IOSR Journal of Electronics and Communication Engineering (IOSR-JECE)
e-ISSN: 2278-2834,p- ISSN: 2278-8735.Volume 17, Issue 1, Ser. I (Jen. – Feb. 2022), PP 46-70
www.iosrjournals.org

Development and statistical modeling of a wireless sensor network (WSN) for bushfire monitoring: a case study of Rufus Giwa Polytechnic environment.

Iyapo Kamoru Olarewaju[1], Oyelakin K. Akinloye[2], & Olanegan Paul[3]
[1,2,3]Department of Science Laboratory Technology, Rufus Giwa Polytechnic, Owo, Ondo State, Nigeria

Abstract:
Fast-Moving wildfires can result in substantial losses of infrastructure and natural resources including thousands of hectares of forest within the Rufus Giwa polytechnic's environment, Owo Ondo, State, Nigeria and during such events, a real-time intelligence system is critical for managing firefighting activities and public safety. The proposed research is focusing on a state-of-the-art wireless sensor network to monitor bushfires for early detection of fire as fast as possible and its exact localization and early notification through GSM technology. The two basic designs were carried out, the first part is the transmitter (End device) which is placed in the forest or any place of interest where measurement of parameters namely temperature and relative humidity is carried out, and the other part is known as the coordinator which consists of ZigBee device, a microcontroller, and a serial interface with a computer Graphical User Interface (GUI) for real-time data acquisition and monitoring. The end-device of the wireless sensor consists of two sensor nodes, the sensirion, SHT11 humidity and temperature sensors are single-chip modules that produce calibrated digital output over a two-wire interface. The collection of repeated data such as temperature and relative humidity to evaluate changes in environmental conditions were recorded on hardware deployment. The proposed design was powered from a 12V battery with a stabled solar panel for continuous measurement and transmission of the acquired data via the GSM module that is been activated. Experimented data were collected 504 times which comprises of the morning, afternoon, and evening respectively and compared with the laboratory calibrated mercury thermometer and hygrometer each period of occurrence has 168 observations of seven days of the two monitoring devices. The parameters were analyzed using the Multiple regression techniques with the aid of statistical package for social science (SPSS) version 20 (SPSS Inc., Chicago, IL) for reliability, and accuracy of the proposed design through performance measure of the experimental collected parameters. The results show that better performance for estimating the burnt areas of the proposed device as compared with the estimated prediction data is recorded for the morning period of temperature readings. The experimented humidity data shows good agreement with the data despite the significant effect of the proposed models for the considered duration as time is significant in line with all dependent variables based on the morning, afternoon, afternoon, and evening. The adjusted value of R square values between 51.2 and 72.9 indicate the fitness of methods used in the current study. This is the deficiency that the present invention attempts to remedy, employing detection of a forest at the early stage within the Rufus Giwa polytechnic Community, Owo, Ondo, State, Nigeria, to ensure the chance to put it out before it has grown beyond control or causes any significant damages. When the temperature exceeded the normal or threshold temperature at a particular time, an alert is sent to a base station through SMS.

***Key Word**: Rufus Giwa polytechnic; Bushfire; GSM; SHT11; Microcontroller; SMS; Multiple Regression Techniques; ZigBee*

Date of Submission: 25-01-2022 Date of Acceptance: 07-02-2022

I. Introduction

Forest fire detection has been a focus of many researchers for the last decade because of increased forest fire case reports from all over the world due to severe damage to society and the environment. The Forest serves not just for economics but also necessary for balance in climate and wildlife conservation. Forests are the protectors of the earth's ecological balance due to inadequate automated systems to monitor the activities in the surrounding area, the forest fire is usually observed when it has already spread over a large area, making its control and stoppage arduous and even impossible at times [1,2]. The result is a devastating loss and irreparable damage to the environment and atmosphere where over 40% of carbon dioxide in the atmosphere comes from the forest and long term disastrous effects on local weather patterns, global warming, and extinction of rare species of flora and fauna[3]. A fire that destroys a vast forest region is usually started either deliberately by people or accidentally in case of a lightning strike or other process. In all cases however the origin is small and can be easily controlled in the first few minutes of its beginning. The problem with forest fires is that forests are usually remote, abandoned areas filled with trees, dry and parching wood, leaves, and so forth that act as a fuel source and these elements form a highly combustible material and represent the perfect context for initial-fire ignition and act as fuel for later stages of the fire[4]. The fire ignition may be caused by human actions like smoking or by natural reasons such as high temperature on hot summer days for a length of time leading to fire ignition. Many research works are being carried out at various institutions across the world to provide a better managed, efficient and cost-effective way for simultaneous measurement of temperature and relative humidity of the surroundings, the quality of satellite images mostly affected some bush fire monitoring devices commonly used nowadays. And this may be prone to errors and low performance[5]. Any existing satellite-based observations for forest fires suffer from severe limitations failing speed and effective control for forest areas[6]. The line of sight and the early stage of the firing process could be solved with the new technology called the wireless sensor network(WSN) which is nowadays receiving more attention and has started to be applied in forest fire detection[7]. The wireless nodes integrate on the same printed circuit board, the sensors, the data processing and the wireless transceiver and they all consume power from the same source batteries. The sensors are devices capable of sensing their environment and computing data, they sense the physical parameters such as temperature and relative humidity. The goal of this research work is to build a wireless sensor network to monitor and detect forest fire as fast as possible and its exact localization and early notification via mobile SMS as preset by the users is vital and when there is no fire, the network senses and communicate the humidity and temperature data, but when there is a fire threat the network operates in an emergency mode, the temperature of the environment rises and there will be a drastic drop in the humidity on the graphic user interface[8].

II. Literature Review

Bushfires are unplanned fire events that occur in forests, buildings, and frequent wildland regions, and devastating environmental hazards that can result in adverse environmental, social, and economic impacts affecting all sustainability pillars[9]. The knowledge gained through monitoring and evaluation of bushfire management outcomes must feedback into future planning to determine if the fuel management strategies are still effective or need to be updated, this ensures a cycle of adaptive management where improvements are made, especially when activities are no longer effective[10]. Outcomes may also need to change as they have been achieved, may be unable to be achieved or no longer represent the desired outcome and these changes will occur as part of the planning process. The studies took into consideration the accuracy, importance and freshness of the reported data in an environmental event detection system[11]. The entire data aggregation algorithm could be used for filtering relevant data and a delayed alert data transmission protocol for rapidly carrying the data to the sink node was integrated into the framework. This type of system can also be used in forest fire detection[12]. The features of forest fires show that to put it out without making any damage in the forest, the firefighters centre must be acquainted with the threat in at most five minutes after the start of the fire[13]. Another alternative technology for spotting forest fires is the use of satellite and satellites images moreover, Satellites provide a whole image of the earth every one to two days, this lengthy scan period is not adequate for spotting forest fires quickly[14]. Wireless sensor networks (WSNs) are the emergent and latest technology that can be used for forest fire detection and interrelated activities described the use of Wireless Sensor Networks where continuous and long term data acquisition such as temperature and humidity is essential to detect wildfire. [15] employed a suitable algorithm to detect the wildfire based on the changes in humidity and temperature during fire outbreaks and presents a methodology based on ZigBee and GPRS where sensor network that can provide cost-effective with long lifetime and good quality service compared with the traditional method of bush fire detection. **[**16] focused the various applications of wireless Sensor Network ranges from a habitat Monitoring, Security and overview of the Sensor nodes for deployment in hostile environments or over a large geographical area. The developed designs were used for the detection of forest fire incorporated with wireless sensor networks to prevent forest fire that can lead to loss of natural resources and experimental system results ensured the reliability of the system to carry out information directly to the base station without any obstruction in its path or interference[17. Wireless sensor nodes are mounted in the forest to collect data such as temperature, humidity, atmospheric pressure and deliver this important data to a based station where incoming data can be analyzed spontaneously. As a result, fires and some other interrelated events can be detected at the centre without requiring a human-centric operation. Bush fires cause the death of humans and animals, harm ecosystems and loss of treasure every year, especially in the harmattan months. Bush fires have adverse effects on people, animals, forests and soil apart from monetary damage. Wireless sensor networks (WSNs) can considerably improve the accuracy and density of parametric measurements of physical phenomena.

III. Materials and Methodology

This system incorporates PIC-18F4520, ZigBee module, and SHTII (temperature and humidity sensor) that will give us an indication of the intensity of the fire outbreak by sending parameters like temperature and relative humidity, a microcontroller, PIC18F4620 which coordinates all the activities of the circuit. This project was designed to provide global access to the system for real-time measurement of weather parameters using a wireless sensor network for communication purposes and ZigBee for device control[18]. The highlights of the system are the long-range of communication and robust coordinating software with a database containing information about the different bushfire monitoring stations. The processor receives inputs from the STH11 temperature and humidity sensor for continuous monitoring. The output from the system will include a small display unit for a visual update of the system status that may include power and network connectivity status as well as the display of log actions performed. The system will also allow manual configuration using the keypad input. The module will also allow for remote configuration from the base station. The system will also contain a GSM/GPRS module to enable communication between the remote. It consists of a software application for coordinating the entire monitoring system installed in the remote stations. The software that run on a PC was connected to a GSM/GPRS module for the reception and transmission of secure information between client and server and verse versa. The received data are from two end devices, which may be stationed at a different location in a typical forest system to measure continually the temperature and humidity of the surrounding environment. After designing the prototype for forest fire detection, the data acquired from the sensors are transmitted wirelessly to the base station where it can monitor it continuously. Wireless sensor nodes are mounted in the forest to collect data such as temperature, humidity, atmospheric pressure and deliver this important data to the based station where incoming data can be analyzed spontaneously. The block diagram of the overall system is shown in Fig.1.

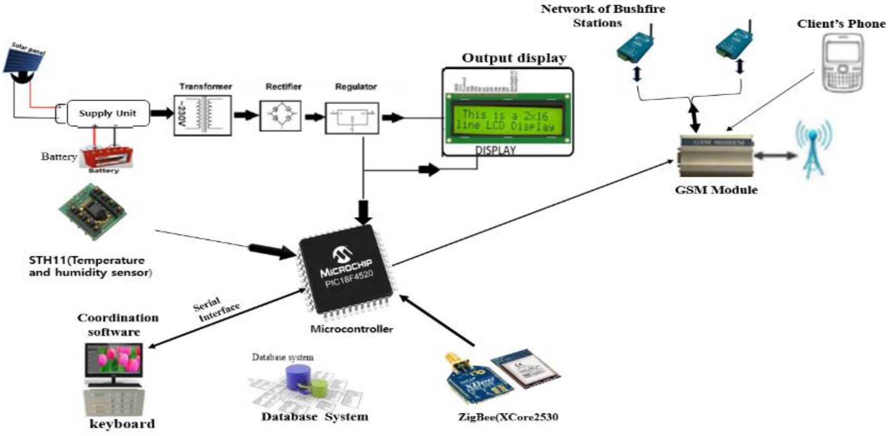


Fig.1. Block diagram of the proposed bushfire monitoring system.

A. ZigBee Module

Fig.2. show the Xcore2530 ZigBee Module used in the proposed design. ZigBee is a wireless network protocol specifically designed for low data rate sensors and control networks. ZigBee is a group of software, hardware and service companies that have developed a common standard for wireless, networking of sensors and controllers. ZigBee is for devices that have smaller throughout needs. The other driving factors are low cost, high security, low battery usage, simplicity, and interpretability with other ZigBee devices. ZigBee performs better than Wifi. In the proposed design, the XCore2530 ZigBee module is used. Combine with the coordinator/router firmware and allow transparent transmission of UART data. ZigBee module eliminates costly, time-consuming RF development and has a wide range of wireless applications[19].

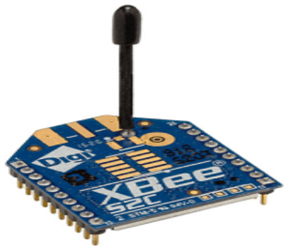


Fig.2. Xcore2530 ZigBee Module

B. **Microcontroller**

In the design, the PIC18F4520 microcontroller was used. The processor was chosen because of its good features and integrated peripherals. Its portability and low power consumption design can satisfy prolonged outdoor work. The PIC18F4520 is a high-performance enhanced flash, microcontroller from microchip with nano watt technology. Microcontrollers can think and this intelligence is fed into them using programming. This Microcontroller offers the advantages of all PIC18 microcontrollers – namely, high computational performance at an economical price with the addition of high-endurance, Enhanced Flash program memory. In addition to these features, the PIC18F4520 introduces design enhancements that make these microcontrollers a logical choice for many high-performance, power-sensitive applications. It can be referred to as a mini-computer, embedded in a compact IC chip, containing an on-chip processor, memory and programmable input and output ports used to interface external devices like LCD, LED, sensors, and printers. C and assembly languages are used for programming a microcontroller, but the HEX file is in machine language which gets uploaded in Microcontrollers. Timers are synchronized with the microcontroller's clock, used for measuring time intervals between two events and can count up to 255 for an 8-bit microcontroller. The microcontroller used in the proposed design is PIC18F4520 is a low-cost, low-power, high-speed 8-bit, fully static Microcontroller unit with 40 pins, 36 of which can be used as I / O pins. It has power-on-reset (POR) and the WDT circuitry (Extended Watchdog Timer), which can be programmed for 4 ms. Thus an 8-bit microcontroller contains an 8 -bit CPU. It has small size compared to the computer. It can execute smaller arithmetic and logic instructions. Most 8-bit microcontrollers are Atmel 8031 and 8051. It is an example of an external memory microcontroller that comes with 128 bytes of RAM and 4KB of built-in ROM. It consists of ROM, CPU, serial communication, timers, interrupts, I/O ports and a set of registers that also behave as RAM. Low power consumption makes this controller an ideal choice for an industrial purpose Low power consumption makes this controller an ideal choice for an industrial purpose. They can operate at a lower voltage ranging from 1.8 V to 5.5 V. It also incorporates its on-chip transceiver and 3.3V regulator and supports the use of external transceivers and voltage regulators. Fig.3. show the pin configuration of the Dual-in-line(DIL) package and the block diagram of the PIC18F4520 [20].

