A Project Proposal Submission
on

Smart Agriculture System using Raspberry Pi and Machine learning

For the course of

Project Based Learning
in
Department of Robotics and Automation

Submitted by,
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Annexure 2

Undertaking for Literature review and Project proposal Submission

Department	**Robotics and Automation**
Batch	**2022-2026**
Name of the Students (PRN)	1. Akshat Singh (22070127009) 2. Bibi Mehnoor (22070127015) 3. Himonish Gupta (22070127025) 4. Yash Golani (22070127072)
Name of the guide(s):	**Dr. Rajesh Bisane**, Assistant Professor, Department of Robotics and Automation
Project Title	**Smart Agriculture System using Raspberry Pi and Machine learning**
Similarity Index (should be less than 10%)	1. Similarity Index: 2. AI Report:

Date: 10/02/2025

Signature of Student(s): **Signature of Project Guide**

1. Akshat Singh -
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Annexure 3

Estimated Project Expenditure

Title of the Project: Smart Agriculture System using Raspberry Pi and Machine learning

Sr. No	Particulars with Justification	Amount (INR)
1	Material	
2	Electronics Hardware Components 1. **Raspberry pi:** (Raspberry Pi 4 B with 4 GB RAM) 2. **DHT11 Sensor:** (DHT11 Sensor Module with LED) 3. **LDR Sensor:** (4mm Photoresistor Photocell 5-10K) 4. **Relays:** AQV258-PANASONIC-DIP-6 5. **Water Pump:** (DC6-12V MINI Pump R385) 6. **Soil Moisture Sensor:** (Smart Elex Moisture Sensor) 7. **Power Supply:** (AC-DC Power Supply 24V 4A) 8. **Light:** LBW 48 LEDs Grow light for indoor plant 9. **pH Sensor:** Electrode Probe for Liquid pH Value 10. **LCD Display:** 16x2 LCD (Green Backlight)	 5549 51 10 534 199 124 335 1200 700 198
3	Software 1. Visual Studio Code 2. Raspberry Pi Imager	
4	Fabrication	1000
5	Others (if any)	1000
	Total	**10,900**

Name and Signature of the Student(s) **Name and Signature of Guide(s)**

1. Akshat Singh -
2. Bibi Mehnoor -
3. Himonish Gupta
4. Yash Golani -

LIST OF ABBREVIATIONS/ SYMBOLS

Abbreviations		**Description**
ML	:	Machine Learning
IoT	:	Internet of Things
ADC	:	Analog to Digital Converter
pH	:	potential of Hydrogen
DT	:	Decision Tree
LSTM	:	Long Short-Term Memory

Abstract

Agriculture stays the inspiration of global food deliver, but conventional farming strategies frequently result in inefficiencies, high useful resource consumption, and inconsistent yields. Advancements in era, especially the Internet of Things (IoT) and statistics-pushed analytics, present a promising option to these demanding situations. This task makes a speciality of developing a smart vertical hydroponic farming machine using Raspberry Pi to monitor environmental elements, optimize nutrient transport, and provide actual-time insights thru predictive analytics. Unlike traditional soil-based agriculture, hydroponics eliminates soil dependency, conserves water, and complements crop increase performance. By integrating sensor-primarily based monitoring with wise choice-making, this gadget objectives to improve productivity, lessen useful resource wastage, and allow price-effective farming. Additionally, it seeks to make precision agriculture extra on hand by means of providing an automated, scalable technique to trendy farming. Expected effects include improved plant health assessment, optimized water and nutrient management, better crop yields, and a sustainable farming model aligned with international meals safety needs.

Keywords: Hydroponics, Machine Learning, Precision Agriculture, Sustainable Technology and Internet of Things.

1. Introduction

The fast rise in the international populace, at the side of the unpredictable effects of climate change, has made meals manufacturing harder than ever. Ensuring a solid food supply whilst maintaining environmental sustainability has come to be an urgent situation for researchers, policymakers, and agricultural experts [1]. While conventional farming strategies have been relied upon for generations, they often face obstacles in performance, adaptability, and resilience [2]. Factors including immoderate resource consumption, soil depletion, erratic weather conditions, and pest infestations retain to threaten agricultural productivity, emphasizing the want for innovative answers that decorate efficiency and lengthy-time period sustainability [3].

