Journal of Independent Studies and Research Computing (JISR-C)
ISSN (P): 2412-0448, **ISSN (E):** 1998-4154

DOI: 10.31645/JISRC.23.21.2.5

Environmental Temperature and Humidity Monitoring at Agricultural Farms using Internet of Things & DHT22-Sensor

Seema Ansari
Electrical Engineering Department,
Institute of Business Management,
Karachi, Pakistan
seema.ansari@iobm.edu.pk

Adeel Ansari
Computer & Information Sciences Department
Universiti Teknologi PETRONAS,
Seri Iskandar, Malaysia
adeel_g02084@utp.edu.my

Adeet Kumar
Electrical Engineering Department,
Institute of Business Management,
Karachi, Pakistan
adeet.kumar@iobm.edu.pk

Rahul Kumar
Electrical Engineering Department,
Institute of Business Management,
Karachi, Pakistan
rahul.kumar@iobm.edu.pk

Tadiwa Elisha Nyamasvisva
Department of Networking,
Infrastructure University Kuala Lumpur,
Kuala Lumpur, Malaysia
tadiwa.elisha@iukl.edu.my

Abstract— Many monitoring systems have been designed and tested by researchers for monitoring environment temperature and humidity for different industrial applications and smart homes using DHT22 or DHT11 with Arduino Uno and wireless communication module. DHT22 is found to have better specifications in terms of performance and accuracy for measuring both temperature and humidity compared to DHT11. Arduino UNO is a microcontroller commonly used in scientific research. There are other more powerful microcontrollers available in the market. We chose ESP32 as its CPU is more powerful and can run upto 240 MHz, whereas Arduino UNO can run upto 16 MHz. In terms of connectivity, there is no Wi-Fi or Bluetooth functionality built in Arduino board, whereas ESP-32 has Wi-Fi and Bluetooth functions built in, which makes it more suitable for IoT projects. This paper aims at using Long Range Wide Area Network (LoRaWAN) Technology to monitor environmental temperature and humidity at the agricultural farm remotely, using DHT22 in conjunction with TTGO T-Beam as it has an ESP32 development board and also includes a GPRS module. ESP32 can be connected to internet using Wi-Fi. The sensor connected to the T-Beam send data to the Cloud through the internet. In this experiment we used Firebase platform to save data in the database. This information can also be received on the serial monitor as well as on smart phones and Web/App by the concerned personnel. The T-Beam module is a reliable module for data communication and covers up to 15Kms range. The LoRaWAN is used as a gateway to connect devices wirelessly to the internet and manages communication between end nodes. The buzzer is set to turn on for temperature ≥ 32 °C and humidity ≤ 60%. The system is designed for monitoring environmental temperature and humidity at agricultural farms it can also be used in other applications like smart homes, industries to control temperature/humidity, poultry farms and environment monitoring in specific locations/areas.

Index Terms— *DHT22, Digital Twins, Environmental Monitoring, Relative Humidity, Temperature Sensor, TTGO T-Beam.*

I. INTRODUCTION

Environmental temperature and humidity have a great impact on plants growth. Humidity refers to the amount of water present in the air [1]. While Relative humidity refers to the moisture contents of the atmosphere, expressed as a percentage of the amount of moisture that can be retained by the atmosphere also called moisture-holding capacity at a given temperature and pressure without condensation [2]. Relative humidity (RH) which compares the water contents in the air(gms/m3) with temperature at a given instant of time is expressed as a percentage. If RH is 100%, it means air is saturated with water, and any further addition of water will result in rain [1]. Circulation of water in plants plays an important role in its growth. It is important for transpiration and transportation. Environmental factors such as air humidity, mineral supply, salinity and biotic effects have great influence on the water contents in various parts of the plant [3]. Plants tissues tend to lose or gain water in order to maintain equilibrium with water in the air. RH directly impact the production quality as RH% decreases, this indicates the increase in rate of water loss. Drier environment causes water loss in plants tissues. Monitoring the RH of the environment in the agricultural fields can assist the farmers to decrease water loss, that impacts the produce, and enhance production [1].Temperature is also one of the important items that can be monitored in IoT applications. Besides agriculture and farming, it can be used in monitoring of poultry farms' temperature by maintaining temperature between 18oC to 22oC [4-6], to prevent chickens from dying. IoT system can also be used in monitoring of greenhouse gases to maintain temperature [7-9]. Another application is monitoring of humidity and temperature in concrete structures [10]. Other applications where DHT22 can be used include [11], measurement of temperature and humidity, automatic control of climate, at local weather stations and for monitoring the environment. Climatic information is very important in identifying cropping patterns and irrigation procedures. This research is about monitoring temperature and humidity at an agricultural farm through LoRaWAN technology, using TTGO T-Beam, Wi-Fi and DHT22 Sensor for measuring environmental Temperature and Humidity. Other researchers have used Arduino-UNO as microcontroller with DHT11 sensor. The reason why we selected DHT22 is its better performance and accuracy. Its wider temperature and humidity range, precise measurement, better resolution for both temperature and humidity [12], details are given in the literature review. Instead of Arduino UNO we preferred to use TTGO T-Beam because of the differences in their built-in capabilities. TTGO T-Beam has an integrated ESP32 development board, 3D antenna, WiFi, Bluetooth with LoRaWAN communication and GPS modules NEO-6M. ESP 32 has more processing power (240 MHz) compared to Arduino UNO (16MHz). Arduino UNO does not have communication features in built, as compared to ESP 32. Our device can transmit data over 15Kms using Wi-Fi and can be received on smart phone or Web/App using LoRaWAN. It allows for remote monitoring and timely action to increase crop yield. The rest of the paper includes literature review in Section II, our proposed device is described Section III, while methodology is discussed in Section IV, followed by result in Section V and finally the conclusion in Section VI.

