

Sustainable Smart Agriculture

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ABSTRACT

As the weather changes drastically, there are natural phenomena that cannot be stopped, such as El Niño. Based on NASA's report, during an El Niño, the tropical Pacific Ocean warms up more than usual and this causes disruption to the planting season. Also, plants usually wither due to the heat, requiring more frequent watering as a result of high chances of evaporation this may lead to over-watering or under watering. Insufficient soil preparation can prevent water and nutrients from reaching plant roots. These are one of many problems faced by gardeners. This project ought to help gardeners successfully harvest crops. Taking the variety of plants, specifically; Chinese White Cabbage (Pechay), Lady Finger's (Okra), and Tomato (Kamatis) as the target group. Additionally, this project offers unique features such as the NPK sensors and the harvest forecasting, another feature is the automatic irrigation of crops, soil moisture sensor will help address problems for soil preparation as this measures the quantity of water in the soil. To add, an application is used to control automation and record parameters such as sensor updates of the NPK and Soil Moisture indicating the level of water and required amount of Nitrogen, Phosphorus, and Potassium.

Hence, Sustainable Smart Agriculture has the potential to completely transform gardening by guaranteeing abundant crop yields.

Keywords

Internet of Things; Irrigation; Arduino Uno; LCD; NPK; Sensor; Soil Moisture; Smart Device

1. INTRODUCTION

From the statistics and facts about agriculture in the Philippines, the major sector of the economy in the Philippines is agriculture, coming third after the Service and Industry sector in the year 2022. Not only the growing population threatens the growth of agriculture development but also the climate change. As the weather changes drastically, there are natural phenomena that cannot be stopped, such as El Niño. Based on NASA's report, during an El Niño, the tropical Pacific Ocean warms up more than usual and this causes disruption to the planting season. Also, plants usually wither due to the heat, requiring more frequent watering as a result of high chances of evaporation this may lead to over-watering or under watering. Insufficient soil

preparation can prevent water and nutrients from reaching plant roots. These are one of many problems faced by gardeners.

Now that technology extends to many areas, agricultural problems can be addressed easily. This project ought to help gardeners successfully harvest crops. To be able to test the functionality of the device three plants will be tested, specifically; Chinese White Cabbage (Pechay), Lady Finger's (Okra), and Tomato (Kamatis). NPK soil sensors will be used to keep these plants in check when fertilizer is needed. Another problem is the low soil quality, which is usually caused by a lack of nutrients. Plants grown in these types of soils are unable to produce more fruits, which reduces yields. NPK are the three elements found in fertilizer mixtures; nitrogen, phosphorus, and potassium that will be used to increase the growth of plants.

The other feature is the automatic irrigation of crops, soil moisture sensor will help address problems for soil preparation as this measures the quantity of water in the soil. There are set thresholds in the algorithm once the values exceed this will allow for automated watering, providing a variable amount of water based on the plants' needs. Simultaneously, when the watering feature is triggered, the program records a timestamp and sensor findings in the database. The recorded parameters in the app are the required nutrients, and time table for expected date of harvesting the plants.

2. RELATED LITERATURE AND STUDIES

Presented below is the estimated total annual volume of wastewater produced from both municipal and major agricultural industries in the Philippines that is calculated to be about 7,465 million cubic meters.

Table 1. Estimates of Wastewater Production and Treatment use in the Philippines

Sources	Raw Production	Unit	Factor	Annual wastewater produced (cum)	Dominant Treatment
Municipal	103,476,574	a/ no. of people	50 gal/day*	7,081,678,033	Primary
Industries					
1. swine production	9,401,896	b/ no. of head	6 cum/hd**	56,411,376	Primary & secondary
2. poultry processing plants	404,898,534	b/ no. of birds	37.5 cum/1000**	15,183,695	Primary & secondary
3. sugarcane milling company	2,244,131	b/ MT	139 cum/MT**	311,934,209	Primary & secondary
GRAND TOTAL				7,465,207,313	

Another representation of water wastage is analyzed in figure 1, from this it can be concluded that the traditional method of

watering plants consumes more water than is required for good yield of a plant and hence water wastage is performed. On the other hand, by using an Arduino project for irrigating plants the right amount of water is provided by calculating moisture content of plant soil therefore no water wastage at all.