Advancements in technology have brought about transformative answers, in particular in vertical hydroponic farming. By integrating the Internet of Things (IoT) with Machine Learning (ML), contemporary hydroponic structures provide particular manipulate over critical environmental elements consisting of nutrient degrees, water availability, temperature, and humidity [4]. IoT sensors constantly reveal real-time situations, and clever data analysis facilitates optimize useful resource allocation while selling more healthy plant boom. Unlike conventional soil-based totally farming, hydroponics removes the reliance on fertile land, considerably reduces water utilization, and improves crop yields, making it an ideal solution for urban farming and regions with restricted agricultural sources [5].

One of the giant blessings of IoT-pushed vertical farming is its ability to maximise aid performance. Automated irrigation and nutrient delivery systems make sure optimum water and fertilizer utilization, notably decreasing waste while promoting healthier crop improvement. Additionally, ML-powered predictive models facilitate early detection of plant pressure, diseases, and nutrient deficiencies, allowing well timed interventions that save you yield losses. These innovations make contributions to sustainable agricultural practices by minimizing chemical runoff, preserving water, and optimizing strength use [6].

The use of smart hydroponic systems has significantly advanced the manner farms are managed, offering farmers extra control and versatility. With actual-time data reachable through cloud structures and cellular apps, growers can display plant fitness, adjust environmental elements, and excellent-song harvesting schedules with no trouble. Automation and robotics similarly streamline operations through lowering the need for guide hard work at the same time as ensuring unique nutrient transport and climate regulation. These technological advancements not only increase universal productiveness however also help cut down on operational prices, making hydroponic farming a more realistic and scalable alternative to conventional strategies [7].

As worldwide agricultural demanding situations continue to grow, the want for modern, technology-pushed farming solutions will become extra apparent [8]. The shift closer to clever vertical hydroponic structures marks a big advancement in accomplishing sustainable, high-yield meals manufacturing capable of withstanding weather fluctuations and assembly rising food needs [9]. By adopting smart farming techniques, farmers and industry leaders can improve performance, limit environmental impact, and make contributions to an extra resilient and sustainable agricultural future [10]. The following sections discover the heritage, significance, and emerging developments in smart hydroponic farming, emphasizing its potential to transform present day agriculture.

1.1 Background and Rationale

For a few years, agriculture has been the muse of human civilization, giving billions of human beings' worldwide access to meals, uncooked assets, and a method of subsistence. However, troubles which include erratic climate patterns, soil erosion, and wasteful water use often plague traditional farming practices. Concerns approximately the financial system and ecology are raised by those issues, which bring about irregular crop yields and immoderate useful resource usage [11]. There is an growing want for creative ways to boost agricultural resilience and increase efficiency because the want for sustainable food production keeps rising.

A progressive technique to these problems is the mixture of Internet of Things (IoT) and device studying (ML) technology in vertical hydroponic farming [12]. Hydroponic structures provide real-time monitoring of important parameters such nutrient ranges, water nice, and weather situations by using smart sensors, automated information collecting, and predictive modeling [13]. In addition to growing productivity, this shift from conventional soil-primarily based farming to generation-pushed hydroponic horticulture optimizes useful resource management and guarantees lengthy-time period financial sustainability. Smart hydroponic farming is a important step closer to achieving sustainable food manufacturing because it maximizes crop yields whilst substantially decreasing environmental effect thru ongoing tracking and adaptive manage [14], [15].

1.2 Significance of the Study

By the use of data-pushed decision-making, smart hydroponic farming allows manufacturers to abandon traditional trial-and-mistakes strategies in prefer of a extra accurate and powerful strategy. These systems greatly growth standard performance while lowering waste with the aid of making the most use of assets inclusive of water, fertilizer solutions, and mild publicity. Furthermore, by means of extensively reducing water usage and eradicating soil erosion, hydroponic farming promotes climate-smart agriculture and is a sustainable substitute for conventional strategies. Predictive analytics improves profitability for each large and small farmers by using facilitating higher aid allocation and planning. Precise crop management, which subsequently results in multiplied yields and consistent produce best, is ensured by real-time tracking of important environmental parameters, together with temperature, humidity, and pH tiers.

