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

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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

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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.

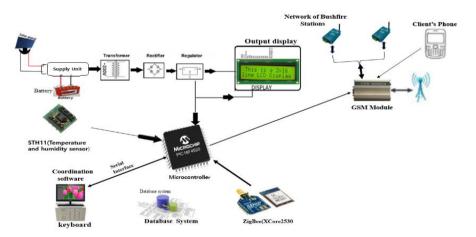


Fig.1. Block diagram of the proposed bushfire monitoring system.

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].

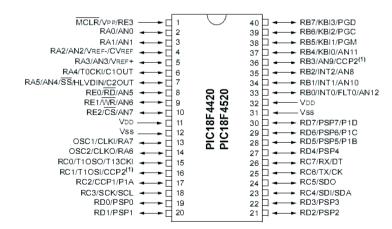


Fig.3. DIL package and the block diagram of the PIC18F4520

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].

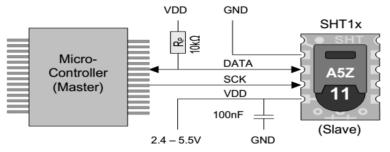


Fig.4. Microcontroller interface to the STH11 sensor.

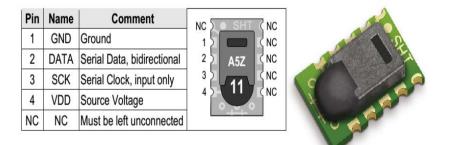


Fig.5. The SHT11 temperature humidity sensor interface Specifications

D. PCB Design

IV. Development of System

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.

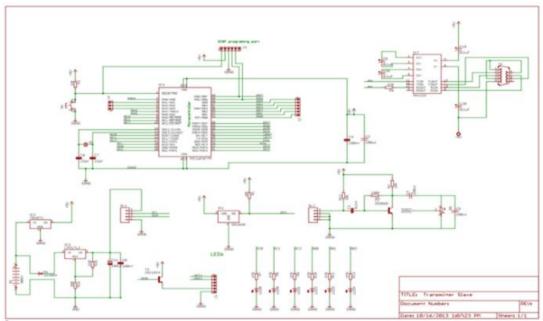


Fig.6. Schematic combinations of coordinator and end device systems

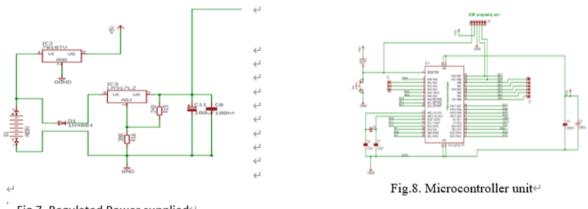


Fig.7. Regulated Power supplied

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].

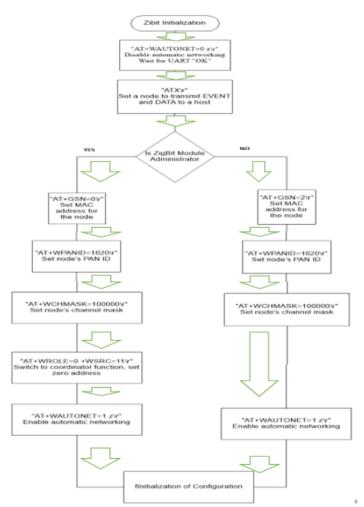


Fig.9. Flowchart for the ZigBee Module Configuration

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.

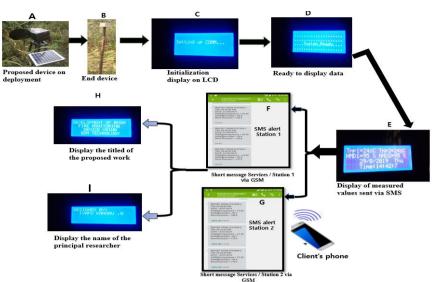


Fig.10. LCD screen showing display result during Hardware deployment

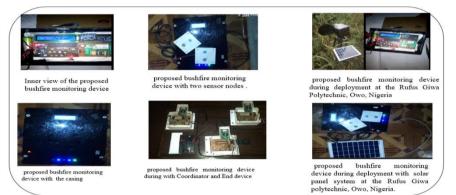


Fig.11. show the working model of wireless bushfire monitoring of the finished product.