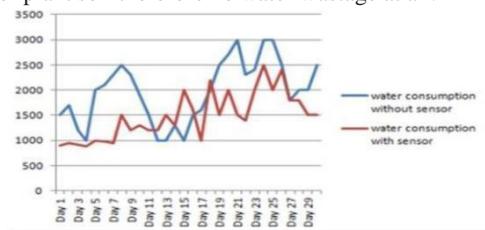


Figure 1. Zig-Zag Representation of Comparison of Water Consumption and Without Water Sensor in Agriculture in the Philippines

From the study Arduino based automatic irrigation system: Monitoring and SMS controlling that are conducted by Yasin et. Al (2019) stated that today's technology has made irrigation simpler. With the help of soil moisture sensors and the measurement of their value through the microcontroller and automatic ordering of irrigation without the need to use workers to do so. One of the things that farmers now must think about is conserving water and time. By providing water in accordance with growth requirements, automated irrigation promotes plant development and decreases leaf withering.

Looking at this study of Koech & Langat (2018) that examined the progress made in increasing irrigation water use efficiency, or WUE, with an emphasis on irrigation in Australia but also including some instances from other nations. There is a discussion of the difficulties faced and the chances that exist. The analysis demonstrated how modernization and automation of irrigation infrastructure have improved it and reduced water consumption. Although the idea of real-time irrigation control and optimization is still in its infancy, it has already shown promise in terms of water savings. To improve WUE, more sophisticated sensors, wireless communication systems, and remote sensing techniques will probably be used in the future. When efficient technologies are deployed, water saved is sometimes repurposed to extend the area under irrigation, which can occasionally lead to a net increase in the amount of water consumed at the basin size. Water-efficient technology and practices must therefore be used in conjunction with other strategies, such as conservation incentives and suitable legislation that restricts water allocation and consumption, in order to achieve net water savings. Engineering and technology developments, advances in plant and pasture science, environmental conditions, and socioeconomic considerations are some of the elements that influence the trends in the irrigation WUE. Potential obstacles include a lack of public support, particularly when the methods being utilized are not cost-effective, and irrigations' reluctance to accept new technologies.

There are three plants used for the testing of the functionality of the device. These are fast growing plants suitable for the Philippine climate condition. The first one is Okra, also known as gumbo or lady finger, is an easy to grow plant under the Philippine's hot climate.

A field experiment was conducted on sandy soil by Mohsen and Abdel- Fattah at El-Khattara Experimental Farm, Faculty of Agriculture, Zagazig University, Sharkia Governorate, Egypt during two successive summer seasons of 2013 and 2014. The experiment was carried out under a drip irrigation system. The treatments consisted of 14 treatments, which were the combination between two botanical compost (without compost and with compost) and seven levels of nitrogen and phosphorus fertilizer, results showed that application of botanical compost led to increase the yield and NPK uptake by okra plant. This

study suggests that okra responds to different levels of nitrogen and phosphorus combined with or without botanical compost under sandy soil in Egypt

Another easy growing plant is Pechay, this plant thrives easily in tropical weather conditions. After 30 or 40 days from planting, mature pechay plants will be ready for collection. From the study of pechay's response to different levels of compost fertilizer conducted by Leif Marvin R. Gonzales and Maita Aban the compost application greatly increased or influenced the growth and development of pechay plants in terms of plant height, number of leaves, and fresh weight per plant and area.

A research study authored by Fucheng et. Al about the effect of organic fertilizer in tomato yield and quality shows an increase in soil organic matter. The nutrient and water retention capacity increased with organic matter accumulation, thus increasing tomato yield.

As stated by M. Yildirim (2016), During the trial, decisions for irrigation were made based on the water level sensor's feedback, and activities were carried out continuously. It emphasizes how crucial a water level sensor is to an effective irrigation system. Additionally, Dursun and Ozden (2011) mentioned there are several benefits to using sensor-based site-specific irrigation, including avoiding trees' moisture stress, lowering of wasteful use of water, guaranteeing weed growth and disparaging presentation.

To better understand the role of fertilizer, Glen Chandler stated on his article What Does Fertilizer Do: Uncovering Its Role in Plant Health and Growth published on March 21, 2024, Fertilizer is an integral component in modern agriculture and horticulture, providing plants with essential nutrients that they need to grow. The primary purpose of fertilizer is to replenish the soil's nutrient content, especially after it has been diminished by previous plantings. Using fertilizers correctly can significantly enhance plant growth and productivity.