II. LITERATURE REVIEW

Several techniques and solutions have been proposed by researchers that uses DHT22 sensor to monitor environmental temperature and humidity. In this section we present a review of the state-of-the-art techniques proposed by the researchers to measure environment temperature and humidity. In [12] author compares the features of DHT22 and DHT11. As per the specifications it is found that although a little expensive, DHT22 performance and specifications are better as compared to DHT11. Its temperature range varies between -40 ℃ to +125 ℃ and humidity range varies from 0 to 100% with an accuracy of ±0.5 degrees in temperature and an accuracy of 2-5% in humidity measurement.. The temperature range of DHT11 is 0 to 50 ℃ with an accuracy of ±2 degrees. Humidity of DHT11 varies between 20 to 80% with an accuracy of 5%. Also the resolution of DHT22 sensor is better compared to that of DHT11. Resolution of DHT22 is 0.1% for humidity and 0.1ºC for temperature, while that of DHT11 is 1% for humidity and 1ºC for temperature. However, the sampling rate for DHT11 is 1Hz which means one reading per second while DHT22 has a sampling rate 0.5 Hz or one reading every 2 seconds. Both sensors operate at 3-5 volts with maximum current of 2.5mA.

In [13] authors have designed a monitoring system for monitoring temperature and humidity in the surrounding environment using DHT22 Sensor and the wireless communication module NRF24L01 built on Arduino Uno. Hardware part consisted of two nodes, named as base node and client node. At the base node they used Arduino Uno and the NRF24L01. They tested the module in different rooms and found the data sent was the same as data received upto a range of 800 m. They kept the threshold temperature as 32 ℃ and humidity as 65%. When the values were exceeded, the buzzer turned on. Authors in [14] talk about the emerging growth of digital twins (DT) technology in the field of engineering and architecture. In their experiments they tested sensors that were low cost and compatible with Arduino for inside environs of countries located in the south of Europe. They tested five dissimilar variety of sensors for measuring temperature (in the range 10 °C and 35 °C), relative humidity (between 50%–95%,) and carbon dioxide. They found that some of the low cost, open-source sensors compatible with Arduino displayed outstanding results with compliance to desired standard values. In [15] authors did experiments for finding temperature, humidity and pH of the soil on the Mt. Sinabung to determine the suitability of the soil for growing strawberries. For temperature and humidity, they used DHT22 Sensor, while pH sensor was used to check the soil pH value. They took the measurements of the temperature, humidity and pH of soil, at four different points on the field where strawberry plantation was to be done. All four results indicated that the soil was suitable for strawberry plantation. In [16] authors have focused on measuring temperature and humidity using DHT11 and Node MCU apparatus in the agricultural sector. In their project DHT11 Sensor detects moistness and temperature in the air and sends the data via Arduino MCU to the Cloud at regular intervals of time through ESP8266 WIFI module. From the Cloud, humidity and temperature values can be seen graphically on Firebase console platform from anywhere in the world. With the help of WiFi module the data can be accessed. Performance of IoT based temperature monitoring system has been evaluated in [17]. Authors designed a Temperature monitoring system using DHT22 temperature sensor and Raspberry Pi. To evaluate its performance, they compared the readings with an industrial grade temperature probe Keithley 6517-TP, connected to Keithley 2110 benchtop digital multimeter as the acquisition system. They found the DHT22 sensor system provides accuracy upto 0.10°C, but is slower in responding to rapid temperature changes detection. They observed that DHT22 is more suitable for environment with gradual changes in temperature. The DHT22 Sensor module works in the ISM (Industrial, Scientific and Medical) frequency band around the globe at 2,400-2,4835GHz, and is able to transmit data upto a maximum of 1 km distance [18]. Author in [18] defines relative humidity as the ratio of the quantity of water vapors present in the air with respect to the maximum moisture holding capacity and is measured as a percentage of total water holding capacity. It may be expressed as:

