

Smart Irrigation System with Indigenous Multilingual Mobile Application



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ABSTRACT: African farmers produce about 80 percent of the food consumed in the African continent yet a large percentage of them are cut off from agricultural innovation due to illiteracy and language barriers. Previous studies have developed mobile applications for smart irrigation systems in English language. This work develops a multilingual mobile App in three major indigenous Nigerian languages Hausa, Yoruba, and Igbo to make the smart irrigation innovation accessible and adaptable to indigenous farmers. The mobile App was developed using Flutter while the English version was translated to indigenous languages. A microcontroller-based laboratory-scale smart irrigation test bed was also developed to which the App was interfaced for testing. Performance evaluation revealed the ability of the App to perform remote control of the irrigation process and display soil moisture, temperature, and humidity of the farm environment on its graphical user interface in English and indigenous languages of Hausa, Yoruba, and Igbo. Further tests under Wi-Fi and Internet network revealed the Wi-Fi network was stable up to 50 meters, beyond which stability declined. The Internet connection remained stable up to 400 km except at certain weak or unavailable coverage points (45 km, 105 km, 210 km). The unique contribution of this work is that while previous studies developed mobile App for smart irrigation system in English language, the multilingual mobile App bridges communication gap and will make smart irrigation technology accessible and adaptable to indigenous farmers in their mother tongues to enhance food security.

KEYWORDS: Smart irrigation, Indigenous languages, Multi-lingual mobile application, Flutter, Firebase

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I. INTRODUCTION

Seventy percent (70 %) of the food consumed in sub-Saharan Africa is produced by smallholder farmers (Giller et al., 2021; IFAD, 2025). Many of these farmers are illiterate and lack adequate technology to enhance productivity resulting in poverty. Despite Nigeria's huge potential in population and land mass, agricultural productivity is low when compared with other nations in Africa (Business Day, 2025). Lawal, (2015) opined that due to the language barrier, rural dwellers are hindered from the technological innovations that could lead to improved agricultural productivity. In order for the Africa continent to unleash the huge potential, there is, the need to leverage indigenous languages in empowering smallholder farmers with adequate skills, information, and technology to enhance food security.

A study by Amery, (2017) revealed that language barrier was the cause of a major communication gap between health practitioners and the indigenous residents in Australia which could have had a significant impact on the mortality rate in that region. To address the language barrier gap regarding farmers in Nigeria, this study focuses on developing a mobile application for smart irrigation systems in the native languages of the farmers to make the technology acceptable and adaptable to local communities to be able to adequately reach them with innovations needed for improved irrigation management

to ensure food security. The case study of this work is Nigeria being the most populous African country (Lawal, 2015; Statistica, 2023; UN Women Africa, 2025). The three major indigenous languages of Hausa, Yoruba, and Igbos in Nigeria was our focus.

Smart Irrigation system is the practice of using cutting-edge technologies such as smart devices such as mobile phones and others for control, monitoring, and management of irrigation processes to enhance food security (Ogidan et al., 2019; Liao, 2021; Obaideen, et al., 2022; Vallejo-Gomez, 2023). Many authors have contributed to Smart irrigation systems utilizing various microcontrollers and technologies. Sathiaseelan (2023) reported on the design and interfacing of a NodeMCU with a smart irrigation system. Although the simulation was done using Proteus software, further real-world testing is necessary. Patankar et al., (2021) discussed the integration of ESP8266 and ESP32 microcontrollers with Wi-Fi connectivity, utilizing Blynk for remote monitoring and control. In Ogidan and Afia (2019), a detail of the development of an Android application for monitoring and controlling a smart irrigation system via the Blynk interface was discussed, effectively transmitting signals from the ESP8266 to the user interface. Vallejo-Gómez et al., (2023) examine smart irrigation systems within urban agriculture, with an emphasis on automation and systematic analysis. Singh et al., (2023) used ESP32 and machine learning algorithms to forecast soil moisture and optimize irrigation schedules, though they

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identified the need for further research to improve system performance. Liao et al., (2021) created a smart irrigation system, incorporating ESP32 and wireless sensor networks, performing remote control and real-time monitoring of soil moisture levels, with plans to enhance system reliability and scalability (Singh, 2023a).

