TEMASEK POLYTECHNIC

SCHOOL OF INFORMATICS & IT

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DIPLOMA IN APPLIED ARTIFICIAL INTELLIGENCE

DIPLOMA IN INFORMATION TECHNOLOGY

IOT APPLICATION DEVELOPMENT (CMC2C16)

Project Proposal

Full Name	Admin No.	Class

The proposal report should include the following sections:

Name of Your IoT Solution

The name of my IoT solution is IntelliFarm

Description

Description of my IoT Solution

IntelliFarm is an IoT-enabled agricultural solution tailored for indoor farming, aiming to optimize crop yield, conserve resources, and minimize manual labour through real-time monitoring and automation. It integrates advanced IoT technologies, including sensors, cloud analytics, and automated systems, to deliver actionable insights that empower farmers to make informed decisions. The system transmits data via a secure IoT architecture, and notifications are delivered to users through Amazon Simple Notification Service (SNS).

At its core, IntelliFarm employs a range of sensors to address critical farming challenges. The first sensor it will be using is a **Soil Moisture Sensor** likeYL-69 measures the water content in the soil by assessing its electrical conductivity. Lower conductivity indicates dryness, prompting IntelliFarm to automatically activate irrigation systems when moisture falls below a set threshold. The sprinklers switch off once the desired moisture level is reached, and users are notified via email with a detailed summary like the starting and stopping times, total runtime, moisture levels, and water usage, ensuring water efficiency and optimal hydration for crops.

To maintain soil health, IntelliFarm uses a **Soil pH Sensor** to monitors the acidity or alkalinity of the soil, critical for ensuring the soil is suitable for specific crops, the sensor uses an electrode that measures hydrogen ion activity in the soil this helps with providing data on soil health to guide fertilizer application and ensures crops grow in optimal conditions for better yield so when the pH levels hits a certain point the user will be emailed to add fertiliser to either reduce or increase the pH of the soil.

Environmental conditions are monitored using **Temperature and Humidity Sensors** like DHT22, which measure ambient temperature and humidity, the DHT sensors use a thermistor to measure temperature and a capacitive humidity sensor to measure relative humidity. These sensors provide critical data at regular intervals, alerting users through real-time notifications when conditions deviate from optimal ranges. IntelliFarm also automates responses such as activating heat pumps for temperature regulation like cooling the room when the temperature is too high or deploying dehumidifiers to control humidity, safeguarding crops from issues like heat stress, dehydration, or fungal infestations.

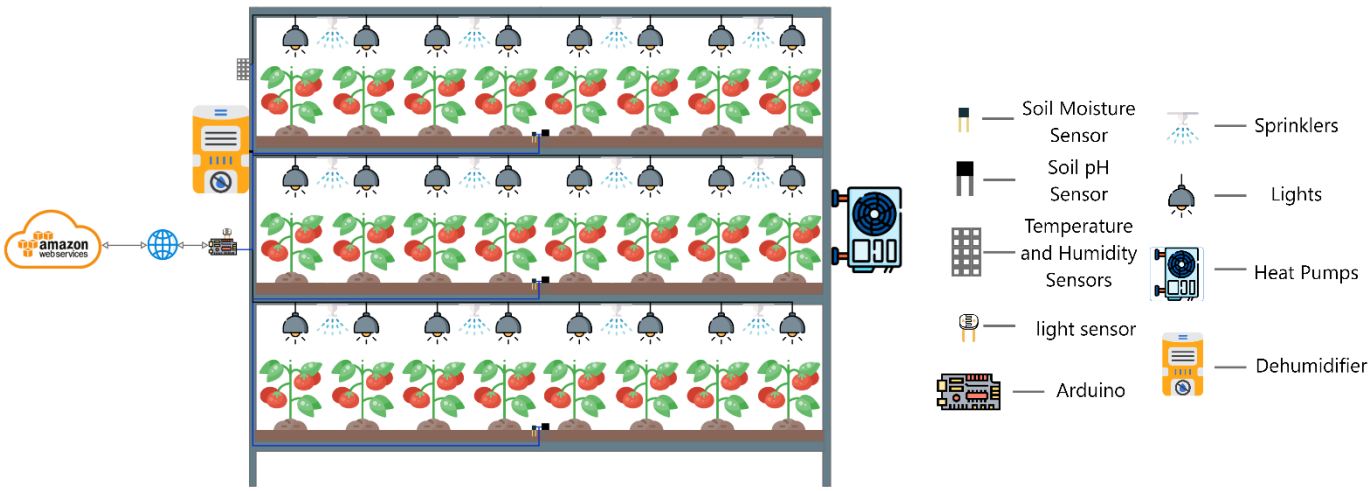
Light management is another essential component of IntelliFarm, achieved through **light sensors** that monitor illumination levels. When natural light is insufficient, the system activates LED grow lights, ensuring consistent lighting for photosynthesis and to optimise