1.3 Current Trends

In order to ensure perfect developing circumstances, hydroponic structures that integrate IoT-enabled automatic records amassing allow consistent tracking of essential elements consisting of temperature, nutrient concentrations, and water great. Predictive analytics powered by way of machine learning further boosts productiveness with the aid of analysing accrued information to forecast capability production, improve plant boom, and identify early ailment symptoms. Furthermore, farmers can also without difficulty perform hydroponic farms from any region thanks to cloud-primarily based farm control answers, which give automatic control and far off tracking. By ensuring transparency, traceability, and protection in food distribution networks and lowering the danger of fraud and inefficiencies, blockchain technology plays a vital function in agricultural supply chains. Furthermore, far off sensing era, such as drones and imaging equipment, display plant fitness and optimize vertical farm layout for max productivity. A critical improvement in modern agriculture is the extensive use of wise hydroponic structures, which provide a scalable, useful resource-green, and climate-resilient alternative for conventional farming. Vertical hydroponic farming actively promotes environmental sustainability at the same time as imparting a possible answer to the problems associated with global meals security via making use of data-pushed technologies.

2. Review of Literature

Extensive research has highlighted the capacity of IoT and gadget learning (ML) in improving precision agriculture. IoT-primarily based structures have been extensively hired to monitor essential environmental parameters in real time, permitting farmers to hold gold standard growing situations with improved accuracy [4]. Meanwhile, ML-pushed fashions have verified giant promise in optimizing nutrient delivery and predicting plant health problems in hydroponic structures. However, challenges inclusive of value-effectiveness, person accessibility, and large-scale deployment keep to restriction enormous adoption [6].

Various ML strategies, together with deep mastering fashions and decision tree algorithms, were explored for their effectiveness in optimizing hydroponic crop boom and detecting nutrient deficiencies [7]. Studies suggest that combining IoT and ML can notably enhance resource efficiency and productivity in soilless farming. However, there may be a gap in studies concerning the development of low-priced and scalable answers tailored for small- and medium-scale hydroponic farmers [11].

Additionally, IoT-enabled sensors for tracking water pH, electric conductivity, and dissolved oxygen levels had been recognized for his or her position in enhancing hydroponic efficiency. However, integrating these sensors with ML-based totally predictive analytics stays an area requiring further exploration. Comparative analyses of ML strategies, which includes aid vector machines (SVM) and convolutional neural networks (CNN), recommend that ML-powered hydroponic monitoring can significantly decorate early detection of plant stress and nutrient imbalances. Nevertheless, the computational complexity of these fashions provides a mission for actual-time implementation in aid-restricted hydroponic farming environments.

3. Research Gap

The massive adoption of clever hydroponic farming technology faces several demanding situations, especially for small- and medium-scale growers, because of excessive preliminary prices that make affordability a prime issue. Additionally, the lack of seamless integration between IoT-based monitoring structures and gadget studying models frequently ends in inconsistencies in real-time facts evaluation, limiting the effectiveness of predictive insights for crop management. Another vital hole in studies is the constrained wide variety of long-time period studies assessing the economic and environmental sustainability of ML-driven hydroponic farming, making it tough to evaluate its lengthy-time period viability. Furthermore, predictive analytics models require sizeable validation across unique environmental conditions to make certain they're adaptable and dependable for numerous hydroponic setups. The computational complexity of superior ML algorithms also provides a project for actual-time processing, emphasizing the need for greater efficient and useful resource-friendly fashions. Lastly, the usability of IoT-powered hydroponic systems remains a subject, mainly for farmers with minimum technical know-how, underscoring the significance of growing person-pleasant solutions and reachable training packages to facilitate broader adoption.

4. Research Questions

- In what ways can IoT-based monitoring systems optimize real-time data collection and improve decision-making in vertical hydroponic farming?
- Which ML techniques yield the highest accuracy in detecting nutrient deficiencies, plant stress, and potential diseases in hydroponic systems?
- How can an IoT-integrated hydroponic farming system be developed to ensure cost-effectiveness and scalability for widespread adoption, particularly among small- and medium-scale growers?
- What are the financial and ecological advantages of incorporating ML-driven predictive analytics into hydroponic farming for sustainable food production?
- What methods can be applied to enhance ML models for hydroponic farming, reducing computational demands while maintaining accuracy and real-time efficiency?

