Development of Green, Low-Cost Smart Crop Health Monitoring System Using IoT

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Abstract: Agriculture has been practised for generations in every country and it's the backbone of Indian economy. India has the second largest agricultural land in the world with half of its population working in this sector. Agriculture is the study and practise of plant cultivation. Agriculture was the primary invention that led to the development of sedentary human civilisation. Hand labour has traditionally been used in agriculture. As the world evolves toward new technologies and uses, the objective of advancing agriculture is crucial. Smart agriculture depends on the Internet of Things.Through automation of agricultural chores, agriculture can change from a manual, static state to a dynamic, intelligent one, resulting in increased productivity with less human control. Most farmers use huge amounts of farmland, making it quite challenging for them to access and navigate all the corners of such vast areas. In Haryana and Punjab, more than 80% of the total land is used for agriculture, rice and wheat being the major crops in these areas. Uneven irrigation is a possibility occasionally.This results in poor quality crops, which cause financial losses and psychological repercussions on farmers. Most of the youth is not interested in farm life and is migrating to bigger cities leaving behind theirfamily-owned farms.Application of IOT in agriculture by automating irrigation, pest management, and plant health monitoring will not only provide remote access to the farms from anywhere in the world but also will reduce the human error and improve the quality and quantity of the yield.This will also significantly reduce the workload for farmers. The prototype developed will be powered by two 4-volt solar panels connected in series making it a green alternative to all the other systems in the market currently reducing the cost of the proposed electronic system even further.

Index Terms: IoT, Node-MCU, Automation, Agriculture, Image Processing, Temperature and Humidity sensor, Solar Panel

1. Introduction

Without agriculture and farming, civilization would not be feasible and human survival would be impossible. Although it may appear simple to obtain food, farmers must sacrifice both their physical and mental health to raise the products that are put on our tables. The yield is poor for several reasons, which has an impact on the farmers' finances. Large tracts of land require a lot of maintenance, and when unskilled labour is used, human error is a factor. A portion of the crop may not receive adequate irrigation at times, or pesticides may be applied in excess or insufficiently.The type of crop health issues and the appropriate treatments are occasionally unknown to farmers. All of this has an impact on crop yield. Additionally, farmers have a wide range of health difficulties while working on a farm because of exposure to pesticides, pollen, parasites, microbes, as well as psychological problems related to the productivity and health of their crops. In this paper, examination of numerous health issues that farmers face and how automation and the Internet of Things (IOT) in agriculture will help farmers deal with these issues and make farming easier for them. Farmers can remotely monitor the basic parameters of the field such as humidity, temperature and soil moisture and can irrigate the land both manually and

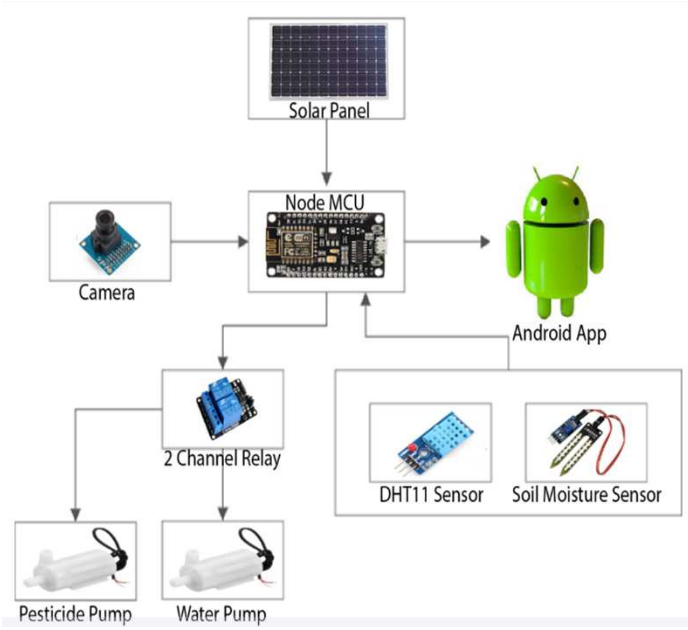

Fig. 1: Block Diagram of the proposed system

automatically in accordance with the water requirements of the crop. The use of solar panels to power the system and all the sensors present in it will make it cost effective and green. Solar panels will make this system usable even in areas where electricity is not continuously present. The health of the crop will be assessed by processing the photographs and comparing them with an existing dataset. A camera will be utilised to take pictures of the crops at customintervals that can be programmed in the software. By comparing Luma and chroma of the image with the given dataset, the health of the plant will be determined. The farmers will be provided with the information about the disease the crop has such as blight, blast or brown spots and will be advised of any necessary actions that the farmers can take in order to cure their crops.The prototype of the system will be composed of Node MCU (ESP 8266), DHT11 sensor, Soil Moisture Sensor, Solar panels, 2 Channel Relay, Water pump and a Camera Module.