Journal of Independent Studies and Research Computing (JISR-C)
ISSN (P): 2412-0448, **ISSN (E):** 1998-4154

$$\text{Relative humidity} = \frac{\text{The quantity of water vapor present in the air}}{\text{The maximum moisture holding capacity}}$$

Authors [20] talks about effect of air humidity on plant tissues: high air humidity causes physiological disorder that frequently occur in plant tissues and leads to a reduction in propagation and significant losses. The cultivation of plants in greenhouses builds up high air humidity resulting in increased water accumulation in shoots. High air humidity results in developmental abnormalities, including poor stomatal function, and leads to reduced transpiration, especially under low light conditions [21].

III. PROPOSED PROJECT

An IoT based temperature/humidity monitoring system has been developed, that sends real time data to users through the internet via Wi-Fi and LoRaWAN technology using DHT22 sensor module to measure Temperature and Humidity. The sensor is interfaced with TTGO T-Beam.

A. About the Components

DHT22 has a dedicated Negative Temperature Coefficient (NTC) to measures temperature. It has an 8-bit microcontroller to give readings of temperature/ humidity as serial data. DHT22 can be interfaced with other microcontroller as well. It can measure a range of temperature from -40°C to 80°C and humidity from 0% to 100% with an accuracy of ±1°C and ±1% [4]. The connection diagram for the sensor is shown in Figure 1.

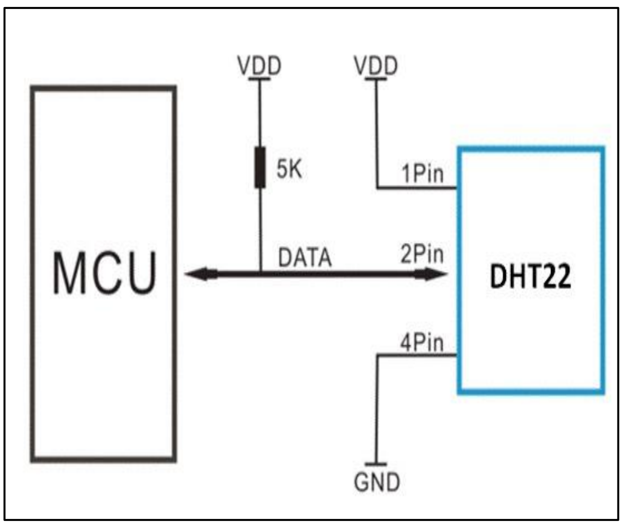

Fig 1 DHT22 connection diagram with MCU [11]

Pin connections are illustrated in Figure 1, where pin 1 is attached to the supply voltage VDD, while the data pin of DHT22 (pin 2) is joined to the I/O pin of the MCU. Connection of a 5k pull up resistor is also shown. The values of the output for temperature/humidity are obtained as serial data from data pin. Pin 4 of the sensor is connected to the ground. Table 1, shows the Pin Identification and Configuration for DHT22 Sensor and DHT22 Module [11], shown in Figure 1 and Figure 2 respectively.

TABLE I PIN IDENTIFICATION AND CONFIGURATION FOR DHT22 SENSOR AND DHT22 MODULE [11]

Pin No.	Pin name	Description
For DHT22		
1.	Vcc	Power supply 3.5V to 5.5V
2.	Data	This pin used to output serial data for both Temperature and Humidity
3.	NC	This Connection is left unused
4.	Ground	Connects to the ground of the circuit
For DHT22 Module		
1.	Vcc	Power supply 3.5V to 5.5V
2.	Data	This pin used to output serial data for both Temperature and Humidity
3.	Ground	Connects to the ground of the circuit

The DHT22 sensor shown in Figure 2 and DHT22 module shown in Figure 3 have the same performance. The sensor has four pins out of which only three pins will be used, this is shown in Figure 2 as DHT22 Pinout while the module has just three pins as illustrated in Figure 3.