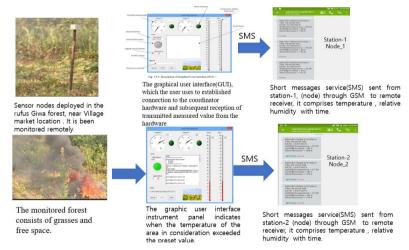


Fig.12. show Graphic user Interphase(GUI) and data received via SMS during hardware deployment

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 , Fstatistics 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
$InTem = \alpha_1 + \beta_1 InTime + U_{t1} \dots \dots$
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}
Afternoon
$InTem = \alpha_9 + \beta_9 InTime + U_{t9}9$
$InHum = \alpha_{10} + \beta_{10}InTime + U_{t10}10$
Evening
$InTem = \alpha_{11} + \beta_{11}InTime + U_{t11}11$
$InHum = \alpha_{12} + \beta_{12}InTime + U_{t12}12$
$\alpha_1, \alpha_2, \alpha_3, \alpha_4, \alpha_5, \alpha_6, \alpha_7, \alpha_8, \alpha_9, \alpha_{10}, \alpha_{11} \& \alpha_{12}$ are constant terms of the respective models and $\beta_1, \beta_2, \beta_3, \beta_4, \beta_5, \beta_6, \beta_7, \beta_8$
$\beta_9 \beta_{10} \beta_{11}$ 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.

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Fi	rst Monitor: Tab	le 1: Morni	
Serial No	TEMP (°C)	HUM	Time(minutes)
1	28	(%) 79.5	20
2	27.5	79.3	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 30	26.5 26.5	81.6 81.7	580 600
30	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 25.5	64	1140
58 59		63.9	1160
<u> </u>	25.5 25.5	64 64.1	1180 1200
61	25.6	64.2	1200
62	25.6	64.2	1220

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 27.3	61.5 61.3	1520 1540
78	27.3	61.5	1560
78	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 96	25 25	70.1 70.1	1900 1920
96	23	70.1	1920
97	24.9	70.1	1940
99	24.9	70.1	1980
100	24.9	70.1	2000
100	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 2260
113 114	24.6 24.6	71 71	2280
114	24.6	71	2280
115	24.0	71	2300
117	24.0	70.9	2320
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

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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
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
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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

Development and statistical modeling of a wireless sensor network (WSN) for Bushfire ...

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.

Firs	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 26.5 79.5 640 33 26.5 79.5 640 33 26.5 79.5 640 33 26.3 80.1 760 36 26.3 79.7 700 36 26.3 80.1 760 39 29 75.1 780 40 29 75.1 800 41 27.2 80.9 840 43 29.1 72.4 860 44 30.3 71.17 880 45 32.1 67.8				
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 79.5 640 33 26.5 79.5 660 34 26.4 79.7 700 36 26.3 79.8 720 37 26.3 80.1 760 38 26.3 80.1 760 39 29 75.1 780 40 29 75.1 800 41 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	22	27	80	440
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 26.5 79.5 660 31 26.5 79.5 640 33 26.5 79.5 660 34 26.4 79.7 700 36 26.3 79.8 720 37 26.3 80.1 760 39 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 62 220 47 36.7 55.2 940 48 39.2 50.6	23	26.7	80.2	460
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 26.5 79.5 640 33 26.5 79.5 640 33 26.5 79.5 660 34 26.4 79.7 700 36 26.3 80 740 38 26.3 80.1 760 39 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 62 220 47 36.7 55.2 940 48 39.2 50.6	24	26.4	80.5	480
26 26.4 80.4 520 27 27 79.6 540 28 226.6 79.4 580 30 26.6 79.5 600 31 26.5 79.5 640 33 26.5 79.5 660 34 26.4 79.7 700 36 26.3 80 740 38 26.3 80.1 760 39 29 75.1 780 40 29 75.1 780 40 29 75.1 780 41 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	25			
27 27 79.6 540 28 26.9 79.2 560 29 26.6 79.5 600 31 26.5 79.5 640 33 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 80.1 760 39 29 75.1 800 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				
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32 26.5 79.5 640 33 26.5 79.5 660 34 26.4 79.7 700 36 26.3 79.8 720 37 26.3 80.1 760 38 226.3 80.1 760 39 29 75.1 780 40 29 75.1 800 41 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 10020 52 <td>30</td> <td>26.6</td> <td>79.5</td> <td>600</td>	30	26.6	79.5	600
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Development and	l statistical	modeling	of a	wireless	sensor network	(WSN)	for Rushfire
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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
100		59.6	2020
	26.3		
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
100	25.9	60.6	2120
108	25.8	60.7	2160
109	25.8	60.9	2180
110	25.7	61	2200
111	25.7	61.1	2220
112		61.2	2240
	25.7		
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	2320
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
122	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
	25.5	62.3	
129			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
133	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
150	29.7	56.6	3020
1.5 1			
150	29.9	56.3	3040
152	30	56.1	3060
153			2000
	26.8	67	3080
153		67 66.9	3080
153 154 155	26.8 26.9	66.9	3100
153 154 155 156	26.8 26.9 26.9	66.9 66.9	3100 3120
153 154 155 156 157	26.8 26.9 26.9 26.9	66.9 66.9 66.8	3100 3120 3140
153 154 155 156 157 158	26.8 26.9 26.9 26.9 26.9 27	66.9 66.9 66.8 66.8	3100 3120 3140 3160
153 154 155 156 157	26.8 26.9 26.9 26.9	66.9 66.9 66.8	3100 3120 3140
153 154 155 156 157 158	26.8 26.9 26.9 26.9 26.9 27	66.9 66.9 66.8 66.8	3100 3120 3140 3160

