IoT based Portable Weather Station for Irrigation Management using Real-Time Parameters

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***Abstract*—Rainfall in India is very unpredictable and is characterised by monsoon gaps. Rainfall prediction is very crucial for irrigation management to enhance farm productivity.. This article presents a portable rainfall prediction device which can be carried to fields. In the field by sensing the current atmospheric parameters like temperature, humidity, atmospheric pressure along with the current status of the sky to know the types of clouds present and gives the chances of rainfall. It is a novel approach in terms of portability of the device and it will give the prediction based on current information at a particular location by combining the predictions from the model of image processing of the clouds using deep learning and the currently sensed weather parameters are processed using machine learning without using WIFI or internet connection by providing Edge analytics where the data processing, rainfall prediction, and decision making is carried out locally on the device without any backend servers or cloud platform which will be very useful for the people like farmers who don't have accessibility to internet in villages. The farmers can decide before every irrigation schedule, based on the prediction to what extent the crops can be irrigated. If chances of rain are very low 90% irrigation can be carried out, If chances of rain are predicted as low to medium then 40 to 60% irrigation can be done and if the prediction says medium to heavy rainfall then no irrigation is recommended.**

Keywords*—Deep learning; edge analytics; internet of things; machine learning; irrigation management; precision agriculture; rainfall prediction

I. INTRODUCTION

The agriculture industry is the backbone of the Indian economy, accounting for roughly 15% of national GDP and about half of India's population is entirely or partially reliant on agriculture and related activities for their living. India is one of the top 15 agricultural commodity exporters in the world. India is also facing an exponential population growth that demands a great need for food in the future. Traditional agricultural practices, on the other hand, must be modified with the help of technology to meet the increasing demand for good quality food to meet the future need of the population. Agriculture development will benefit not just farmers, but also a huge portion of the people living in rural areas that are actively involved in agriculture or indirectly tied to agriculture as consumers. More efficient production methods would produce a more conjugative environment in the country for the overall development of the economy and greater agricultural income. Small and marginal farmers will be empowered via education, reforms, and development, resulting in better, more efficient, and stronger Indian agriculture. New production and marketing models, as well as raising awareness and providing education to farmers in villages, will aid in the sector's development and, more crucially, improve the economic situation of impoverished farmers [1].

Precision agriculture is the most promising approach to farm management in today's era, as it uses technology Internet of Things (IoT) to monitor the spatial and temporal parameters of the field and ensures that input resources such as water, fertilizers, pesticides, and other chemicals are applied to the crops at the right time, in the right place, and the right amount. Traditional agricultural surveillance tactics were modified by IoT-based agriculture applications, which quickly provided quantitative data with great temporal and spatial resolution. Ecological data is collected in real-time from the surroundings of the agriculture field using various sensors installed in the fields, which will be communicated and analyzed to determine various problems. This collected data is analyzed and processed to extract the proper information and is utilized to decide on various tasks performed in the field to automate the agriculture process to overcome certain difficulties. Multidisciplinary methods that combine remote sensing, modelling, and deep learning techniques can aid in the improvement of agricultural operations and, as a result, crop output [2].

Collecting data manually from a big field is challenging, and it results in fluctuation when compared to inaccurate field measurements. Wireless sensor networks (WSN) help in integrating various sensors in the field for the collection of different parameters from the field and environment. Various farm monitoring applications like crop selection according to the soil in the farm, soil monitoring to make zones with similarity to promote multi cropping and to assist farmers with various decision making like when and in what amount of fertilizer to be used, when to irrigate the crop, early disease predictions etc. are possible due to several emerging technologies like WSN, Deep learning, Machine learning, IoT etc.

Agriculture utilizes 85 percent of the world's available freshwater resources, and this fraction is progressively rising in parallel with population expansion and rising food demand. As a result, there is a need to develop more efficient methods to ensure that water resources are properly utilized in irrigation. New innovative plans in this direction are needed in research to boost productivity and water management through novel irrigation techniques [3].

Proper irrigation aids in the growth of crops, landscape maintenance, and revegetation of disturbed soils. In addition to frost protection, weed suppression in grain fields, and soil consolidation prevention, irrigation plays important role in healthy crop cultivation. Irrigation management is required even in places with abundant rainfall to boost farm productivity. Monsoon gaps are a feature of Indian rainfall. As a result, sometimes it won't rain for two or more weeks during the rainy season, causing agricultural damage in the absence of irrigation.

In the near future, proper integration of advanced agricultural practices based on various technologies and adaptation by rural communities should be secured. Climate change will have extensive consequences in the next decades. As a result, laws, and practices must be devised to protect farming communities, particularly small landholders, from the immediate losses caused by extreme events [4].

The most important reasons for India's need for perfect irrigation are:

- Chaotic nature of climate.
- Uneven Rainfall Distribution.
- Optimized use of water resources to meet crop needs and soil requirements.
- To maximize crop production.
- To manage supplement supply even in areas with abundant rainfall.

Irrigation scheduling is managed by rainfall forecast based on weather conditions, which determines the amount of water to be supplied by irrigation to maintain the threshold value of water (moisture) required by the crop at any given time.

Automatic irrigation scheduling systems have replaced manual irrigation based on soil water monitoring. While implementing, the plant evapotranspiration was taken into account, which was based on many climatic characteristics such as humidity, wind speed, solar radiation, and even crop aspects such as stage of growth, plant density, soil attributes, and pest.

Weather forecasting does an excellent job of providing people with early warnings and alerts about severe climate change events, however, due to a lack of infrastructure, people in remote regions such as villages do not receive information on time due to the absence of internet, and forecasting is not very accurate for any given location. As a result, this portable device may be taken anywhere and used to anticipate the state of rainfall by sensing current atmospheric characteristics and present sky status to identify clouds related to rainfall.

Most of the farmers are living in rural areas and are not able to access the internet and weather forecasting applications at remote locations like fields. This article presents a portable weather station that uses a novel approach that predicts the intensity of rainfall as No Rain to very Low Rain, Low to Medium Rain or, Medium to high Rain based on the combined approach of identifying types of clouds present in the sky and some important weather parameters such as temperature, humidity, and atmospheric pressure using affordable sensors that are within the reach of farmers and will work independently of WIFI or internet.

This device consists of Raspberry pi with an integrated camera for taking digital images of the sky to know the type of clouds present in the sky along with some atmospheric parameter sensors like DHT11 sensor, BMP 180 etc. to sense temperature, humidity, and atmospheric pressure and will give the prediction on rainfall by both approach from cloud status and sensed atmospheric parameters. Improvement in crop production and planning by using local climate prediction without the internet can definitely help an individual farmer to increase his yield by managing the irrigation cycle by avoiding irrigating the crop with extra water or less water.