2. Need of Work

Recently, researchers are working to use the concepts of machine learning and deep learning to solve real-life issues [1], [2] . In this context, vadapalli et al. [3] proposed a paper in which Wireless Sensor network were used to regularly monitor the changes in environmental conditions. Sensors such as Soil Moisture sensor, raindrop sensor, temperature and humidity sensor connected to Arduino board. All sensors send data to Arduino and data is forwarded to WSN systems. Munir Et al. paper [4] focuses on an intelligent technique, i.e., machine learning [5], to decide watering requirements for a particular plant. By considering many other suitable parameters for the plant growth, i.e., climate, weather, and soil type, it aims to design a smart irrigation system in a different and more efficient way. Imteaj et al. paper [6] focuses on using Raspberry Pi in addition with Arduino, Wi-Fi module, GSM shield, relay boards, couple of sensors. Depending on daylight intensity and moisture level of farmland, system can detect appropriate time of water supply in the trees. Garcia Et al. [7] research provides an overview of the state of the irrigation systems. It determines the parameters that are monitored in irrigation system provided the water quantity and quality, soil characteristics, weather conditions, and fertilizer usage. It also provides an overview of the most utilized nodes and wireless technologies employed to implement WSN and IoT based smart irrigation systems. Torky Et al. presented a technique for precision agriculture [8] in which blockchain was integrated with the precision agricultural discipline. Here, IoT systems were integrated with the blockchain to provide immutable and decentralized architecture. This scheme provided transparent and more reliable solutions for implementing precision agriculture. Chavan Et al. paper [9] main objective is to develop a remote monitoring system using Zigbee. These nodes send data wirelessly to a central server, which collects the data, stores it and will allow it to be analysed then displayed as needed and can also be sent to the client mobile. Baba Et al. paper [10] considers using solar power to irrigate the agricultural land. Also use global system for mobile communication which is used to transmit and receive data between controller and user. Solar power drives water pumps to pump water from bore well to a tank and the outlet valve of tank is automatically regulated using Arduino UNO, GSM, and moisture sensor to control the flow rate of water from the tank to the irrigation field which optimizes the use of water. Saranya Et al. proposed a pest controlling system [11] which confirms the presence of pests in the field through PIR sensor and image processing technique and generates ultrasound which is intolerable to rodents and insects. By doing this, it can prevent the pests feeding on the plants which results in the increase of crop's health and production thus increasing the economic level of farmers. Agrawal Et al. research displays the detected disease in respective plant [12] and reason behind the cause and what method should be applied to control the disease. For example, it displays moisture, humidity, temperature etc. of the leaf. It uses different sensors, MATLAB software, Arduino software and LCD display. Chaudhary Et al. proposed a system [13] which can automatically identify the disease and detect the part of plant affected by it using genetic algorithm which is relatively simple to implement and can be used in image segmentation, image classification and image reconstruction.