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.

Firs	t Monitor: Table	3: Evening L	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

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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 30.9 1220 61 44.1 30.9 1220 62 39 41.6 1240 63 38.8 42.2 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 37.3 44.5 1400 74 36.5 45.9 1500 <t< td=""><td></td><td></td><td></td><td></td></t<>				
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	121	40.6	36.5	2420
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			26.0	(1440)

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
140	37.2	41.8	2820
142	37	42.1	2840
142	36.9	42.3	2860
143	40.2	35.6	2880
144	40.2	35.8	2880
145	39.8	36	2900
146	39.8	36.3	2920
147	39.7		2940
148	<u> </u>	36.5	2980
-		36.7	
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.

Sec	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		

20 25.4 63.1 400 21 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 63.7 540 27 25.3 63.7 540 28 25.3 63.8 560 29 25.3 64 600 31 225.5 64 6400 31 225.5 64 6400 33 25.5 64.1 6600 34 225.6 64.2 700 36 225.8 64.1 700 36 25.8 64.1 700 36 25.8 64.1 700 37 25.9 63.8 740 39 26.1 63.5 780 40 26.2 63.4 800 41 26.3 63.3 820 41 26.5 62.9 880 111 42 26.4 63.1 44 26.5 62.9 800 111 44 26.5 62.9 450 27.2 61.5 980 51 27.4 61.1 1020 52 25.2 69.9 1180 46 25.1 69.9 1180 55 25.2 69.9 1180 55 25.2 69.9 1120 56 25.2 69.9 <td< th=""><th></th><th></th><th></th><th></th><th></th></td<>					
16 25.4 62.8 320 17 25.4 62.9 360 19 25.4 63.1 400 20 25.4 63.1 400 21 25.4 63.1 400 22 25.4 63.2 460 23 25.4 63.2 460 24 25.3 63.5 500 26 25.3 63.6 520 27 25.3 63.8 560 29 25.3 64 600 31 25.5 63.9 620 32 25.5 64.1 660 33 25.5 64.2 700 36 25.8 64.1 720 37 25.9 63.6 760 38 26.6 63.6 760 39 26.1 63.5 780 100 38 26.6 860 41 26.3 63.3 <td>15</td> <td>27.2</td> <td>82.9</td> <td>300</td> <td>85</td>	15	27.2	82.9	300	85
17 25.4 62.8 340 18 25.4 $63.$ 380 20 25.4 $63.$ 400 21 25.4 $63.$ 420 22 25.4 $63.$ 440 23 25.4 63.3 440 25 25.3 63.5 500 27 25.3 63.6 520 27 25.3 63.6 520 27 25.3 63.8 560 29 25.3 64.4 580 30 25.4 64.2 680 31 25.5 64.1 660 33 25.5 64.1 660 34 25.6 64.2 680 33 25.6 64.2 680 340 26.1 63.5 780 40 26.2 62.0 920 41 26.5 62.2 920					
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21 25.4 63.1 420 91 22 25.4 63.2 460 92 24 25.4 63.3 480 95 26 25.3 63.5 500 95 27 25.3 63.6 520 96 27 25.3 63.8 560 98 29 25.3 64 580 99 30 25.4 64 660 100 31 25.5 64.1 660 100 33 25.6 64.2 680 100 34 25.6 64.2 700 100 37 25.9 63.8 740 100 38 26 63.6 760 100 39 26.1 63.3 820 111 42 26.6 62.6 860 111 44	19	25.4	63	380	89
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42 26.4 63.1 840 112 43 26.6 62.6 860 113 44 26.5 62.9 880 114 45 22.7 61.9 900 115 46 26.9 62.2 920 116 47 27 61.9 940 115 49 27.2 61.5 980 119 50 27.3 61.3 1000 122 51 27.4 61.1 1020 122 53 25.2 69.9 1040 122 54 25.2 69.9 1000 122 56 25.2 69.9 1100 122 56 25.2 69.9 1160 122 58 25.2 69.9 1160 122 59 25.2 69.9 1120 122 60 25.2 69.9 1220 133 61 25.1 69.9 1240 133 65 25 70 1320 133 66 25 70 1320 133 66 25 70.1 1440 144 71 24.9 70.1 1440 74 24.8 70.2 1500 144 75 24.9 70.1 1440 74 24.6 70.8 1540 76 24.6 70.8 1540 79 24.6 70.9 1660 80 <td< td=""><td></td><td></td><td></td><td></td><td>111</td></td<>					111