5. Statement of the Problem

A vital improvement in modern-day agriculture is the extensive use of smart hydroponic systems, which provide a scalable, useful resource-green, and climate-resilient alternative for traditional farming. Vertical hydroponic farming actively promotes environmental sustainability at the same time as offering a viable answer to the troubles related to international meals protection through utilizing data-driven technologies. The key challenges currently faced in conventional farming include:

- Inefficient resource utilization
- High water consumption
- Limited adoption of advanced technologies

The efficiency of hydroponic farming is often hindered by the absence of real-time monitoring systems, leading to either excessive or insufficient nutrient and water supply, which directly impacts plant growth. Traditional irrigation methods further contribute to this issue, as they result in significant water wastage, whereas hydroponic systems require precise water management to maximize efficiency. While the combination of IoT and machine mastering in agriculture gives giant ability, the widespread adoption of those technology stays gradual, hindering development in the direction of extra green, information-pushed farming strategies.

The primary mission lies in making these innovations extra available and low-priced for farmers, mainly the ones running on a smaller scale. Developing price-effective smart farming answers that optimize useful resource use and improve sustainability is critical for making sure broader implementation. This undertaking seeks to address these challenges by means of improving agricultural productivity, selling environmentally pleasant practices, and making precision hydroponic farming both scalable and sensible for a much wider range of growers.

6. Objectives of the Study

- To develop an IoT-based smart agriculture system using Raspberry Pi.
- To conduct predictive analysis using machine learning algorithms.
- To evaluate system's performance in improving crop yield, cost effectiveness and efficiency.

7. Scope and Limitations

7.1 Scope:

The task's scope includes designing and enforcing a Raspberry Pi-based IoT-powered smart agricultural system for actual-time tracking in vertical hydroponic farming. In order to research environmental information and provide forecast insights that improve crop improvement and maximize aid utilization, it incorporates system studying algorithms. To confirm the device's accuracy, performance, and flexibility, its performance can also be assessed in a lot of hydroponic configurations.

7.2 Limitations:

Without automated nutrient delivery or pH balancing structures, the machine is in most cases supposed for tracking and predictive evaluation. Its capacity to store facts in the cloud and carry out sophisticated analytical processing relies upon on regular internet get admission to. Additionally, the precision of sensors and the overall effectiveness of the device gaining knowledge of models used have an impact on prediction accuracy.

8. Research Hypothesis

8.1 Research Hypothesis (H_1):

According to the studies hypothesis (H_1), incorporating IoT and system getting to know into vertical hydroponic farming will notably growth efficiency by presenting continuous, actual-time environmental component tracking. Improved crop yields and accelerated average productivity can also end result from this proactive monitoring. Utilizing facts-driven insights permits for the optimization of crucial resources, inclusive of energy, water, and fertilizers, decreasing waste and increasing performance. Additionally, the device makes it easier to perceive plant strain, diseases, and pest threats early on, allowing well timed motion to lower crop losses and beautify plant fitness. Hydroponic farming becomes extra cost-effective and sustainable whilst essential tactics are automatic, which also decreases running prices and lessens the want for human labour.

8.2 Null Hypothesis (H_0):

On the opposite hand, the null speculation (H_0) indicates that, in contrast to traditional hydroponic strategies, using an IoT and ML-powered smart farming gadget in vertical hydroponics might not constantly result in statistically full-size increases in crop output. Without precise optimization, the performance gains in useful useful resource intake, including water and nutrient manipulate, won't be considerable. Furthermore, despite the fact that the gadget presents computerized disorder and strain detection, it can no longer constantly beat manual tracking strategies. Finally, at the same time as conventional hydroponic farming currently makes use of distinctly effective automation and help management strategies, operational prices and exertions dependency might not experience full-size discounts.

Through practical utility, wherein overall performance metrics which includes crop productiveness, aid utilization, and device correctness are assessed, these theories will be verified.

