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Application of Machine Learning in Precision Agriculture using IoT

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***Abstract*: The demand for food has been increasing over the past six decades with the global population increase. Scientists have been finding different ways to meet this demand, such as; green revolution and genetically modified crop methods. These involve an unnatural technique to increase the yield, such as chemical fertilizers, pesticides, and modified seeds; these might be beneficial in the short term but might slowly disturb the internal body mechanism. In recent years, consumers are becoming more concerned about their food intake and prefer food with no adulteration and harmful pesticides. This has brought in the hype for a subdivision of framing, organic farming, where organic fertilizers and pesticides are used to retain the quality and nutrition values of the crop bring harvested. In organic farming, the right crop must be chosen according to the soil type and climate. This reduces the chance of pre-harvest crop losses caused by the abiotic stress in the environment, such as the soil pH levels, improper irrigation, climate, and temperature. However, when the desired conditions are provided to the crop, we can reduce the pre-harvest loss up to 35%. This paper offers a practical approach to reduce this loss by predicting what crop can be planted according to the present soil conditions and climate to prevent pre-harvest losses. The model involves a temperature and humidity sensor, a soil moisture sensor, a soil pH sensor, IoT, and a water pump under a greenhouse environment connected with the help of a development board, Raspberry pi, and machine learning techniques.**

Keywords: Machine learning, pre-harvest Loss, Internet of Things (IoT), soil pH sensors, soil moisture sensors, temperature sensors, precision agriculture

I. INTRODUCTION

Agriculture is an essential sector in a nation's economy. With the increasing global population and the per capita income, the demand for food crops is also increasing, and it is estimated that the crop demand will increase about 100%-110% from 2005-2050 [1]. As per the study, the demand for food by 2030 will be more than today as the world population is expected to be 8.5 billion [2]. Search for the solution to meet this demand in an ongoing process, but we can yield the maximum from crops by providing the basic needs that a crop requires. Most crops are seasonal; therefore, it is important to choose the crop according to the soil's climatic conditions, temperature, and moisture content. Temperature also plays a very important role as high temperature (680 F to 860 F) is required for the germination process, and in low temperature, the plant growth is hindered, and seeds enter the dormancy stage. Some of the main factors that affect crop yield are temperature and water levels; it is important to keep the moist soil while not overwatering it to prevent the roots from rotting. Pre-harvest crop losses are due to biotic and abiotic stress. In a year, about 35% of the possible yield of rice crops is damaged before the harvest. Pests, weeds, bacteria, etc cause biotic stress. Whereas abiotic stress is caused by temperature, drought, soil pH levels. Soil pH needs to be maintained between (5.5 to 8) less or more than this range is not optimum for crops, soils beyond this range will make the crop disease-prone, and high pH levels will decrease the phosphorus levels is necessary for flowering and fruiting. Water stress that is caused by overwatering or under watering can inhibit plant growth and the process of photosynthesis. Therefore, it is necessary to keep checking the crops based on these factors, but it is time-consuming to do this physically on a regular basis; therefore, this can be achieved with an application program through machine learning method.

II. MACHINE LEARNING

Machine Learning is the subtopic of artificial intelligence; it is a set of algorithms that make a system adaptive, which is the system learns from its experience not to perform the same mistake or task again. Machine learning works with a huge amount of data to provide accurate predictions. Machine learning is being used in most places, such as for programming virtual voice assistance like Siri and Google Assistant, and for product recognition in e-commerce websites uses machine learning to predict what the customer might purchase in the near future. Even in agriculture, we can use machine learning to predict the type of crop that might yield better in an environment depending upon the temperature and soil pH levels to automate the irrigation process according to the soil moisture content. As one of the reasons for pre-harvest crop losses is due to insufficient irrigation and climate. The data of the soil moisture, climate, and pH levels can be derived from the respective sensors; the machine learning programmed application will use these data to suggest what crops to be planted when connected to an automated watering system. It can also irrigate the field when necessary. Through the use of this technology, we can reduce pre-harvest crop loss.

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III. IoT AND AGRICULTURE

In agriculture, farmers can understand the amount of water present in plants, pH level, temperature, etc. [3]. Such an agricultural method is often termed smart farming, where IoT sensors are equipped, and they provide information to farmers and then can act upon the input provided by the user [4]. Food availability is a key factor in the continuing life of future generations, so should there be technology like IoT in improving the yield and efficiency of the crops. As per study 70%, more food should be produced by the world in 2050 when compared with the year 2006 so that life continues as per the UN (United Nations) Food and Agriculture Organization (FAO) and mentions that there would be a hike of 75 million in 2020 from 30 million in 2015 in the IoT devices installation [5]. In the agricultural world, which is a compound annual growth of 20%. Fig.1 depicts an increase in the agricultural IoT device shipments, proving that IoT in agriculture is proliferating over the years.