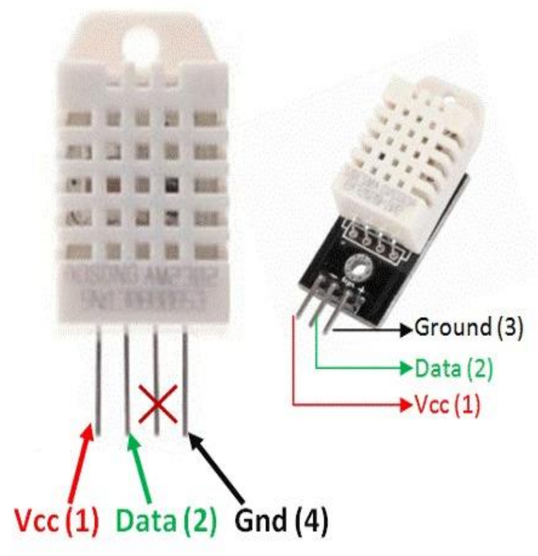

Fig 2 DHT22 Sensor pinout [11]

The modification in the DHT22-module is that it has an inbuilt filtering capacitor and pull-up resistor. In case of sensor these will be connected externally if needed. Figure 3 below shows the DHT22 module with three pins and an inbuilt filtering capacitor and pull-up resistor. This sensor module is a digital signal acquisition sensor. Its function is to evaluate temperature and humidity readings as analog output for further processing by a microcontroller. The sensor is small in size, consumes less power, high accuracy and anti-interference ability and low cost. DHT22 operates at 3.5V to 5.5V. Its operating current is 0.3mA and outputs serial data. Its temperature range varies from -40°C minimum and 80°C maximum while humidity ranges between 0% to 100%. Its resolution is 16 bits for temperature and humidity, showing precision of ±0.5°C and ±1% [11].

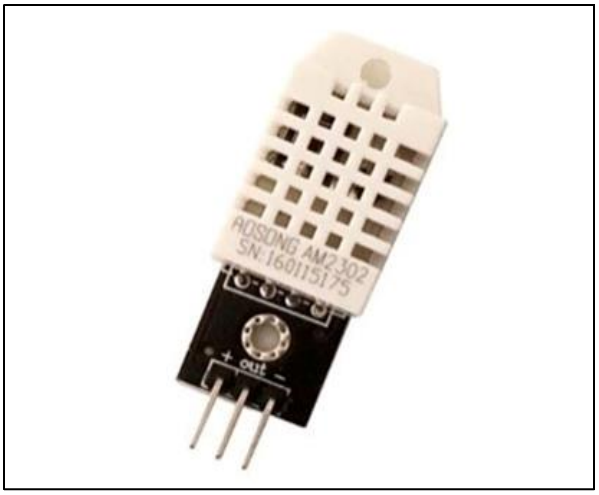

Fig 3 DHT22 Temperature Sensor module [11]

Figure 4, shows the TTGO T-beam. TTGO T-Beam features integrates an ESP32 development board with 4 MB Flash, 8 MB PSRAM, 3D Antenna, WiFi, Bluetooth with LoRaWAN communication, GPS modules NEO-6M, 3V-5V power supply Universal.

Fig 4 LILYGO® TTGO T-Beam V1.1 ESP32 433/868/915/923Mhz WiFi Wireless Bluetooth Module GPS NEO-6M SMA LORA 32 18650 Battery Holder with SoftRF [19]

The Working voltage of T-Beam is 1.8~3.7v, its acceptable current is 10~14mA, operating frequency is 433MHz.

IV. METHODOLOGY

In our Temperature/Humidity Measurement system we have used DHT22 sensor module as the input, interfaced with TTGO T-Beam. On the output side a serial monitor display, a buzzer and an LED is connected. Figure 5 shows the block diagram of the Temperature and Humidity monitoring system. DHT22 sensor sends data to the TTGO T-Beam that controls, receives and processes the data received from the sensors. Results of the data received are displayed on the serial monitor. The LED indicator and buzzer will turn ON, when the temperature and humidity will exceed the threshold values.

