroller processes the data from the sensors in real time, adjusting variables like misting intervals, light exposure, and nutrient composition accordingly.

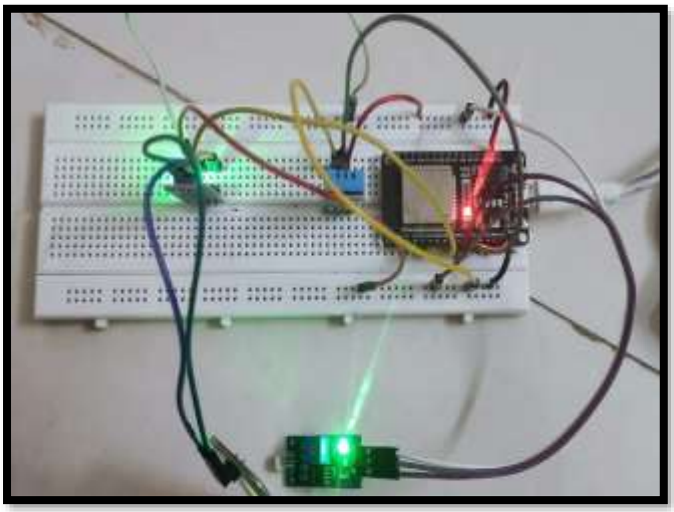

Fig: 3.2 Sensor Integration

Humidity sensors maintain optimal moisture levels for plant roots, pH sensors ensure nutrient solution remains within the range for plant uptake, & light sensors monitor illumination levels, which can be adjusted with grow lights to supplement natural light as needed.

Data Analysis:
Collection and analysis of data on plant growth, resource usage, and environmental conditions for system optimization. The system collects data on plant growth, resource consumption, and environmental conditions, which is crucial for performance evaluation and optimization. Advanced algorithms analyze this data to identify patterns and trends, such as the impact of specific misting intervals on plant growth or the correlation between light intensity and nutrient absorption. These insights enable fine-tuning of system parameters, ensuring maximum efficiency and consistent yield. The data can also be stored and visualized through user-friendly dashboards, allowing users to monitor the system's performance remotely.

Testing and Optimization:
Fine-tuning misting intervals and nutrient levels based on real-time data to achieve maximum efficiency. The final stage involves rigorous testing and iterative optimization to refine the system's performance. Real-time data from the sensors is used to adjust misting intervals, light intensity, and nutrient composition to meet the specific needs of different plant species.
For example, leafy greens may require shorter misting intervals compared to fruiting plants. Testing also involves evaluating the durability of system components, ensuring reliable operation over extended periods. Through continuous optimization, the system can achieve peak efficiency, providing faster plant growth, higher yields, and reduced resource wastage.

II. Software Requirements:

Assumptions and Dependencies: Reliable internet connectivity is necessary for remote monitoring. Continuous power supply is needed for sensor operations and the microcontroller. The system assumes proper functioning of sensors after calibration.