An efficient hardware-supported and parallelization architecture [23] for intelligent systems and the development of green, low-cost smart crop health monitoring systems using IOT share common principles and goals related to the use of specialized hardware and advanced analytics to improve efficiency, reduce costs, and promote sustainability. AutoML [19] has the potential to be the future of computational intelligence, and it can play a crucial role in the development of a green, low-cost smart crop health monitoring system using IOT. AutoML can automate the process of building machine learning models [28] [29], making the system more cost and energy-efficient. However, challenges such as the need for large amounts of labelled data and interpretability must be addressed. A sustainable framework [24] for meta-verse security and privacy involves the development of guidelines, policies, and technologies to ensure the security and privacy of users in virtual environments. This includes protecting user data, preventing unauthorized access, and ensuring that users have control over their personal information. Similarly, the development of smart crop health monitoring systems using IoT requires a focus on privacy and security to protect the data collected from sensors and ensure that farmers have control over how their data is used. It is determined that the parameters that are monitored in irrigation system provided the water quantity and quality, soil characteristics, weather conditions, and fertilizer usage. It also provides an overview of the most utilized nodes and wireless technologies employed to implement WSN and IoT based smart irrigation systems. IoT systems were integrated with the blockchain to provide immutable and decentralized architecture. This scheme provided transparent and more reliable solutions for implementing precision agriculture. IOT technology [33] and its uses in security surveillance can have a significant impact on the development of green, low-cost smart crop health monitoring systems. By leveraging IOT sensors and surveillance cameras, farmers can monitor their crops in real-time and detect any issues before they become serious problems. MIoT [30] devices such as wearables, sensors, and mobile apps can enable remote monitoring and improve patient outcomes by providing real-time data about patients' health. In the case of smart crop health monitoring systems, MIoT devices can similarly enable remote monitoring of crop health and allow farmers to detect issues early, take corrective action, and reduce crop failure rates. One opportunity is the potential to improve the security and privacy [24] of the IoT sensors and devices used in the crop health monitoring system. With a sustainable framework for metaverse security and privacy, there could be increased attention and resources dedicated to improving the security of IoT devices and ensuring that personal data collected by these devices is protected. This could be particularly beneficial for the crop health monitoring system, where the data collected from IoT sensors could be sensitive and valuable. The impact and usability of AI [34] in manufacturing workflows to empower Industry 4.0 can have significant implications for the development of a green, low-cost smart crop health monitoring system using IoT. AI can improve production processes, enable predictive maintenance, reduce the need for human labor, improve energy efficiency, and enhance sustainability. However, there are also challenges associated with the implementation of AI systems, such as the need for skilled personnel and potential impacts on employment. Moreover, the development of a green, low-cost smart crop health monitoring system using IoT can benefit from the use of VGG [35] models. The system can use image analysis to detect various crop diseases, including wheat rust, by capturing images using IoT sensors and analyzing them using VGG models. This can lead to more accurate and timely detection of crop diseases, allowing for targeted treatment and prevention of crop losses. In the context of the development of a green, low-cost smart crop health monitoring system using IOT, architectural modelling can play a critical role. The system requires a combination of hardware and software components, including IOT sensors, data processing modules, and communication interfaces. Architectural modelling can help in the design of an efficient system that meets the requirements for low power consumption and cost-effectiveness. DLT [16] can be used to create a secure and transparent system for tracking and sharing data about crop health. This data can be stored on a blockchain ledger, allowing multiple parties such as farmers, distributors, and consumers to access and verify the information in real-time.

3. IoT in Agriculture

In this section, we will discuss the numerous health issues that farmers encounter because of farming and how the project we're putting forward will lessen all these effects on farmers and make their lives easier. The following health issues that farmers have because of their job in the fields:

3.1. Respiratory Illness and Exposures

Numerous respiratory toxins, many at doses higher than in other industries, are potentially present in agriculture. Farmers have a higher frequency of various acute and long-term respiratory illnesses despite low cigarette smoking rates.

1) Inorganic Dusts - Inorganic dust exposure in the agricultural industry has been linked to adverse respiratory impacts, according to a recent study [20]- [22]. This is especially dangerous in farming areas with arid climates, like California and the Southwest. Silicates predominate in inorganic dusts, which are generally derived from soil components but may also contain significant amounts of crystalline silica. Interstitial fibrosis, macules, and nodules may develop in agricultural laborers exposed to inorganic dusts, which are frequently combined with organic dusts and other substances. It is uncertain whether this illness affects agricultural workers and how it develops naturally.
2) Agriculture Associated Cancers - Cancers linked to alcohol and tobacco use have declined thanks to farmers. However, numerous cancers have been linked to farming in epidemiological research, but the results are erratic, and the cause of the associations is not clear. Only lip cancer was found to be elevated in a meta-analysis of cancers and agricultural associations [11], and multiple myeloma was significantly associated with farming in both men and women in a different meta-analysis. Non-Hodgkin's lymphoma (NHL), prostate, skin, melanoma, brain, and soft tissue sarcoma are further malignancies with inconsistent links to farming. Certain malignancies have been linked to exposures, and they may be more common in certain subgroups of agricultural workers. The strongest link between NHL and phenoxy acetic acid herbicides, such as 2,4 D, has been found (, however the results

have not always been reliable. Leukemia and dichlorvos, camphor, and natural pyrethrin were associated with an increased OR in one research; herbicides were not significantly associated with an increased OR. Endocrine disruptors and cancer have garnered significant attention. Although DDE and PCBs have not consistently been linked to breast cancer, organochlorines are mild endocrine disruptors.