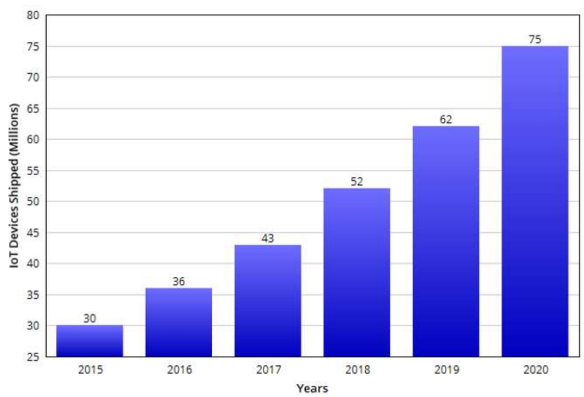

Fig.1. Estimated Agricultural IoT Devices Shipments

IV. LITERATURE REVIEW

It is an extensive challenge to satisfy the growing food demand with the finite recourse available and preserve the land's fertility; thus, a sustainable intensification process was required. This process is achieved when the agricultural technique does not affect the environment and uses only the land permitted for agriculture. [6]

Sustainable intensification is believed to increase the yield and reduce environmental damage simultaneously. The population pressure has reduced land resources, demanding farmers to opt for a sustainable farming technique. The only limitation is the greater yield gap. [7]

Crop yield and quality reduces when the abiotic stress such as the water level, climate, and soil pH levels are high. These abiotic stresses cause almost 69% of crop loss; with proper and timely care, this can be overcome with sensors' help to monitor the climate & field, water pumps to irrigate.[8]
Internet of Things (IoT) has become a common term in recent years, it is helpful to communicate with devices (transfer data back and forth) from anywhere around the globe, with the only requirement being the Internet. IoT technologies are beneficial in automating many processes in various domains like in industrial agriculture [9], smart home [10], tourism [11], people analytics [12], transportation [13], parking management [14], healthcare [15] security, and so on. Evolution is IoT in precision agriculture has helped to collect data about the field and give proper inputs as required [16]

Machine learning has emerged with the developing data technologies, which has opened up new opportunities in the agricultural sector. In crop management, it is used for yield prediction and disease spots. Machine learning uses the data(examples) given, which has different attributes; data is analyzed with these attributes' help. The Machine Learning model is given a set of test data to improve the model through experience [17].

As insufficient or excessive irrigation can develop abiotic stress, it is important to monitor the soil moisture levels. It is important to maintain the moisture levels between the minimum balance level and field capacity, which may vary with the soil type and crop. When the moisture levels go below the minimum balance, then the plant develops stress, which can reduce its quality. Through soil moisture sensors, data is collected to manage the irrigation system. [18]

Soil moisture sensor measures the moisture content through the soil technique's electrical resistivity; when there is more moisture, the resistivity will be low, and with low moisture levels, the resistivity will be high (Fig.2) [19]. The data collected will be sent to the Raspberry Pi, analyzing and determining when to turn on the water pump and for how long.

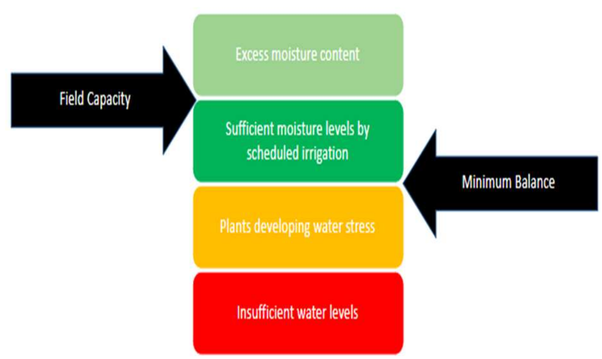

Fig.2. Soil moisture and its resistivity

The optimum pH for plants is between 5.5 pH to 6.5 pH beyond this range makes the plants prone to disease. Crops in this optimum range have proven to produce more; through soil pH management techniques the global crop production can increase up to 60% to 120% by 2050. PH levels can be observed with the help of soil pH sensors. [20]

Humidity is the amount of water vapor in the atmosphere; too much humidity can reduce the evaporation rates, leading to a decrease in the soil's nutrients. Humidity rates are high in cold temperatures. In a warm climate and low humidity rates, transpiration increases, helping nutrients from the soil to continuously circulate in the plant. It is essential to irrigate according to the humidity levels. [21]