One of the types of fertilizer is biofertilizer, Anchita Borah and Hiren Das highlighted the use of this in their study Liquid Bio-Fertilizers: A Replacement Tool for Chemical Fertilizer. Just Agriculture multidisciplinary e-Newsletter. Biofertilizers enhance factory nutrient vacuity and soil fertility, with microorganisms playing a salutary part in nitrogen obsession, phosphate solubilization, and biomass product. They're provident, renewable, and eco-friendly, but cannot replace chemical diseases entirely. Biofertilizers are essential for Integrated Nutrient Management and organic husbandry, as changing agrarian practices and environmental hazards demand a more significant part for biofertilizers.

Shanal Aggarwal uncover the evolution of the Internet of Things (IoT) he asserted that The Internet of Things, or IoT, is like a giant invisible web that connects everyday objects to the internet. Here are some studies that shows the successful emergence and usage of IoT.

In order to help farmer in analyzing and make better decision in any stage of cultivation Internet of Things pave its way, Senapaty et. Al published an article entitled IoT-Enabled Soil Nutrient Analysis and Crop Recommendation Model for Precision Agriculture. From this, the proposed model consists of phases, similar as data collection using IoT detectors from civilization lands, storing this real- time data into pall memory services, penetrating this pall data using an Android operation, and also pre-processing and periodic analysis of it using different literacy ways. The fact results from the experimental data that applying liquid diseases with humic substances in several phases during shop foliage is a feasible result for carrying assured yield increases. It'll allow the planter to assay his own field data with a more detailed approach for making better opinions regarding crops and maintaining soil health, if the operation is used regularly by a planter to maintain his own field information. The planter can take the necessary way to enhance the soil quality with limited

investment in minerals. The model aids in lowering the use of fertilizers in soil in order to improve productivity.

Moreover, this study of Liang & Shah IoT in Agriculture: The future of Precision Monitoring and Data-Driven Farming provides an overview of the impact of IoT on agriculture, pressing its transformative potential. IoT bias, including detectors and drones, are considerably stationed in granges to cover vital parameters similar to soil humidity, temperature, moisture, crop health, and beast conditions. Real-time data collected by these biases is transmitted to a central platform, empowering growers to cover their fields and creatures with unknown delicacy. The operation of perfection monitoring enables early issue discovery and visionary interventions, minimizing losses and maximizing yields. IoT in agriculture optimizes the operation of critical coffers by furnishing real-time data on soil humidity situations and crop health. This allow growers to precisely apply water and nutrients, reducing destruction and promoting resource conservation while securing the terrain. robotization and smart husbandry systems influence IoT bias integrated with selectors and regulators. These systems automate tasks like irrigation, fertilization, and pest control grounded on predefined conditions or data inputs. Robotization reduces homemade labor, streamlines operations, and enhances effectiveness.

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Another technology that helps farmers is the use of AI, the study of Thilakarathne et. Al, A cloud enabled crop recommendation platform for Machine Learning-Driven precision farming, they give an overview of AI-driven perfection farming/agriculture with affiliated work and also propose a new pall-grounded ML-powered crop recommendation platform to help growers in deciding which crops need to be gathered based on a variety of known parameters.

Just like the previous literature, Teen et. Al authored Soil analysis and nutrient recommendation system using IoT and Multilayer Perceptron (MLP) model the researcher used AI and IoT to solve several issues such as human errors, poor performance of sensors, and inaccurate data reports. Soil operation systems need to be enhanced with the integration of AI algorithms and machine literacy. In this chapter, an upgraded multilayer perceptron(MLP) model is proposed to enhance the soil operation system. The model is grounded on data collected from an IoT-enabled soil monitoring system. The performance of the proposed methodology is assessed through the use of colorful evaluation criteria, including mean absolute error(MAE), mean square error(MSE), and root mean square error(RMSE), as well as several statistical tests. The experimental issues indicate that the MLP model proposed in this study outperforms traditional machine learning algorithms.

A supporting article about soil analysis was uploaded by the University of Massachusetts Amherst, stated here that soil test is important for several reasons: to optimize crop production, to protect the environment from contamination by runoff and leaching of excess fertilizers, to aid in the diagnosis of plant culture problems, to improve the nutritional balance of the growing media and to save money and conserve energy by

applying only the amount of fertilizer needed.

