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IoT Based Low-cost Weather Station and Monitoring System for Precision Agriculture in India

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Abstract—**In recent times it is seen that the climatic and weather conditions not only in India but also in other countries have become uncertain and unpredictable, which may have devastating effects on the agriculture production. India being an agricultural country, most of the farmers largely rely on monsoons and agricultural production is weather dependent. The environmental factors like temperature, humidity, moisture, precipitation and many other parameters keep on changing rapidly and unpredictably. This unpredictable nature, variability of climatic or weather conditions makes the life of farmers quite miserable as they are unable to take proper decisions at the right time. Thus, it is the need of the hour to have a real-time, local weather station which would keep the farmers informed well in advance about the prevailing weather conditions so that they can take appropriate decisions at the right time and save their crops from loss. Precision Agriculture (PA) is an art of using the latest available technologies in the agriculture domain so as to make traditional agriculture more profitable and sustainable while reducing the wastage of resources. The penetration of internet into India is very deep and very fast, especially due to the Jio mania by Reliance Jio Infocomm Limited last year, high speed internet is now possible even in rural areas. This paper proposes a IoT based real-time local weather station for PA, that would provide farmers a means of automizing their agricultural practices (irrigation, fertilization, harvesting) at the right time. The proposed system would also aid the farmers to carry out the agricultural tasks on real-time bases, which in turn helps them to use the agricultural resources in efficient way and at the time when needed by the crops. The proposed weather system is a small step towards the development of PA system considering the Indian scenarios.**

Key words: Precision Agriculture, IoT, Weather Station, Monitoring System

I. INTRODUCTION

India still occupies the second position in the list of most populated countries in the world. It is also predicted that by 2030, India will surpass China to occupy the first place in terms of population. If the present situation of Indian agriculture prevails, the day is not far away when we will have to grow our own crops or vegetables to survive. It has been seen that, India being agricultural country, is unable to cater to the increasing demands for agricultural products due to exponential rise in the population. The population explosion has very devastating effects on the Indian agriculture. Due to increase in population and urbanization, the agricultural land is decreasing alarmingly as shown in the study [1]. In the present context, the agriculture is not proving to be a profitable and sustainable alternative for Indian farmers at least. In spite of the hard work, the present agricultural practices are not yielding the desired results in favor of farmers. There is a lot of pressure on farmers to fulfill the ever increasing demands for the agricultural products while the resources are scarce like water, machinery and tools (high cost). Apart from these factors, the Indian agriculture is also effected by present climatic conditions like humidity, wind speed, moisture levels have significant role in growth of the crop [2]. Population control and climate control seems to be insurmountable at least in the near future. The alternative to this would be to develop a low-cost weather prediction and monitoring system which would provide the farmers with the local, real-time climatic and prevailing weather conditions, so that most of the agriculture tasks can be carried out on time and which in turn would avoid untimely losses. One of the earliest implementations of weather station was developed with serial communication. The work in [3], showed implementation of weather system based on serial communication. Then came the research works of [4] with the internet connectivity option using GSM and Ethernet modules. The parameters monitored were humidity, temperature, rain, solar radiation and UV radiations. The ZigBee communication technology is well associated with automation and its low-data rate capability makes it as good choice for PA systems, especially in weather stations.

Two such implementations came up back-to-back with ZigBee protocol and Arduino [5] and [6] which were able to measure the weather data, including barometric pressure, dew point temperature, air temperature, wind speed and wind direction, relative humidity in first implementation, while the latter collected the air temperature and humidity values. With the popularity of ZigBee technology, one more research article

[7] came up with mini weather station which provided crop protection against frost and strong winds. The system was controlled by a central station that processes the data from mini stations and as an output it generated alarms well in advance against high amplitudes of frost or winds so that the necessity actions could be initiated. Meanwhile, due to miniaturizations and recent developments in semiconductor technologies, reduced costs, led researchers to make use of wireless sensor networks for sensing the weather parameters.

In [8], a rainfall monitoring system was developed using wireless sensor networks, the rain gauge measurements were sent to the public web server via General Packet Radio Service(GPRS). One of the implementations of monitoring system based on wireless sensor network in green houses was developed by [9]. Some of the parameters like temperature, humidity and illumination were measured, the performance and the effectiveness of the proposed algorithm was done in terms of data delivery rates. Similar implementation based on wireless sensor networks [10] could be seen as the design and operation of data acquisition system, which provides different functionalities to ascertain irrigation requirements based on weather and percolation of soil (lysimetric data). Some researchers thought of making use of non-conventional energy resources into the weather systems.