Lower temperatures promote fungal and bacterial growth in plants or soil, leading to rotten roots and crop failure. Temperature can be controlled through the greenhouse method [19]. Drought stress in plants occurs when the temperature is high, and the relative air humidity is low, a rise of 10 – 15 0C above the optimal temperature can lead to lower photosynthesis and transpiration (ex: 22 0C-320C, which can reduce the root growth and drying up of leaves. [22]

Therefore, it is essential to monitor the crop for any fungal or pest infestation and predict them according to the temperature. This can be done by a Humidity and Temperature sensor like the DTH11 is a digital sensor and can be directly connected to the microcontroller/ single-board computer, and it gives new data every 2 seconds. [23]

Monitoring the crop for plant growth and microbial growth can be done through image processing techniques. Scheduled capturing the image of the crop gives the leaf pattern. As plants communicate through leaves its color, shape, and pigmentation pattern can tell us about the plant's health condition. The image captures by the webcam undergoes numerous computer algorithms to perform image processing where the input (which can be an image or video) is processed by pattern recognition, attribute extraction, signal analysis, and projection in the Raspberry Pi. [24]

Irrigation is done through water pumps, which are timely, turned on and off according to the requirement, the data collected from the sensors and transmitted to the Raspberry Pi, which sends the instruction to turn ON or OFF the water pump through intranet. [25]

A. *Green House*

As plants grow efficiently in a warm and moist environment, Greenhouse protects the plants from extreme cold and controlling the temperature inside. [26]

When the temperature inside the greenhouse reduces below a specific temperature, the external heating system must increase the temperature. [27]

The growing environment for plants can be very well controlled under a greenhouse; greenhouse farming has proven to provide better yield and a healthier agro ecosystem. It has increased vegetable production by 35% in China, according to (National Bureau of Statistics of the People’s Republic of China [NBSC], 2014). [28]

B. *Image Processing*

In image processing, the web camera captures the image and sent to Raspberry pi, compared with the reference image; objects absent in the reference image are considered weeds and pests. Edge detection, color segmentation, and clustering are techniques under image processing to differentiate the weeds and crop based on the edge frequency and color of the plant, both crop and weed. Image processing can also identify the growth of weeds as some weeds dominate the crops and thrive consuming the nutrients present in the soil; this leads to nutrition definitely for the neighboring plants. [29]

Image processing helps to detect fungal or pest activities in their early stage. Thus, early diagnosis is made to prevent any significant damage to the crop. The output from the Raspberry pi is sent to the application and can be viewed by the farmer, who can make appropriate decisions based on it. [24]

V. Framework For Precision Agriculture

Following Fig.3, represent the framework for the precision agriculture model, where raspberry Pi plays a very important role in processing the information, collected through various connected sensors.

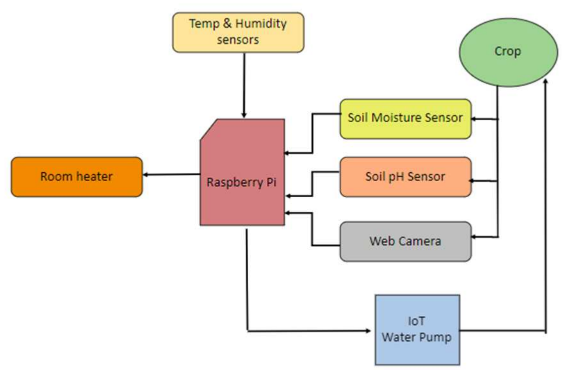

Fig.3. Framework for data collection

VI. Hardware Requirements

A. *Raspberry Pi*

Raspberry Pi, a single-board computer used for small computing and networking, provides connectivity to the Internet of Things (IoT devices) and can be accessed through the internet from anywhere around the globe. Data from sensors are sent to the Raspberry Pi, which acts as the microcontroller to perform the task. Raspberry Pi consists of a high-end CPU and sufficient RAM to process; it also offers GPIO (General Purpose Input and Output) pins, where all the sensors can be connected and a camera interface for connecting the webcam for image processing. [30]

B. DHT 11 Sensor

DHT 11-sensor module is a temperature and humidity of the immediate environment and gives a digital output signal. Its humidity measurement component is resistive type and NTC (Negative Temperature Coefficient) type component for measuring the temperature. The DTH sensor also consists of an 8-bit inbuilt microcontroller. [31]

C. Soil Moisture Sensor

Resistive soil moisture sensors are the most cost-efficient sensors. It consists of two electrode probes that pass current through the soil and determine the moisture levels based on the resistivity. It can give both digital and analog outputs. [32] These sensors are best under greenhouse conditions. [33]

D. pH Sensor

pH sensor determines the pH levels based on the hydrogen ion present in the soil. It has two electrodes and between the electrodes is the sensing layer. [34]

E. Relay

Relay is a device used to separate two circuits electrically while connecting them using electromagnetic properties. With this device, we can turn OFF the water pump without disturbing the remaining circuit. This is used to turn ON and OFF the water pump. [34]

F. Solar Air Heater

Solar air heater provides up to air mass flux of 0.012 kg/s m^2 this contributes to 84% of daily heat requirement in a greenhouse. [35]

G. Water Pump

The water pump is connected to the Raspberry Pi which controls the on and off the water pump according to the data received from the soil moisture sensor [16].