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48 27.1 61.8 960 118 49 27.2 61.5 980 119 50 27.3 61.3 1000 120 51 27.4 61.1 1020 121 52 25.2 69.9 1040 122 53 225.2 69.9 1060 122 54 25.2 69.9 1100 122 56 25.2 69.9 1100 122 56 25.2 69.9 1140 122 58 25.2 69.9 1160 122 59 25.2 69.9 1180 122 60 25.2 69.9 1120 133 61 25.1 69.9 1200 133 64 25.1 69.9 1240 133 64 25.1 70 13300 133 66 25 70 1330 133 66 25 70 1330 133 66 25 70 1340 133 66 25 70.1 1440 144 71 24.9 70.1 1440 144 72 24.9 70.1 1440 144 75 24.9 70.2 1500 144 76 24.6 70.8 1540 144 77 24.6 70.8 1540 144 78 24.6 70.8 1560 155 81 24.6 <					
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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 1160 60 25.2 69.9 1200 61 25.1 69.9 1220 62 25.1 69.9 1220 63 25.1 69.9 1260 64 25.1 70 1280 65 25 70 1300 66 25 70 1300 66 25 70 1340 67 25 70 1340 69 25 70.1 1440 71 24.9 70.1 1440 71 24.9 70.1 1440 74 24.8 70.2 1500 76 24.6 70.7 1520 76 24.6 70.8 1560 79 24.6 70.8 1560 79 24.6 70.8 1560 79 24.6 70.9 1640 81 24.6 70.9 1640 83 24.6 70.9 1660					
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57 25.2 69.9 1140 127 58 25.2 69.9 1160 128 59 25.2 69.9 1180 60 25.2 69.9 1200 61 25.1 69.9 1220 63 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 1340 69 25 70.1 1440 71 24.9 70.1 1440 72 24.9 70.1 1440 74 24.8 70.2 1500 76 24.6 70.8 1540 77 24.6 70.8 1560 79 24.6 70.9 1660 81 24.6 70.9 1660	56	25.2	69.9	1120	126
58 25.2 69.9 1160 128 59 25.2 69.9 1180 129 60 25.2 69.9 1200 130 61 25.1 69.9 1220 131 62 25.1 69.9 1240 132 63 25.1 69.9 1260 133 64 25.1 70 1280 133 65 25 70 1300 135 66 25 70 1320 136 67 25 70 1340 135 68 25 70 1360 133 69 25 70.1 1440 142 70 24.9 70.1 1440 71 24.9 70.1 1440 74 24.8 70.2 1500 76 24.6 70.7 1520 77 24.6 70.8 1540 78 24.6 70.8 1560 80 24.6 70.9 1600 81 24.6 70.9 1600 81 24.6 70.9 1640 83 24.6 70.9 1660					
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62 25.1 69.9 1240 132 63 25.1 69.9 1260 133 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 1440 72 24.9 70.1 1440 74 24.8 70.2 1500 76 24.6 70.7 1520 77 24.6 70.8 1560 79 24.6 70.8 1560 79 24.6 70.9 1600 81 24.6 70.9 1600 83 24.6 70.9 1660	61	25.1	69.9	1220	131
63 25.1 69.9 1260 64 25.1 70 1280 65 25 70 1300 66 25 70 1300 66 25 70 1320 67 25 70 1340 68 25 70 1340 69 25 70.1 1380 70 24.9 70.1 1400 71 24.9 70.1 1440 72 24.9 70.1 1440 73 24.9 70.1 1440 74 24.8 70.2 1500 76 24.6 70.7 1520 77 24.6 70.8 1540 79 24.6 70.8 1560 80 24.6 70.9 1600 81 24.6 70.9 1660 83 24.6 70.9 1660					
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$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	72	24.9	70.1	1440	142
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33 24.0 70.7 1000 133 84 26.5 81.5 1680 154					
ο 4 20.3 δ1.3 1080 154					133
	04	20.3	01.3	1080	154