plant growth. Users are notified of changes, and energy-efficient LED technology minimizes operational costs while optimizing crop productivity.

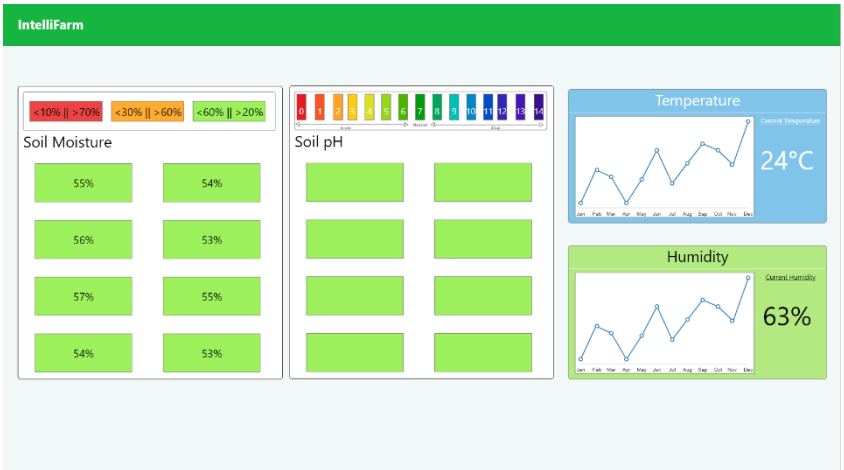
IntelliFarm incorporates an Arduino-based microcontroller, such as the ESP32, to serve as the central hub for sensor integration and device control. This cost-effective and versatile microcontroller collects real-time data from various sensors deployed in the indoor farming environment, including soil moisture sensors, soil pH sensors, temperature and humidity sensors, and light sensors. The ESP32 processes this data and uses Wi-Fi connectivity to securely transmit it to AWS for storage and analysis. The ESP32 also facilitates bidirectional communication, allowing IntelliFarm to not only monitor conditions but also execute automated responses. For instance, the microcontroller activates sprinklers when soil moisture falls below a set threshold, controls heaters and dehumidifiers to maintain ideal environmental conditions, and manages LED grow lights to supplement natural lighting as needed. This integration of an ESP32 ensures cost-effectiveness, energy efficiency, and reliable connectivity, making IntelliFarm an accessible yet sophisticated IoT solution for indoor farming.

The integration of these sensors and systems creates a seamless, real-time data flow stored in AWS DynamoDB, which ensures scalability and reliability. The IntelliFarm dashboard offers a user-friendly interface with visualizations such as line graphs for environmental trends and heatmaps for soil conditions, enabling quick issue identification and corrective action.