Coding was done in C++ to connect the system to the cloud using firebase platform and the internet using Wi-Fi. The data stored can be accessed on the smart phone as well as Web Application developed for this purpose. The system was tested at 500m distance between Transmitter and receiver and the data sent was successfully displayed on the serial monitor and also received on the smart phone and Web/App.

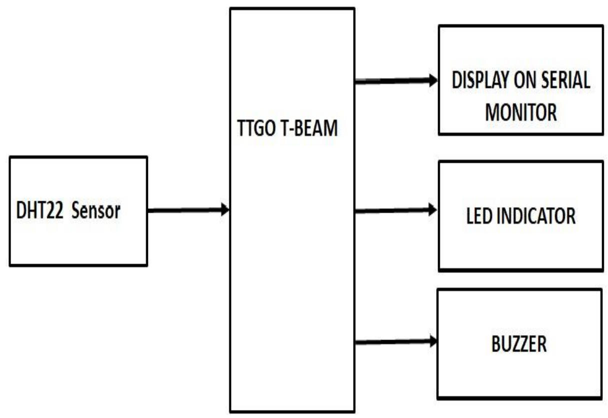

Fig 5 Block diagram of Temperature/Humidity Measurement System

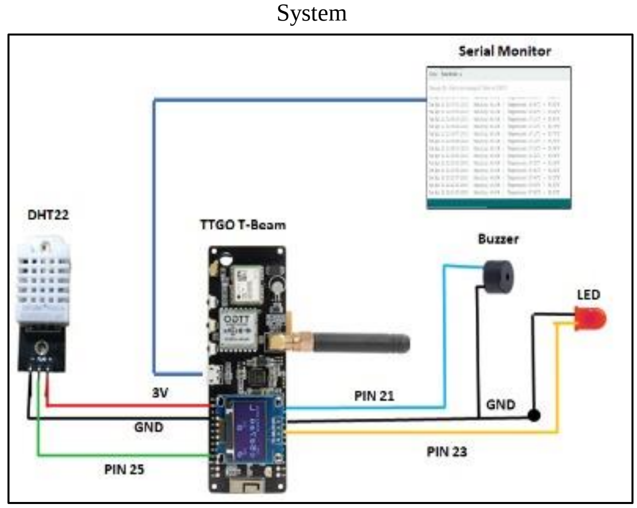

Fig 6 Circuit diagram measuring Environment Temperature / Humidity using TTGO T-Beam and DHT22.

Figure 6 illustrates DHT22 Sensor module used in conjunction with TTGO T-Beam. Experiments were conducted in the IoT Lab environment from 8:00 AM to 2:00 PM. Figure 7 and 8, illustrates the circuit connections made for temperature/humidity monitoring with DHT22 Sensor module and buzzer.

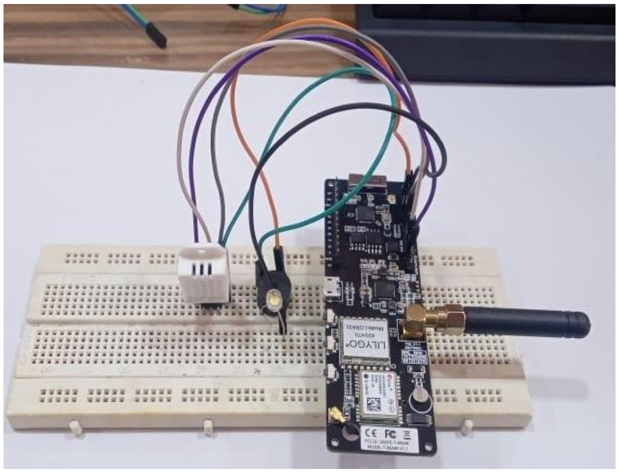

Fig 7 A pictorial view of the project.