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 2020
101 102	25.4	62.9 63	2020
102	25.4	63.1	2040
103	25.4	63.1	2080
104	25.4	63.1	2100
105	25.4	63.2	2100
100	25.4	63.3	2120
107	25.3	63.5	2140
100	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 2540
127 128	26.6 26.7	67.5 67.4	2560
128	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 40.6	43.5	2980
150 151	40.6	44.4 45.1	<u>3000</u> 3020
151	<u>40.3</u> 39.9	45.1	3020
		45.9	3040
153	39.6		

Development and statistic	al modeling of a wireless	s sensor network (WSN) for Bushfire
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Development and	l statistical modelin	ng of a wireless	s sensor network	(WSN) for Bushfire
= = = = = = = = = = = = = = = = = = = =				

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.

Seco	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
47	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 31.2	1180 1200
60 61	47.8 47.9	31.2	1200
62	47.9	30.2	1220
63	48	30.2	1240
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 78	29 28.3	83 33.5	1540 1560
78	28.5	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 95	26.5 26.4	59.1 59.1	1880
93	26.4	59.1	1900 1920
90	26.4	59.4	1920
98	26.4	59.5	1940
99	26.3	59.6	1980
100	26.3	59.7	2000
100	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
113 114	25.6 25.6	61.4 61.4	2260 2280
114	25.6	61.4	2280
115		61.5	2300
116	25.6		

-			
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
130	25.4	62.6	2620
132	25.4	62.6	2640
132	25.4	62.7	2660
133	27.6	60.8	2680
134	27.0	60.1	2080
135	27.8	60.4	2700
	27.8	59.8	2720
137			
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	80.5	3360
168	28.6	80	3380
100	20.0	00	5500

Development and statistical modeling of a wireless sensor network (WSN) for Bushfire ...

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.

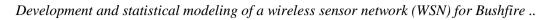
Second Monitor: Table 6: Evening Data				
Serial No	TEMP (°C)	HUM (%)	Time(minutes)	
1	30.6	54.9	20	
2	30.7	54.7	40	
3	30.8	54.6	60	
4	30.8	54.5	80	
5	30.9	54.4	100	
6	30.9	54.4	120	
7	30.9	54.5	140	
8	30.8	54.6	160	

		(J
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
20	25.4	70.2	540
28	25.4	70.2	560
28	25.3	70.1	580
30	25.3	70.1	600
30	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	1340
69	36.9	45.1	1380
70	36.8	45.3	1380
70	36.6	45.6	1400
72	36.5	45.9	1420
72	36.3	45.9	1440
73			1460
	36.2 36	46.4 46.6	
75		1	1500
	35.9	46.9	1520
76	25 7	477 1	1540
76 77 78	35.7 35.6	47.1 47.4	1540 1560