One such related work was carried by [11] in which a solar powered remote weather station was developed for measuring relative humidity and temperature, solar radiation and rain. The developed system relied completely on the sun's energy, which could create problems during cloudy and rainy conditions due to the absence of backup power storage module to make sure that it does work without interruption in unfavorable climatic conditions. Apart from harvesting sun's energy, it the requirement of any PA system that it has to use the scarce agricultural resources such as water and fertilizers very wisely.

This requirement of PA system was fulfilled by [12], where authors were able to design and test a web-based decision support system for conserving water and intelligently scheduling irrigation process. The system used Geographic Information System maps to provide the information about the climate and soil properties. Another requirement of PA systems is that it has to use the latest cutting edge technologies, but at the same time the cost factor is to be kept at the minimum. It was in the same year, when an embedded design of a low-cost weather station was developed [13] which monitored three weather parameters; wind speed, wind directions and temperature. The implementation involved only basic types of sensors (a reflective optical sensor, potentiometer and a temperature sensor) to make it cost-effective. In a similar work [14] developed a low-cost sensing platform and tested it by mounting it on a small Unmanned Arial Vehicle (UAV) which was used to measure and monitor the canopy temperature in a sugar beet field so as to manage the irrigation of the field. Temperature measurements were done using a cost-effective infra-red sensor. IoT is one of the latest cutting edge platform which is capable of providing one more dimension to the present conventional agriculture practices to a connected (Internet) farming or smart farming so as take the Indian agriculture altogether to new heights which would ease the burden on the farmers and make agriculture sustainable and profitable for them. This requirement led the researchers all over the world to develop precise weather system for the farmers so that they get the reward for their hard work and avoid them from going into debts and losses. Due to the emergence of the IoT that has led to lots of startups, skill upgradation in the industries for automation. It has become the latest trend in connecting the things (objects, actuators and other devices) to the internet to get most out of the data generated. This resulted in the requirement of IoT based weather stations.

It is clear from the literature survey that there has been so may advancements that have been added to the earlier weather systems to keep them up to date with the latest available technologies. But when it comes to the Indian scenario, in spite of so much technological advancements in recent times, the agriculture field is the one which has not seen any significant technological advancements like improved quality & quantity, resource utilization, atomization to name a few. Thus it is necessary for us to bring agriculture closer to the technology, and IoT is one such platform which has the potential of completely transforming the present agriculture practices to more profitable, less labor intensive and more sustainable practices. The availability of broadband internet, falling prices of smartphones and computing devices has resulted in applications of IoT almost everywhere like smart cities, smart homes, smart industries and so on. The purpose of this research is to attract the attention of the researchers towards the agriculture domain, so that the small to medium holding farmers get benefitted from the cutting edge technologies like IoT and get the reward for their on-field hard work.

A donut chart as shown in Fig. 1 depicts the applications of IoT in various fields.

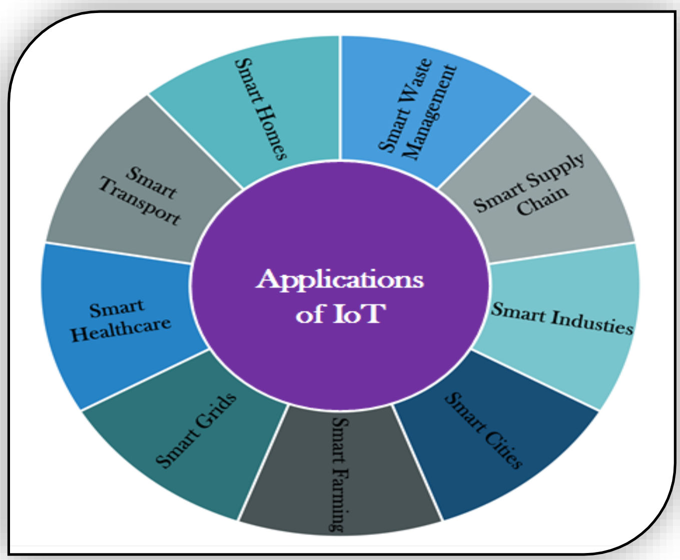

Fig. 1. Applications domains of IoT.