A. *Novelty*

The proposed work is distinguished from previous work by its multi-modal integration of two separate techniques. The majority of previous research has proposed solutions in irrigation management by providing automatic irrigation based on either atmospheric parameters collected from nearby weather stations / using sensors or only by capturing sky images, but the proposed system takes advantage of both approaches where real-time atmospheric parameters on the fields are sensed using sensors and the sky image at that location is captured to provide better rainfall predictions without using WIFI or internet so that it can be used by farmers or people at remote locations. Due to the global shortage of clean water resources, it is critical that they be utilised to their full capacity, which may be accomplished by utilising water resources wisely and paying equal attention to irrigation water management. This device will help farmers to take decision before every irrigation scheduled cycle to what extent the field should be irrigated by predicting the intensity of rainfall as low, medium or high.

The rest of the article is arranged as follows: Section 2 describes relevant work, Section 3 discusses the proposed system in detail, Section 4 discusses methods and methodology, Section 5 discusses findings, and Section 6 discusses conclusion and future work.

II. Related Work

Weather conditions play an important role in both irrigation requirements and crop performance. Researchers used various weather parameters and different technologies and algorithms to predict the weather to know the status of climate to control the use of water in Irrigation.

The evapotranspiration of water in the soil is affected by temperature and humidity. The thermic level of the atmosphere is described as air temperature, which is generally measured in Celsius, Fahrenheit, or Kelvin degrees. It is the most closely observed weather metric. The presence of water vapour in the air is known as humidity. The proportion of water vapour in the air is expressed in percentage (%). The other major parameters considered by the researchers are luminosity and is defined as the brightness or intensity of light. Lux is the unit of measurement. It causes more water loss from the soil as the temperature rises with the direct solar radiation. The most important parameter is the rainfall or amount of precipitation that influences whether or not irrigation is necessary as well as the amount of water to be used if irrigation is required. The author in [5] presents a detailed survey on the IoT systems and recent sensors used in an automatic smart irrigation system in Precision Agriculture and discussed various weather monitoring parameters, sensors, soil characteristics. The author in [6] proposed an automated irrigation system which starts the motor and water is supplied only if the level of soil moisture goes below the threshold and the amount of water supply is managed by considering the weather parameters temperature and humidity sensed by the sensor to predict the type of climate as sunny (no rain), cloudy (rain chances <50%) or rainy (rain chances>50%). In [7] to add intelligence to the existing idea of automatic irrigation systems, an autonomous irrigation system is proposed that employs machine learning and predictive algorithms to predict the status of rainfall using historical climate data for the amount of water to be used by calculating the time of motor to be ON based on the soil moisture value for each zone separately. Work proposed in [8] is the development of an efficient IoT architecture that monitors soil, microclimate, and water parameters, as well as performing proper irrigation management based on challenges studied in irrigated farmland of Ethiopia, Kenya, and South Africa. For educated decision making and effective operation of the irrigation management system, indigenous agricultural and expert knowledge, local climate information, particular features of crop and soil are provided to the system. Broadband connection and cloud services are either unavailable or too costly in Sub-Saharan Africa. To overcome these constraints, data processing, network administration, irrigation choices, and farmer communication are all done locally, with no back-end servers involved. In the article [9] the technique was evaluated using five crops at four European sites with varying weather circumstances to optimize irrigation water consumption by taking into consideration soil water availability, local weather predictions, crop physiological condition, and water demands in real-time. Main observations are the major effect of inaccurate predictions of the forecast, unless the target yield was excessively high, was that the target yield was not attained, but the irrigation schedule stayed near to optimum, according to the data. In other words, while the actual yield did not match the objective, just a little amount of irrigation water was lost. In [10] author proposed an idea to automate the irrigation process to manage the motor's pumping by taking into account the soil moisture content and rainfall forecast. Soil moisture data is continuously sensed using a soil moisture sensor and is sent to raspberry pi and depends upon the value a rainfall prediction is obtained from Openweather API to decide on irrigating the field or not and the Android Application is used to track the complete irrigation process for the agricultural field. The article [11] effectively shows a simple, low-cost, and somewhat accurate system for monitoring current meteorological conditions and forecasting rain. This system has a significant benefit over comparable Arduino-based weather monitoring systems in that it also provides rain probability at the current moment using weather parameters namely temperature, humidity, light intensity, and wind conditions. The goal of this study [12] was to provide a way for a reliable irrigation system based on a suitable rainfall forecast algorithm. The new approach, which is Romyan's method is introduced to calculate water requirement for crops, as well as the time necessary for the motor to be turned on. The author in [13] presents a technique for high-accuracy rainfall forecasting that combines two types of data i.e., cloud imaging data and humidity as an atmospheric parameter in numerical form. Convolution Neural Network is used for image recognition by extracting important features using ResNet. In this research, a novel network is built that combines the cloud picture with other meteorological information and creates the result, to forecast rainfall with greater accuracy than the existing ResNet image recognition alone.

A comparison of the existing and proposed work based on the parameters and technology along with methods and methodologies used are shown in Table I. The comparative analysis of the previous research work has revealed that most of the models used either atmospheric parameters or cloud images for the prediction of rainfall and only one paper proposed a system using a combined approach but using only one parameter as humidity. However, after researching existing systems it is clear that the combined approach of two modalities to predict rainfall gives more clarity and would be very useful. In this regard, the system proposed uses a multisource data approach that combines predictions from digital cloud images and atmospheric parameters to provide an improved rainfall prediction system.

TABLE I. COMPARISON OF THE PROPOSED SYSTEM WITH EXISTING SYSTEMS

Model	Atmospheric Parameters used	Source of weather data	Sky status	Methodology used	Output
[6]	temperature and humidity sensors	Sensor deployed in the field	No	Controllers, sensors, and algorithm	Climate predicted as sunny, cloudy, or rainy
[11]	temperature, humidity, light intensity, and wind conditions	Sensors	No	Matlab, Arduino IDE	Automatic Irrigation using soil moisture and rainfall prediction
[8]	Soil and microclimate parameters	sensors	No	IoT, GPRS/GSM communication	autonomous actuations for smart irrigation management
[14]	Temperature, humidity, pressure, and uv_index	Sensors	No	algorithms like SVM, KNN, ANN, etc. explored	Gives rainfall prediction for the next four days
[13]	Humidity	Sensors	yes	CNN, RESNET, and Neural network	rainfall forecasting with cloud imaging data and humidity
Proposed System	***Temperature, Humidity, and pressure***	***Sensors***	***yes***	***Transfer learning, IoT, Machine learning***	***Rainfall intensity as No rain, Low rain, and High rain***

The suggested system addresses the optimal integration of different sensing modalities as well as their practical execution. Additionally, machine learning approaches and deep learning architectures are applied to the different inputs and the final decision is provided by combining the output from both approaches to predict rainfall and gives an appropriate decision on the amount of irrigation to be done. In comparison to current procedures, the suggested approach has presented a technology-based solution that would be beneficial to the agricultural and scientific communities in terms of its portability and use of edge analytics where input is processed and output is given at the device level only without cloud platforms, internet or WiFi.