H. Web Camera

Web Camera captures the image during scheduled time and send the image to raspberry pi for image processing. [16]

Table-1 represents approximate costing of the hardware requirement based on international price collected from popular E-commerce websites on Dec 2020.

Table-1 Approximate Estimated Hardware Cost

Hardware name	**Approximate price in USD**
Raspberry Pi	$ 35~$50
DHT 11 Sensor	$10-$20
Soil Moisture Sensor	$10-$20
pH Sensor	$10-$20
Relay	$10-$20
Solar Air heater	Room Heater- $100~$120 Solar Panel- $50-$100
Water Pump	$50~$60
Web Camera	$50~$60
Total	$400-$500

As crops, give a better yield under greenhouse conditions. This setup is proposed for greenhouse farming. The solar air heater's solar panels are placed on the rooftop and the heater in the greenhouse's central area (Fig.4). The webcam is set up over the crop and captures its image periodically.

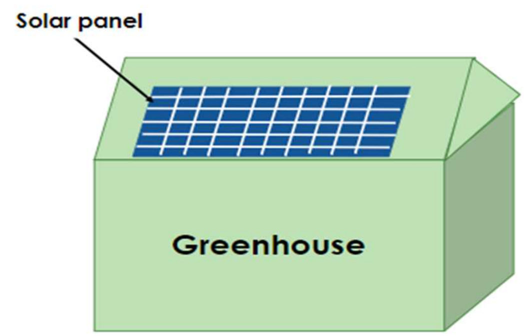

Fig. 4. Logical representation of Greenhouse

The soil moisture sensor and pH meter are kept in the soil, and the temperature and humidity sensor is set near the ceiling of the greenhouse. The sensors and cameras are connected to the Raspberry pi. Before the sowing of seeds, using the collected data gives a prediction of what crop might suit the condition.

In addition, during the growing season, it uses this data to irrigate the field by triggering the water pump to ON and OFF through the intranet. It also predicts the harvest period.

Raspberry pi will be programmed through a machine learning method. The programmed application will use the collected data to predict the crop to be planted and predict the amount of water required to irrigate the fields depending upon the crop and climate. The machine-learning algorithm in the Raspberry Pi examines the data collected from the sensors. This technique can be helpful to obtain a maximum yield without the use of any inorganic substance or unnatural means; it will reduce the workload and time as the application itself will give records and data of the soil condition, climate, and irrigation requirement thus it a practical and reliable solution for organic farming.
YAK Utama et al. have proposed a similar approach, where their system monitors the weather and soil humidity, automatically pumps in water to irrigate the field, and sends updates to the farmer. However, in this solution, in addition to automatic irrigation, the system uses Machine Learning to

suggest to the farmer what crop to be shown using the data collected by the sensors. As the system's main motive is to reduce the pre-harvest losses, it makes sure that all the growing conditions will be met for the growing crop.

In comparison with another model, our proposed model includes a greenhouse; therefore, it is easier to maintain and monitor the environment in which the plants grow; thus, during any climatic changes when the temperature drops down below the desired range, the automated room heating system can stabilize the temperature within the greenhouse.

That is why, our proposed model will help the farmer to choose the right crop, monitor the growing conditions, and detect any pest invasion so that the right care is provided for the crops.

VII. CONCLUSION

As the global demand for food has been increasing for the past six decades, it is necessary to develop a sustainable farming methodology. For a successful crop yield, its environment and growing conditions are of at most importance. It is vital to choose the crop based on the current growing condition; once the crop enters the fruiting stage, it is significant to avoid the pre-harvest losses caused due to the abiotic stress like the soil conditions (such as pH and moisture), irrigation, and climate. It is also necessary to ensure that the crop is not affected by any pest invasion. All these factors can be overcome under a controlled and monitored environment. In a greenhouse set up with different sensors to observe each element, namely soil moisture sensor, soil pH sensor, temperature and humidity sensor, web camera are also used to identify pests. The microcontroller collects these data, which analyses the data and irrigates the field through IoT water pumps. When all these growth factors are handled systematically, it will lead to a higher organic yield.

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