This is not the exhaustive list of IoT application domains, in near future due to seamless connectivity provided by IoT, almost all the sensors or devices will be interconnected to provide real-time control of sensors and devices surrounding us.

II. Materials and Methods

This section defines the materials and methods used in the development of the proposed prototype of Weather Monitoring system.

A. Materials

The problem definition is to develop a low-cost Weather Monitoring system for Precision Agriculture implementation in India. The materials required are classified into two categories: Hardware and Software. The proposed system uses open source hardware and software platforms. The hardware part consists of a low-cost and low power System on-Chip (SoC) microcontroller that has integrated Wi-Fi and dual mode Bluetooth. ESP32 is based on dual-core 32-bit Tensilica Xtensa LX6 microprocessor. ESP32 belongs to the class of ES8266 microcontrollers but has many outstanding features like ultra-low power coprocessor, more number of General Purpose Input and Output Pins (GPIOs) built-in sensors (touch sensors, temperature sensor and Hall effect sensor), 18 channels of 12-bit ADCs, two 8-bit DACs and many more other features that makes it the ideal choice for IoT applications. Apart from this the other hardware includes the low-cost sensor modules. The sensors used to provide the precise parameters includes rain sensor (YL-83+LM393), air temperature and humidity sensor (DHT22), atmospheric pressure sensor (BMP180) and LDR based intensity sensor. These sensors sense the respective parameters and forward the data to ESP32 module where the data is preprocessed by the microcontroller. The data is displayed on to the 0.96-inch OLED (yellow and blue color) graphic display that has 128x64 bit resolution with capability of providing communication using Inter-Integrated Circuit (I2C) protocol. ESP32 SoC prototyping board has many features which makes it a suitable choice for monitoring applications such as weather station. Apart from having extra ordinary capability, it is quite affordable when compared to its counterparts available in the market today.

The software part consists of open-source Arduino Integrated Development Environment (IDE) [15], where the programming is done using C/C++ language functions. *ThingSpeak* IoT platform [16] is used to collect, store, visualize and analyze the sensor data. ThingSpeak is an open-source IoT platform and Application Programming Interface (API) that can store and retrieve sensor data using HTTP protocol over the internet. ThingSpeak helps to collect the data, store it, provide the visualization of data, and its analysis. It can also provide the triggers (action) that can be used to control the devices through the actuators. As the proposed system makes use of both open-source hardware and software platforms, the system cost is brought down to the lowest level possible.

B. Methods

The methodology involved in the development of the proposed system is to intelligently select the low-cost sensors (without compromising with the accuracy and precision), collect data in real- time, store the data in cloud sever, perform visualization of the sensor data, carry out analytics on the data to study its current behavior so as to predict its future behavior.

The block diagram of the proposed weather system is as shown in Fig. 2.