III. Proposed System

The study of clouds and their characteristics is crucial for a wide range of applications. It's been utilized to produce precise weather forecasts via nowcasting. There exist many clouds in the sky but only a few clouds are responsible for rain. Identification of rainclouds can be done using image classification with the help of deep learning on a ground-based image cloud dataset. To make the predictions more accurate the atmospheric parameters like temperature, humidity, atmospheric pressure is taken into account which can be easily sensed by the sensors and are affordable. The results from both approaches are combined and the final output is given as the prediction on the rainfall as No rain, Low to Medium rain, or heavy rain as shown in Fig. 1 as a multi-modal proposed system on basis of which many agriculture-related activities can be carried out like managing irrigation by taking in account the status and intensity of rainfall.

A. Components used

1) BMP180: BMP180 is a barometric sensor with an I2C ("Wire") interface, used to measure pressure surrounding it and altitude. It is also used to measure temperature. It works on push sensor BMP180 and can measure the pressure in the range of 300 to 1100 hPa with relative pressure error to 0.12 hPa (1m height). The BMP180 outputs absolute pressure in pascals (Pa). By observing variations in pressure short-term weather changes can be predicted. Dropping pressure, for example, frequently indicates the arrival of rain or a storm (a low-pressure system is moving in). When the pressure rises, it usually signals that clear weather is on the way (a high-pressure system is moving through).

2) DHT11 sensor is a basic and commonly used to record temperature and humidity from the atmosphere in the digital form. This sensor utilizes a thermistor and a capacitive humidity sensor to detect the surrounding air. To monitor humidity and temperature instantly, it may be simply interfaced with any microcontroller such as Arduino, Raspberry Pi, and so on.

3) Raspberry Pi 4: Raspberry Pi 4 is the latest model and is a tiny processor or a controller with great processing power integrated with Broadcom 2711, 64-bit quad-core Cortex-A72 processor and is available with 1 GB, 2 GB, or 4 GB RAM. It features a true gigabit Ethernet port, 2 x USB 3.0 "Super-Speed" ports which can be used to attach mouse and keyboard. It comes as a size of the credit card so is portable and easy to carry. New version comes with a combination of small footprint, low-power drop, customization and amazing community support and the pi can be used in several.

4) USB camera: Logitech HD webcam c270 has a USB interface that makes it easy to connect and has 3-megapixel image resolution along with superb color-rich imaging even in ultra-low light with HD support.

5) OLED Display Screen: To display the output as the atmospheric parameters along with the status of rainfall and the decision based on the rainfall is displayed on an OLED display screen. The OLED display screen is very thin and light-weighted with a size of 0.96 inches comes with a resolution of 128X64. It has 4 pins named VCC: 3.3-5V GND: Ground SCL: Serial Clock SDA: Serial Data to carry out I2C communication.

6) Basic Shield: Basic Shield is a component provided with 8 LED's, 2 push buttons and is very popular for interfacing electronics components like a push button, potentiometer, LDR, buzzer, etc. and can be easily connected with 5 V/3.3 V microcontrollers.

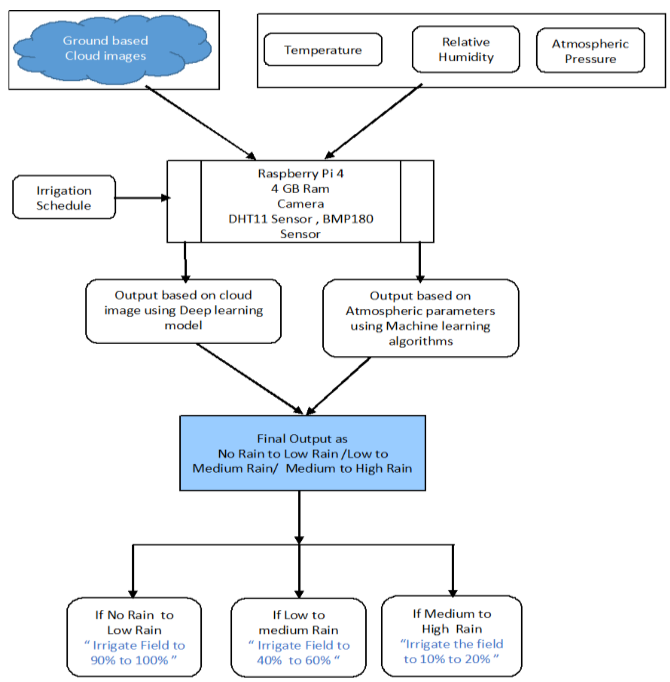


Fig. 1. Proposed System.