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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		1900
		30.4	
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
101	44.4	30.9	2040
102	43.9	31.5	2040
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
110	42.1	34.3	2220
			2220
112	41.9	34.6	
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
-			2400
120	40.2	37.1	
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
127	38.8	39.2	2560
128	38.5	39.2	2580
			2580
130	38.3	40	
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			2720
	37.4	41.4	
137	37.4	41.4	
137	37.3	41.6	2740
138	37.3 37.2	41.6 41.8	2740 2760
138 139	37.3 37.2 37	41.6 41.8 42.1	2740 2760 2780
138 139 140	37.3 37.2 37 36.9	41.6 41.8 42.1 42.3	2740 2760 2780 2800
138 139 140 141	37.3 37.2 37 36.9 40.2	41.6 41.8 42.1 42.3 35.6	2740 2760 2780 2800 2820
138 139 140	37.3 37.2 37 36.9 40.2 40	41.6 41.8 42.1 42.3	2740 2760 2780 2800
138 139 140 141	37.3 37.2 37 36.9 40.2	41.6 41.8 42.1 42.3 35.6	2740 2760 2780 2800 2820
138 139 140 141 142 143	37.3 37.2 37 36.9 40.2 40 39.8	41.6 41.8 42.1 42.3 35.6 35.8 36	2740 2760 2780 2800 2820 2840 2860
138 139 140 141 142 143 144	37.3 37.2 37 36.9 40.2 40 39.8 39.7	41.6 41.8 42.1 42.3 35.6 35.8 36 36.3	2740 2760 2780 2800 2820 2840 2860 2880
138 139 140 141 142 143 144 145	37.3 37.2 37 36.9 40.2 40 39.8 39.7 39.5	41.6 41.8 42.1 42.3 35.6 35.8 36 36.3 36.3 36.5	2740 2760 2780 2800 2820 2840 2860 2880 2900
138 139 140 141 142 143 144 145 146	37.3 37.2 37 36.9 40.2 40 39.8 39.7 39.5 39.3	41.6 41.8 42.1 42.3 35.6 35.8 36 36.3 36.3 36.5 36.7	2740 2760 2780 2800 2820 2840 2860 2880 2900 2920
138 139 140 141 142 143 144 145	37.3 37.2 37 36.9 40.2 40 39.8 39.7 39.5	41.6 41.8 42.1 42.3 35.6 35.8 36 36.3 36.3 36.5	2740 2760 2780 2800 2820 2840 2860 2880 2900

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	



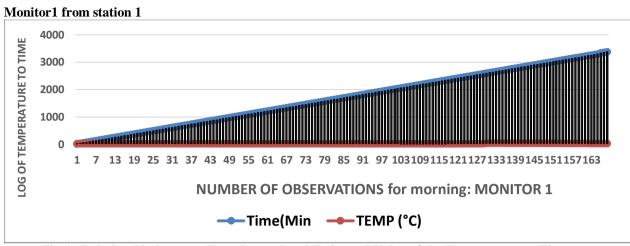


Fig A: Relationship between Experimental and Estimated Value of the Temperature to Time

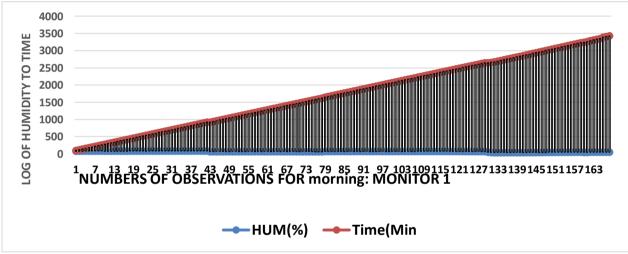


Fig B: Relationship between Experimental and Estimated Value of the Humidity to Time