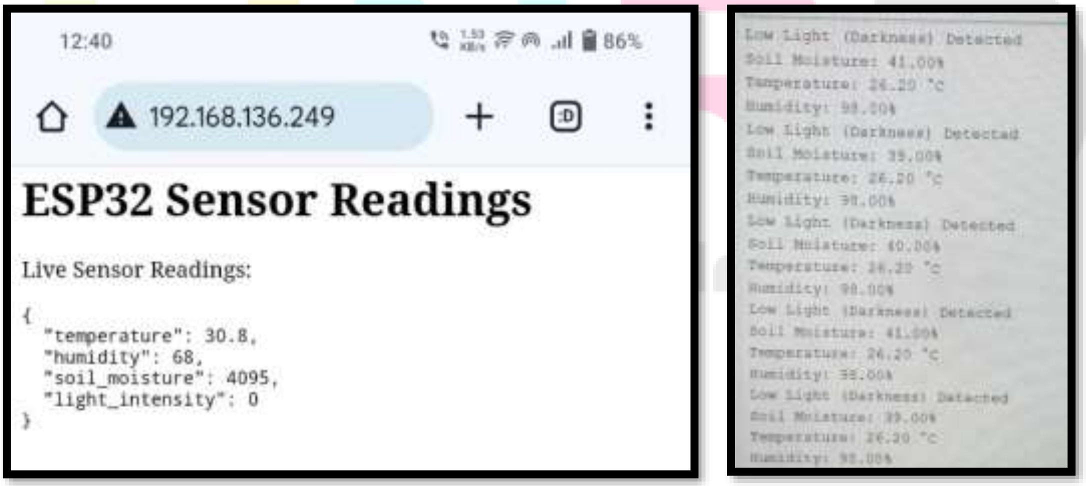

Fig: 4.1 Real time Data from Tower

All sensors (e.g., humidity, temperature, pH) are assumed to function correctly and accurately after calibration. The system assumes continuous access to power for uninterrupted operation of sensors and microcontroller. The system is depended on external weather conditions, and any drastic changes could affect performance.

III. Functional Requirements

Automated Environmental Control: The system automatically controls misting cycles and nutrient delivery based on real-time sensor data. The microcontroller shall automatically control misting cycles based on sensor readings (e.g., triggering mist when humidity drops below 60%). The system shall allow users to adjust misting intervals and nutrient delivery schedules manually through the user interface. Users can manually adjust environmental settings through a user interface. Nutrient monitoring. The system monitors pH and nutrient levels, automatically adjusting nutrient delivery when needed. Sends alerts when parameters deviate from optimal ranges.

External Interface Requirements:

User Interfaces Web or mobile dashboard for real-time data monitoring and control adjustments. The system shall have a web-based dashboard or mobile app, enabling users to monitor real-time sensor data, adjust settings, and view alerts. The interface shall provide graphical representation of environmental data (temperature, humidity, pH) for easy monitoring.

Hardware Interfaces: ESP32 microcontroller, sensors (humidity, temperature, light, pH), and water pumps for misting control.

Software Interfaces: APIs for cloud data storage and remote access. The microcontroller firmware is interface with sensor libraries and hardware drivers for data acquisition and control.

COMMUNICATION INTERFACES: WI-FI COMMUNICATION BETWEEN THE MICROCONTROLLER AND THE REMOTE DASHBOARD

VI.CONCLUSION/FUTURE SCOPE

The **Aeroponic Smart Farming System**, powered by micro-controllers, offers a revolutionary approach to sustainable agriculture, excelling in water efficiency and high-value crop production. By automating nutrient delivery and environmental control, the system ensures precise regulation of factors like humidity, oxygen, and light, leading to faster growth and higher yields while minimizing water and resource use.

Comparative Results: Aeroponic Farming vs. Traditional Farming for Mint and Basil (5 kg)

Parameter	Aeroponic Farming	Traditional Farming
Water Usage	10-20 liters (precision irrigation)	500-700 liters (soil-based)
Time to Harvest	Mint: 18-21 days Basil: 20-25 days	Mint: 30-35 days Basil: 35-40 days
Space Efficiency	High (vertical stacking possible)	Low (requires more land area)
Yield Consistency	Higher and consistent	Variable, depends on soil quality
Nutrient Usage	Lower (recycled nutrient solutions)	Higher, with potential runoff
Labor Requirements	Low (automated systems)	High (manual watering and maintenance)
Pest and Disease Control	Minimal (controlled environment)	Higher risk, requires pesticides
Initial Setup Cost	High (equipment and automation)	Low (basic farming tools)
Long-Term Cost Efficiency	High (lower resource usage)	Moderate to high

Observations:

Fig. No. 7.1 Comparative Results

1. **Mint and Basil Growth:**
    - Aeroponic systems enable faster growth cycles, allowing for multiple harvests in the same time frame compared to traditional farming.
2. **Yield per Cycle:**
    - Both methods produce 5 kg, but aeroponics achieves this faster with better control over quality and fewer resources.

Aeroponic farming proves to be more efficient in terms of water, space, and time, while traditional farming is more accessible due to lower initial costs. For high-value crops like mint and basil, aeroponics offers long-term sustainability and profitability.

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