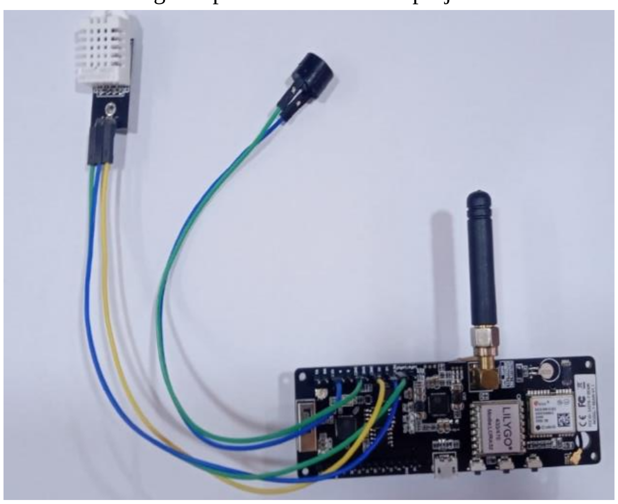

Fig 8 DHT22 with T-Beam and Buzzer

Tests were also conducted for communication between two T-Beams placed far apart. The data received at the receiving T-Beam was exactly the same as sent by the sending T-Beam. The receiving T-Beam was connected to cloud via internet. The same data was received on the smart phone. This module will help in monitoring the temperature and humidity of environment at the farm remotely.

V. RESULT

Experiments for Temperature and humidity tests were performed in the IoT Research lab of IoBM from 8:00 AM to 14:00 Hrs. The sensor transmitted data to the T-beam and readings were displayed on the serial monitor. The temperature and humidity measurements are shown in Table 2. The threshold value for testing Temperature was kept as 32°C. When the temperature reached 32°C the buzzer turned ON, indicating high temperature. Similarly, the threshold for humidity was kept as 60%. When the humidity value reached 60%, the buzzer turned ON. These readings were also received on the smart phone, notifying the concerned personnel for appropriate action as required by the application.

TABLE II RESULTS SHOWING TEMPERATURE AND HUMIDITY MEASUREMENT

Time	Temperature °C	Humidity %	Buzzer
8:00:00	25.3	52.3	OFF
8:30:00	26	50.6	OFF
9:00:00	27.4	51.5	OFF
9:30:00	28.8	53	OFF
10:00:00	29.3	54.2	OFF
10:30:00	30.9	55.8	OFF
11:00:00	29.4	54.6	OFF
11:30:00	31.6	55.9	OFF
12:00:00	32.2	57.5	ON
12:30:00	32.1	58.6	ON
13:00:00	31.92	60.1	ON
13:30:00	29.5	58.9	OFF
14:00:00	27.5	55.9	OFF

A plot of Temperature readings is shown Figure 9. The curve indicates temperature variation in the environment from 8:00AM to 14:00. From 8:00 to 11:30 the temperature is below 32°C. At 12:00:00 it goes to 32.2°C. At this value the buzzer turned ON, see Table 2. The data from the sensor was received on the serial monitor as well as on the smart phone and Web/App.

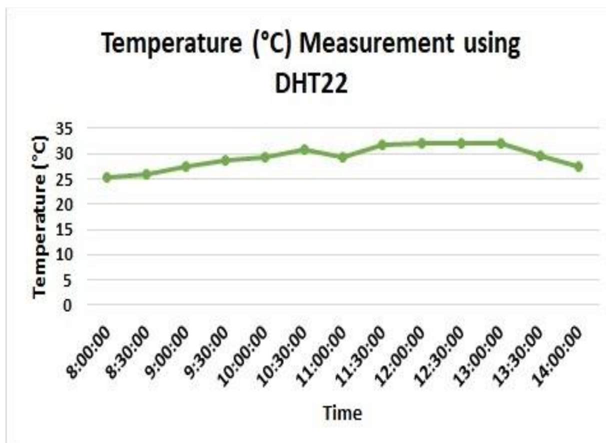

Fig 9 Plot of Temperature measurement with DHT22 sensor module

Similarly, the plot of humidity measurement is shown in Figure 10. The curve shows humidity variation from 8:00AM to 14:00. At 13:00:00, humidity reading is 60.1% indicating value above threshold which is 60% as is seen in the plot. The buzzer turned ON shown in Table 2, and the alert notification was received on the smart phone via cloud.

A combined plot of both temperature and humidity is illustrated in Figure 11. Y-axis for both Temperature and humidity are shown separately. Humidity is shown in percentage on the Y-axis on the right. While the Y-axis on the left shows the Temperature in °C. The chart can be used for analysis and necessary action based on farm requirement for crop growth, or any other application.