9. Methodology, Tools and Techniques

9.1 Methodology

This system is designed to combine IoT sensor technology with machine learning analytics, enabling real-time monitoring and predictive insights for precision agriculture. The development process will proceed through the following steps:

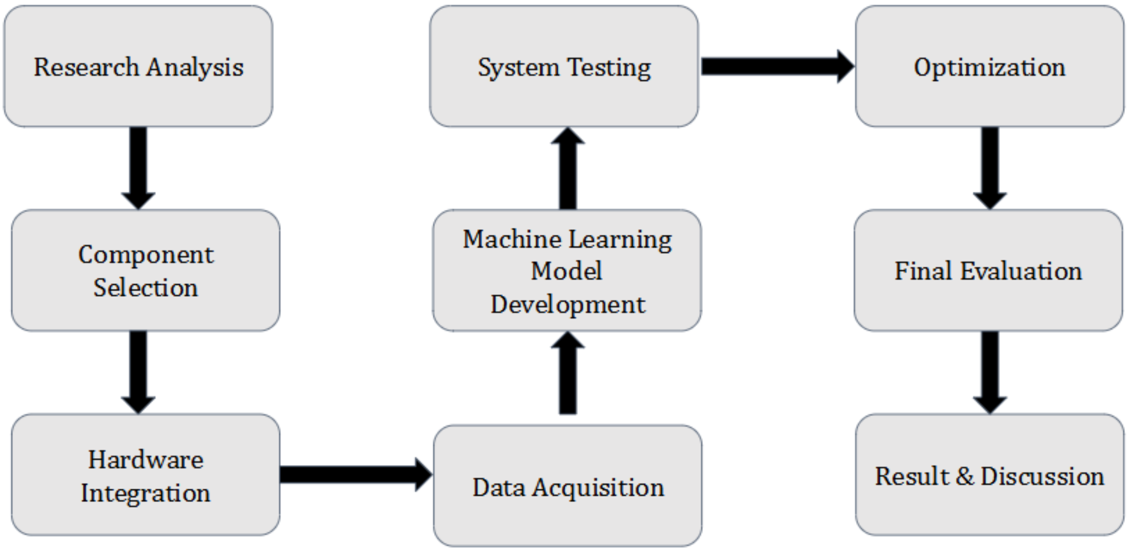

Fig.1 Methodology

9.1.1 Conceptualization & Planning

The development and implementation of an IoT-incorporated vertical hydroponic farming machine start with conceptualization and planning, wherein a detailed system structure is designed to integrate sensors, microcontrollers, and device getting to know models. Essential hardware additives, consisting of sensors, actuators, Raspberry Pi, ADC, and LED develop lighting fixtures, are identified and procured, together with cloud structures and ML frameworks for software program improvement.

9.1.2 Hardware Deployment

In the hardware deployment phase, environmental sensors are mounted to reveal temperature, humidity, water degree, and nutrient attention, with facts acquisition facilitated by way of connecting the sensors to a Raspberry Pi through an Analog-to-Digital Converter (ADC). To optimize plant growth, artificial lights is included the usage of LED develop lighting that simulate sunlight. Wireless connectivity is installed the usage of Wi-Fi or LoRa networks, making sure seamless real-time data switch for continuous tracking.

9.1.3 Software Development

The software development phase involves programming embedded systems on the Raspberry Pi to handle data collection, preprocessing, and transmission. Cloud integration is implemented using AWS IoT Core for data storage, real-time monitoring, and remote accessibility. Machine learning models are incorporated using TensorFlow and Scikit-learn to analyse sensor data and generate predictive insights for crop health assessment.

9.1.4 Machine Learning Model Construction

To develop the machine learning models, Decision Tree and Long Short-Term Memory algorithms are trained using both historical and real-time sensor data. Regression analysis and time-series forecasting methods are applied to accurately predict plant growth patterns, identify potential anomalies, and optimize crop yield estimation.

9.1.5 System Integration & Validation

For successful implementation, all hardware and software components are carefully integrated to ensure seamless communication and functionality. Real-world testing is conducted within a vertical hydroponic farming environment to evaluate sensor accuracy and assess the reliability of the machine learning predictions.

9.1.6 Evaluation & Analysis

Finally, the evaluation and analysis phase assess the accuracy of machine learning predictions by comparing them with actual crop performance metrics. Resource efficiency is reviewed by analysing water, energy, and nutrient consumption to determine optimization effectiveness.