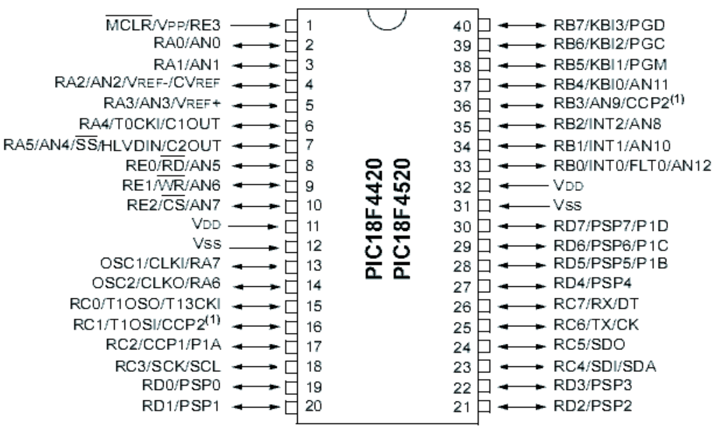


Fig.3. DIL package and the block diagram of the PIC18F4520

DOI: 10.9790/2834-1701014670

C. The SHTII Sensor

Fig.4. shows the recommended microcontroller interface to the sensor. SHT11 belong to the Sensirion's family of surface-mountable relative humidity and temperature sensors. The sensors integrate sensor elements plus signal processing on a tiny footprint and provide a fully calibrated digital output. A unique capacitive sensor element is used for measuring relative humidity while the temperature is measured by a band-gap sensor. Based on the timing diagram for developing a driver firmware to interface the SHT11 temperature humidity software to microcontroller software, the DATA tri-state pin from the SHT11 sensor is used to transfer data in and out of the sensor. This results in superior signal quality, a fast response time and insensitivity to external disturbances (EMC). The SHT11 is pre-calibrated in a precision humidity chamber. The calibration coefficients are programmed into an inbuilt memory on the chip. The 2-wire serial interface and internal voltage regulation allow for easy and fast system integration. Fig.5. shows the SHT11 temperature humidity sensor with its interface specifications. The supply voltage of SHT11 must be in the range of 2.4 – 5.5V, recommended supply voltage is 3.3V. Power supply pins Supply Voltage (VDD) and Ground (GND) must be decoupled with a 100 nF capacitor[21].

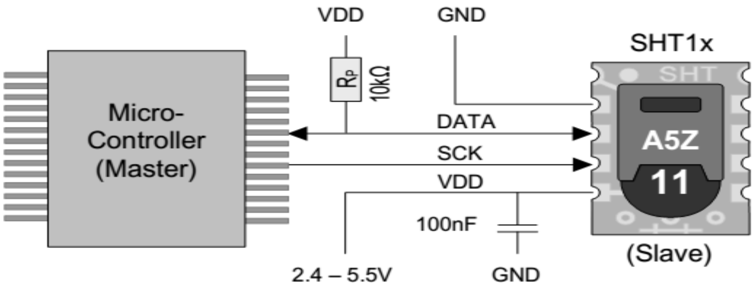
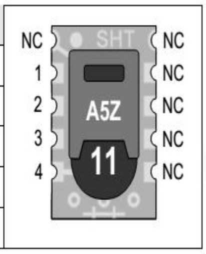


Fig.4. Microcontroller interface to the STH11 sensor.

Pin	Name	Comment
1	GND	Ground
2	DATA	Serial Data, bidirectional
3	SCK	Serial Clock, input only
4	VDD	Source Voltage
NC	NC	Must be left unconnected



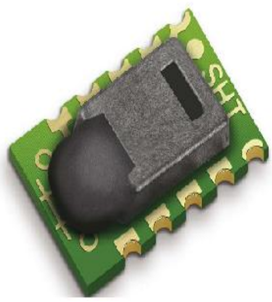


Fig.5. The SHT11 temperature humidity sensor interface Specifications

IV. Development of System

D. PCB Design

The system circuit diagram is shown in Figure.6. shows the final schematic combinations of coordinator and end device systems for the proposed Wireless sensor network for bushfire monitoring device implemented for a dual-layer PCB board which was carried out using an embedded tool known as Eagle PCB designer software before being transferred to a PCB layout. The placement was done to ensure the shortest possible distance between related components. The component was soldered into the respective component slots using a 30W soldering Iron and the entire component electrical connection was auto routed using the routing component of the Eagle PCB software. The actual implementation of the PCB design was achieved using the toner transfer method of the image of the design onto the copper cladding board where the initial testing of the board was carried out using a continuity meter to ensure all short circuit faults were properly cleared[22]. Fig.6 show the schematic combination of coordinator and End Device systems. Fig.7&8 illustrate the regulated LM7805 supply for the proposed design, the microcontroller units.

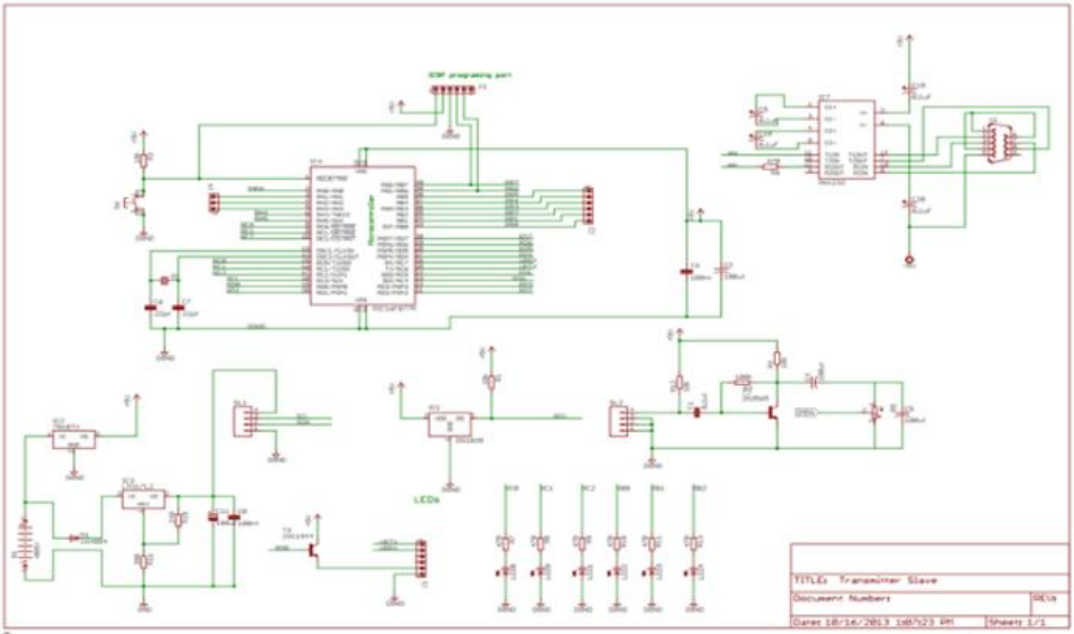


Fig.6. Schematic combinations of coordinator and end device systems

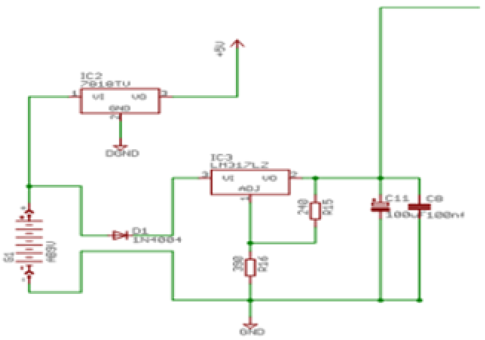


Fig.7. Regulated Power supplied

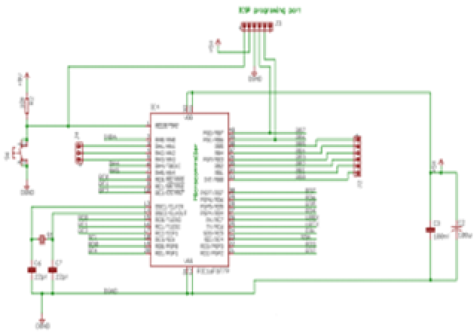


Fig.8. Microcontroller unit

E. Flowchart for Wireless Sensor Network for Bushfire Monitoring Device

The system flowchart is shown in Figure.9. represents the sequence process and steps taken to carry out specific action with the application. The ZigBee module is configured separately as the End Device and the coordinator. The system starts with the ZigBee initialization. It set nodes for stations 1& 2 to transmit events and data to a host. The decision was set up with the ZigBee administrator for the initialization of the configuration. When the system was started, the value of parameters such as temperature and relative humidity are read on the node. And then, these values that detect the condition of the forest are transmitted with character by using the ZigBee module. The sensor values that come from the node are checked if data was collected or not. If not, read the sensor from the node, it starts again. The sensor value from nodes are transmitted to the main node and together display on LCD and finally sent to the remote receiver via SMS through GSM modem as preset by the users[23].

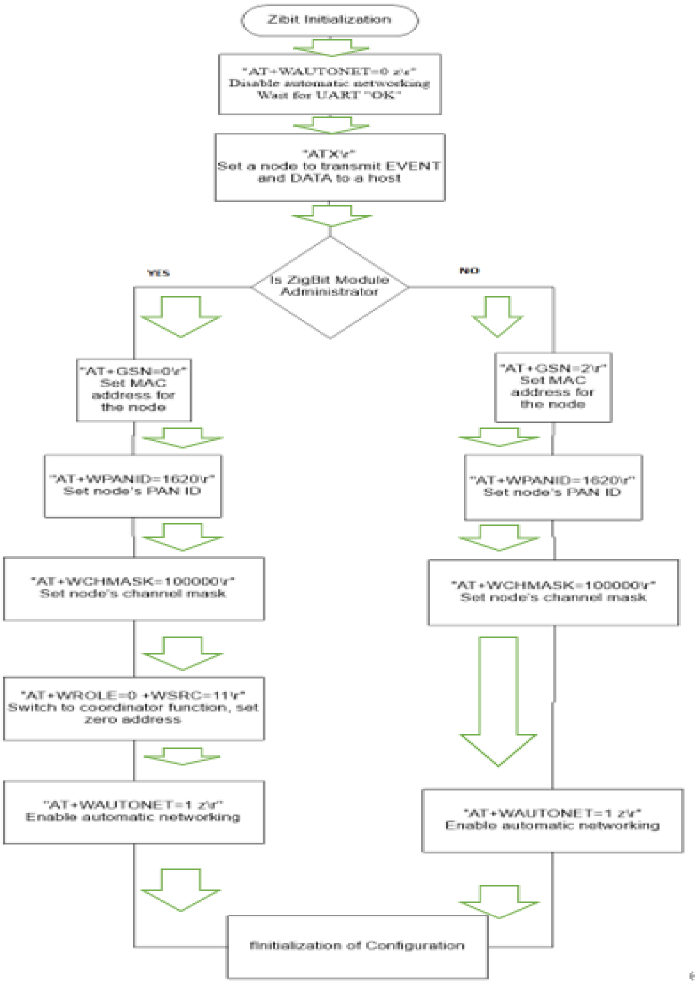


Fig.9. Flowchart for the ZigBee Module Configuration

V. Experimental results

E. Hardware Deployment

Fig.10. shows the LCD output displays as temperature and relative humidity change with time and date. On hardware deployment, the LCD initialization message display checking the modem is connected or not. The GSM is connected and later search for network time. The status of the system is displayed every second on an LCD and also an alert message(SMS) is sent to the authorized person through the GSM when it reaches preset values. The main components of this circuit are PIC18F4520 Processor of 8-bit with 40pins, temperature and humidity sensor(SHT11), GSM modem, ZigBee, LCD, Solar panel, and 12V Battery was used as the power supplied to the circuit. Fig.11. show the working model of wireless bushfire monitoring of the finished product. Fig.12. show the roles of GUI and data received via SMS when the proposed device was deployed to detect bushfire in the environment for the time duration. The computer software used for the capturing of the measured data via the serial port was implemented on a windows 8 operating system and was written using Visual Studio 2018 from Microsoft. The Graphical User Interface (GUI), which the user uses to establish a connection to the coordinator hardware and the subsequent reception of transmitted measured value from the hardware. Response of end device temperature and humidity was recorded on deployment for the time duration.