3) Non-Cancer Pesticide Related Illnesses - Headache, irritated skin, irritated eyes, and exhaustion are signs of pesticide exposure. With a high pesticide exposure event, more than half of private applicators experienced symptoms. Only half of these people sought medical attention from a healthcare professional [30]- [32]. Farmers in Iowa who applied livestock pesticides reported experiencing respiratory and flu-like symptoms as well as exposure to their hands or arms. Chronic pesticide exposure and its detrimental effects on reproduction have recently drawn attention. Thiocarbamates, carbaryl, and other unclassified pesticides and chemical activity have been linked to miscarriages, while mixing or using yard herbicides has been linked to preterm birth. There was no clear or consistent relationship between pesticide exposure and the timing of pregnancy. However, there was a link between infertility and women who lived on farms or worked in industries related to agriculture.

3.2. Farmers' Sucides: A Global Perspective

At least 2.7 lakh farmers have committed suicide since 1995, at a rate of 46 farmers per day on average, according to the National Crime Records Bureau (NCRB). Every two days, a farmer commits suicide in France. Male farmers experience suicide rates twice as high as the overall population in the American Midwest. Every week, at least one farmer commits suicide in Great Britain. In India, a farmer committed suicide every 32 minutes between 1997 and 2005. Every four days, one farmer commits suicide in Australia. Farmer suicides can result from any one of three causes: economic, social, or physical. Rising debt is the main factor stressing out farmers. The agrarian crisis influences farmers, who are said to be the group most at risk. The main agrarian problems include a lack of agricultural investment, inadequate irrigation, the use of cash crops, an increase in the use of non-institutional loan sources, the reduction of trade barriers, debt buildup, improper crop planning, and poor agricultural finance.In India, farming is primarily a solitary profession with a tiny, tight-knit family and coworker network. These cultures experience significant pressure and are impacted by societal norms. Everywhere in the world, mental diseases are stigmatized. When a farmer discusses his or her sadness, other farmers frequently dismiss him or her as strange and unreliable. Depression and other treatable mental diseases go untreated. A recurring issue is the unequal distribution of psychologists and psychiatrists between the rural and urban population. The outlook and job options for farmers are severely limited due to a lack of education among them. High levels of stress are caused by several things. Farmers may choose to commit suicide if they receive no help.The physical environment is the third factor. All cultures share a variety of biological, physical, and chemical risks that are present in the farming environment. The health of farmers is negatively impacted by the rise in pesticide use. Farmers' suicide rates and the use of genetically modified crops are related. Agriculture is negatively impacted by factors including climate change, decreased soil nutrient levels, and declining water levels.

4. Proposed Answer

As was previously mentioned, all the mental and physical issues farmers encounter are caused by overworking the fields, which weakens their bodies, using pesticides, which has an adverse effect on their skin and respiratory system when they inhale it, working in dust and pollen, and the psychological effects caused by poor yield quality and quantity. Implementing automation and IOT in agriculture can help to some extent mitigate these negative consequences, which will make a difference. Most of the farm work will be completed by machines such as irrigation, pest management, and plant health monitoring using the method we are proposing in this study. This

epoch	train_loss	valid_loss	accuracy	time
0	0.002727	0.266066	0.916667	01:07
1	0.003063	0.250173	0.937500	01:05
2	0.003583	0.233275	0.937500	01:04
3	0.003112	0.213977	0.958333	01:05
4	0.005991	0.200139	0.979167	01:05
5	0.004999	0.192230	0.979167	01:04
6	0.004238	0.186447	0.979167	01:05
7	0.003835	0.179881	0.979167	01:06
8	0.003404	0.174438	0.979167	01:05
9	0.003059	0.172244	0.979167	01:06
10	0.002858	0.168526	0.979167	01:06
11	0.002705	0.166184	0.979167	01:05

Fig. 2: Testing Cycles for Densenet201

will lessen the farmers' physical engagement, hence reducing their exposure to dust, pollen, and pesticides, both organic and inorganic. Thanks to technology, farmers will be able to work from a distance. Additionally, this will lessen the amount of physical labor they must undertake each day and cut down on human mistakes, which results in poor crop quality. The farmers will have access to precise temperature, humidity, and moisture information. Automation will allow farmers who are disabled to adequately care for their crops. Even the health of the plants will be monitored, and the farmers will be given scientifically supported advice on how to improve the quality and quantity of their yield while reducing any potential psychological consequences. Because it will be powered by solar panels, the system will be less expensive than the expense of manual labor and use relatively little electricity.