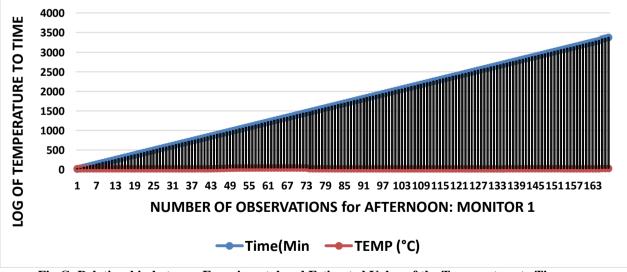
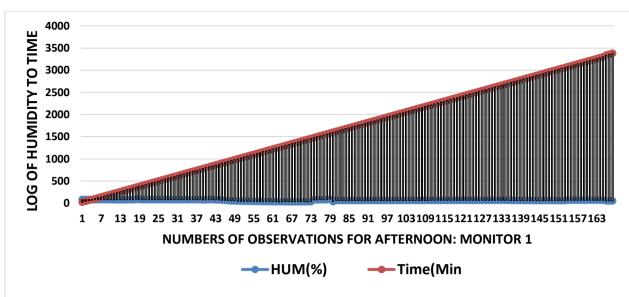


Fig C: Relationship between Experimental and Estimated Value of the Temperature to Time



Development and statistical modeling of a wireless sensor network (WSN) for Bushfire ..

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

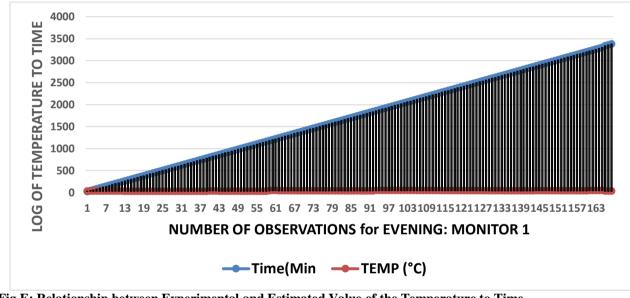


Fig E: Relationship between Experimental and Estimated Value of the Temperature to Time

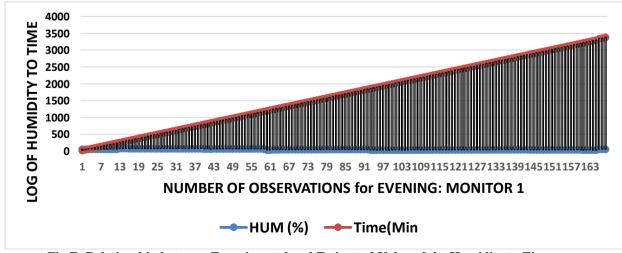
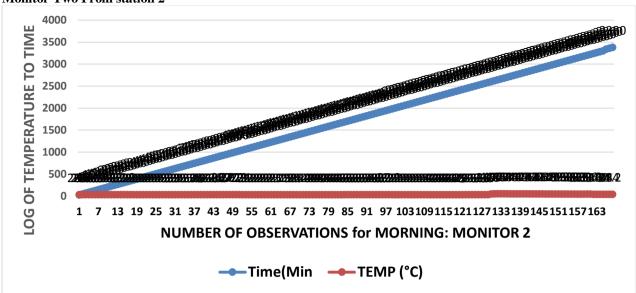


Fig F: Relationship between Experimental and Estimated Value of the Humidity to Time



Monitor Two From station 2

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

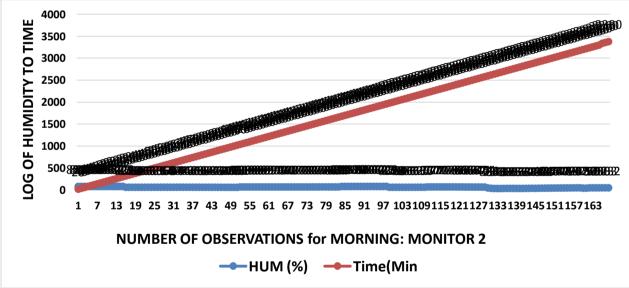


Fig H: Relationship between Experimental and Estimated Value of the Humidity to Time

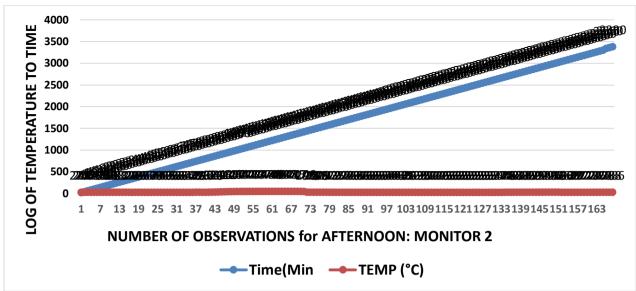


Fig I: Relationship between Experimental and Estimated Value of the Temperature to Time