Then the authors Sujatha et al. developed a smart agriculture system grounded on the IoT that's able to automate irrigation and monitoring crop fields using colorful detectors, including those for light, moisture, temperature, and soil humidity. To enable irrigation in a proper manner, this exploration design incorporates a variety of features like soil humidity, temperature, and a moisture detector by the authors C. Mageshkumar and Sugunamuki. In this exploration, the work proposed by the authors Dahane et al. is based on wireless detector network technology, and its perpetration includes three main stages: data gathering using detectors placed in an agrarian field, data cleaning and storehouse, and vaticination processing using some AI ways.

3. PROPOSED ARCHITECTURE

This section shows the connection of the application and the hardware between each other's interaction.

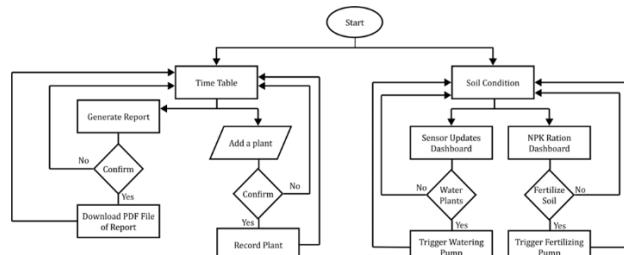


Figure 1. Device Block Diagram

Figure 2 is the hardware architecture of this project consisting nine (9) major hardware components, including: an Arduino Uno Microcontroller which serves as the main controller and coordinator of the other components, Moisture Sensor, Water Level Sensor, LCD I₂C, two (2) 5V Relay Module and 6 Mini water pumps with small pipe, LCDI2c, and a NodeMCU ESP8266 which allows it to transverse and receive critical data and instructions to the application.

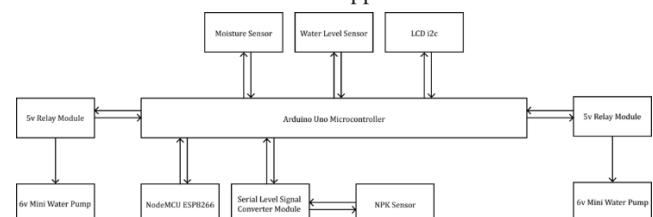


Figure 2. Design Flowchart of Device's Application

Figure 3 shows the visual representation of the application's design flow. The application will consist of two (2) main sections: Time Table section and Soil Condition section. The Time Table section includes the time table of the plants. It consists of the date of when the plant is planted, assumed date of harvest, and watering and fertilization history of the plant. On the other hand, the Soil Condition section includes a dashboard where you can monitor the sensor updates such as real-time temperature, humidity, soil moisture, and water level available on the water tank. Under the senor updates dashboard is a button for triggering the water pump. Once clicked and the action is confirmed, the application will send an instruction to the device to water the garden otherwise it will cancel the action. As shown in Figure 2, another thing inside the Soil Condition section is the NPK ratio dashboard where you can monitor the real-time nitrogen, phosphorus, and potassium (NPK) ratio on the garden's soil as well as the required amount NPK for it. In order for the user to take an action in an instant, there is also a trigger button under the NPK ratio dashboard. Once this button is clicked and the action is confirmed, the application will send an instruction to the device to

fertilize the soil otherwise the action will again be disregarded.