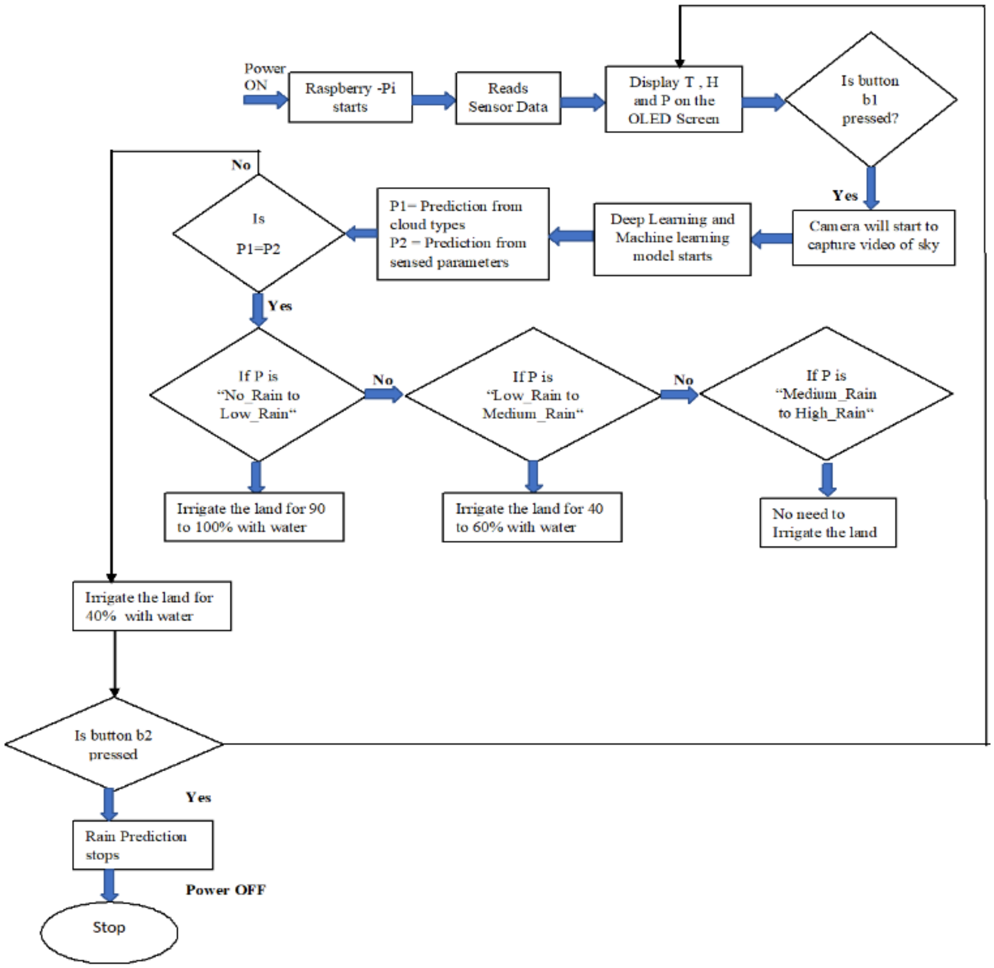


Fig. 2. Working Flow of the Device.

B. Working Principle of the Device

The Device consists of Raspberry Pi 4 Model B and components DHT 11, BMP 180, OLED display screen, USB camera, and Basic-Shield are connected to the respective pins. Power is provided to Raspberry Pi using a power bank with a C-Type cable to make the device portable. The work is shown in Fig. 2. Sensors sense the atmospheric parameters like temperature denoted by T, Humidity denoted by H, and Pressure is denoted by P. Once power is supplied to the device the code snippet for collecting sensor data will start and will get displayed on the screen after regular intervals. To start the Rain prediction push-button b1 needs to press. Once b1 is pressed camera will start and the video will be captured, so the camera should be faced towards the sky to get the proper input, which is fed as input to deep learning model at the same time machine learning code will also be executed by giving values T, H, and P as input parameters.

IV. Methods and Technology

A. Irrigation Scheduling

Irrigation scheduling is critical for ensuring that crops receive the right quantity of water at the right time to minimize crop water stress and optimize output [15]. Water stress can affect vegetable crops in two ways: when there is a lack of water (drought stress) or when there is an abundance of water (water stress) caused due to waterlogging or soil water saturation. A water deficit occurs when water is supplied at the wrong time or insufficiently, reducing the amount of water available to plants in the soil. Long durations of irrigation or high-water application rates can produce excess soil moisture, wasting water and causing nutrient loss. Crop water stress can also have an impact on crop management. Wilting occurs when soil moisture falls below a certain level, preventing plants from drawing water into their roots. Furthermore, in low moisture circumstances, any moisture-activated herbicides and nutrients would not be efficiently used by plants. Presently, many different approaches are adopted for irrigation scheduling as listed in Table II to optimize the water application to crops. These methods are ranked according to the level of management required for water application [16]. Irrigation scheduling is different for a different crop at every growth stage and must be followed to optimize the crop yield and the use of water.

TABLE II. IRRIGATION SCHEDULING METHODS

Rank	Method	Type of water management
0	The "Irrigate whenever" method	Water is applied without scheduling
1	"Feel and appearance" method	The irrigation manager decides the amount of water to be applied and when by observing the soil sample and assessment is done by comparing it with the soil reference images.
2	Systematic method	Regardless of considering weather or soil water conditions, the application of water is done based on the amount or time.
3	Crop water demand method	The amount of water applied is determined by the crop's evapotranspiration (ETc). This strategy involves calendar-based scheduling based on prior seasons and should take into account rainy days.
4	Soil water status method	Water is supplied to the crop root system based on soil moisture levels, usually by giving a proportion of soil accessible water. Rainfall occurrences should be taken into consideration with this technique.
5	Water budgeting method	Water application is dependent on crop evapotranspiration, soil moisture content at the root level, and water budgeting.

The first method is completely traditional and requires human interventions and results in lots of water wastage in terms of irrigation as management was not done properly and no parameters are considered. The second and third methods considered soil parameters and timings as well as an amount for application of water which reduced the water wastage but may result in water stress as no weather conditions are considered. The last three methods are improved and make use of technology by considering various parameters like soil moisture content and rainfall events to plan the irrigation scheduling thus optimizing the use of water resources. From the above table, we can see that Irrigation scheduling is very important to optimize the water application thus by improving the yields and rainfall is one such important factor that must be taken into account to protect the crop from the application of excess water thus improving the Irrigation Management system.

B. *Internet of Things (IoT)*

Every element of traditional farming processes may be substantially altered by incorporating the newest sensor and IoT technology into agricultural practices. Currently, Wireless sensors and the Internet of Things (IoT) are being integrated into smart agriculture and are capable of taking agriculture sector to next level. Soil, humidity, wetness, light, air temperature, CO2, solar energy sensors, and a variety of other IoT sensors are all employed in agriculture. Sensors, which are placed across the fields, on smart agriculture vehicles, in IoT-based monitoring systems, and weather stations, collect data in real-time and give farmers visibility and control over their activities. Fig. 3 shows the basic architecture of IoT.

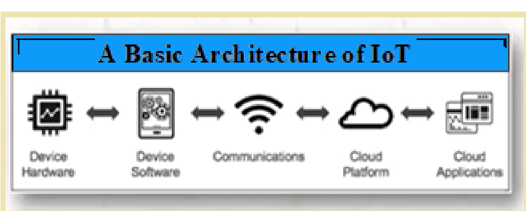


Fig. 3. A Basic Architecture of IoT.

IoT architecture consists of various hardware components like sensors as per the requirement to sense the data from surroundings which requires software and various communication technologies to exchange the data among the devices and finally, the data sensed by the interrelated devices gets stored on the cloud for further analysis and various application are developed to convert this data into important information required for many useful or decision-making activities.