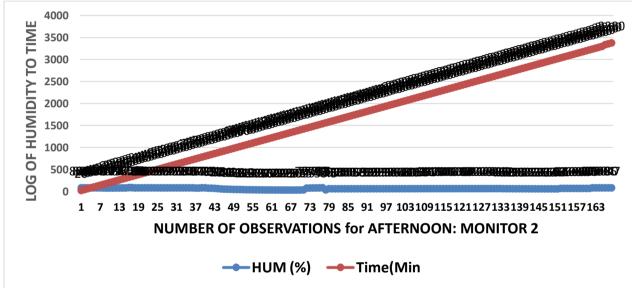


Fig J: Relationship between Experimental and Estimated Value of the Humidity to Time

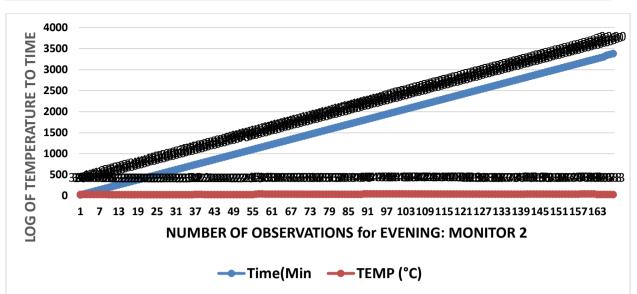


Fig K: Relationship between Experimental and Estimated Value of the Temperature to Time

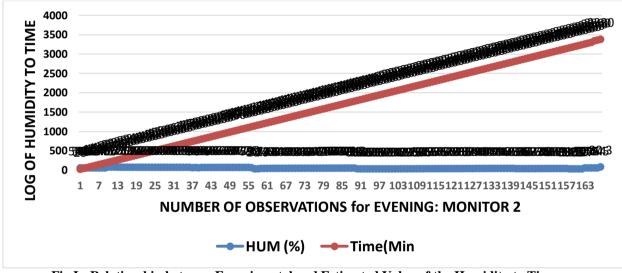


Fig L: Relationship between Experimental and Estimated Value of the Humidity to Time

ble of Regression models for the investigated duration									
Figures	Duration	Models for Monitor 1	\mathbf{R}^2	Adj R ²	F-stat	(F-stat) P-value			
Α	Morning	$InTem = 1.056 + 1.113InTime + U_{t1}$	51.4%	51.2%	101.19	0.000			
В		InHum= 2.367 +1.209InTime + U _{t2}	73.1%	72.9%	248.30	0.000			
С	Afternoon	$InTem = 1.266 + 2.085InTime + U_{t3}$	35.3%	35.2%	32.23	0.000			
D		InHum= 2.239 +2.174InTime + Ut4	52.6%	52.2%	81.11	0.000			
Е	Evening	$InTem = 1.370 + 1.050InTime + U_{t5}$	21.4%	20.1%	17.12	0.000			
F	_	InHum= 1.924 -1.076InTime + U _{t6}	23.7%	22.3%	16.42	0.000			
	Duration	Models for Monitor 2	\mathbf{R}^2	Adj R ²	F-stat	(F-stat) P-value			
G	Morning	InTem= $2.332 + 0.079$ InTime + U _{t7}	52.6%	51.4%	11.148	0.007			
Н		InHum= $2.332 + 1.079$ InTime + U _{t8}	72.6%	71.4%	10.248	0.007			
I	Afternoon	InTem= 2.798 -1.386InTime + U _{t9}	25.1%	24.8%	14.35	0.000			
J		InHum= $2.332 + 2.079$ InTime + U _{t10}	17.6%	17.4%	86.55	0.000			
K	Evening	InTem= $1.360 + 0.223$ InTime + U _{t11}	54.4%	53.9%	101.19	0.000			
L		InWind= $1.360 + 1.223$ InTime + U _{t12}	23.4%	22.9%	275.30	0.003			

VI. **Analysis and Discussion**

Та

Morning Period

VII. Discussion

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 (\mathbb{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 \mathbb{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 R² 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 tstatistics 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.

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