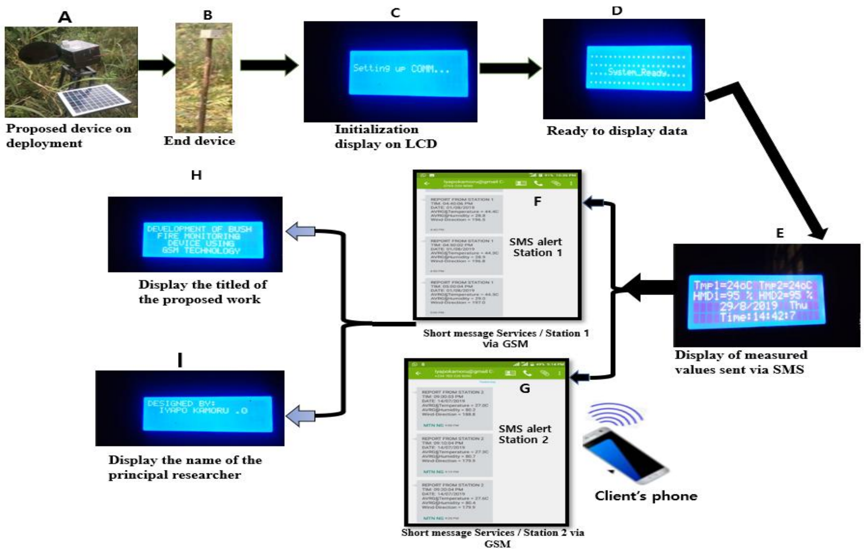


Fig.10. LCD screen showing display result during Hardware deployment

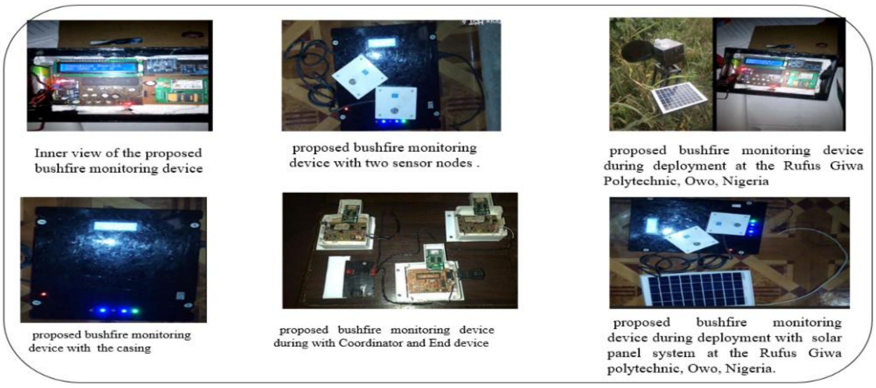


Fig.11. show the working model of wireless bushfire monitoring of the finished product.

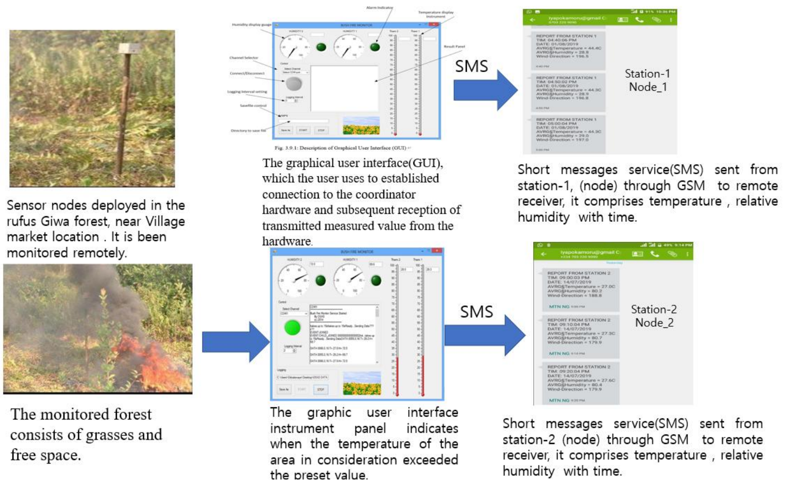


Fig.12. show Graphic user Interphase(GUI) and data received via SMS during hardware deployment

G. Statistical Analysis with Multiple Regression Techniques

The study uses a wireless sensor network to monitor bushfires for early detection of fire within the Rufus Giwa Polytechnic environment. The measurement was carried out in a remote location far from human intervention and another source of disturbance which comprises morning, afternoon and evening for 3380 minutes. The data were collected 504 times which comprises of morning, afternoon and evening respectively and compared with the laboratory calibrated mercury thermometer and hygrometer for more accuracy. Each period of occurrence has 168 observations of seven days of the two monitoring devices. The proposed device is powered from 12V batteries deployed within the purposed location and powered on for continuous measurement and transmission of the acquired temperature and humidity through a GSM module that is been activated and sent messages to the user's mobile**.** The experimental values were determined and analyzed using Multiple regression techniques with the aid of statistical package for social science (SPSS) version 20 for reliability, and accuracy of the proposed design through performance measure of the experimental collected parameters. To evaluate the performance of the models, four statistical parameters(i.e correlation coefficient(R), Adjusted R^2, F-statistics and P-value were calculated and presented in the table of observations respectively. The results of the text received from the GSM modem is as shown in table 1.0 to 6.0 which revealed the recorded values of the laboratory readings and the proposed device for temperature and relative humidity for the two considered duration. A higher value of correlation coefficient(R) and smaller value of root-means square and Mean absolute percentage error would indicate a better performance of the model.

F. Result

1. Model Computation

Functional form

Tem= f (Time)......................................1

Hum= f (Time)……..…..……………..…..2

Where;

Temp= Temperature (°C),

Hum= Humidity (%),

All these are dependent variables, while the only independent variable is time (T). All variables are log (In) to uniform the value.

Model Structure

First Monitor

Morning

InTem= $\alpha_1 + \beta_1$InTime + U_{t1}……………………1

InHum= $\alpha_2 + \beta_2$InTime + U_{t2}..…………………..2

Afternoon

InTem= $\alpha_3 + \beta_3$InTime + U_{t3}…………….………3

InHum= $\alpha_5 + \beta_5$InTime + U_{t4}……………………4

Evening

InTem= $\alpha_5 + \beta_5$InTime + U_{t5}…………….……….5

InHum= $\alpha_6 + \beta_6$InTime + U_{t6}…………………….6

Second Monitor

Morning

InTem= $\alpha_7 + \beta_7$InTime + U_{t7}……………………..7

InHum= $\alpha_8 + \beta_8$InTime + U_{t8}..……………………8

Afternoon

InTem= $\alpha_9 + \beta_9$InTime + U_{t9}…………….……….9

InHum= $\alpha_{10} + \beta_{10}$InTime + U_{t10}……….............10

Evening

InTem= $\alpha_{11} + \beta_{11}$InTime + U_{t11}………………….11

InHum= $\alpha_{12} + \beta_{12}$InTime + U_{t12}..………………..12

$\alpha_1, \alpha_2, \alpha_3, \alpha_4, \alpha_5, \alpha_6, \alpha_7, \alpha_8, \alpha_9, \alpha_{10}, \alpha_{11}$ & α_{12} are constant terms of the respective models and $\beta_1, \beta_2, \beta_3, \beta_4, \beta_5, \beta_6, \beta_7$ β_8 β_9 β_{10} β_{11} and β_{12} are coefficient parameters for logTime in the formulated models above.

Table .1.0

The comparison of Temperature Measurement for morning duration during deployment of the proposed bushfire monitoring device at the Rufus Giwa Polytechnic, Owo for morning data.

First Monitor: Table 1: Morning Data

Serial No	TEMP (°C)	HUM (%)	Time(minutes)
1	28	79.5	20
2	27.5	79.7	40
3	27.3	80.1	60
4	27.2	80.9	80
5	27.2	80.3	100
6	27.2	80.4	120
7	27.1	80.5	140
8	27.1	80.5	160
9	27.1	80.4	180
10	27.1	80.2	200
11	27.1	80.1	220
12	27.1	80.1	240
13	27	80.1	260
14	27	80.1	280
15	27	80.1	300
16	27	80.1	320
17	27	80.2	340
18	26.9	80.4	360
19	26.8	80.5	380
20	26.8	80.7	400
21	26.8	80.8	420
22	26.7	80.9	440
23	26.7	80.1	460
24	26.6	81.1	480
25	26.6	81.3	500
26	26.6	81.3	520
27	26.6	81.4	540
28	26.5	81.5	560
29	26.5	81.6	580
30	26.5	81.7	600
31	26.5	81.8	620
32	26.5	81.8	640
33	26.4	81.9	660
34	26.4	82	680
35	26.3	82.1	700
36	26.3	82.1	720
37	26.3	82.1	740
38	26.3	82.2	760
39	26.3	82.2	780
40	26.2	82.2	800
41	26.2	82.3	820
42	27.2	82.9	840
43	25.4	62.8	860
44	25.4	62.8	880
45	25.4	62.9	900
46	25.4	63	920
47	25.4	63.1	940
48	25.4	63.1	960
49	25.4	63.1	980
50	25.4	63.2	1000
51	25.4	63.3	1020
52	25.3	63.5	1040
53	25.3	63.6	1060
54	25.3	63.7	1080
55	25.3	63.8	1100
56	25.3	64	1120
57	25.4	64	1140
58	25.5	63.9	1160
59	25.5	64	1180
60	25.5	64.1	1200
61	25.6	64.2	1220
62	25.6	64.2	1240
63	25.8	64.1	1260
64	25.9	63.8	1280
65	26	63.6	1300
66	26.1	63.5	1320
67	26.2	63.4	1340
68	26.3	63.3	1360
69	26.4	63.1	1380
70	26.6	62.6	1400
71	26.5	62.9	1420
72	26.7	62.4	1440
73	26.9	62.2	1460
74	27	61.9	1480
75	27.1	61.8	1500
76	27.2	61.5	1520
77	27.3	61.3	1540
78	27.4	61.1	1560
79	25.2	69.9	1580
80	25.2	69.9	1600
81	25.2	69.9	1620
82	25.2	69.9	1640
83	25.2	69.9	1660
84	25.2	69.9	1680
85	25.2	69.9	1700
86	25.2	69.9	1720
87	25.2	69.9	1740
88	25.1	69.9	1760
89	25.1	69.9	1780
90	25.1	69.9	1800
91	25.1	70.0	1820
92	25	70.0	1840
93	25	70.0	1860
94	25	70.2	1880
95	25	70.1	1900
96	25	70.1	1920
97	24.9	70.1	1940
98	24.9	70.1	1960
99	24.9	70.1	1980
100	24.9	70.1	2000
101	24.8	70.2	2020
102	24.9	70.2	2040
103	24.6	70.7	2060
104	24.6	70.8	2080
105	24.6	70.8	2100
106	24.6	70.8	2120
107	24.6	70.8	2140
108	24.6	70.9	2160
109	24.6	70.9	2180
110	24.6	70.9	2200
111	24.6	71	2220
112	24.6	71	2240
113	24.6	71	2260
114	24.6	71	2280
115	24.6	71	2300
116	24.6	71	2320
117	24.7	70.9	2340
118	24.8	70.9	2360
119	24.9	70.7	2380
120	25	70.6	2400
121	25.1	70.4	2420
122	25.5	69.6	2440
123	25.9	68.9	2460
124	26.1	68.5	2480
125	26.3	68.1	2500
126	26.5	67.7	2520
127	26.6	67.5	2540
128	26.7	67.4	2560
129	26.8	67.1	2580
130	41.2	47.8	2600

131	45.5	38.8	2620
132	46.7	35.3	2640
133	46.8	34.5	2660
134	46.4	34.5	2680
135	45.5	35.8	2700
136	44.6	37	2720
137	44.2	37.5	2740
138	44.3	37.1	2760
139	44.4	36.6	2780
140	44.5	36.1	2800
141	44.1	36.7	2820
142	43.6	37.7	2840
143	43	38.8	2860
144	42.6	39.8	2880
145	43	38.8	2900
146	42.2	40.8	2920
147	41.8	41.8	2940
148	41.4	42.7	2960
149	41	43.5	2980
150	40.6	44.4	3000
151	40.3	45.1	3020
152	39.9	45.9	3040
153	39.6	46.5	3060
154	39.3	47.2	3080
155	39.1	47.8	3100
156	38.9	48.3	3120
157	38.5	49.2	3140
158	38.3	49.7	3160
159	38.1	50.1	3180
160	39.3	43	3200
161	39.3	42.7	3220
162	34.2	50	3240
163	34.2	50	3260
164	34.1	50.2	3280
165	34	50.3	3300
166	34	50.3	3340
167	34.2	50	3360
168	34.0	50	3380

Table .2.
The comparison of Temperature Measurement for Afternoon duration during deployment of the proposed bushfire monitoring device at the Rufus Giwa Polytechnic, Owo for afternoon data.