The information about IoT technology stack that contains companies and produce different level IoT boards or controllers, then come communication technologies NB-IoT, LoRaWAN, ZigBee, Bluetooth, etc. supported by many Communication protocols such as MQTT, COAP, AMQP, and many more as shown in Fig. 4.

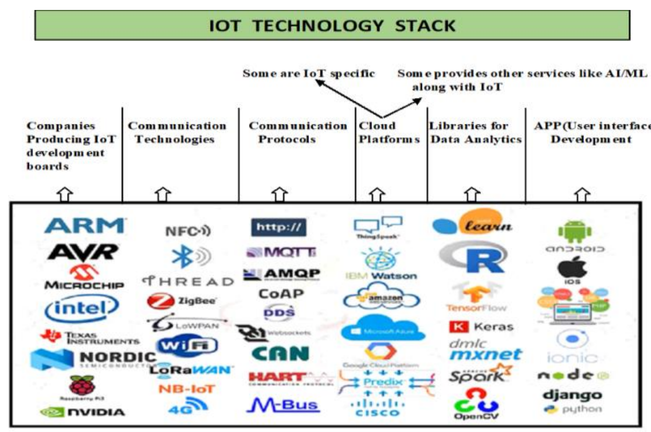


Fig. 4. IoT Components and Technologies.

Today we have clouds like Thingspeak, IBM Watson specifically for IoT along with general-purpose cloud platforms (AWS Amazon, Google, Cisco). Once the data is stored it is analyzed with analytical tools like keras, Tensorflow, OpenCV is libraries with very powerful functions and finally, the information retrieved after analysis of data is used for various applications.

C. *Edge Analytics*

Sensors are used to collect data from the environment or surroundings and Actuators are the devices that will take action based on the output of processed data. If the Analytics is performed at the device level that concept is called Edge Analytics. Only data for storage is sent to the cloud. If analytics is done in the cloud, then it is called cloud analytics. This experiment used DHT11 and bmp180 sensors to sense temperature, Relative humidity, and atmospheric pressure, and the data is fed to a machine learning algorithm (pickle file) to get the status of rainfall based on these real-time parameters. Along with it, raspberry pi is integrated with a digital camera to capture the image of the sky at that location, and the image is given as the input to the deep learning model (.h5 file) to get the status of rainfall based on the types of clouds present in the sky at that time. The processing is done in Raspberry pi and the predictions are displayed on the screen attached to it. This proposed device uses Edge analytics to give output as the processing is done at device level and does not depend on WIFI or internet. The cloud can be used to just store the data collected by the sensor only when Wi-Fi is available. The cost of data storage and management is reduced using edge analytics. It also saves operational costs, bandwidth requirements, and time spent on data analysis. Despite the widespread use of internet-connected gadgets, connection problems persist due to the unavailability of the internet or limited network access. Edge analytics guards against possible network failures by ensuring that applications aren't hampered by internet issues or limited network access [17]. This is especially beneficial in rural regions (remote locations) or when trying to save communication expenses with costly technologies like cellular.

D. Deep Learning

Clouds are crucial in climate forecasting. Rainfall forecasting is also heavily influenced by the state and kinds of clouds in the sky. CNN model is used with transfer learning to classify clouds based on their features like texture, color, etc. to know the type of cloud and rainfall can be predicted using the precipitation associated with that cloud. Ground-based cloud images are readily available compared to satellite cloud images and provides information about the local atmosphere by analyzing bottom-level features of clouds like cloud height, cloud type, and cloud cover [18]. Rain clouds are mainly classified as Cirrus, Stratus, and Cumulus [19] and the main clouds are shown in Fig. 5.

The proposed device is provided with 8 megapixels digital camera integrated into Raspberry-pi to capture live sky images at any location by clicking a button on the device to activate the device. A cloud image is given as input to the convolution neural network (CNN) and the SoftMax activation function is used to classify the cloud into No Rain to very Low Rain, Low to Medium rain, or Medium to High Rain based on the amount of precipitation associated with each cloud. According to the Precipitation and the amount of Rainfall as shown in Table III, all cloud images are classified into three classes or groups.

The operation of the deep learning model as shown in Fig. 6 where the weights of the pretrained model are downloaded first, followed by freezing of all the layers except the top layer, which is used for classification in the fresh dataset, and finally the training of the model. All of the layers are unfrozen for fine-tuning, and the model is trained on a new dataset with a very low learning rate. Once trained, the model was able to accurately predict the outcome. All three pre-trained models, VGG16, Inception-V3, and Xception, follow the identical flow and concluded with The Xception model gives better accuracy to predict Rainfall based on cloud images taken from the ground, giving output whether Rain or little Rain or medium Rain or high Rain as compared to VGG 16 and Inception-V3. Rain Prediction using deep learning on ground-based cloud images using transfer learning, is presented in [20].

E. Machine Learning

To support the rain prediction model based on cloud images, atmospheric parameters are also considered which also plays vital role in determining the rainfall. Temperature, humidity, and pressure in the atmosphere fluctuate rapidly, causing instability in the atmosphere, which can result in rain, storms, and even lightning and thunder. The most significant elements in predicting precipitation are temperature and humidity [21]. Air pressure, dewpoint temperature (or relative humidity), wind speed, and cloud cover are four more meteorological factors that are substantially connected to rainfall [22]. But as the device is portable so only the most important variables are chosen for the experiments which are temperature, relative humidity, and air pressure that can be sensed with affordable sensors and are sufficient to predict the status of the rainfall.

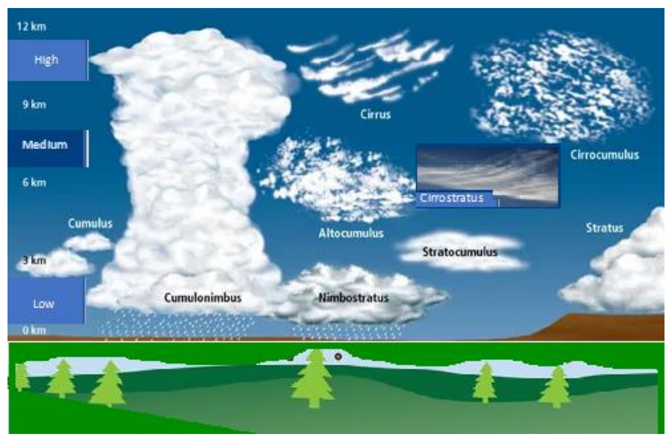


Fig. 5. Types of Clouds.