Example of the sensors placement



Example of IntelliFarm dashboard



<u>The problem that my IoT Solution is trying to solve.</u>

The problem that my IoT Solution is trying to solve is the key challenges faced by farmers, including inefficiencies in farming practices, water wastage, unpredictable weather patterns of outdoor farming, and the lack of actionable data for decision-making. Traditional farming methods often result in poor crop health due to resource mismanagement, excessive manual labour, and guesswork. My solution solves these problems by offering precision farming capabilities that optimize resource usage, conserve water, and ensure healthier crops. By reducing inefficiencies through automation, providing real-time data, and enabling informed decisions, it also boosts agricultural productivity, reduces the workload on farmers, and contributes to sustainable farming practices. Reference: Indoor vs. Outdoor Farming: A Comprehensive Comparison

Justification

<u>Business Sector</u>

My IoT solution is in the Indoor Agriculture / Urban Agritech part of the business sector. Indoor farming falls under the growing field of agritech, focusing on controlled-environment agriculture (CEA). This sector is rapidly expanding due to increasing urbanization, the need for sustainable food production, and limitations on arable land. IntelliFarm caters to this niche by enabling precision farming practices tailored for indoor systems such as vertical farms, hydroponic setups, and climate-controlled greenhouses.

<u>Target Audience</u>

The target audience for my solution comprises operators of medium to large-scale indoor farming facilities, including vertical farms, hydroponic systems, and climate-controlled greenhouses. These stakeholders often face challenges in manually monitoring and maintaining consistent environmental conditions across extensive setups and wish for a simple and efficient solution to automate critical processes and provide real-time alerts for any deviations that require attention to enhance productivity, optimize resource use, and focus on scaling their operations effectively.

<u>Need for your IoT Solution</u>

Indoor farming is emerging as a vital component of the global agricultural landscape, offering a sustainable alternative to traditional outdoor farming. However, it also introduces challenges such as maintaining precise environmental conditions, optimizing resource utilization, and reducing labour-intensive operations. IntelliFarm directly addresses these challenges with advanced IoT-enabled solutions tailored for controlled-environment agriculture (CEA).

Water management is a critical concern in agriculture, with inefficiencies resulting in significant wastage. According to the Food and Agriculture Organization (FAO), agriculture accounts for approximately 70% of global freshwater use, with nearly 60% of this water lost due to inefficient irrigation practices. IntelliFarm combats this issue with soil moisture sensors that automatically activate irrigation systems when necessary, conserving water and reducing costs for indoor farmers. This precise approach to irrigation is essential for hydroponic systems and other water-sensitive indoor setups.

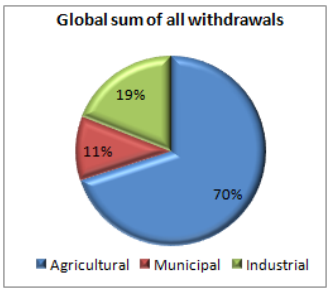
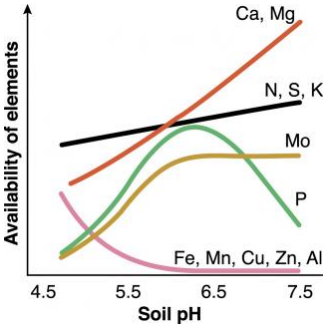


Photo credit

Soil health is equally vital, especially for high-yield indoor farming where nutrient-rich soil is key to maximizing output. Research by the American Society of Agronomy indicates that poor soil pH management can decrease crop yields by up to 30%. IntelliFarm's pH sensors monitor soil acidity in real time, providing actionable insights via email using SNS that enable users to apply corrective fertilizers promptly like adding lime to an acidic soil to reduce the pH. This not only boosts crop health but also minimizes nutrient runoff and ensures long-term soil viability, even in small-scale indoor farming operations.