First Monitor: Table 2: Afternoon Data			
Serial No	**TEMP (°C)**	**HUM (%)**	**Time(minutes)**
1	27	80.2	20
2	27	80.7	40
3	27.6	80.4	60
4	27.7	80.3	80
5	27.8	80.3	100
6	27.8	80.4	120
7	27.8	80.5	140
8	27.8	80.7	160
9	28.6	80	180
10	28	77.7	200
11	28	75.3	220
12	28	75.9	240
13	28	76.4	260
14	28.1	77	280
15	28.2	77.4	300
16	28.2	77.7	320
17	28.2	77.9	340
18	27	87.3	360
19	26	85.7	380
20	28	78.8	400
21	27	80	420
22	27	80	440
23	26.7	80.2	460
24	26.4	80.5	480
25	26.3	80.6	500
26	26.4	80.4	520
27	27	79.6	540
28	26.9	79.2	560
29	26.6	79.4	580
30	26.6	79.5	600
31	26.5	79.6	620
32	26.5	79.5	640
33	26.5	79.5	660
34	26.4	79.6	680
35	26.4	79.7	700
36	26.3	79.8	720
37	26.3	80	740
38	26.3	80.1	760
39	29	75.1	780
40	29	75.1	800
41	27.2	80.9	820
42	27.2	80.9	840
43	29.1	72.4	860
44	30.3	71.7	880
45	32.1	67.8	900
46	34.1	62	920
47	36.7	55.2	940
48	39.2	50.6	960
49	41.7	49.1	980
50	43.3	46.3	1000
51	44.2	43.8	1020
52	45.4	43.1	1040
53	46.1	41.4	1060
54	46.2	39.9	1080
55	46.6	37.2	1100
56	47.1	36.2	1120
57	47.3	35.3	1140
58	47.4	34.5	1160
59	47.7	33.7	1180
60	47.8	32.5	1200
61	47.8	31.7	1220
62	47.8	31.2	1240
63	47.9	30.7	1260
64	48	30.2	1280
65	48	30.2	1300
66	48.2	29.8	1320
67	48.2	29.5	1340
68	48.1	29.4	1360
69	48	29.3	1380
70	47.7	29.6	1400
71	47.4	29.9	1420
72	47	30.5	1440
73	45.6	32.9	1460
74	29.8	73.7	1480
75	29	75.5	1500
76	29	77.6	1520
77	28.6	78.3	1540
78	28.4	79.5	1560
79	29	83	1580
80	28.3	33.5	1600
81	27.9	59.7	1620
82	27.5	58.8	1640
83	27.2	58.4	1660
84	27.2	58.4	1680
85	27.2	58.4	1700
86	27.1	58.5	1720
87	26.9	58.5	1740
88	26.8	58.7	1760
89	26.7	58.8	1780
90	26.6	58.9	1800
91	26.6	59	1820

92	26.5	59.1	1840
93	26.5	59	1860
94	26.5	59	1880
95	26.5	59	1900
96	26.5	59.1	1920
97	26.4	59.1	1940
98	26.4	59.2	1960
99	26.4	59.4	1980
100	26.4	59.5	2000
101	26.3	59.6	2020
102	26.3	59.7	2040
103	26.3	59.8	2060
104	26.1	60.1	2080
105	26.1	60.1	2100
106	26	60	2120
107	25.9	60.6	2140
108	25.8	60.7	2160
109	25.8	60.9	2180
110	25.7	61	2200
111	25.7	61.1	2220
112	25.7	61.2	2240
113	25.7	61.3	2260
114	25.7	61.3	2280
115	25.6	61.4	2300
116	25.6	61.4	2320
117	25.6	61.5	2340
118	25.6	61.6	2360
119	25.6	61.6	2380
120	25.6	61.7	2400
121	25.6	61.8	2420
122	25.5	61.8	2440
123	25.5	61.9	2460
124	25.5	62	2480
125	25.5	62	2500
126	25.5	62.1	2520
127	25.5	62.2	2540
128	25.5	62.2	2560
129	25.5	62.3	2580
130	25.5	62.4	2600
131	25.4	62.4	2620
132	25.4	62.5	2640
133	25.4	62.6	2660
134	25.4	62.6	2680
135	25.4	62.7	2700
136	27.6	60.8	2720
137	28	60.1	2740
138	27.8	60.4	2760
139	28.1	59.8	2780
140	28.3	59.2	2800
141	28.4	59.2	2820
142	28.6	58.6	2840
143	28.7	58.6	2860
144	28.9	58.3	2880
145	29.1	57.9	2900
146	29.2	57.6	2920
147	29.4	57.3	2940
148	29.2	57.6	2960
149	29.4	57.3	2980
150	29.6	56.9	3000
151	29.7	56.6	3020
152	29.9	56.3	3040
153	30	56.1	3060
154	26.8	67	3080
155	26.9	66.9	3100
156	26.9	66.9	3120
157	26.9	66.8	3140
158	27	66.8	3160
159	27	66.8	3180
160	27.1	66.8	3200
161	27.2	66.7	3220
162	27.3	66.6	3240
163	27.4	66.4	3260
164	27.4	66.3	3280
165	27.4	66.4	3300
166	34	50.3	3340
167	34	50.1	3360
168	34.0	50.4	3380

Table.3.

The comparison of Temperature Measurement for Evening duration during deployment of the proposed bushfire monitoring device at the Rufus Giwa Polytechnic, Owo for Evening data.

First Monitor: Table 3: Evening Data			
Serial No	**TEMP (°C)**	**HUM (%)**	**Time(Min**
1	30.2	55.8	20
2	30.3	55.5	40
3	30.5	55.2	60
4	30.6	54.9	80
5	30.7	54.7	100
6	30.8	54.6	120
7	30.8	54.5	140
8	30.9	54.4	160
9	30.9	54.4	180
10	30.9	54.5	200
11	30.8	54.6	220
12	30.8	54.6	240
13	26	78.1	260
14	26.1	77.5	280
15	25.9	77.3	300
16	25.9	72.5	320
17	25.9	72.2	340
18	25.9	71.9	360
19	25.9	71.6	380
20	25.8	71.4	400
21	25.7	71.2	420
22	25.7	71	440
23	25.6	70.8	460
24	25.6	70.7	480
25	25.5	70.6	500
26	25.5	70.5	520
27	25.5	70.4	540
28	25.4	70.3	560
29	25.4	70.2	580
30	25.4	70.2	600
31	25.4	70.1	620
32	25.3	70.1	640
33	25.3	70	660
34	25.3	70	680
35	25.3	69.9	700
36	25.2	69.9	720
37	25.2	69.9	740
38	25.2	69.9	760
39	25.2	69.9	780
40	32	60.9	800
41	31.9	65.8	820
42	32.1	58.6	840
43	27.4	66.4	860
44	27.4	66.5	880
45	27.4	66.6	900
46	27.4	66.6	920
47	27.4	66.6	940
48	27.4	66.7	960
49	27.3	66.7	980
50	27.3	66.8	1000
51	27.3	66.9	1020
52	27.3	67	1040

53	27.2	67	1060
54	27.2	67.1	1080
55	27.1	67.2	1100
56	27.1	67.3	1120
57	27	67.6	1140
58	26.9	67.9	1160
59	38	59.7	1180
60	45.1	30	1200
61	44.1	30.9	1220
62	39	41.6	1240
63	38.8	42	1260
64	38.4	42.6	1280
65	38.2	43	1300
66	38	43.3	1320
67	37.8	43.6	1340
68	37.6	43.9	1360
69	37.5	44.2	1380
70	37.3	44.5	1400
71	37.1	44.8	1420
72	36.9	45.1	1440
73	36.8	45.3	1460
74	36.6	45.6	1480
75	36.5	45.9	1500
76	36.3	46.1	1520
77	36.2	46.4	1540
78	36	46.6	1560
79	35.9	46.9	1580
80	35.7	47.1	1600
81	35.6	47.4	1620
82	35.5	47.6	1640
83	35.3	47.8	1660
84	35.2	48.1	1680
85	35.1	48.3	1700
86	35	48.5	1720
87	34.8	48.7	1740
88	34.7	48.9	1760
89	34.6	49.2	1780
90	34.5	49.4	1800
91	34.4	49.6	1820
92	34.3	49.8	1840
93	45	30.7	1860
94	45	30.6	1880
95	44.9	30.7	1900
96	44.8	30.7	1920
97	44.8	30.7	1940
98	44.9	30.5	1960
99	44.9	30.4	1980
100	45	30.2	2000
101	45	30.1	2020
102	45	30.1	2040
103	44.8	30.4	2060
104	44.6	30.6	2080
105	44.4	30.9	2100
106	43.9	31.5	2120
107	43.7	31.9	2140
108	43.4	32.2	2160
109	43.2	32.5	2180
110	43.2	32.5	2200
111	43	32.9	2220
112	42.8	33.2	2240
113	42.5	33.6	2260
114	42.1	34.3	2280
115	41.9	34.6	2300
116	41.4	35.2	2320
117	41.4	35.2	2340
118	41.2	35.6	2360
119	41	35.9	2380
120	40.8	36.2	2400
121	40.6	36.5	2420
122	40.4	36.8	2440
123	40.2	37.1	2460
124	40.2	37.1	2480
125	40	37.3	2500
126	39.8	37.6	2520
127	39.5	38.2	2540
128	39.3	38.4	2560
129	39.1	38.7	2580
130	39	37.5	2600
131	38.8	39.2	2620
132	38.5	39.7	2640
133	38.3	40	2660
134	38	40.5	2680
135	38	40.7	2700
136	37.7	40.9	2720
137	37.4	41.4	2740
138	37.3	41.6	2760
139	37.4	41.4	2780
140	37.3	41.6	2800
141	37.2	41.8	2820
142	37	42.1	2840
143	36.9	42.3	2860
144	40.2	35.6	2880
145	40	35.8	2900
146	39.8	36	2920
147	39.7	36.3	2940
148	39.5	36.5	2960
149	39.3	36.7	2980
150	39	37.2	3000
151	38.7	37.6	3020
152	38.6	37.8	3040
153	38.4	38	3060
154	38.1	38.4	3080
155	38	38.7	3100
156	37.8	38.9	3120
157	37.7	39.1	3140
158	37.6	39.3	3160
159	37.4	39.4	3180
160	37.3	39.6	3200
161	43.4	30.5	3220
162	43.4	30.5	3240
163	43.6	30.2	3260
164	43.8	30	3280
165	44	29.7	3300
166	30.5	54.6	3340
167	30.6	54.5	3360
168	30.7	54.4	3380

Table 4.

The comparison of Temperature Measurement for morning duration during deployment of the proposed bushfire monitoring device at the Rufus Giwa Polytechnic, Owo for Morning data.

Second Monitor: Table 4: Morning Data			
Serial No	**TEMP (°C)**	**HUM (%)**	**Time(minutes)**
1	26.5	81.5	20
2	26.5	81.6	40
3	26.5	81.7	60
4	26.5	81.8	80
5	26.5	81.8	100
6	26.4	81.9	120
7	26.4	82	140
8	26.3	82.1	160
9	26.3	82.1	180
10	26.3	82.1	200
11	26.3	82.2	220
12	26.3	82.2	240
13	26.2	82.2	260
14	26.2	82.3	280

15	27.2	82.9	300
16	25.4	62.8	320
17	25.4	62.8	340
18	25.4	62.9	360
19	25.4	63	380
20	25.4	63.1	400
21	25.4	63.1	420
22	25.4	63.1	440
23	25.4	63.2	460
24	25.4	63.3	480
25	25.3	63.5	500
26	25.3	63.6	520
27	25.3	63.7	540
28	25.3	63.8	560
29	25.3	64	580
30	25.4	64	600
31	25.5	63.9	620
32	25.5	64	640
33	25.5	64.1	660
34	25.6	64.2	680
35	25.6	64.2	700
36	25.8	64.1	720
37	25.9	63.8	740
38	26	63.6	760
39	26.1	63.5	780
40	26.2	63.4	800
41	26.3	63.3	820
42	26.4	63.1	840
43	26.6	62.6	860
44	26.5	62.9	880
45	26.7	62.4	900
46	26.9	62.2	920
47	27	61.9	940
48	27.1	61.8	960
49	27.2	61.5	980
50	27.3	61.3	1000
51	27.4	61.1	1020
52	25.2	69.9	1040
53	25.2	69.9	1060
54	25.2	69.9	1080
55	25.2	69.9	1100
56	25.2	69.9	1120
57	25.2	69.9	1140
58	25.2	69.9	1160
59	25.2	69.9	1180
60	25.2	69.9	1200
61	25.1	69.9	1220
62	25.1	69.9	1240
63	25.1	69.9	1260
64	25.1	70	1280
65	25	70	1300
66	25	70	1320
67	25	70	1340
68	25	70	1360
69	25	70.1	1380
70	24.9	70.1	1400
71	24.9	70.1	1420
72	24.9	70.1	1440
73	24.9	70.1	1460
74	24.8	70.2	1480
75	24.9	70.2	1500
76	24.6	70.7	1520
77	24.6	70.8	1540
78	24.6	70.8	1560
79	24.6	70.8	1580
80	24.6	70.8	1600
81	24.6	70.9	1620
82	24.6	70.9	1640
83	24.6	70.9	1660
84	26.5	81.5	1680
85	26.5	81.6	1700
86	26.5	81.7	1720
87	26.5	81.8	1740
88	26.5	81.8	1760
89	26.4	81.9	1780
90	26.4	82	1800
91	26.3	82.1	1820
92	26.3	82.1	1840
93	26.3	82.1	1860
94	26.3	82.2	1880
95	26.3	82.2	1900
96	26.2	82.2	1920
97	26.2	82.3	1940
98	27.2	82.9	1960
99	25.4	62.8	1980
100	25.4	62.8	2000
101	25.4	62.9	2020
102	25.4	63	2040
103	25.4	63.1	2060
104	25.4	63.1	2080
105	25.4	63.1	2100
106	25.4	63.2	2120
107	25.4	63.3	2140
108	25.3	63.5	2160
109	25.3	63.6	2180
110	25.3	63.7	2200
111	24.6	71	2220
112	24.6	71	2240
113	24.6	71	2260
114	24.6	71	2280
115	24.6	71	2300
116	24.6	71	2320
117	24.7	70.9	2340
118	24.8	70.9	2360
119	24.9	70.7	2380
120	25	70.6	2400
121	25.1	70.4	2420
122	25.5	69.6	2440
123	25.9	68.9	2460
124	26.1	68.5	2480
125	26.3	68.1	2500
126	26.5	67.7	2520
127	26.6	67.5	2540
128	26.7	67.4	2560
129	26.8	67.1	2580
130	41.2	47.8	2600
131	45.5	38.8	2620
132	46.7	35.3	2640
133	46.8	34.5	2660
134	46.4	34.5	2680
135	45.5	35.8	2700
136	44.6	37	2720
137	44.2	37.5	2740
138	44.3	37.1	2760
139	44.4	36.6	2780
140	44.5	36.1	2800
141	44.1	36.7	2820
142	43.6	37.7	2840
143	43	38.8	2860
144	42.6	39.8	2880
145	43	38.8	2900
146	42.2	40.8	2920
147	41.8	41.8	2940
148	41.4	42.7	2960
149	41	43.5	2980
150	40.6	44.4	3000
151	40.3	45.1	3020
152	39.9	45.9	3040
153	39.6	46.5	3060
154	39.3	47.2	3080

155	39.1	47.8	3100
156	38.9	48.3	3120
157	38.5	49.2	3140
158	38.3	49.7	3160
159	38.1	50.1	3180
160	39.3	43	3200
161	39.3	42.7	3220
162	34.2	50	3240
163	34.2	50	3260
164	34.1	50.2	3280
165	34	50.3	3300
166	34	50.3	3340
167	34.2	50.3	3360
168	34.0	50.2	3380

Table.5.
The comparison of Temperature Measurement for Afternoon duration during deployment of the proposed bushfire monitoring device at the Rufus Giwa Polytechnic, Owo for afternoon data.