TABLE III. CLOUDS CLASSIFICATION BASED ON ASSOCIATED PRECIPITATION

Cloud	Associated Precipitation	Class
Cirrus Cirrostratus Cirrocumulus Altocumulus	None None None None	No Rain to Very Low Rain
Altostratus Stratus Stratocumulus Nimbostratus	Produces light showers or sprinkles, drizzle or Bring a light or moderate Rainfall of long duration	Low to Medium Rain
Cumulus Cumulonimbus	Showers or snow Heavy Rain with lightning, hail, or snow	Medium to Heavy Rain

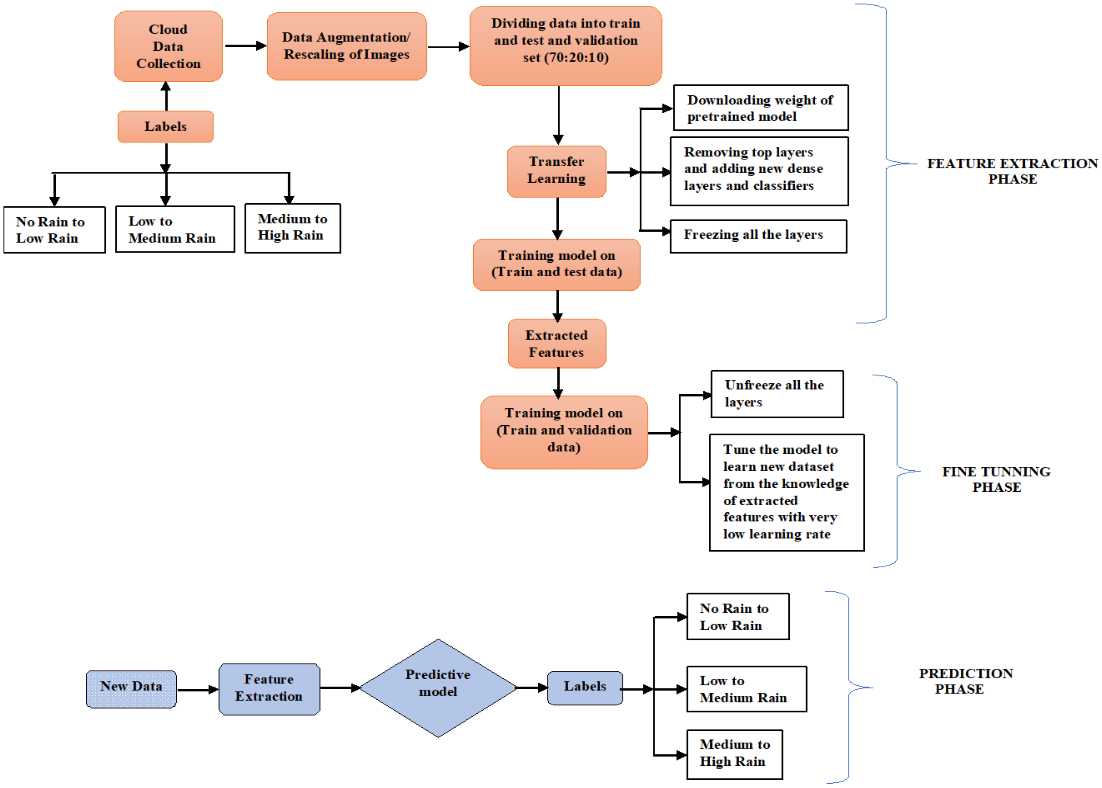


Fig. 6. Working of Deep Learning Model.

Rainfall intensity is classified according to the rate of precipitation, which depends on the considered time. The following categories are used to classify rainfall intensity [23]:

- Low rain — when the precipitation rate is < 2.5 mm (0.098 in) per hour
- Medium rain — when the precipitation rate is between 2.5 mm (0.098 in) and 7.6 mm (0.30 in) or 10 mm (0.39 in) per hour
- High rain — when the precipitation rate is > 7.6 mm (0.30 in) per hour, or between 10 mm (0.39 in) and 50 mm (2.0 in) per hour
- Very High rain — when the precipitation rate is > 50 mm (2.0 in) per hour

Here also the data is classified in the same categories as in cloud dataset as No Rain to Very Low Rain, Low to Medium Rain, and Medium to Heavy Rain based on the precipitation rate.

The data is collected for the city of Hyderabad, Telangana, from Nasa Power Data viewer for Daily data, which contains various climatic parameters, but only the most significant ones are picked, and the data is collected over a 40-year period from 1981 to May 2021. Because there are an average of 64-65 rainy days each year, collecting sufficient data over a long period of time is required. The dataset contains many attributes (columns), but for this experiment, the independent variables are Temperature, Relative Humidity, and Pressure, and the dependent variable is Condition, which is labelled in three categories based on precipitation: No rain to very low rain, Low to medium rain, and Medium to high rain. Various steps carried out to train the model from collecting dataset to cleaning of the dataset, balancing the dataset, feature extraction, and then partitioning of the dataset into train and test sets as shown in Fig. 7. After that various classification models are applied on the training set to train the model on selected parameters then the performance is analyzed by calculating the accuracy based on the predictions from the test dataset.

It has been observed, that among all individual machine learning models RandomForest and KNN gave a good prediction as compared to others. Logistic regression and SVM also performed well while predicting the values but Decision Tree and Naïve Byes performance was poor in estimating the predictions compared to other models as shown in Fig. 8. For evaluating the machine learning models a very effective technique called K-FOLD CROSS VALIDATION is used where the model is tested on part of the dataset which was not used for training. In this experiment, value of k is set to 5 in the K-fold cross-validation technique to check the accuracy attained by various models used. Although predictions from stacking Ensemble are better than voting, the calculation time is three times that of individual machine learning models. As a result, the RandomForest classifier was chosen to implement in hardware since it is faster and has similar accuracy to Stacking Ensemble.