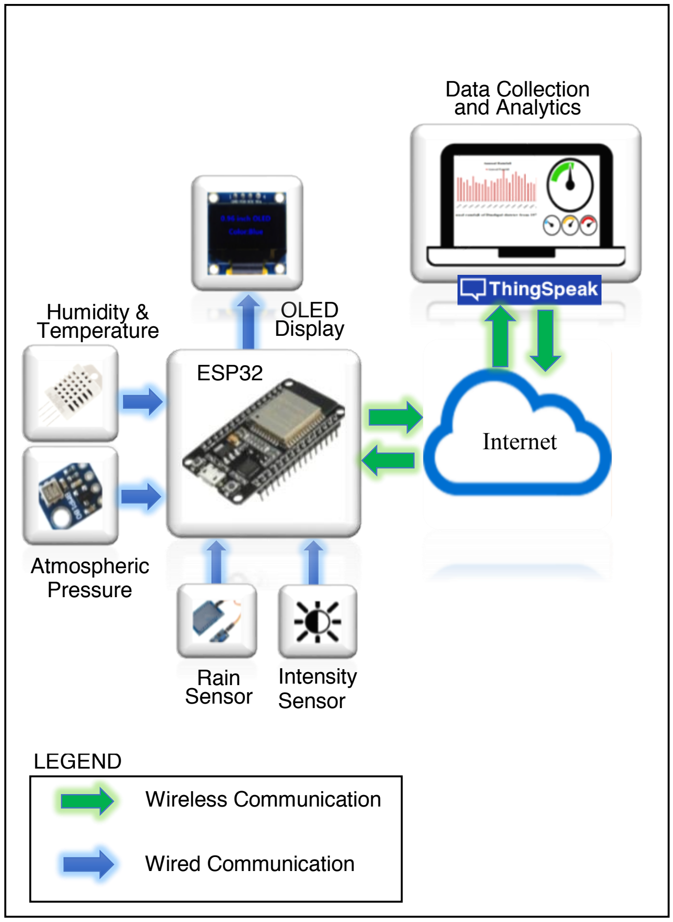

Fig. 2. Block diagram of proposed weather system.

The system mainly consists of three parts; the first part consists of data collection, the second part is the data storage and the third one is the data analysis and prediction. Weather data is collected from the sensors (Temperature, Humidity, Dew Point (derived from temperature and humidity), Absolute Pressure, Relative Pressure, Light Intensity and Rain data). Once the sensor data is collected, it is subjected to local processing by the microcontroller where the raw data is converted to meaningful one. After local processing, the data can be stored optionally by using a SD card module. The data is then sent to the ThingSpeak cloud server for visualization and analysis.

ThingSpeak helps in sending the notifications either in the form of Tweet or email to the users whenever the aforementioned parameters cross thresholds levels.
ThingSpeak apart from providing visualization, helps in storing the data in the server by creating a channel that can store up to eight fields of data. In this weather system, eight fields were used to store data. The other functionality provided by the ThingSpeak cloud server is data analytics. The data analytics is provided in the form of MATLAB Analysis and Visualizations.

Figure. 3 shows the flowchart for the proposed weather system. Once the system is powered ON, the microcontroller and the sensors connected to it are initialized.

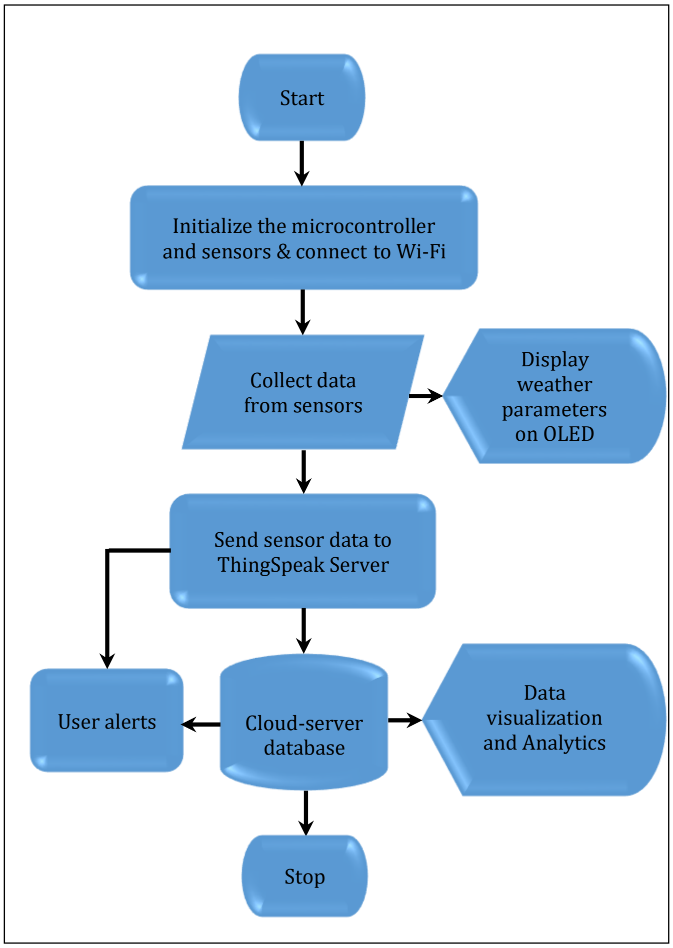

Fig. 3. Flowchart for the proposed weather station.

If the initialization of DHT22 and BMP180 sensor goes well, then the program is executed and sensor data is collected by the microcontroller but if the initializations fails, then the program is not executed. The raw data from various sensors is collected and locally processed by the microcontroller by converting the raw data from the sensors into usable and meaningful one. The data is displayed and visualized on an OLED graphic display locally. The weather parameters are then sent to the ThingSpeak cloud server. ThingSpeak cloud server serves two purposes here. First is to provide visualization and second to provide analytics which can further provide the predictions of prevailing weather conditions in near future.