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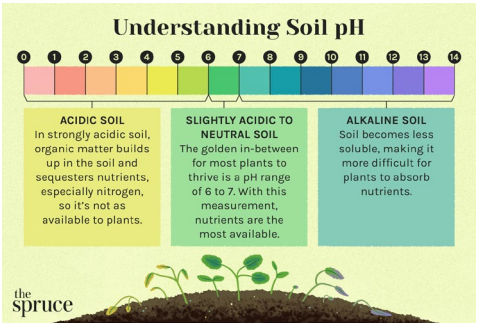


Photo credit

Temperature and humidity fluctuations pose another major challenge. Indoor farms often house crops that are sensitive to environmental changes, with deviations potentially leading to issues such as poor pollination, dehydration, and fungal infections. IntelliFarm's temperature and humidity sensors continuously monitor these conditions, alerting users to any anomalies via real-time notifications. For example, by detecting high humidity, IntelliFarm can help farmers deploy dehumidifiers to prevent pest infestations and other adverse effects, reducing yield losses and ensuring optimal growth conditions. Another example would be by detecting high heat when unnecessary for that point of a plant's growth, the Heat Pumps will be put in cooling mode and cool the general area.

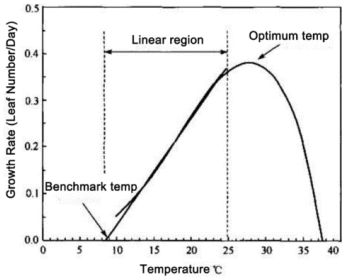


Photo credit

Light management is a cornerstone of indoor farming, where artificial lighting plays a critical role in plant growth and productivity. IntelliFarm's light sensors monitor and adjust artificial lighting to maintain ideal levels for photosynthesis. When natural light is insufficient, the system automatically activates grow lights and notifies users of the change. According to a report by the Department of Energy (DOE), advanced LED grow lighting systems can increase crop yields by up to 40% in controlled environments while reducing energy consumption by up to 50% compared to traditional lighting systems. By leveraging such precise lighting controls, IntelliFarm not only improves plant growth but also minimizes energy costs, addressing a major operational expense for indoor farms.

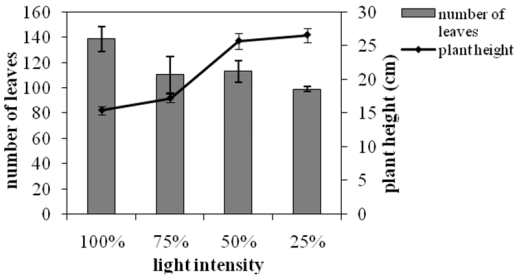


Photo credit

Labor efficiency is another key factor driving the need for IntelliFarm. According to the USDA, agricultural labour costs in the United States have risen by 16% over the past decade. Medium to large-scale indoor farming operations require automated solutions to reduce reliance on manual monitoring and repetitive tasks. IntelliFarm's automation capabilities alleviate this burden, enabling farmers to focus on strategic activities while ensuring consistent operational efficiency.

By addressing these pressing challenges, IntelliFarm empowers indoor farming operations to achieve higher productivity, sustainability, and cost-efficiency. The solution's ability to conserve water, maintain optimal growing conditions, and automate critical tasks highlights its value in the rapidly evolving agritech landscape. Indoor farmers can rely on IntelliFarm to make data-driven decisions, reduce waste, and ensure consistent yields, thereby solidifying its role as a transformative tool in modern agriculture.

Tangible and intangible benefits of the IoT Solution for potential users

The first tangible benefit is it directly contributes to a measurable **increase in crop yields** by enabling precision agriculture. Real-time monitoring of soil and environmental conditions ensures that crops grow under optimal conditions, safeguarding soil health and optimizing irrigation schedules. This translates to higher productivity and an increase in the quantity of market-ready produce, enhancing both profitability and reliability for farmers. Another significant tangible benefit is the **optimization of agricultural resource usage**, resulting in reduced wastage. With IntelliFarm, farmers receive timely alerts for soil chemical adjustments, eliminating the guesswork associated with fertilizer or lime application. Soil moisture sensors further conserve water by automating irrigation, activating sprinklers only when necessary and halting them once the optimal moisture level is reached. This targeted approach minimizes resource consumption and reduces operational costs, making indoor farming more sustainable and cost-efficient. Additionally, the **real-time alerts provided** by IntelliFarm empower farmers to pre-emptively address environmental risks. Delivered via email, these notifications inform users about critical factors such as temperature, humidity, and light levels, enabling them to take timely corrective actions to mitigate risks like heat stress, pest outbreaks, or environmental imbalances. This capability enhances farm management strategies, leading to a significant reduction in crop losses and ensuring smoother operations.