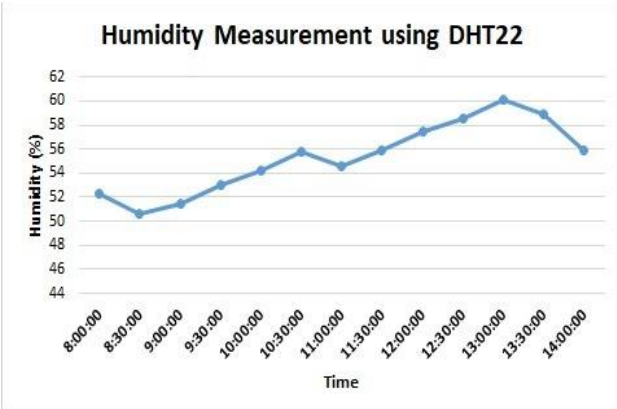

Fig 10 Plot of Humidity measurements with DHT22 sensor module

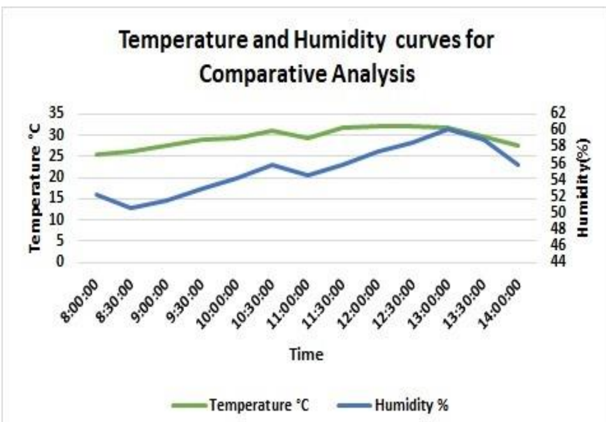

Fig 11 Comparative analysis of temperature and Humidity measurements

The system designed for environmental temperature and humidity monitoring will be useful in monitoring temperature and humidity at the agricultural farms, as plants growth is affected by the environmental changes. It can also be used at the poultry farms in monitoring and maintaining poultry farms' temperature to prevent chicken from dying. It will also be useful in monitoring of humidity and temperature in concrete structures as well as food industries where temperature maintenance is an important factor.

VI. CONCLUSION

This project aimed at developing an IoT based system using LoRaWAN technology to monitor environment temperature and humidity for an agricultural farm producing Sunflower crop from which cooking oil is extracted. DHT22 Temperature/Humidity sensor module was interfaced with a TTGO T-BEAM to measure environmental temperature and humidity. The T-Beam has a range of 15 Kms. DHT22 sensor was connected to the T-Beam. The T-Beam collects the data from the sensor and transmits to the cloud using firebase platform via internet. Experiments were conducted in the IoT research Lab at the Electrical Engineering department of the Institute of Business Management. The module was found to be reliable for data communication, as data received was in accordance with the data sent. The test was also conducted sending data to another T-Beam at a distance of 500m, the data received on the Receiving T-Beam was successfully received. The buzzer worked well, turning ON for temperature ≥ 32 °C and humidity ≥ 60%. This set up will be useful on projects located at distant locations to control temperature/humidity remotely on agricultural farms and poultry farms. Real time data will be displayed on serial monitor, smart phone and Web/App.

ACKNOWLEDGMENT

Authors are grateful to the Institute of Business Management for providing the IoT Research Lab facility to conduct the prototype project experiment and providing funding. The project will be implemented on the Sunflower farms at Gharo, Sindh in Pakistan.

REFERENCES

[1] Measuring humidity using Temp/Humidity Sensor, https://www.instructables.com/Measuring-Humidity-Using-Sensor-DHT11/ (last accessed on March 27, 2023).

[2] Elhadi M. Yahia, "Postharvest Technology of Perishable Horticultural Commodities", Chapter 1, 2019, Pages 1-41, https://doi.org/10.1016/B978-0-12-813276-0.00001-8

[3] Gederts levinsh, "Content of Plant Tissues: So Simple That Almost Forgotten?", Plants 2023, 12(6), 1238; https://doi.org/10.3390/plants12061238, Published: 8 March 2023

[4] H. Mansor, A. N. Azlin, T. S. Gunawan, M. Md Kamal, and A. Z. Hashim, "Development of smart chicken poultry farm," Indonesian Journal of Electrical Engineering and Computer Science, vol. 10, no. 2, pp. 498-505, 2018.

[5] T. S. Gunawan, M. F. Sabar, H. Nasir, M. Kartiwi, and S. Motakabber, "Development of Smart Chicken Poultry Farm using RTOS on Arduino," in 2019 IEEE International Conference on Smart Instrumentation, Measurement and Application (ICSIMA), 2019: IEEE, pp. 1-5.