Second Monitor: Table 5: Afternoon Data			
Serial No	**TEMP (°C)**	**HUM (%)**	**Time(minutes)**
1	27.6	80.4	20
2	27.7	80.3	40
3	27.8	80.3	60
4	27.8	80.4	80
5	27.8	80.5	100
6	27.8	80.7	120
7	28.6	80	140
8	28	77.7	160
9	28	75.3	180
10	28	75.9	200
11	28	76.4	220
12	28.1	77	240
13	28.2	77.4	260
14	28.2	77.7	280
15	28.2	77.9	300
16	27	87.3	320
17	26	85.7	340
18	28	78.8	360
19	27	80	380
20	27	80	400
21	26.7	80.2	420
22	26.4	80.5	440
23	26.3	80.6	460
24	26.4	80.4	480
25	27	79.6	500
26	26.9	79.2	520
27	26.6	79.4	540
28	26.6	79.5	560
29	26.5	79.6	580
30	26.5	79.5	600
31	26.5	79.5	620
32	26.4	79.6	640
33	26.4	79.7	660
34	26.3	79.8	680
35	26.3	80	700
36	26.3	80.1	720
37	29	75.1	740
38	29	75.1	760
39	27.2	80.9	780
40	27.2	80.9	800
41	29.1	72.4	820
42	30.3	71.7	840
43	32.1	67.8	860
44	34.1	62	880
45	36.7	55.2	900
46	39.2	50.6	920
47	41.7	49.1	940
48	43.3	46.3	960
49	44.2	43.8	980
50	45.4	43.1	1000
51	46.1	41.4	1020
52	46.2	39.9	1040
53	46.6	37.2	1060
54	47.1	36.2	1080
55	47.3	35.3	1100
56	47.4	34.5	1120
57	47.7	33.7	1140
58	47.8	32.5	1160
59	47.8	31.7	1180
60	47.8	31.2	1200
61	47.9	30.7	1220
62	48	30.2	1240
63	48	30.2	1260
64	48.2	29.8	1280
65	48.2	29.5	1300
66	48.1	29.4	1320
67	48	29.3	1340
68	47.7	29.6	1360
69	47.4	29.9	1380
70	47	30.5	1400
71	45.6	32.9	1420
72	29.8	73.7	1440
73	29	75.5	1460
74	29	77.6	1480
75	28.6	78.3	1500
76	28.4	79.5	1520
77	29	83	1540
78	28.3	33.5	1560
79	27.9	59.7	1580
80	27.5	58.8	1600
81	27.2	58.4	1620
82	27.2	58.4	1640
83	27.2	58.4	1660
84	27.1	58.5	1680
85	26.9	58.5	1700
86	26.8	58.7	1720
87	26.7	58.8	1740
88	26.6	58.9	1760
89	26.6	59	1780
90	26.5	59.1	1800
91	26.5	59	1820
92	26.5	59	1840
93	26.5	59	1860
94	26.5	59.1	1880
95	26.4	59.1	1900
96	26.4	59.2	1920
97	26.4	59.4	1940
98	26.4	59.5	1960
99	26.3	59.6	1980
100	26.3	59.7	2000
101	26.3	59.8	2020
102	26.1	60.1	2040
103	26.1	60.1	2060
104	26	60	2080
105	25.9	60.6	2100
106	25.8	60.7	2120
107	25.8	60.9	2140
108	25.7	61	2160
109	25.7	61.1	2180
110	25.7	61.2	2200
111	25.7	61.3	2220
112	25.7	61.3	2240
113	25.6	61.4	2260
114	25.6	61.4	2280
115	25.6	61.5	2300
116	25.6	61.6	2320

117	25.6	61.6	2340
118	25.6	61.7	2360
119	25.6	61.8	2380
120	25.5	61.8	2400
121	25.5	61.9	2420
122	25.5	62	2440
123	25.5	62	2460
124	25.5	62.1	2480
125	25.5	62.2	2500
126	25.5	62.2	2520
127	25.5	62.3	2540
128	25.5	62.4	2560
129	25.4	62.4	2580
130	25.4	62.5	2600
131	25.4	62.6	2620
132	25.4	62.6	2640
133	25.4	62.7	2660
134	27.6	60.8	2680
135	28	60.1	2700
136	27.8	60.4	2720
137	28.1	59.8	2740
138	28.3	59.2	2760
139	28.4	59.2	2780
140	28.6	58.6	2800
141	28.7	58.6	2820
142	28.9	58.3	2840
143	29.1	57.9	2860
144	29.2	57.6	2880
145	29.4	57.3	2900
146	29.2	57.6	2920
147	29.4	57.3	2940
148	29.6	56.9	2960
149	29.7	56.6	2980
150	29.9	56.3	3000
151	30	56.1	3020
152	26.8	67	3040
153	26.9	66.9	3060
154	26.9	66.9	3080
155	26.9	66.8	3100
156	27	66.8	3120
157	27	66.8	3140
158	27.1	66.8	3160
159	27.2	66.7	3180
160	27.3	66.6	3200
161	27.4	66.4	3220
162	27.6	80.4	3240
163	27.7	80.3	3260
164	27.8	80.3	3280
165	27.8	80.4	3300
166	27.8	80.5	3340
167	27.8	80.7	3360
168	28.6	80	3380

Table.6
The comparison of Temperature Measurement for Evening duration during deployment of the proposed bushfire monitoring device at the Rufus Giwa Polytechnic, Owo for evening data.

Second Monitor: Table 6: Evening Data			
Serial No	**TEMP (°C)**	**HUM (%)**	**Time(minutes)**
1	30.6	54.9	20
2	30.7	54.7	40
3	30.8	54.6	60
4	30.8	54.5	80
5	30.9	54.4	100
6	30.9	54.4	120
7	30.9	54.5	140
8	30.8	54.6	160
9	30.8	54.6	180
10	26	78.1	200
11	26.1	77.5	220
12	25.9	77.3	240
13	25.9	72.5	260
14	25.9	72.2	280
15	25.9	71.9	300
16	25.9	71.6	320
17	25.8	71.4	340
18	25.7	71.2	360
19	25.7	71	380
20	25.6	70.8	400
21	25.6	70.7	420
22	25.5	70.6	440
23	25.5	70.5	460
24	25.5	70.4	480
25	25.4	70.3	500
26	25.4	70.2	520
27	25.4	70.2	540
28	25.4	70.1	560
29	25.3	70.1	580
30	25.3	70	600
31	25.3	70	620
32	25.3	69.9	640
33	25.2	69.9	660
34	25.2	69.9	680
35	25.2	69.9	700
36	25.2	69.9	720
37	32	60.9	740
38	31.9	65.8	760
39	32.1	58.6	780
40	27.4	66.4	800
41	27.4	66.5	820
42	27.4	66.6	840
43	27.4	66.6	860
44	27.4	66.6	880
45	27.4	66.7	900
46	27.3	66.7	920
47	27.3	66.8	940
48	27.3	66.9	960
49	27.3	67	980
50	27.2	67	1000
51	27.2	67.1	1020
52	27.1	67.2	1040
53	27.1	67.3	1060
54	27	67.6	1080
55	26.9	67.9	1100
56	38	59.7	1120
57	45.1	30	1140
58	44.1	30.9	1160
59	39	41.6	1180
60	38.8	42	1200
61	38.4	42.6	1220
62	38.2	43	1240
63	38	43.3	1260
64	37.8	43.6	1280
65	37.6	43.9	1300
66	37.5	44.2	1320
67	37.3	44.5	1340
68	37.1	44.8	1360
69	36.9	45.1	1380
70	36.8	45.3	1400
71	36.6	45.6	1420
72	36.5	45.9	1440
73	36.3	46.1	1460
74	36.2	46.4	1480
75	36	46.6	1500
76	35.9	46.9	1520
77	35.7	47.1	1540
78	35.6	47.4	1560

79	35.5	47.6	1580
80	35.3	47.8	1600
81	35.2	48.1	1620
82	35.1	48.3	1640
83	35	48.5	1660
84	34.8	48.7	1680
85	34.7	48.9	1700
86	34.6	49.2	1720
87	34.5	49.4	1740
88	34.4	49.6	1760
89	34.3	49.8	1780
90	45	30.7	1800
91	45	30.6	1820
92	44.9	30.7	1840
93	44.8	30.7	1860
94	44.8	30.7	1880
95	44.9	30.5	1900
96	44.9	30.4	1920
97	45	30.2	1940
98	45	30.1	1960
99	45	30.1	1980
100	44.8	30.4	2000
101	44.6	30.6	2020
102	44.4	30.9	2040
103	43.9	31.5	2060
104	43.7	31.9	2080
105	43.4	32.2	2100
106	43.2	32.5	2120
107	43.2	32.5	2140
108	43	32.9	2160
109	42.8	33.2	2180
110	42.5	33.6	2200
111	42.1	34.3	2220
112	41.9	34.6	2240
113	41.4	35.2	2260
114	41.4	35.2	2280
115	41.2	35.6	2300
116	41	35.9	2320
117	40.8	36.2	2340
118	40.6	36.5	2360
119	40.4	36.8	2380
120	40.2	37.1	2400
121	40.2	37.1	2420
122	40	37.3	2440
123	39.8	37.6	2460
124	39.5	38.2	2480
125	39.3	38.4	2500
126	39.1	38.7	2520
127	39	37.5	2540
128	38.8	39.2	2560
129	38.5	39.7	2580
130	38.3	40	2600
131	38	40.5	2620
132	38	40.7	2640
133	37.7	40.9	2660
134	37.4	41.4	2680
135	37.3	41.6	2700
136	37.4	41.4	2720
137	37.3	41.6	2740
138	37.2	41.8	2760
139	37	42.1	2780
140	36.9	42.3	2800
141	40.2	35.6	2820
142	40	35.8	2840
143	39.8	36	2860
144	39.7	36.3	2880
145	39.5	36.5	2900
146	39.3	36.7	2920
147	39	37.2	2940
148	38.7	37.6	2960
149	38.6	37.8	2980
150	38.4	38	3000
151	38.1	38.4	3020
152	38	38.7	3040
153	37.8	38.9	3060
154	37.7	39.1	3080
155	37.6	39.3	3100
156	37.4	39.4	3120
157	37.3	39.6	3140
158	43.4	30.5	3160
159	43.4	30.5	3180
160	43.6	30.2	3200
161	43.8	30	3220
162	44	29.7	3240
163	30.5	54.6	3260
164	30.6	54.5	3280
165	30.7	54.4	3300
166	30.8	54.4	3340
167	30.8	54.5	3360
168	28.3	80.3	3380

Monitor1 from station 1

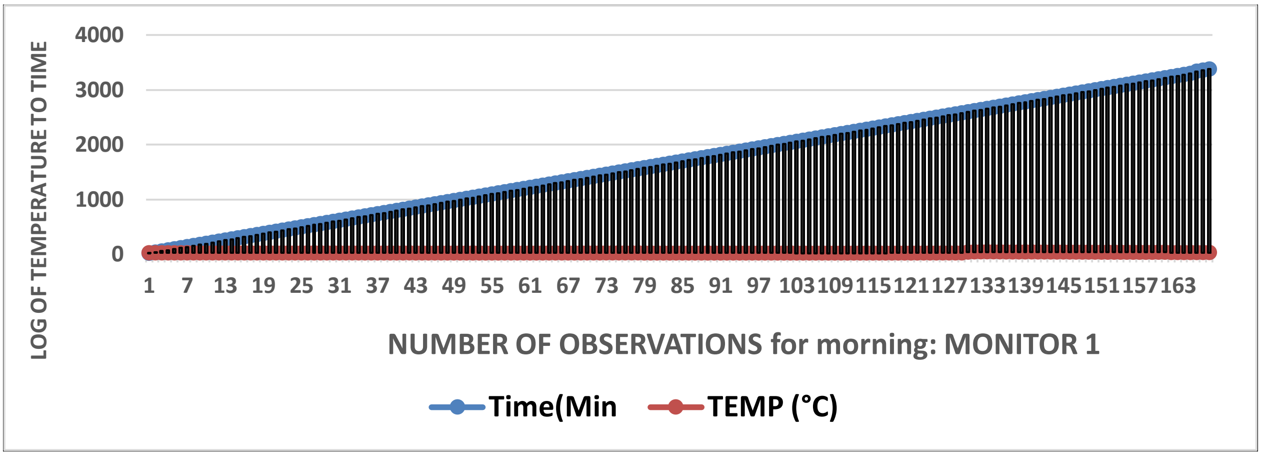


Fig A: Relationship between Experimental and Estimated Value of the Temperature to Time