On the intangible side, IntelliFarm plays a vital role in **promoting sustainable farming** practices. By conserving water, reducing chemical overuse, and maintaining soil health, it contributes to ecological balance and helps mitigate the effects of climate change. This alignment with sustainable practices not only benefits the environment but also enhances the reputation of farms, meeting modern consumer expectations for responsible resource management. The **enhanced decision-making capabilities** provided by IntelliFarm represent another critical intangible benefit. By delivering actionable insights based on real-time data, the solution empowers farmers to make smarter, data-driven decisions. This reduces dependency on guesswork and fosters confidence in farm management, paving the way for strategic planning and long-term improvements in productivity and operational efficiency. Finally, IntelliFarm significantly improves **the well-being of farmers** by automating labour-intensive tasks. The system reduces the need for manual monitoring and intervention, alleviating physical strain and saving valuable time. This

allows farmers to focus on strategic aspects of their operations or enjoy a better work-life balance, an immeasurable yet profoundly impactful benefit. Together, these tangible and intangible benefits make IntelliFarm a cornerstone solution for modern indoor farming, ensuring greater productivity, sustainability, and farmer satisfaction.

Scope

Functionalities and capabilities of your IoT Solution

IntelliFarm offers a robust IoT-enabled platform specifically tailored to meet the challenges of indoor farming. Its functionality revolves around advanced sensors, seamless connectivity, and intelligent data processing to optimize resource utilization, boost productivity, and ensure sustainability. The core features of IntelliFarm leverage real-time data collection and automation to empower farmers with actionable insights and precise control over environmental conditions.

The Soil Moisture Sensor, such as the YL-69 or Capacitive Soil Moisture Sensors, plays a pivotal role in water management. These sensors monitor the water content in the soil by measuring its electrical conductivity, with lower conductivity indicating drier conditions. When soil moisture falls below a predefined threshold, IntelliFarm automatically activates irrigation systems via an Amazon Lambda function, ensuring that crops receive optimal water levels. Once the soil reaches the desired moisture content, the sprinklers shut off, and a detailed email is sent through Amazon SNS. This email provides a summary of the operation, including starting and stopping times, total runtime, moisture levels, and water usage. This precision in irrigation minimizes water waste while maintaining ideal growing conditions.

IntelliFarm's Soil pH Sensor ensures soil health by monitoring its acidity or alkalinity through an electrode that detects hydrogen ion activity. By storing the pH data in DynamoDB, farmers have access to real-time insights into soil conditions. When the pH values deviate from optimal ranges, an automated alert via email suggests corrective measures, such as applying lime to reduce acidity. The system's regular monitoring intervals ensure timely actions, enhancing crop suitability and preventing nutrient imbalances that could compromise yield. The integration of AWS DynamoDB allows IntelliFarm to efficiently handle large-scale data, ensuring scalability and seamless integration with other AWS services.

The solution also incorporates Temperature and Humidity Sensors like the DHT22, which provide critical data on environmental conditions. These sensors use a thermistor for temperature readings and a capacitive humidity sensor for relative humidity. Data is collected at intervals and analysed in real time to detect deviations. If conditions become unfavourable, farmers are alerted immediately via email. Additionally, IntelliFarm can automate responses such as activating heat pumps to cool or warm the environment or deploying dehumidifiers to maintain optimal humidity levels. This automation helps

mitigate risks such as heat stress, dehydration, or fungal infestations, ensuring consistent crop health.

Light management is another essential component of my solution, facilitated by light sensors that monitor and adjust illumination levels to optimize photosynthesis. When natural light is insufficient, the system automatically activates LED grow lights and notifies users of the adjustment. This intelligent light management ensures crops receive consistent lighting for maximum productivity while minimizing energy consumption. By leveraging energy-efficient LED systems, IntelliFarm also reduces operational costs, addressing a significant expense in indoor farming.