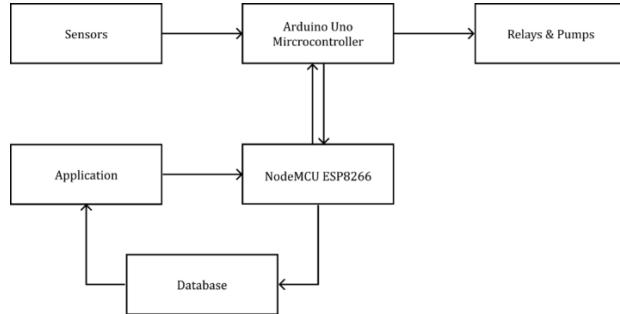


Figure 3. Hardware, Application, and Database Connection Block Diagram

Figure 4 shows the connections between the three (3) departments of the project with Arduino as its center. Sensors are devices to collect data from the physical environment. In this project, we used different sensors such as soil moisture sensor, NPK sensor, temperature sensor, etc. To transverse the necessary data from these sensors, we used the Arduino Uno microcontroller as the central system of our project. Arduino Uno interfaces with these sensors and we will write a block of codes in order to process the data coming from those. Via the built-in Wi-Fi capabilities of NodeMCU ESP8266 which is a node microcontroller unit connected to the Arduino Uno, we can now wirelessly transverse the sensor data to a database assuming that its connection is already established. The application, on the other hand, will retrieve these sensor data from the database. Once filtered and processed, it will be displayed more appealingly. Moreover, inside the application are features to remotely control the physical device as shown on figure 12. The instructions from the application can be passed through via sending control signals to NodeMCU again. These control signals will be received by Arduino Uno through serial communication. Now, Arduino Uno interprets these signals and makes decisions such as toggling relays of pumps.

4. METHODOLOGY

At the first phase of this project, three different types of plants were planted, specifically; Chinese White Cabbage (Pechay), Lady Finger's (Okra), and Tomato (Kamatis). These variety of plants have different duration of growth, for Chinese White Cabbage (Pechay) it takes 30 days, for Lady Finger's (Okra) it takes 50 to 65 days to grow full size, and for Tomato (Kamatis) it takes between 60 to 100 days from when they were sown. The plants grow to vegetative stage under 33 days of observation. This means that the plants is at the 6th stage of plant growth showing stems and foliage.

The second phase is construction of the platform. In order to ensure a precise measurements and design the students created a 3D model.

The platform is ground-level using a lumber wood with 1 meter measurement for the 4 bases dimension. Strip pine wood serves as the beams of the roof measuring .5 meters in height, and using dynamo to control the automatic or manual opening of the roof this will be controlled through the app. For the plants bed, the students uses PVC pipe arranged side by side, PVC pipes offers less rigid; has high impact strength; is easier to extrude or mould; has lower temperature resistance; is less resistant to chemicals, and usually has lower ultimate tensile strength Sustainable Smart Irrigation uses PVC pipes for the plant containers, blocking both ends, and letting water flow freely without being enclosed and drowning the plants by placing tiny holes at the bottom of the pipe.

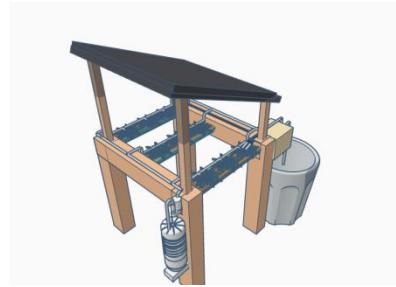


Figure 4. 3D Model of Smart Sustainable Agriculture

The third phase is installation of sensors. Smart Sustainable Agriculture uses many sensors, first is the NPK sensor, based from the article Arduino and NPK Sensor Project NPK is used to monitor the nutrition content available for plants in the soil. NPK (Nitrogen, Phosphorus, and Potassium) are plants' three vital macro nutrients, this NPK is buried in the soil. Another sensor used is the soil moisture sensor, defined from the section What is Soil Moisture? In the article Soil Moisture Sensors: Smart Tool For Precision Farming, soil moisture is an appliance for monitoring the moisture levels in the soil. Integrating this tool in the irrigation system may allow for more precise watering scheduling than is possible with past information or weather forecasts, likewise with the placement of the NPK sensor, the soil moisture sensor is also buried in the soil. To be able to keep track of the water for the automated irrigation of plants, water level sensor is used, this water sensor or water level sensor is used to detect water leakage, rainfall, tank overflow, or to measure the water level. For monitoring both the fertilizer and water level a Arduino-UNO submersible pump is used, this is submersed deep in the bottle where the fertilizer and water is contained.