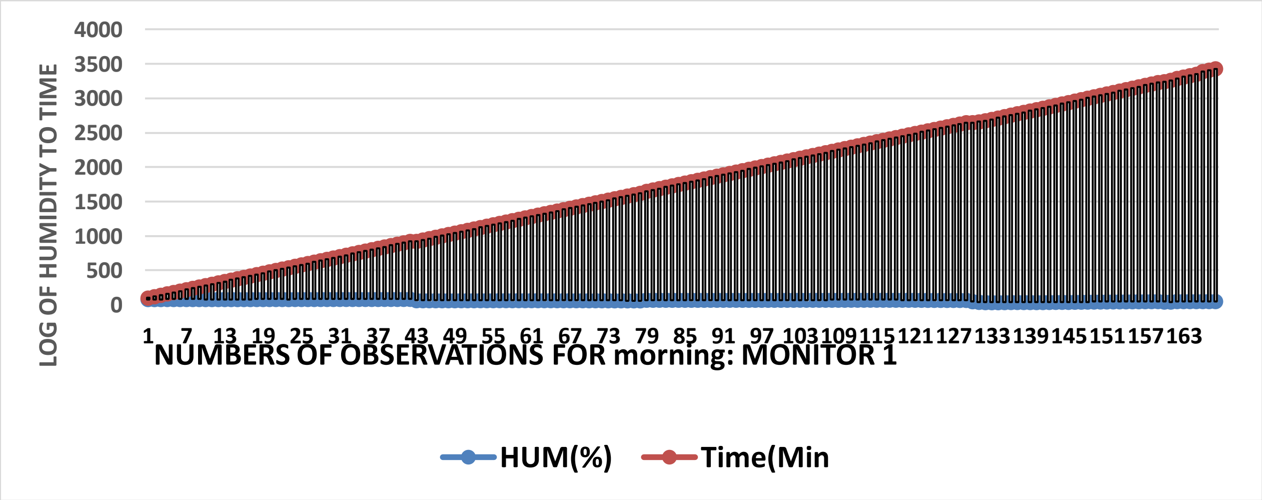


Fig B: Relationship between Experimental and Estimated Value of the Humidity to Time

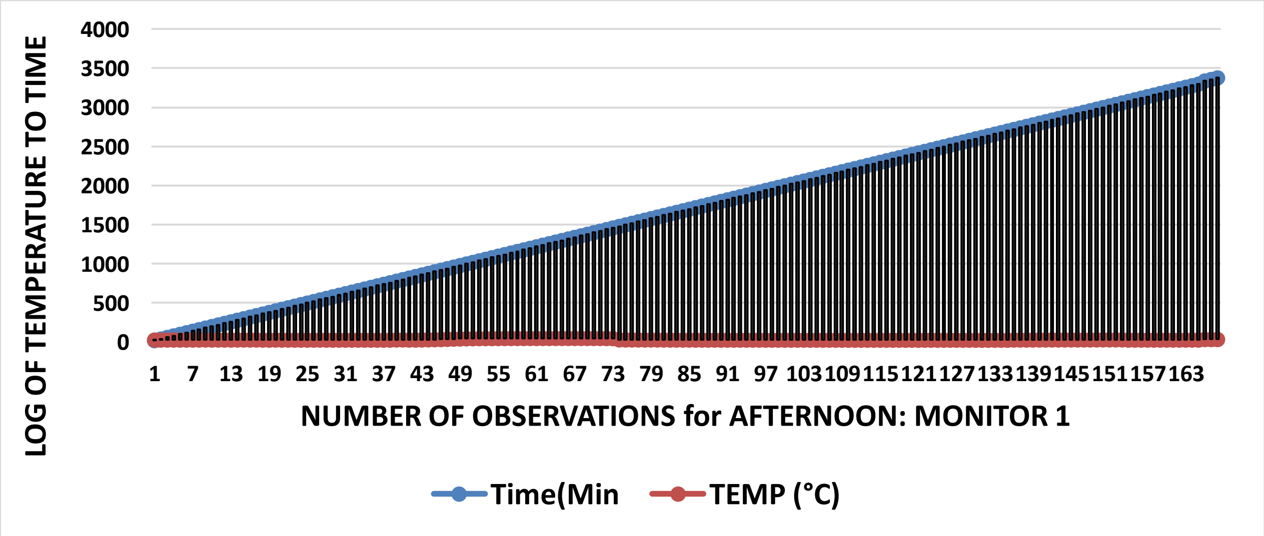


Fig C: Relationship between Experimental and Estimated Value of the Temperature to Time

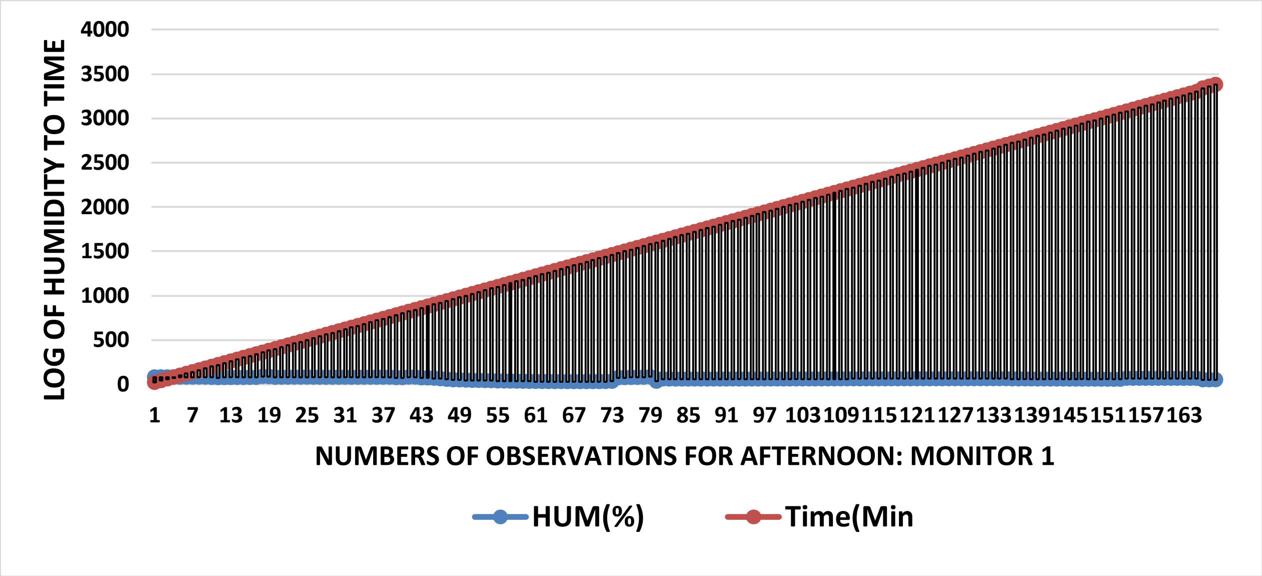


Fig D: Relationship between Experimental and Estimated Value of the Humidity to Time

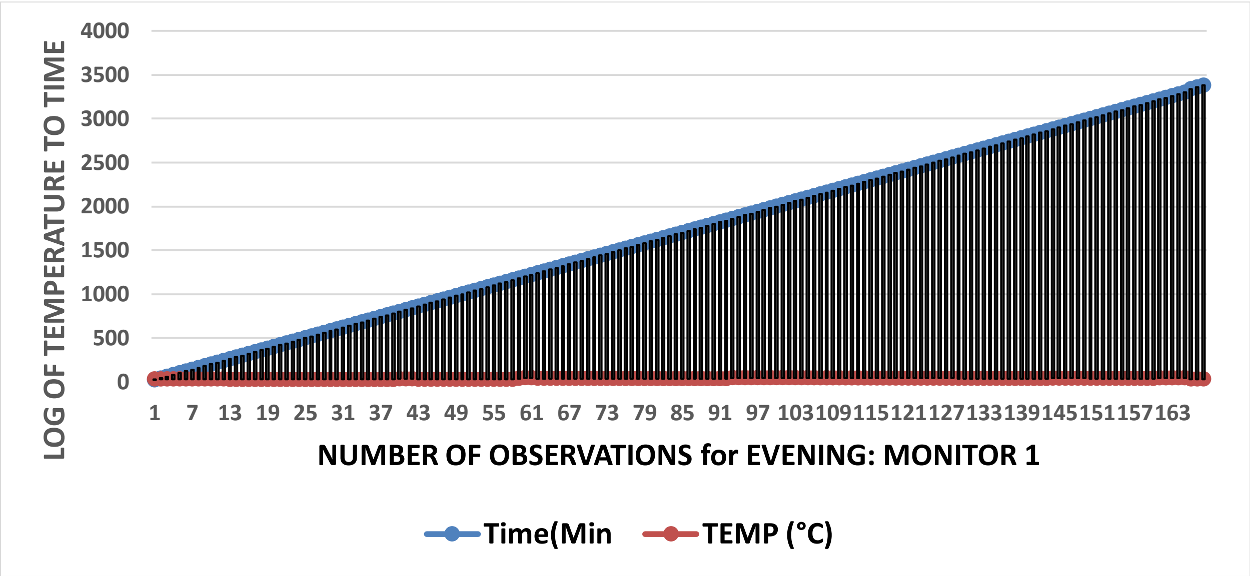


Fig E: Relationship between Experimental and Estimated Value of the Temperature to Time

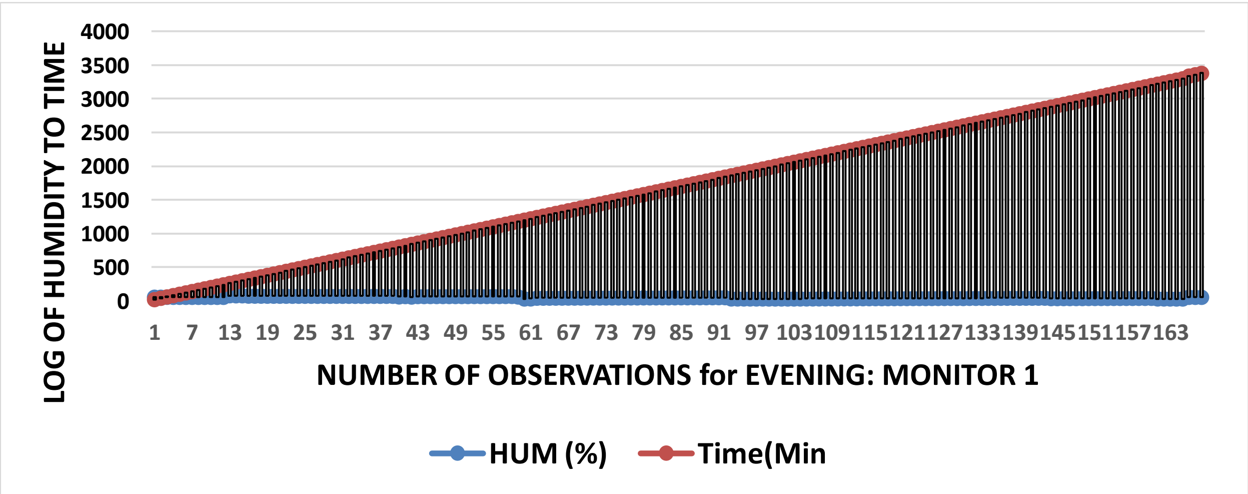


Fig F: Relationship between Experimental and Estimated Value of the Humidity to Time

Monitor Two From station 2

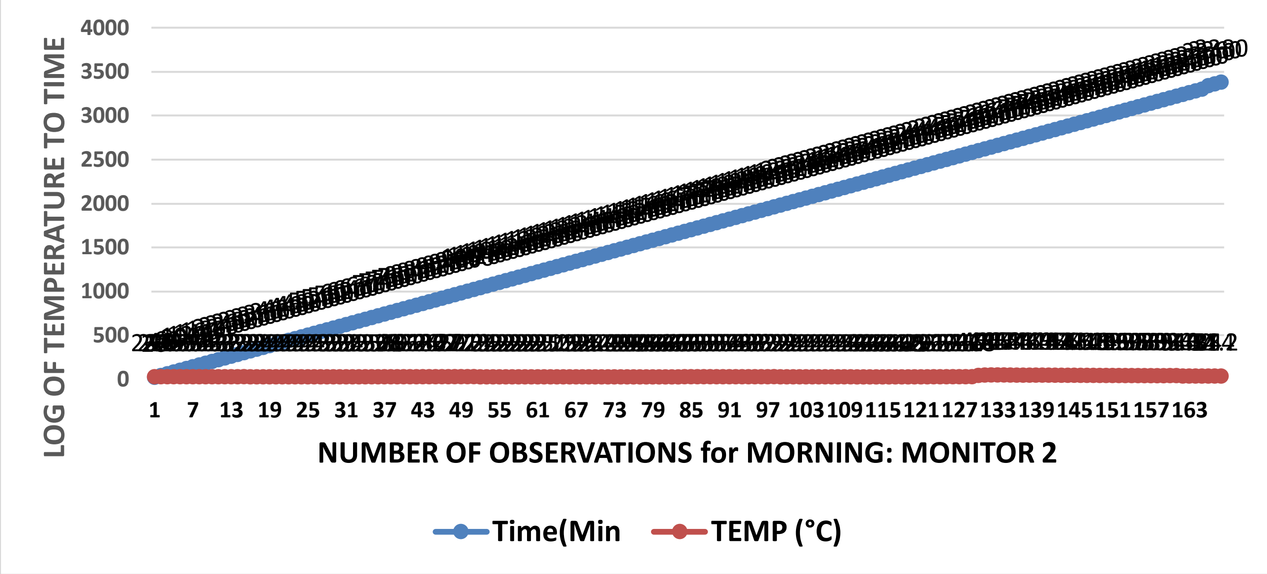


Fig G: Relationship between Experimental and Estimated Value of the Temperature to Time

