A Comprehensive Overview of Indoor Farming System - Hydroponics

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ABSTRACT : The quality of life is advancing quickly due to new innovations, but we're also encountering new challenges. One such challenge is the shrinking land and water resources as the population grows, which could have unforeseen effects. Hydroponics presents an innovative solution to this issue. It's a rapidly evolving field with numerous benefits for agricultural practices. This study explores current Research in Hydroponics and Design our own system concerning it.

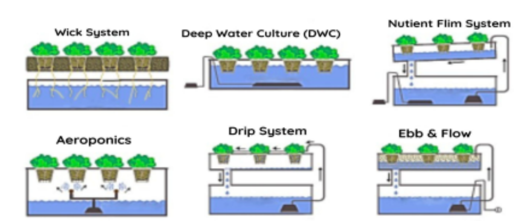
Keywords—Agriculture automation, Hydroponics system, IOT, Image Analysis

I. Introduction

World is changing rapidly, bringing resource scarcity, population explosion, climate changes, and urbanization have affected food supply and led to food insecurity and undernourishment. To fight these problems, hydroponics, which is a soilless culture, is presented as an alternative to conventional farming. Hydroponics is a sustainable model where plant are grown without soil, using nutrient film techniques or equivalent to supply essential minerals directly to the plant roots. The most optimal quality of hydroponics is that it provides accurate control over the distribution of nutrients, resulting in higher nutrient uptake by plants and reducing the need for excessive fertilizer use that promote faster and healthier plant growth[1].

II. LITERATURE REVIEW

A. Hydroponics: Types and Setups



Technique	Medium for nutrient supply	Works well for	Root exposure to nutrients	Pumped Water supply
Wick system	Wick	Small Plants, Home grown	Root receives nutrient water through wicks	NO
Deep Water Culture	Plants held in netted Pots	Compact and scalable	Roots throughout dipped in water nutrient solution	Filled container
Nutrient Film Technique	Sloping channels for nutrient water	Domestic and Commercial hydroponics	Partial thin film of exposure to nutrient solution	24 X 7 pumping through a sloped channel
Ebb and flow method	Flooded & drained with nutrient water	Small scale and large-scale implementation	Root exposure in bursts	Intermittent supply of water
Drip Irrigation	Drip line via pump & timer	Commercial application	On & Off exposure to Nutrient solution during the drip	Pipe supply and dnp cmitter
Aeroponic	Atomizers are required	Commercial application	Exposure in bursts	Sprinkler with mist nozzles

Table 1. Comparison Of Various Methods Used In Hydroponics[2]

B. Parameters of Automations

Parameters	**Recommended Values**	**Effect on plants**	**Imbalance**
EC/TDS [3]	0.8-1.2(ppm/lit)	Nutrients absorption rate	nutrient imbalances and toxicity
pH level [3]	5.4 to 6.6	Nutrients absorption rate	nutrient lockout mean unable to take even if unavailable
Temperature[4]	17–25°C	nutrient uptake, enzymatic activity	reduce photosynthetic efficiency,inhibit nutrient uptake
Light Intensity[4]	400-500 lux for 0-12 hours	support photosynthesis	elongated and weak stems, and poor fruit or flower production
Humidity[5]	50–70% - rest	affect transpiration rates	leading to water stress and wilting,increase fungal diseases
CO2 levels[5]	1000-1500 ppm	rate of photosynthesis	carbon dioxide toxicity,reduce plant growth
Nutrient solution composition[6]	micronutrients & macronutrients (NPK).	supplies vital minerals and nutrients	nutrient imbalances
Substrate [7]	Cocopeat/ Biochar	promote oxygen availability to the roots	waterlogging

C Automation Technologies

The sensors measure accurate and real-time data, enabling farmers to decide with knowledge and adjust the system accordingly.actuators are used to automate tasks such as adjusting pH levels, controlling nutrient delivery, pumps, valves, fans and providing aeration.These control systems receive data from sensors and use algorithms & logic to evaluate the information and decide how to change the parameters. Iot is a technology that used to connect sensors, actuators, and control systems,and allow someone to monitor and control in a live feed. while also allowing data sharing with other devices over the network. Data analysis improve efficiency by optimizing resource usage, identify potential issues or anomalies, and improve overall system efficiency.

D. Environmental conditions for hydroponics

1) Ambient conditions based on spatial and temporal dimensions

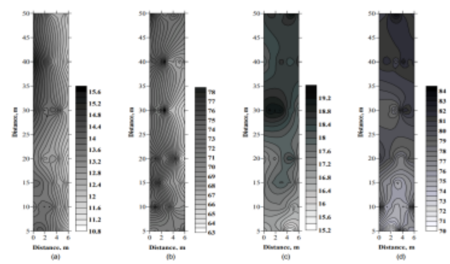


Fig. 1: Spatial Distribution of temp. and humidity a) 11a.m b) 12-2pm c) window one side open d)without ventilation [8].

In any plantation, the ambient conditions are not fully uniform. The ambient conditions can be classified as spatial, vertical, and temporal.[8].

2) Time and season-based variations

The variance in energy use in plantations occurs since certain parameters must be controlled to a specific range that includes temperature, relative humidity and so on. [9].