Sensor data is stored in AWS DynamoDB, chosen for its low latency, high scalability, and compatibility with AWS Lambda for event-driven processes. To optimize storage and processing, IntelliFarm collects sensor readings at intervals tailored to the specific requirements of indoor farming, such as every 15 minutes. This strategy strikes a balance between providing granular insights and maintaining storage efficiency.

The IntelliFarm dashboard, designed with user-friendliness in mind, provides farmers with a comprehensive overview of their farm's conditions. Real-time visualizations, such as line graphs for temperature and humidity trends or heatmaps for soil moisture and pH variations, enable quick identification of issues. AWS QuickSight powers these visualizations by transforming and analysing structured data stored in AWS S3. Through integrations with AWS Athena, the dashboard reflects real-time updates, allowing farmers to make data-driven decisions. Moreover, the dashboard includes preconfigured insights, such as optimal ranges for soil moisture and pH for specific crops, eliminating the need for external research and enabling faster corrective actions.

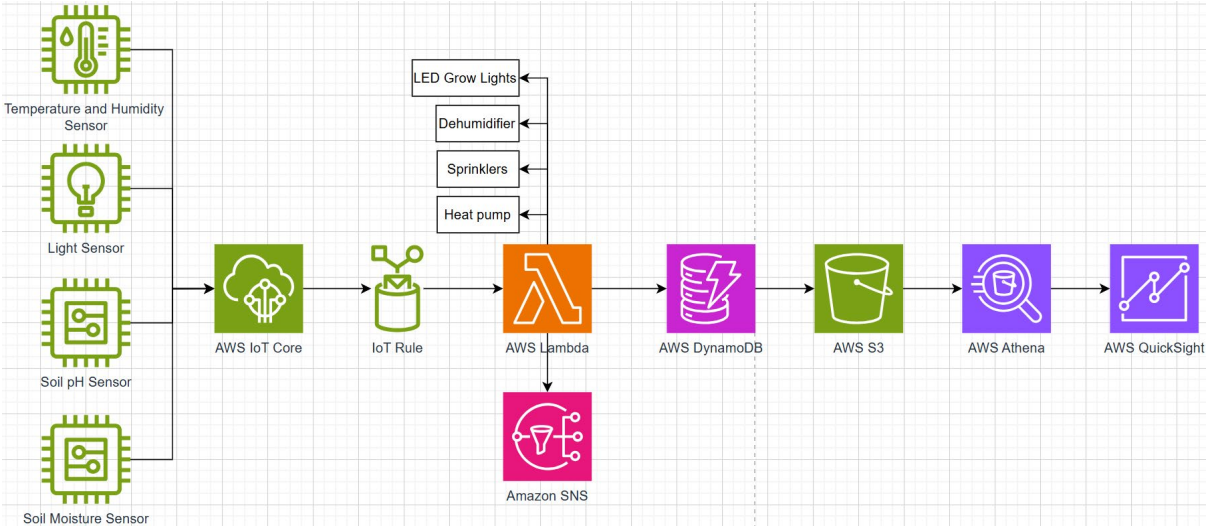
Data transmission in IntelliFarm relies on Wi-Fi as the primary connectivity solution. Wi-Fi provides a cost-effective and reliable network infrastructure for medium to large-scale farms, allowing the sensors to transmit data to amazon web services in real time. By leveraging existing Wi-Fi networks, IntelliFarm ensures minimal additional infrastructure costs while maintaining high-speed, low-latency communication. This connectivity enables seamless integration between IoT devices, AWS services, and the user dashboard, ensuring data flows uninterrupted and users are promptly informed of any significant changes in their farm's conditions.

IntelliFarm is powered by the Arduino-based ESP32 microcontroller, which acts as a centralized control hub, connecting all devices. It collects real-time data from sensors (soil moisture, pH, temperature, humidity, and light) and processes this information for automated decisions. The ESP32's built-in Wi-Fi enables secure data transmission to AWS for storage and analytics, while also allowing bidirectional communication to control actuators like irrigation systems, LED lights, and heat pumps. This integration ensures

efficient, real-time monitoring and control, enhancing productivity and user experience for farmers.