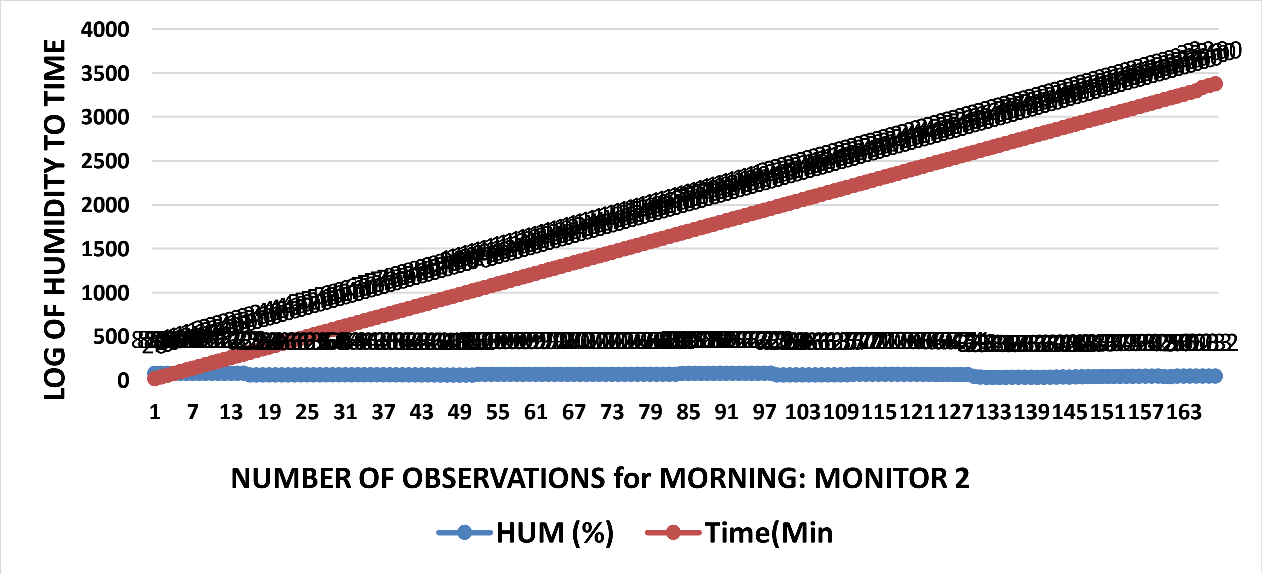


Fig H: Relationship between Experimental and Estimated Value of the Humidity to Time

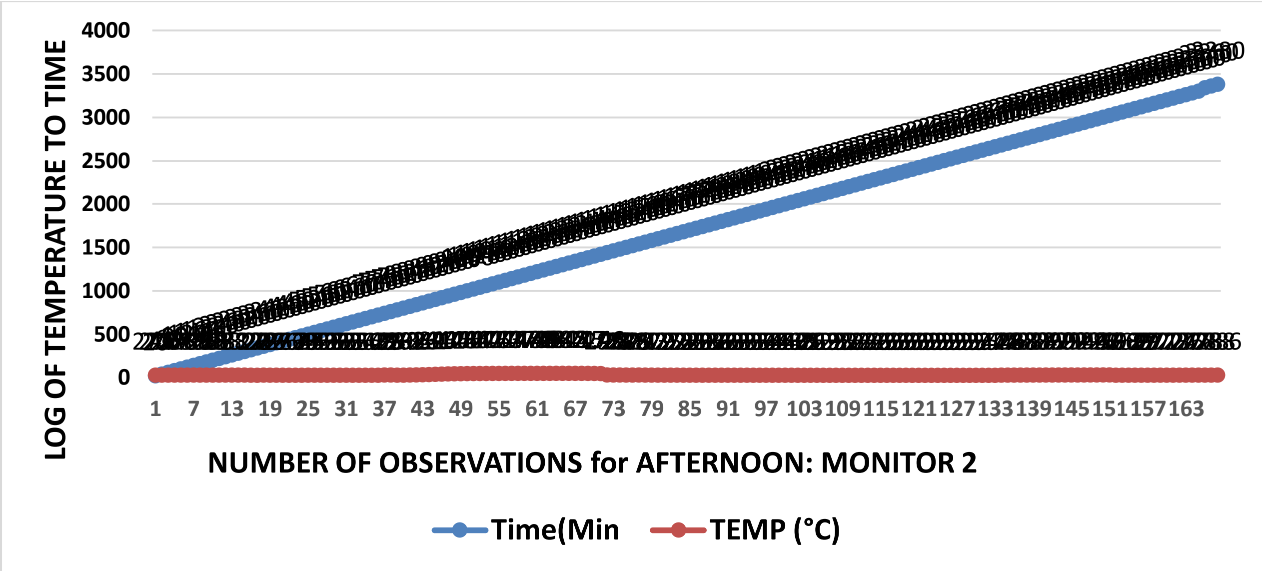


Fig I: Relationship between Experimental and Estimated Value of the Temperature to Time

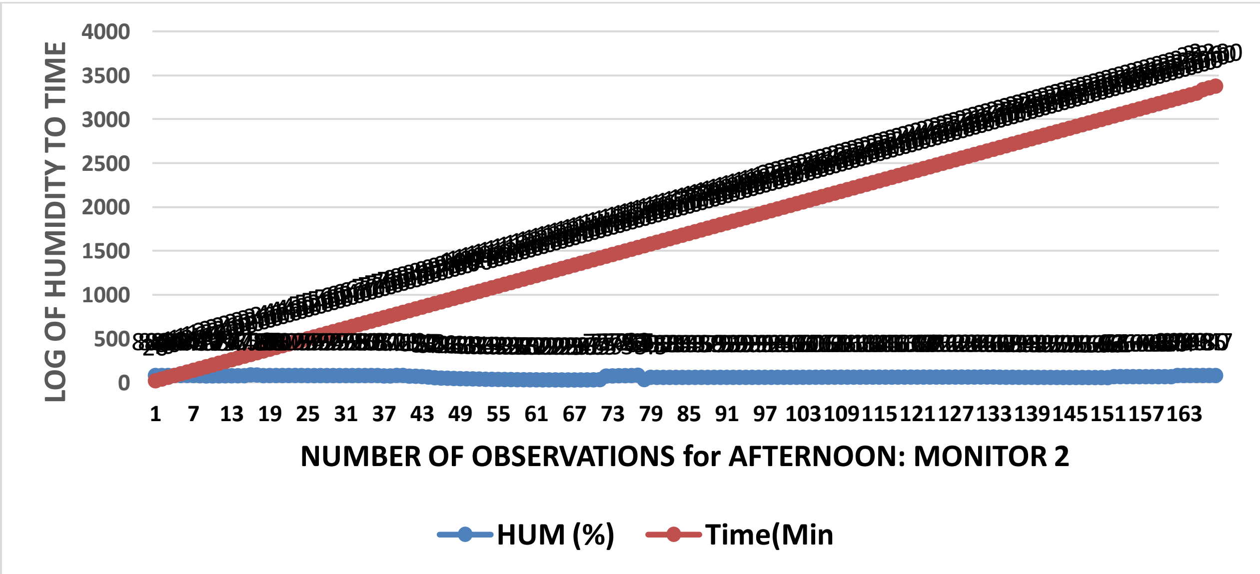


Fig J: Relationship between Experimental and Estimated Value of the Humidity to Time

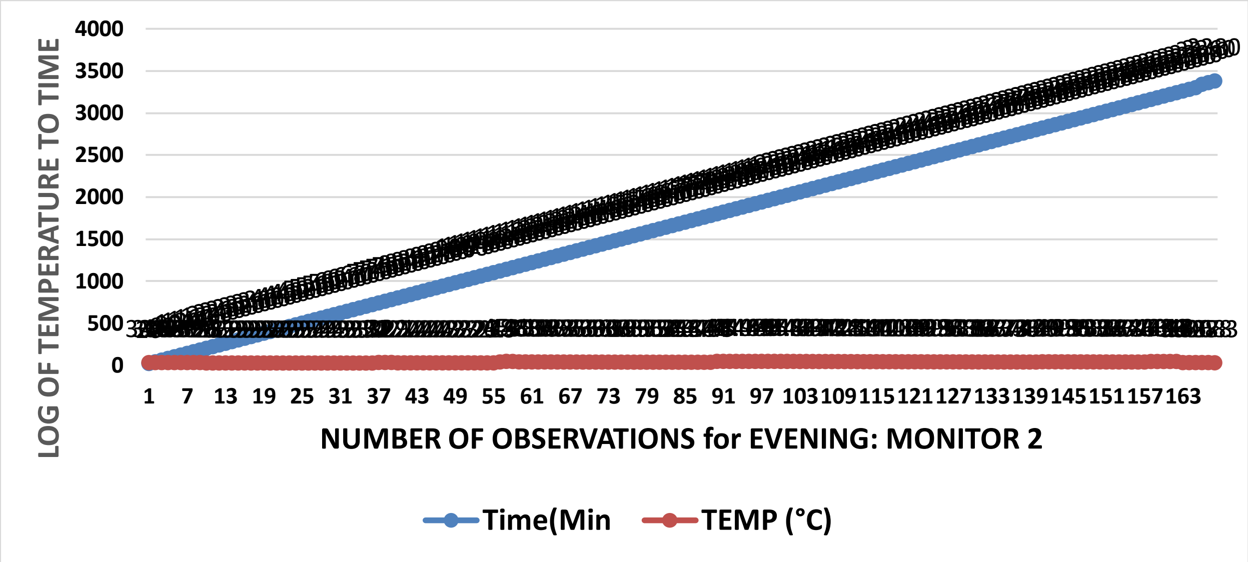


Fig K: Relationship between Experimental and Estimated Value of the Temperature to Time

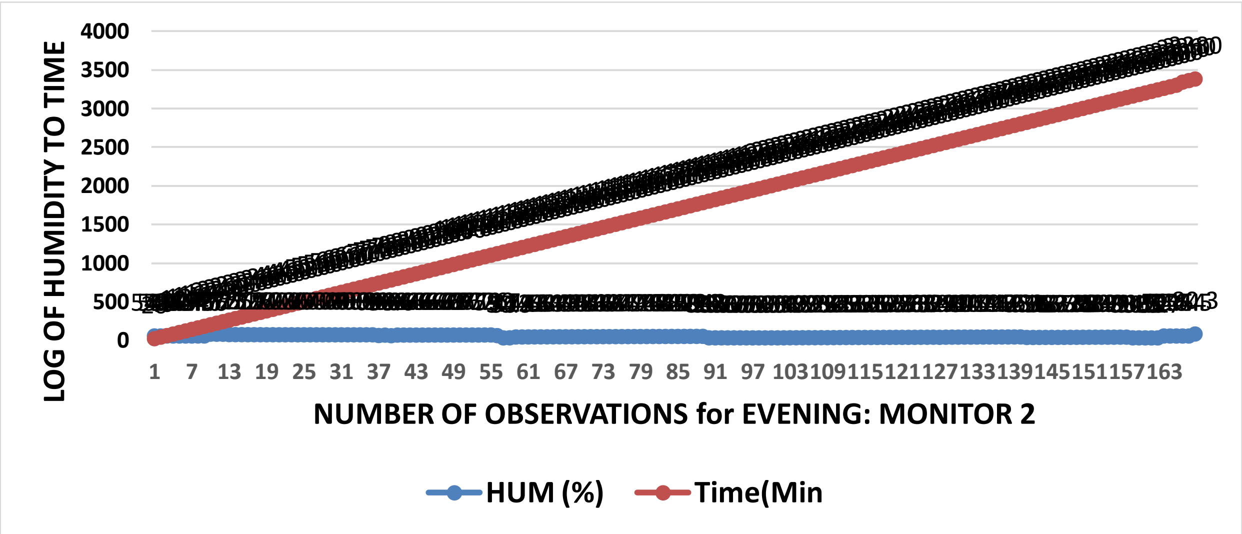


Fig L: Relationship between Experimental and Estimated Value of the Humidity to Time