5. Methodology

India today has about 150 million farmers, and more than half of them possess huge farmlands. A large amount of labor is needed to maintain a respectable-sized farm to monitor the soil's temperature, water the land, and spray pesticides on the crops. Water is the most crucial component for the crop to grow. The crops must be watered at the right intervals, and if a portion of the land is not adequately irrigated, the output is poor, which has an impact on the farmer's psychological well-being as well as his or her financial situation. The Internet of Things can be used in agriculture to autonomously irrigate the farm and monitor the conditions in which the crop is present. In this prototype, Node MCU is interfaced with DHT11 sensor that monitors the humidity and temperature of the field and with a soil moisture sensor that monitors the soil moisture of the crop. If the soil moisture goes below the fixed value based on the requirements of the crops(¡ 55% in this prototype), the system will irrigate the field automatically with the help of a relay and water pump. For rice, which is one of the most cultivated crops in Haryana and Punjab, the soil moisture should be more than 70%. Two 4-volt solar panels are connected in series and are used to charge two 4-volt lithium-ion batteries with the help of a charge controller. These batteries are then used to power the whole prototype making it a green alternative to all the systems present in the agriculture sector currently. For image processing and disease classification, a camera module is connected to the Node MCU which clicks images of the crop and process them over the cloud, giving the type of disease present in the plants. Based on these results, the farmerscan either irrigate the field or spray pesticides using the mobile application. For disease classification, a dataset of rice crops is made containing data of three diseases i.e., bacterial leaf blight, blast and brown spots. Three convolutional neural network model namely Densenet201, Resnet50 and Alexnet are trained with this dataset and when test data is given to them, Densenet201 provides the highest accuracy of 98%. The results are attached:

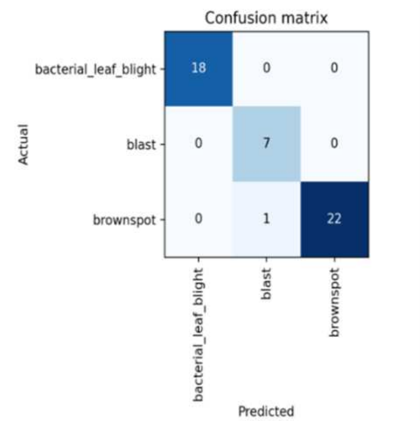

Fig. 3: Confusion Matrix for Test Data

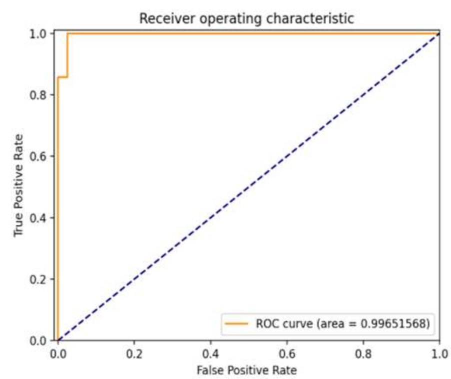

Fig. 4: Receiver operating characteristics

The proposed system will be a more affordable option than hiring all the necessary laborers and will make it much simpler to irrigate and manage a sizable farm at a low cost. SDN-Aided Edge Computing [27] can play an important role in the development of green, low-cost smart crop health monitoring systems. By leveraging SDN technology and edge computing, it is possible to reduce the amount of data that needs to be transmitted to cloud servers, which can help to reduce energy consumption and improve the overall sustainability of the system.

6. Conclusion

In this paper, we have discussed about the problems that farmers face while working in their fields, the physical and mental health issues they deal with, and developed a prototype using IOT and automation which can help solve these problems for them. Famers work way too hard in the fields so that they can earn some money for their families but even after all this hard work, when the yield is not up to the mark, they end up dealing with physical and mental issues that might lead to suicides. There are too many factors that affect the crops such as improper irrigation, too much or too little pest control and microorganisms. With the help of the proposed system, the farmers will be able to remotely monitor almost all the factors that affect the yield of their crops such as soil moisture, temperature and humidity and can automatically irrigate the field based on these factors. The system will also predict the type to disease present in the crop and will suggest the cure for it. Based of the disease classification, pest control can also be done with the help of this system.

Solar panels are used to power the system making it a green alternative to all the similar systems present in the agriculture sector and cost effective compared to manual labour. Overall, the integration of edge computing [27] and cloud computing, along with the development of green, low-cost smart crop health monitoring systems using IoT [25], [26], can greatly benefit the agriculture industry by improving efficiency, reducing waste, and increasing yields. The development of smart crop health monitoring systems using IoT involves the collection and analysis of large amounts of data on various environmental parameters [20]. The use of parallel processing and specialized hardware, such as low-power microcontrollers, can help to reduce the computational overhead of these systems and improve their overall efficiency [23]. However, addressing the challenges associated with these technologies will be crucial to their widespread adoption and success. The introduction of this system in the agriculture sector will be revolutionary and lifesaving.

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