Overall, IntelliFarm integrates precision farming technologies with advanced data analytics to deliver a transformative solution for indoor agriculture. By automating critical processes and offering detailed insights, the platform enhances productivity, reduces resource wastage, and ensures sustainable farming practices. With its ability to monitor, alert, and act in real time, IntelliFarm sets a new standard for efficiency and innovation in controlled-environment agriculture.

Architecture Diagram



Data Table

Attributes	Data Type	Description	Example
DateTime	String (Partition Key)	A time stamp of when the data was read	"2024-12-03T10:15:30Z"
SoilPH	Number	The pH level of the soil, indicating its acidity or alkalinity. A pH of 7 is neutral, lower values indicate acidity, and higher values indicate alkalinity.	6.8
SoilMoisture	Number	The water content in the soil, typically represented as a percentage of soil saturation. Higher values indicate wetter soil.	45.5
Temperature	Number	The ambient temperature at the time the data was recorded, typically measured in degrees Celsius	25.3

Humidity	Number	The percentage of moisture present in the air, relative to the maximum amount the air can hold at a given temperature.	60.2
LightIlluminance	Number	The intensity of light in the environment, measured in lux (lumens per square meter). Higher values indicate brighter conditions	1500

Limitations

One significant limitation of IntelliFarm is its reliance on stable internet connectivity for real-time operations, which can pose challenges in areas with poor or unreliable internet infrastructure. For instance, the solution depends on Wi-Fi to transmit sensor data to AWS for storage and analysis and to deliver notifications via Amazon SNS. This dependency limits the utility of IntelliFarm for farmers in remote or rural areas where network coverage may be inconsistent. A potential mitigation strategy involves integrating alternative connectivity solutions such as Low-Power Wide-Area Networks (LPWAN), including LoRaWAN or Sigfox, which are specifically designed for long-range, low-power communication in challenging environments. Additionally, satellite-based communication could serve as a fallback for extremely remote locations. Incorporating an offline data storage mechanism within the system would further ensure that sensor readings are temporarily stored locally when internet access is disrupted and synced with cloud services once connectivity is restored. This hybrid approach would enhance IntelliFarm's reliability across diverse farming setups.

Another notable limitation is the high initial cost associated with implementing IntelliFarm. The expense of acquiring advanced sensors, integrating IoT infrastructure, and setting up cloud services can be prohibitive for some farmers, particularly those operating in regions with limited access to funding or subsidies. This high cost could deter adoption, even among medium to large-scale farmers who are the target audience for this solution. To address this issue, several approaches can be explored. Governments or non-governmental organizations could provide subsidies or grants to promote the adoption of IoT-based precision agriculture tools. Agricultural cooperatives can also play a role by negotiating bulk purchases to lower costs for their members. Alternatively, IntelliFarm could be offered through leasing models, which would allow farmers to pay for the solution over time rather than incurring a substantial upfront expense. This would reduce the financial burden and make the system more accessible to a broader audience.

A further limitation is the potential for sensor calibration issues, which can compromise data accuracy over time. Sensors used for soil moisture, pH, temperature, humidity, and light measurement may drift from their original calibration due to prolonged use, exposure to harsh environments, or manufacturing variances. If not promptly detected and recalibrated, these inaccuracies could lead to suboptimal irrigation, lighting, or fertilization decisions, ultimately impacting crop health and yields. To mitigate this, IntelliFarm could include automated calibration checks and alerts, notifying users when a sensor requires recalibration or replacement. For example, the system could compare

sensor readings against known reference conditions or introduce redundancy by using multiple sensors in critical areas to cross-verify data accuracy. Providing users with straightforward calibration tools or partnering with local service providers for maintenance support would further reduce the impact of this limitation. These measures ensure sustained accuracy and reliability, vital for the long-term success of IntelliFarm in precision indoor farming.

References

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