III. Experimental Setup

The prototype was developed to provide precise weather conditions prevailing in and around the agricultural fields. This prototype would serve to be an integral part of any Precision Agriculture system where the weather parameters are to be precisely measured and monitored. The experimental setup for the prototype included both hardware and software components. The hardware component consisted of sensors and the microcontroller, while the software components consisted of Arduino IDE used for coding the microcontroller. The experimental setup for the prototype is as shown in Fig. 4.

Fig. 4. Experimental setup.

IV. Results and Discussion

After the successful development of the prototype, it was tested in laboratory for data collection and monitoring. The prototype was able to precisely collect all the weather parameters (Temperature, Humidity, Dew Point, Absolute Pressure, Relative Pressure, Light Intensity and Rain fall amount) in real-time. The results obtained were used for two purposes, out of which the first one is data visualization and the second one is the data analysis.

A. ThingSpeak Visualizations

ThingSpeak cloud server provides two functionalities, first one visualization and second analysis or analytics based on MATLAB. The visualization functionality was used to visualize eight sensor fields (parameters). The important tabs pertaining to the dashboard of ThingSpeak are the channel id and API keys (read and write). The channel can be made private or public (visible to others). In this prototype, the channel is made private at present. Along with the other tabs for visualizations, it also provides MATLAB Analysis and Visualization as shown.

The templets used for MATLAB Visualizations for the developed prototype were used to visualize all the eight field parameters, Histogram plot of humidity and temperature to understand data variation, correlated or scatterplots of (temperature & humidity, Absolute & relative pressures, Humidity & dew point and finally Temperature & dew point).

The field 1 chart corresponds to temperature while field 2 chart represents absolute pressure. As seen from the first plot Fig.5 (a), over the time, increase in the temperature can be seen till 2:00 p.m. in the afternoon while slow fall in temperature thereafter. Similar observation was made with the second field chart Fig.5 (b), where a steady increase is seen. Field chart 3 and 4 in Fig.6 (a) and Fig.6 (b) corresponds to relative pressure and humidity respectively. It can be observed from the plots of Fig.5 (a) and Fig. 6 (b) that the temperature and humidity are inversely related, that is increase in temperature causes decrease in humidity and vice-versa.

Figure. 7 (a) and (b) gives the variation of light intensity and dew point variations with respect to time.

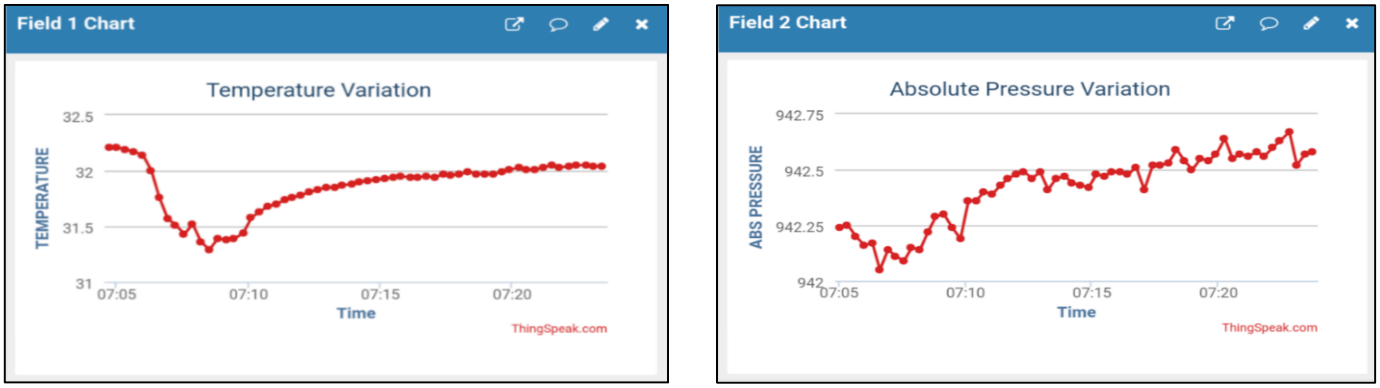

Fig. 5. Real-time variation in (a) Temperature (field chart 1) (b) Absolute Pressure (field chart 2)