VI. Analysis and Discussion

Table of Regression models for the investigated duration

Figures	Duration	Models for Monitor 1	R^2	Adj R^2	F-stat	(F-stat) P-value
A B	Morning	InTem= 1.056 + 1.113InTime + U_{t1} InHum= 2.367 +1.209InTime + U_{t2}	51.4% 73.1%	51.2% 72.9%	101.19 248.30	0.000 0.000
C D	Afternoon	InTem= 1.266 + 2.085InTime + U_{t3} InHum= 2.239 +2.174InTime + U_{t4}	35.3% 52.6%	35.2% 52.2%	32.23 81.11	0.000 0.000
E F	Evening	InTem= 1.370 + 1.050InTime + U_{t5} InHum= 1.924 -1.076InTime + U_{t6}	21.4% 23.7%	20.1% 22.3%	17.12 16.42	0.000 0.000
	Duration	Models for Monitor 2	R^2	Adj R^2	F-stat	(F-stat) P-value
G H	Morning	InTem= 2.332 + 0.079InTime + U_{t7} InHum= 2.332 +1.079InTime + U_{t8}	52.6% 72.6%	51.4% 71.4%	11.148 10.248	0.007 0.007
I J	Afternoon	InTem= 2.798 -1.386InTime + U_{t9} InHum= 2.332 +2.079InTime + U_{t10}	25.1% 17.6%	24.8% 17.4%	14.35 86.55	0.000 0.000
K L	Evening	InTem= 1.360 + 0.223InTime + U_{t11} InWind= 1.360 + 1.223InTime + U_{t12}	54.4% 23.4%	53.9% 22.9%	101.19 275.30	0.000 0.003

VII. Discussion

Morning Period

The two dependent variables captured in this research were significant in respect to time by observing the t-statistic values of ((A) 10.19 and (B) 8.30), ((G) 11.19 and (H) 9.10) respectively in respect to time. The ratio of the temperature and humidity to time models for the morning period displayed a high significant value of the coefficient of determination (R^2) of ((A) 51.2% and (B) 73.1%) ((G) 51.4% and (H) 71.4%) respectively and which is also best explained through the adjusted R^2 value of (51.2% and 72.9%) respectively as in Table 1. This value implies that about 51.2% and 72.9% have been explained by time based on the bushfire monitoring system design of the model while 48.8% and 27.1% remain unexplained in the models which were due to error terms as indicated in the model structure. The calculated F-statistic values (101.19 and 248.30) of the P-values (0.000 and 0.000) of the log (In) of the temperature and humidity to time models are lesser than the test of significance at 0.05 (5%); this also explained the significant effect of the models. However, the models displayed the best goodness fit. The validation of the models as shown in Figures A, B, G and H, revealed that the model can predict accurately the temperature which will be in agreement with the experimental investigation from the bushfire monitoring system design and humidity predict high tends of time to the experimental data deviated from a period even as it shows a kind of agreement at the beginning.

Afternoon Period

The two dependent variables captured in this research were significant in respect to time by observing the t-statistic value of ((C) 5.037, and (D) 3.793) and ((I) -5.037, and (J) 3.793) respectively, all were significant in respect to time. The ratio of the temperature and humidity direction to time models for the afternoon period displayed a high significant value of t-statistics and coefficient of determination (R^2) of ((C) 35.3% and (D) 52.6%) ((I) 25.1% and (J) 17.6%) respectively which is also best explained through the adjusted R^2 value of (35.2% and 52.2%) and (24.8% and 17.4%) respectively as in Table 1. This value implies that about (35.2% and 52.2%) and (24.8% and 17.4%) were been explained by time based on the bushfire monitoring system design of the model while (64.7% and 47.4%) and (74.9% and 82.4) remain unexplained in the models which were due to stochastic error as indicated in the model structured. The calculated F-statistic values (32.23, and 81.11) and (14.35 and 86.55) of the P-values (0.000 and 0.000) of the log (In) of the temperature and humidity to time models are lesser than the test of significance at 0.05 (5%); this also explained the significant effect of the models. However, the models displayed the best goodness fit to explain the best of the model. The validation of the models as shown in Figures C, D, I and J, revealed that the model can predict accurate temperature which agreed with the experimental investigation from the bushfire monitoring system design and humidity predict high tends of time to the experimental data and temperature and wind complied with period even as it shows a kind of agreement at the beginning.

Evening Period

The two dependent variables captured in this research were significant in respect to time by observing the t-statistic value of (2.050, and -3.060) respectively, all were significant in respect to time. The ratio of the temperature and humidity direction to time models for the evening period displayed a high significant value of t-statistics and coefficient of determination (R^2) of ((E) 21.4% and (F) 23.7%) ((K) 54.4% and (L) 23.4%) respectively which is also best explained through the adjusted R^2 value of (20.1% and 22.3%) and (53.9% and 22.9%) respectively as in Table 1. This value implies that about ((E) 21.4% and (F) 23.7%) ((K) 54.4% and (L) 23.4%) has been explained by time based on the bushfire monitoring system device of the model while (78.6% and 76.3%) and (45.6% and 76.6) remain unexplained in the models which were due to stochastic error as indicated in the model structured. The calculated F-statistic values (17.2 and 15.427 and 16.24) and (101.19 and 275.30) with P-values (0.000 and 0.000) of the log (In) of the temperature and humidity to time models are lesser than the test of significance at 0.05 (5%); this also explained the significant effect of the models. However, the models displayed the best goodness fit to explain the best of the model. The validation of the models as shown in Figures E, F, K and L, revealed that the model can predict accurately temperature and humidity which will agree with the experimental investigation from the bushfire monitoring system device and humidity predict high tends of time to the experimental data and temperature and wind complied with period even as it shows a kind of agreement at the beginning.

VIII. Conclusion

Forest fires have multidimensional negative effects on social, economic, and ecological matters. It is wise to invest in early warning systems which are much less costly overall. WSNs are thus the right choice and the least costly of all surveillance and early detection systems. The proposed research work consists of the 'Development and statistical modeling of a wireless sensor network for bushfire monitoring: a case study of Rufus giwa polytechnic environment'. As a first step, this paper presents several results that relate the time to detection and the burned area to the number of sensor nodes in the region that is protected. It is proved that the probability distribution of the size of the burned area at the moment of detection is approximately exponential, given that some hypotheses hold: the positions of the sensor nodes are independent random variables uniformly distributed and the number of sensor nodes is large. This conclusion depends neither on the number of ignition points nor on the propagation model of the fire. Wireless communication is a cheap and easy way to provide network communication at places where there is no wired infrastructure. In this design, ZigBee provides low power consumption, simple wireless communication to send the values of fire parameters such as temperature and relative humidity for maximum coverage area. SHT11 sensor is connected to an 8-bit processor and temperature and humidity result is sent to GSM modem which simultaneously displays on LCD and the measured parameters can be transmitted via the cloud, storage or SMS to a distant user mobile as preset by the users. Because of the flexibility of the wireless system, the proposed design is very much compatible with any system. The developed device would make the Rufus Giwa Polytechnic environment much saved from any fire outbreak in the nearest future. The proposed design can be greatly used in agriculture practice at the Rufus giwa polytechnic environment as well as the Department of survey and informatics, Weather station and Meteorological department. The proposed device has proved so useful for anyone who wishes to monitor bushfires of a location without being physically present.

Acknowledgements

The author appreciates the Tertiary Education Trustfund(TETFUND) of the Federal Republic of Nigeria in collaboration with the Centre for Research and Development(CRD), Rufus Giwa Polytechnic, Owo, Ondo, State, Nigeria, for being fully supported in the proposed research work titled 'Development and statistical modeling of a wireless sensor network for bushfire monitoring: a case study of Rufus'giwa polytechnic environment'. The project was developed and analyzed by Iyapo Kamoru Olarewaju, the principal researcher and his team at the department of science laboratory Technology, Physics unit, Rufus Giwa Polytechnic, Nigeria.

References

[1]. Munawar, H.S, Ullah F, Khan, S.I, Qadir, Z and Qayyum S, UAV Assisted Spatiotemporal Analysis and Management of Bushfires: A Case Study of the 2020 Victorian Bushfires, *MDPI*. 2021: 4(3): 1-34.

[2]. Whittaker, J, Taylor M, Bearman C, why don't bushfire warnings work as intended? Response to official warnings during bushfires in New south wales, Australia, *International Journal of Disaster Risk Reduction*. 2020; 45(101476): 1-10.

[3]. Spits, C, Wallace L, Reinke K, Investigating surface and near-surface bushfire fuel attributes: A comparison between visual assessments and image-based point clouds. *MDPPI* (Sensors). 2017, 17(4): 1-19.

[4]. Jadhav, P. S, Deshmukh, V. U, Forest Fire Monitoring System Based On Zigbee Wireless Sensor Network..*International Journal of Emerging Technology and Advanced Engineering*. 2012; 2(12), 187-191.

[5]. Hlaing, S, Aung S.N, monitoring of forest Fire detection system using ZigBee. *International Journal of Trend in Scientific Research Development (IJTSRD)*. 2019; 3(4): 1332-1334

[6]. ZHANG, J, LI W, HAN, N, KAN, J, Forest fire detection system based on a ZigBee wireless sensor network, *ResearchGate*, 2008; 3(3): 369–374.

[7]. Ngai, E, Zhou, Y, Lyu, N. A Delay-Aware Reliable Event Reporting Framework for Wireless sensor-actuator Networks, *Ad Hoc Networks*. 2010; 8(7), 694-707.

[8]. Joseph, J. K, Kargil J, Andrady J.A, Mithum V. M, Sanju B, Forest Fire Detection using Zigbee Wireless Sensor Networks, GRD Journals | GRD *Journal for Engineering | National Conference on Emerging Research Trend in Electrical and Electronics Engineering* (ERTE'19) | 2019; e-ISSN: 2455-5703: 332-335.

[9]. Kumar, D.K, Kishore, G, Kumar, T.V.S, Fire Monitoring System for Fire Detection using ZigBee and GPRS System, *IOSR Journal of Electronics and Communication Engineering (IOSR-JECE)*. 2017; 12(1): 23-27.

[10]. Arriagada, B.N, Palmer, A.J, Bowman, D.M, Morgan, G.G, Jalaludin, B.B, Johnston, F.H, Unprecedented smoke-related health burden associated with the 2019–20 bushfires in eastern Australia. *Medicinal Journal of Australia*. 2020: 213(6): 282–283

[11]. Sun, Y, Yuan Q, Sarawi, Y.S, 'A Bushfire Monitoring and detection system for Smart home using ZigBee technology', *International Journal of Computer-Aided Engineering and Technology*. 2010;2(2/3): 234-249.

[12]. Rehman, A, Qureshi, M.A, Ali, T, Irfan .M, Abdullah, S, Yasin, S, Draz U, Glowacz, A, Nowakowski, G, Alghamdi, A, Alsulami A.A, egrzyn M.W, Smart Fire Detection Deterrent System for human Savior by using Internet of Thing (IoT). *MDPI*. 2021; 14(7): 1-30.

[13]. North, M, Stephens, S, Collins, B, Agee, J, Aplet G, Franklin J, Fule P.Z, Reform Forest fire management. *Science*, 2015: 349(6254): 1280–1281.

[14]. Yuanbin, W, Langfei, D, Jieying, R, Forest fire image recognition based on convolutional neural network, *Journal of Algorithms and Computational Technology*. 2019; 13: 1-11.

[15]. Tehrany, M.S, Özener, H, Kalantar B, Ueda N, Habibi, M R, Shabani, F, Saeidi, V, Shabani, F, Application of an Ensemble Statistical Approach in Spatial Predictions of Bushfire Probability and Risk Mapping, *Hindawi Journal of Sensors*, 2021; Article ID 2793474, 2021. https://doi.org/10.1155/2021/2793474: 1-15

[16]. Cao, Q, Zhang, L, Su Z, Wang, G, Sun S, Guo F, comparing four regression techniques to explore factors governing the number of forest fires in Southeast, China, *Journal of Geomatics, Natural Hazards and Risk*, 2021: 12(1): 500-521.

[17]. Plucinski, M.P, McCaw, W.L, Gould, J. L, Wotton, B. M, Predicting the number of daily human-caused bushfires to assist suppression planning in south-west Western Australia, *International Journal Association of Wildland Fire*. 2014; 23(4): 1-19.

[18]. Abid, F, Izeboundjen, N, Predicting Forest Fire in Algeria Using Data Mining Techniques: Case Study of the Decision Tree Algorithm, *ResearchGate*. 2020; 3(2): 365-370

[19]. Meaghan, E. J, Bedward, M, Price O, Bradstock R.A, Modelling Bushfire Fuel Hazard Using Biophysical Parameters, *MDPI.* 202O; 11(9) :1-13.

[20]. Aarthi, R, Dharshini, V.J, Razavi, S, Suryalakshmi, R, Vigneswaran, S, Low Cost & Effective Early Forest / Bush Fire Detection with Wireless Sensor Technology Using Matlab, *International Journal of Innovative Research in Electrical, Electronics, Instrumentation and Control Engineering (IJIREEICE)*. 2021; 9(3): 109-114.

[21]. Aarthi, N, Aiswariya, R. R, Kamimozhi, C.T, Kiruthika, S, Yogeswaran, S, IOT Based Data Logger System for Weather Monitoring, *International Journal of Scientific Research in Computer Science, Engineering, and Information Technology*. 2017: 2(2): 51-55.

[22]. Rao, B.S, Rao, K.S, Ome, N, Internet of Things (IoT) Based Weather Monitoring System, *International Journal of Advanced Research in Computer and Communication Engineering.* 2016;5(9):312-319.

[23]. Hung, N O, Babel, M.S, Weesakul, S, Tripathi, N. K, An artificial neural network for rainfall forecasting in Bangkok Thailand. *Hydro and Earth system science.* 2009: 13: 1413-1425.

[24]. Iyapo, K. O, Oni O.T, Odo E.A, Rahim O.A, Statistical Modelling and Validation of performance Evaluation of Weather Monitoring System Using Global System for Mobile Communication Technology, *Asian Journal of Engineering and Applied Technology*. 2017; 6(2): 1-8.