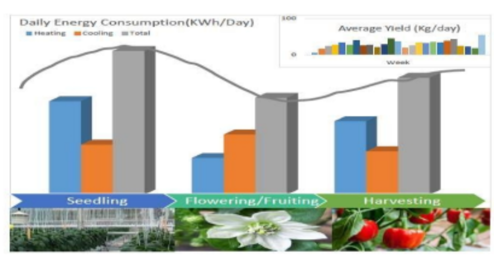


Fig. 2: Expected Energy Consumption Chart[9].

3) Conditions based on location

This is the most complex issue whenever a plantation needs to be set-up. Prior data of the location is always useful but actual cost and energy requirements vary as per different climate and environmental factors. In such cases government statistics should be prepared[10].

III. METHODOLOGY

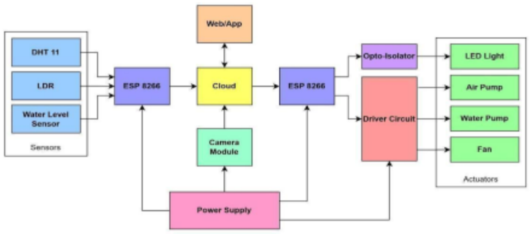


Fig. 3: Block Diagram of the System

The hydroponic system functions through a series of interconnected blocks. The IoT & Cloud Block enables communication with external networks or devices, allowing for remote monitoring and control. Furthermore, Data from the sensors is ingested into a channel, which serves as a conduit for transmitting data to external platforms for further processing. The ThingSpeak platform enables proactive management of the hydroponic system. The Actuator Block encompasses various components responsible for executing commands based on sensor readings and user inputs. The Camera Block, utilizing the ESP32-CAM module, enables visual monitoring of the hydroponic setup. The Power Supply Block ensures uninterrupted operation of the system by providing a steady 5V 2A power supply. Finally, The Web/App Block allows remote monitoring and control of the hydroponics system, empowering users to adjust parameters as necessary for optimal plant growth.

IV. RESULT & DISCUSSION

A. Setup

Fig. 4: Setup with Lights OFF

Fig. 5: Setup with Lights ON

The two-stack hydroponic automation system integrates LED violet lights, an air pump, a water pump, and a fan, all managed by sensor and actuator modules alongside a UPS module for uninterrupted power supply. This setup optimizes plant growth by providing consistent light, proper aeration, and hydration. Additionally, a time schedule control feature schedules the activation of UV lights and the air pump according to preset timings.

B. Web Interface

Fig. 6: Web Interface with Login and Password

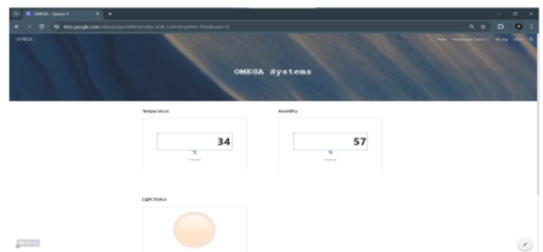


Fig. 7: Web Interface to Control the Actuators

The web interface screenshots depict a user-friendly control panel for managing the hydroponic automation system.This seamless integration enables users to monitor and adjust settings remotely from anywhere in the world. This hydroponic automation system offers the flexibility of configuring Wi-Fi credentials for both sensor and actuator modules, akin to setting up new products from the market using softAP technology.

D. TDS Research

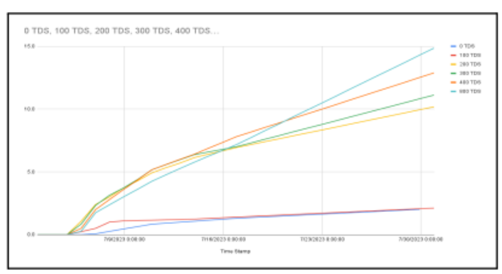


Fig. 12: Plant Height over Growth at Different TDS

The experiment showed that small plants thrive with low TDS levels, while medium-sized ones grow best with around 400 TDS for optimal growth. At the harvest stage, plants need about 800 TDS for faster growth, neither too high nor too low. This TDS consists of one-third each of NPK for appropriate nutrition and healthy development.

E. TDS Recommendation using Camera

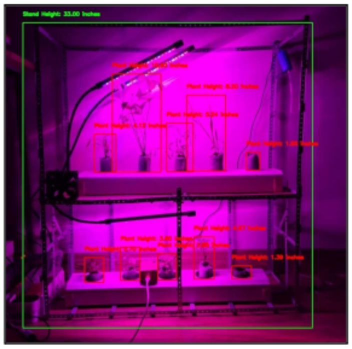


Fig. 13: **Output of yolo8s Model**

Using yolov8s model trained over 100 epochs, the system accurately predicts the Total Dissolved Solids (TDS) required for optimal growth based on height of plants. On accessing the webpage, users are presented with a clear indication of the TDS needed – whether it's 200 TDS, 400 TDS, 600 TDS, or 800 TDS. Alongside each TDS value is a measure of prediction accuracy, displayed on a scale from 0 to 1, allowing users to gauge the reliability of the system's recommendation. With this seamless integration of imaging technology and predictive analytics, users can effortlessly maintain the ideal nutrient balance for their hydroponic setup, ensuring healthy and thriving plant growth.