Findings from the study are documented, and recommendations are made for future enhancements to refine and advance the smart hydroponic farming system.

9.2 Tools and Techniques

9.2.1. Hardware Tools:

- **Sensors:** Soil moisture sensors (Smart Elex Soil Moisture Sensor), humidity sensors (DHT11 Sensor), pH sensors (Gravity Analog pH Sensor) and temperature sensors (LDR sensor).
- **Actuators:** Water pump (DC6-12V MINI Aquarium water Pump R385) and LED Grow Lights (Full Spectrum Artificial Sunlight LED).
- **Power Supply:** AC-DC Power Supply Module 24V 4A Switching Power Supply Board.
- **Microcontrollers:** Raspberry Pi for data processing and communication.
- **Communication Modules:** Wi-Fi or LoRa for data transmission.
- **Other(s):** AQV258-PANASONIC-DIP-6 Solid State Relays (MOS Output) ROHS and Analog-to-Digital Converter (ADC).

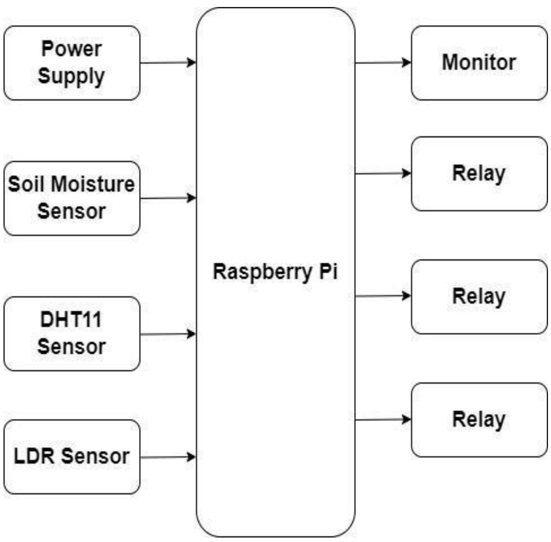

Fig.2 Block Diagram

9.2.2. Software Tools:

- **Programming Languages:** Python 3 for ML implementation, C++ for microcontroller programming.

- **Data Processing & Storage:** Firebase or AWS IoT for cloud-based storage.
- **Machine Learning Frameworks:** TensorFlow, Scikit-learn for ML model training.

9.2.3. Techniques Used:

- **Supervised Learning:** Decision Tree / Random Forest for environmental data analysis and anomaly detection.
- **Time-Series Analysis:** LSTM for forecasting crop yield trends based on historical sensor data.
- **Data Preprocessing:** Filtering and normalizing sensor data to ensure high-quality inputs for ML models.
- **Feature Engineering:** Selecting and refining critical data features to enhance predictive accuracy.
- **Edge Computing:** Processing real-time data on Raspberry Pi to minimize cloud dependence.

10. Expected Outcome

Present work focuses on the development of smart agriculture system for the improvement of hydroponics farm. In which different parameters will be evaluated like, temperature, humidity, soil quality, pH of water etc. It is extended to improve the yield of crop to some extend on the basis of smart control of the mention parameters and beneficial to the farmer and society. Fig.3 shows the tentative smart agriculture setup with different equipment.

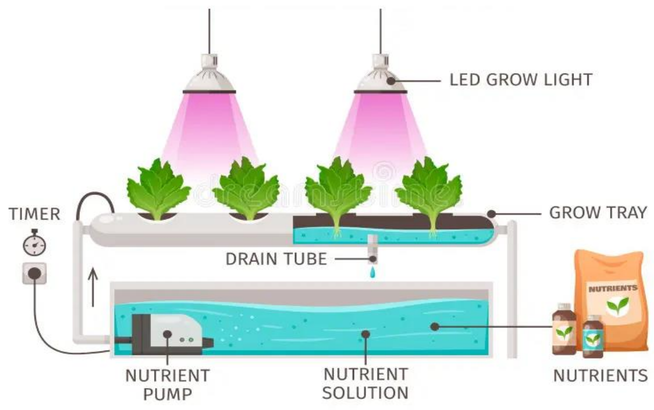

Fig.3 Tentative smart agriculture setup

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