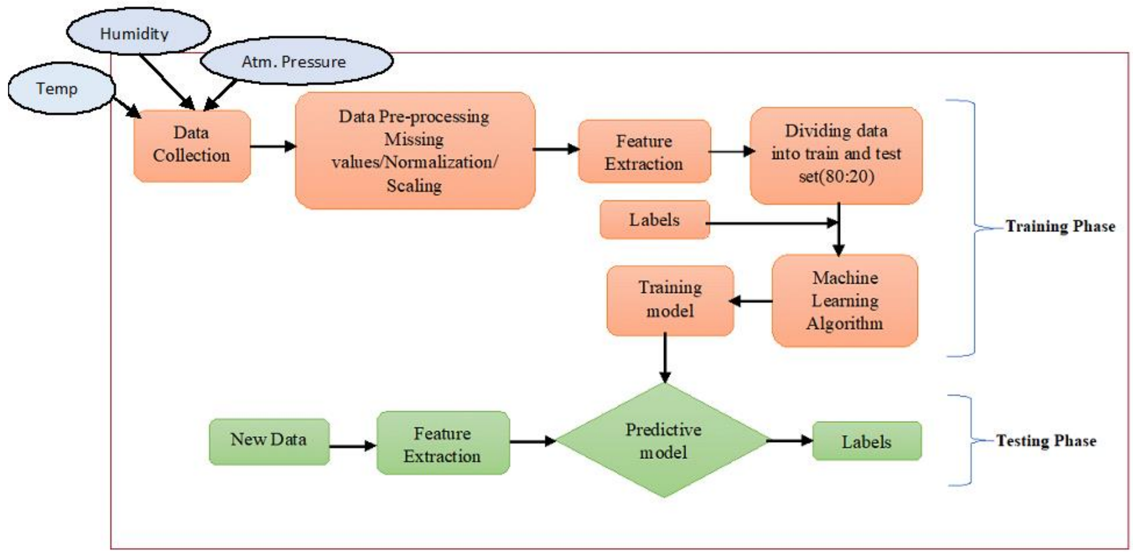
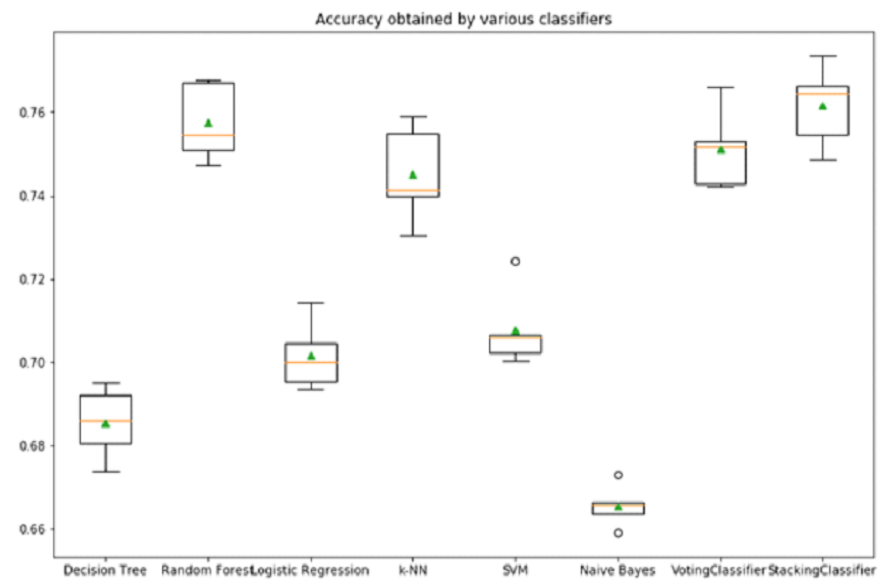


Fig. 7. Machine Learning Model for Rain Prediction based on Atmospheric Parameters.



Model	Accuracy Obtained
Decision Tree	0.686
Random Forest	0.758
Logistic Regression	0.702
K-Nearest Neighbor	0.745
Support Vector Machine	0.708
Naïve Bayes	0.666
Voting Classifier (Hybrid)	0.751
Stacking Ensemble	0.761

Fig. 8. Accuracy Obtained by Different Classifiers and Ensemble.

F. Device Setup

All the components are connected to Raspberry Pi as shown in Fig. 9. The screen displayed the currently sensed parameter values when the power is given to the device.

No internet or WIFI module is used in this device and the power can be given by the power bank to make the portable device so that it can be carried to any location. Logitech USB Camera is used to capture the video of the sky which will be divided into continuous image frames and given as input to the Deep learning model to get the rainfall prediction based on the clouds present in the sky. Data sensed by the DHT11 sensor and BMP180 i.e. temperature, humidity, and pressure is given as input to the machine learning model. The predicted rainfall from both the models is displayed on the OLED screen and the final decision for the amount of irrigation is also displayed on the screen. Based on the output the motor can be switched ON to irrigate the land for the appropriate amount of water based on the decision given. The instrument is tested and found to give very correct predictions based on both approaches. This rainfall system would be very much useful in many agricultural events where the rainfall prediction needs to be considered. Prediction is given based on two different models where atmospheric parameters and clouds both are considered. The most important is this device works without the internet only power is needed. The device can also be used only to monitor individual atmospheric parameters temperature, humidity, or pressure which can be used to make a decision on food storage, or crop harvesting.

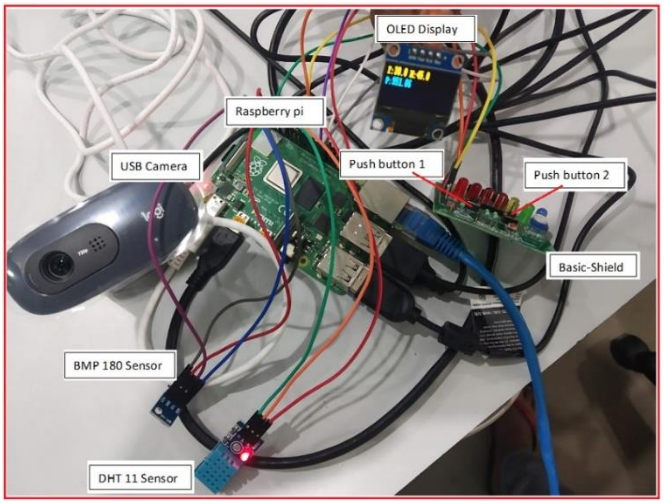


Fig. 9. Device Setup.

G. Tools and Libraries used

To execute the Deep learning model Debian GNU/Linux (64 bit) aarch 64(beta version) is installed which is a free and open-source operating. Debian GNU/Linux is a unique software distribution that combines Debian's philosophy and methodology with GNU tools, the Linux kernel, and other key free software to make aarch 64. Because of its technical brilliance and profound dedication to the requirements and aspirations of the Linux community, Debian is especially popular among expert users. The Deep Learning model and machine learning models were trained on python 3 so all the supporting libraries with the required versions Keras – 2.4.3, Tensor Flow-2.4.0-rc2, Scikitlearn-0.20.2, and OpenCV -4.5.3 are installed.