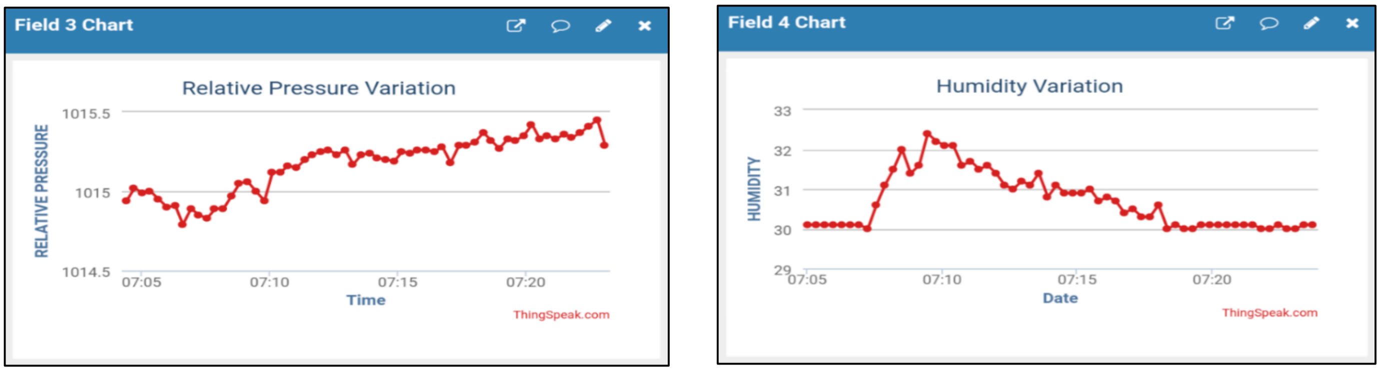

Fig. 6. Real-time variation in (a) Relative Pressure (field chart 3) (b) Humidity (field chart 4)

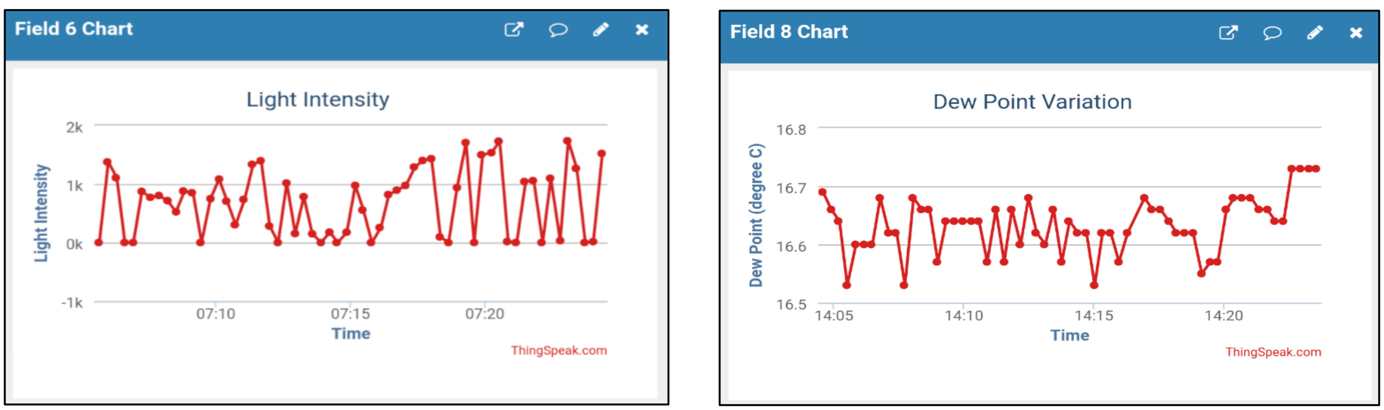

Fig. 7. Real-time variation in (a) Light Intensity (field chart 6) (b) Dew Point (field chart 8)