G. Water usage

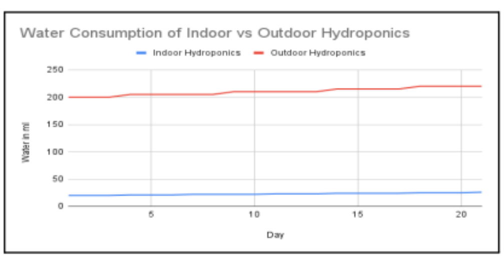


Fig. 16: **Water Consumption of Indoor vs Outdoor Hydroponics**

As seen above we can see that water consumption is 8 times less when indoor as compared to outdoor while variation in values of both stay constant. Hence there is a very high incentive to go for indoor hydroponics given the considerations given above and data collected.

H. Power optimization

To optimize the power, we programmed the system to use one major function at a time without changing its effectiveness. And as agricultural systems no precise time budget and hence allowing for tasks parallel execution. The rough way of time allocation can be understood as

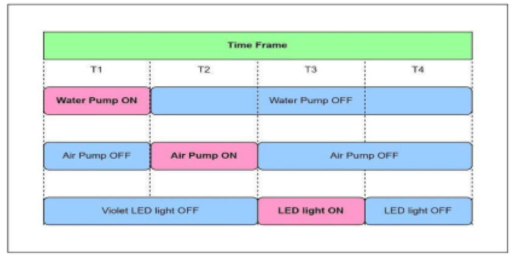


Fig. 17: **Power Optimization using Time Slotting**

L. Time Scheduling and Email Alerts

This Time scheduling capability, integrated with the ThingSpeak Cloud, enables users to program specific timings for these essential components such as lighting and aeration at optimal times. This feature enabled users to receive real-time notifications via email regarding critical events detected within the cultivation environment.

O. light Intensity and Air Pump

Plants require full and direct sunlight, hence Violent light as a substitute for sunlight (why this is a viable option is explained in above review) was at maximum intensity for 12 hours Daily Cycle

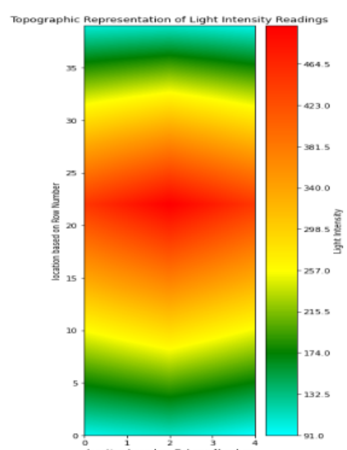


Fig. 22: **Topographic distribution of light intensity**

Following is representation of light intensity, as can be seen reading becomes less as we go on away from center. This affects the plants growth slightly as plants closer to center grow faster, but this difference in growth is small and in acceptable margins. Also, we observed that the plant grows efficiently with 30 mins air pump and 1-hour intervals.

V. Challenges in Automation

1) Power Optimization

When it comes to power optimization, there are two scales to consider. On a large and small scale. On a larger scale, it has to do with precision hardware control and optimized power consumption strategies and has technical issues with energy storage such as battery degradation and limited capacity. Furthermore, small-scale power optimization involves increasing the effectiveness of certain systems and devices to reduce power consumption but these all involve technical complexities [11].

2) Hardware Selection

In hydroponics , a lot of electronics hardware needs to handle various constraints like power, i/o specification, and technical expertise required to handle them. However, that is not the only thing. We also need to consider enclosed and other planting tools procurements as lots of locations do have metal resources for manufacturing, while plastics ones do not.

3) Automation Challenges

Challenges like sensor reliability, and system complexity are all some technical constraints that must be taken into consideration while building any embedded system. Data security and human Interventions are other aspects of design as it must be understood that not every security solution provides a similar level of security towards diverse types of attacks and malicious parties that exist, on the contrary, each and every solution must be created and/or modified for any and all particular type of threats that arise.[12].

VI. Future Enhancements of the Hydroponic System

1) Hydroponics for Space

Hydroponics for space is a heavily researched field that focuses on its applications in water purification, oxygen and carbon dioxide balance in space stations, and astronaut nourishment[13]. In-depth study is being done in this area since it is imperative for long-term space initiatives , well being and safety of the crew on manned space flights.[14].

2) Overcome Adverse Effects of Brackish Water

The utilization of brackish water (meaning water occurring in a natural environment that has more salinity than freshwater, but not as much as seawater) in agriculture may cause the soil's salt content to rise, which may have an adverse effect on plant output. Hydroponics is a technique that includes nurturing plants in a NFT solution rather than soil driven. Even by utilization of brackish water, this approach promotes superior plant growth and development.

VII. Conclusion

The synthesis of hydroponics and electronics and other deep technologies presents a compelling avenue for innovation in modern agriculture. The potential for applying electronic expertise in optimizing and advancing these technologies for sustainable agriculture is seen as a key theme.

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