V. Result

Some of the screenshots of output are shown in Fig. 10. Here in the display screen T denotes Temperature, H denotes Humidity and P denotes Pressure sensed by the sensor and are displayed as soon as Raspberry Pi starts. The Value of T, H, and P keeps on displaying on the screen. When button b1 is pressed its status changed from 1 to 0 and the rain prediction model starts by starting the camera to capture the sky image and is given as input to the deep learning and T, H, and P values are passed to the machine learning model. P1 denotes output from deep learning (i.e. from clouds) and P2 denotes output from machine learning (i.e. from Parameters).

The device is tested in the open space in residential area by powering it with the USB power bank as the Raspberry Pi requires a 5volt input voltage, which is provided via the USB type-C connection. The input voltage should actually be a little higher than 5 volts. Because power losses occur in the connectors and wires of the circuit's transmission, 5.1–5.2 Volts would be optimum. The results obtained as the intensity of rainfall were compared with the open weather API for the same day and time and found that the device prediction gives 70-75% accurate results which will be really helpful in many areas that require instant information on the rain at particular location and time. The device must be operated in open space and camera should be kept facing towards the sky to capture the cloud images. Device can be used as many times by rotating the facing of camera to capture sky in all directions.

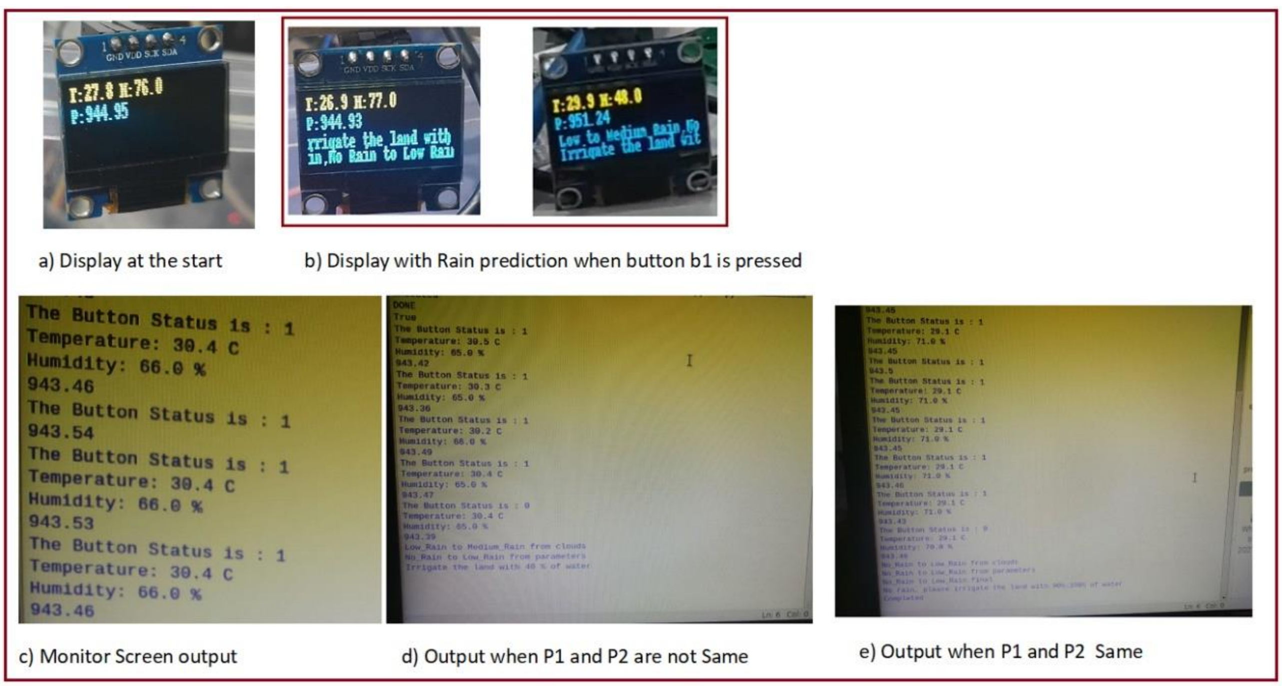


Fig. 10. Final Output at Different Stages.

VI. Conclusion and Future Scope

In this era of technology people like farmers must be able to use various technologies to increase their decision-making in various agriculture processes like the timing of irrigation, spraying of pesticides, use of fertilizers in the right amount, and at right time needed by the crops. But there are some limitations as unavailability of WIFI, No Internet, lack of knowledge while using the technologies. This IoT based portable device is a small effort for people like farmers, transporters where rain prediction is of utmost use for decision making and the main advantage of this device is that it will be operated without the internet and will give the prediction by sensing the atmospheric parameters and sky status at the current location. Compared to the previous devices this proposed system gives rainfall prediction based on atmospheric parameters along with present cloud/sky status specific to that location, hence is very useful in agriculture for monitoring the weather status without the use of any internet and the device require very low power which can be given by a power bank using USB-C Type cable to a raspberry pi.

Farmers cultivating crops under irrigation can benefit from climate prediction of precipitation and temperature at various stages of the growing season. These forecasts enable farmers to better manage the timing of water application and apply the appropriate amount of water to maximize crop production. This device can also be used to monitor individual parameters as per the requirement like temperature, humidity, or atmospheric pressure. The device works in two modes for monitoring individual parameters and gives rain prediction only after pressing the push button. Rain prediction is given by combining output from machine learning by giving atmospheric parameters as input and deep learning by taking sky image as input. For a deep learning model Xception model gives better accuracy of around 80% as compared to VGG16 and Inception V3. Whereas for the Machine learning approach among all individual machine learning models RandomForest and KNN gave a good prediction as compared to others. Logistic regression and SVM also performed well while predicting the values but Decision Tree and Naïve Byes performance was poor in estimating the predictions compared to other models. The device is handy and requires human intervention for pressing the button to get the rainfall prediction as per the requirement. Before reaching the final decision of irrigating the land the device can be used after every 1 or 2 hours to monitor the changes in the atmosphere. The sensed data can be stored in excel in Raspberry-pi and whenever a WIFI is available the data can be stored on the cloud for future use.

For future work, the GSM module can be integrated to operate the device automatically at regular intervals and the prediction can be sent to the farmer's mobile and also the motor can be switched ON/OFF as per the suggestion based on the rainfall prediction. Water wastage may be greatly reduced by including a smart irrigation system, which can reduce water consumption by 20%. The integration of smart technology, such as machine learning, IoT, the web, and the mobile framework, has been a major driver in achieving sustainable precision irrigation. Some of the study's findings show that sustainable precision irrigation management can help farmers achieve food security and avoid water constraint.

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