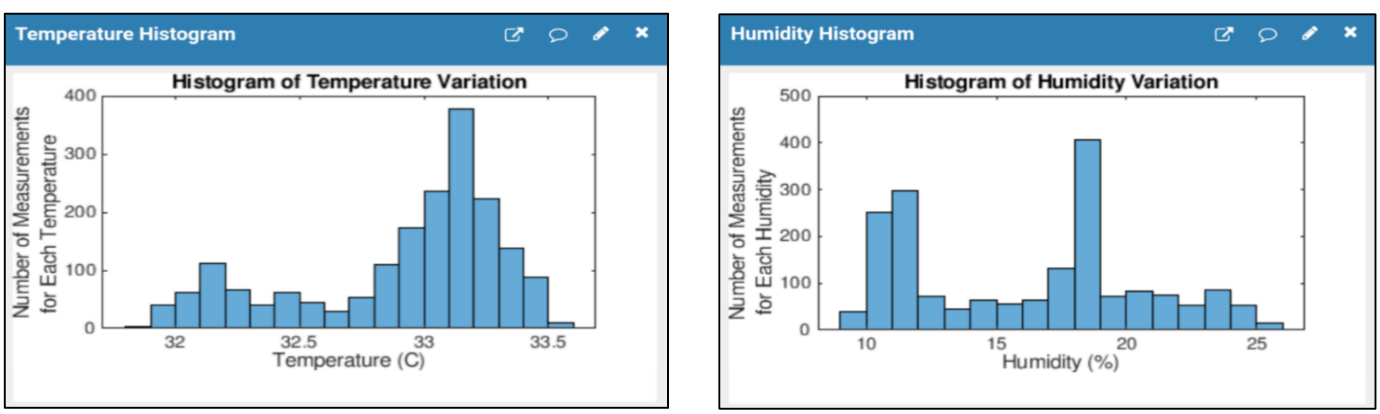

Fig. 8. Histogram plot of (a) Temperature and (b) Humidity.

Figure 8 (a) & (b) represents the histogram plots of temperature and humidity respectively. The histogram plots provide the important insights about the frequency of occurrence of the data. These plots are helpful in creating the data sets corresponding to different frequency of data occurrence.

Figure 9 shows the channel location in terms of latitude and longitude.

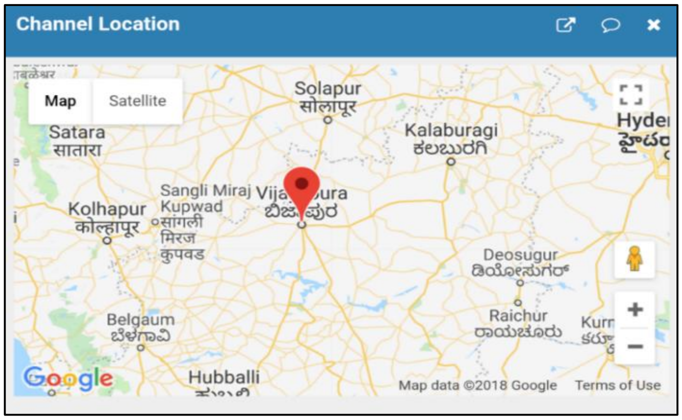

Fig. 9. Channel location (Latitude = 16.852517, Longitude = 75.725228 and Elevation = 592 m).

B. ThingSpeak Analytics (MATLAB analysis and Visualization)

The data analytics helps in studying the current behavior of atmospheric weather, its past and how it may behave in future, that is its prediction. The data collected is grouped into data sets and are subjected to data analytics or predictive analytics. The analytics was carried out by using MATLAB analysis and Visualization provided by the ThingSpeak.

The templets used for MATLAB Analysis for the developed prototype were to calculate and display average humidity and temperature, calculate and display average absolute and relative pressures, calculate and display average dew point calculate high and low temperatures.

Similarly, the average variation of any field parameter over any span of time can be obtained and these fields can be updated in new channel in real-time.

V. CONCLUSION

The developed prototype for precision weather station is capable of providing the farmers with real-time weather situation and conditions prevailing in and around the agricultural field. The developed prototype is an important part of PA systems. The low-cost (open source hardware/software, low cost sensors) nature of the developed prototype will aid the farmers to carry out agricultural task at right and favorable time. This is a small step to bring the technology into the agricultural sector, thereby making the agricultural practices more and more profitable and sustainable for farmers especially from India. As a future enhancement, few more sensors will be used to sense wind speed and direction and deploying the prototype into the agricultural field and monitor weather parameters and convert this prototype in a full-fledged Precision Weather Station which can serve as an integral part of PA system.

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