For the fourth phase, coding and wiring. The application, database, and hardware are connected as explain in Figure 4. In this phase, the sensors undergoes countless of trial and errors in order to achieve the goal; to record accurate data. One of the required parameters of the software is the calculation of the right amount of NPK, from the article Fertilizer Numbers - What is NPK? Stated that typically, there are three numbers on a fertilizer label separated by dashes, representing the percentage of N, P and K and knowing the right amount of these numbers will help for the selection of the appropriate fertilizer of the plant. Coming from the same article in the section of How to Calculate for NPK Fertilizer, The fertilizer numbers can be used to calculate how much of a fertilizer needs to be applied to equal 1 pound (0.45 kg) of the nutrient to be add to the soil. So, if the numbers on the fertilizer are 10-10-10, divide 100 by 10 and this will tell mean that it need 10 pounds (4.5 kg.) of the fertilizer to add 1 pound (0.45 kg) of the nutrient to the soil. If the fertilizer numbers were 20-20-20, divide 100 by 20 and it will take 5 pounds (2.2 kg) of the fertilizer to add 1 pound (0.45 kg) of the nutrient to the soil. This calculation leads for the successful recommendation of the software about the right amount of fertilizer to be used and to provide the needed fertilizer for the plant. Additionally, for the harvesting forecast of the system, the day of planting was measured, depending on the recommended days of the plants harvest, the system will provide report of the date of harvesting the plants. NPK sensors are useful instruments for farmers because they enable precise monitoring of the soil's levels of nitrogen, phosphorus, and potassium. To monitor the ions of interest, these sensors usually use ion-selective electrodes. These days, NPK sensors that use sophisticated electrochemical or spectroscopic methods do not require reagents.

Last phase, surveys. The students gathered 30 respondents for the testing of the application and platform. Majority of the population

are inclined with gardening or farming.

With these phases in this project, the completion of the application and platform of Sustainable Smart Agriculture was made possible.

5. RESULT AND DISCUSSION

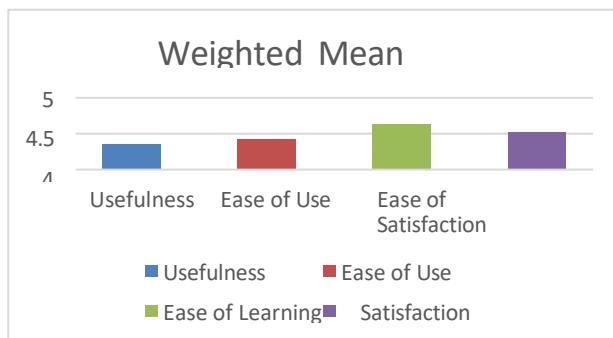


Figure 6. Weighted Mean of System Evaluation

The bar chart titled "Weighted Mean" is shown in the image, comparing four distinct categories: usefulness, ease of use, ease of learning, and satisfaction. A colored bar representing each category shows its weighted mean value on a scale that goes from 4.25 to 4.7. This indicates that the respondents strongly agree at Sustainable Smart Agriculture as valuable because it falls into the "Strongly Agree" category (4.21 - 5.00). 'Ease of Use' is represented in orange with a value slightly higher than 'Usefulness', indicating that the respondents strongly agree that the project is easy to use. "Ease of Learning" is shown in gray, and the respondents firmly seem to agree that the item is easy to learn, as indicated by the highest score of 4.6. A high degree of satisfaction among the respondents is shown by the yellow representation of "satisfaction," which has a value of about 4.53.

The weighted mean ratings for these categories are effectively communicated by this chart, which is the result of a survey or study evaluating these characteristics of the functionality, ease of use, usefulness, and satisfaction. According to the research, the respondents are rather happy with the project and found it to be easy to understand.

Based from the graph presented above the total combined weighted mean of usefulness, ease of use, ease of learning and satisfaction is 4.48. The Smart Irrigation System is rated strongly agree by the respondents, implying that the system performs exceptionally well across these dimensions, indicating positive user experiences.

6. CONCLUSION

To sum up, Sustainable Smart Agriculture has the potential to completely transform gardening by guaranteeing abundant crop yields. The companion app for the project tracks the needs of the plants and reports on water and fertilizer requirements in addition to managing harvesting forecast. The software helps users maintain ideal water levels, and the integration of NPK soil sensors enables accurate monitoring of soil nutrients. This technical development has improved crop production of crops including pechay, okra, and kamatis and strengthened agricultural resilience, especially against El Niño's erratic patterns. Both too little and too much watering can harm a great deal of plants and increase their susceptibility to illness. Plants that receive consistent, well-managed watering grow stronger,

happier, and more vibrantly, which requires less work to maintain a beautiful garden. The programme has streamlined gardening tasks by integrating an automatic watering system with NPK and soil moisture sensors. Furthermore, the app's ability to predict harvest timings has shown confirmed findings, paving the way for a revolutionary transformation in precision farming and providing long-term answers to the problems brought on by climate change.

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