[6] M. F. H. Hambali, R. K. Patchmuthu, and A. T. Wan, "IoT Based Smart Poultry Farm in Brunei," in 2020 8th International Conference on Information and Communication Technology (ICoICT), 2020: IEEE, pp. 1-5

[7] R. Gao, H. Zhou, and G. Su, "A wireless sensor network environment monitoring system based on TinyOS," in Proceedings of 2011 International Conference on Electronics and Optoelectronics, 2011, vol. 1: IEEE, pp. V1-497-V1-501.

[8] T. S. Gunawan, Y. M. S. Munir, M. Kartiwi, and H. Mansor, "Design and implementation of portable outdoor air quality measurement system using arduino," International Journal of Electrical and Computer Engineering, vol. 8, no. 1, p. 280, 2018

[9] M. F. M. Pu'ad, T. S. Gunawan, M. Kartiwi, and Z. Janin, "Performance evaluation of portable air quality measurement system using raspberry Pi for remote monitoring," Indonesian Journal of Electrical Engineering and Computer Science, vol. 17, no. 2, pp. 564-574, 2020

[10] N. Barroca, L. M. Borges, F. J. Velez, F. Monteiro, M. Gorski, and J. Castro-Gomes, "Wireless sensor networks for temperature and

humidity monitoring within concrete structures," Construction and Building Materials, vol. 40, pp. 1156-1166, 2013.

[11] DHT22 for measuring Temp/Humidity, https://components101.com/sensors/dht22-pinout-specs-datasheet (last accessed on March 27, 2023).

[12] Dejan, "DHT11 & DHT22 Sensors Temperature and Humidity Tutorial using Arduino" https://howtomechatronics.com/tutorials/arduino/dht11-dht22-sensors-temperature-and-humidity-tutorial-using-arduino/

[13] Azhari , T I Nasution , S H Sinaga , and Sudiati, Design of Monitoring System Temperature And Humidity Using DHT22 Sensor and NRF24L01 Based on Arduino, Journal of Physics: Conference Series 2421 (2023) 012018, IOP Publishing doi:10.1088/1742-6596/2421/1/012018

[14] Pedro F. Pereira*, Nuno M.M. Ramos, Low-cost Arduino-based temperature, relative humidity and CO2 sensors - An assessment of their suitability for indoor built environments, Journal of Building Engineering, Volume 60, 15 November 2022, 105151

[15] Yuan Alfinsyah Sihombing and Sustia Listiari, Detection of air temperature, humidity and soil pH by using DHT22 and pH sensor based Arduino Nano microcontroller, AIP Conference Proceedings 2221, 100008 (2020); https://doi.org/10.1063/5.0003115, Published Online: 31 March 2020.

[16] Ms.Sujeetha. R/AP, K Reddy Deeraj, B Bhaskar Yeseswi, Lenin Sade, Humidity and Temperature Monitoring System using IoT, International Journal of Engineering and Advanced Technology (IJEAT) ISSN: 2249-8958 (Online), Volume-9 Issue-2, December, 2019.

[17] Y. A. Ahmad, T. S. Gunawan, H. Mansor, B. A. Hamida, A. F. Hishamudin, F. Arifin, "On the Evaluation of DHT22 Temperature Sensor for IoT Application", 8th International Conference on Computer and Communication Engineering (ICCCE), 978-1-7281-1065-3/21 ©2021 IEEE, DOI: 10.1109/ICCCE50029.2021.9467147, June 2021

[18] H. R. Nasution, A. E. Fahrudin, and A. A. Harnawan, "Prototype of Sensor Network System for Monitoring of Database-Based Surface and Sub-Surface Humidity of Peatlands," J. Fis. FLUX, vol. 13, no. 1, pp. 70–78, 2016]

[19] TTGO T-Beam features: http://www.lilygo.cn/claprod_view.aspx?TypeId=62&Id=1281&FId=t28:62:28 (Accessed April 9, 2023).

[20] Kevers, C.; Franck, T.; Strasser, R.J.; Dommes, J.; Gaspar, T. Hyperhydricity of micropropagated shoots: A typically stress-induced change of physiological state. Plant Cell Tissue Organ Cult. 2004, 77, 181–191. [Google Scholar] [CrossRef]

[21] Apostolo, N.M.; Llorente, B.E. Anatomy of normal and hyperhydric leaves and shoots of in vitro grown Simmondsia chinensis (Link) Schn. In Vitro Cell. Dev. Biol. Plant 2000, 36, 243–249. [Google Scholar] [CrossRef]