Previous literature (Ogidan and Afia, 2019, Edodi et al., 2022; Singh et al., 2023a) have reported mobile applications for a smart irrigation system that were developed in the English language which is alien to many Indigenous smallholder farmers in Nigeria and Africa due to their low level of literacy. The novelty of this work is that it develops a multi-lingual mobile application for smart irrigation systems in Nigerian indigenous languages of Hausa, Yoruba, and Igbo. This is with a view to addressing the communication gap due to the language barrier on the part of indigenous farmers and to making the technology adaptable to the Nigerian context. This is believed to improve productivity in the agricultural sector.

Smart irrigation systems leverage the Internet of Things and Web technology to provide cutting-edge solutions for irrigation systems (Ogidan et al., 2019; Liao, 2021; Vallejo-Gomez, 2023). The system uses sensors to detect when the soil is dry automatically supplies water to crops and stops the water supply when it senses that the soil is wet enough. The operator (farmer) can view the farm's environmental conditions such as soil moisture level, temperature and humidity, and so on from remote locations using a smartphone. The farmer has the option of starting/stopping irrigation pumps on the farm from remote locations based on sensor values received on his mobile device (Bhardwaj, 2018; Ogidan and Afia, 2019; Vallejo-Gomez, 2023). Flutter is an excellent option for developing cross-platform mobile applications and software development kits (SDK). It is a well-structured design framework that is open to external contributions. The server is essential to the interaction between the mobile application and the Internet of Things device (Podcaster, 2024). The rest of the paper is arranged as follows: Section 2 discusses the hardware and software requirements of the developed system as well as its step-by-step operation. Section 3 considers the data acquisition test, the remote-control test, comparison with contemporary mobile App showing and their results with discussions. The paper concludes with section 4.

II. METHODOLOGY

The stages involved in this study as illustrated in Figure 1 include hardware development, software (mobile App) development, hardware and mobile App integration, step-by-step operation of the system, and evaluation of performance.



Figure 1. Procedure involved in research implementation

A. Hardware Development

The system architecture shown in Figure 2, the hardware components include the microcontroller, four-channel relay, soil moisture sensor, temperature and humidity sensor

(DHT11) the DC water pump, and power backup.

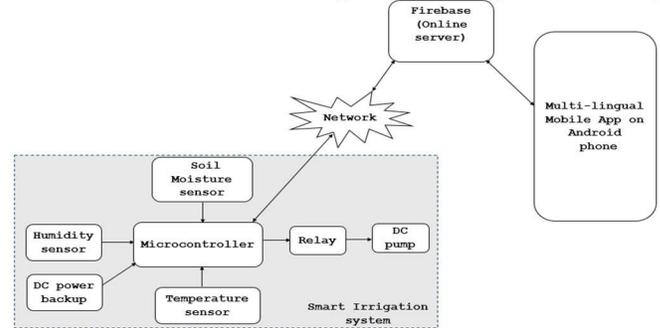


Figure 2 Architecture of the developed system

The ESP 32 microcontroller is the choice in this research because of its ease of use with a breadboard, its flexibility the fact that it is very compact, and the fact that it has an in-built Wi-Fi module. A 4-channel relay is employed to switch on and off the DC water pump. The direct current (DC) motor used in this work is from the battery rated 12 V, 1.5 A which provides power for the 4-channel relay. The sensors used in this project are for the acquisition of data for soil parameters e.g. temperature, soil moisture and humidity of the soil. Figure 3a is the schematic circuit diagram of the system. The battery supplies 12 V DC power to the buck converter which steps it down to 5 V which is the power required by the ESP 32 microcontroller. The 4-channel relay is connected to its respective pins i.e. pins 12, 13, 14, 27 and other sensors are also connected to the respective pins. Figure 3b illustrates the components being coupled.

B. Software development

An integrated development environment (IDE) is a suite of products that includes the basic tools needed to write and test programming. The programming language adopted for designing the mobile App is flutter which is an open-source user interface (UI) software development kit (SDK) created by Google. It is used to build natively compiled applications for mobile, web, and desktop systems from a single codebase (Altexsoft, 2025). As shown in the flowchart in Figure 4, when a user launches the application, it undergoes the initialization process waiting for the user to login with authenticated credentials. After the login stage, the system acquires sensor values which are sent over a wireless network to a remote database and finally displayed on the mobile App graphical interface. The system evaluates whether adjustments in humidity temperature and soil moisture levels are necessary based on the algorithm analysis, if adjustments are needed to maintain the desired microclimate, the system proceeds to activate the DC pump. If no adjustments are needed, the system maintains the current humidity temperature and soil moisture levels. The system continues to loop continuously monitoring and adjusting the soil environment parameters as needed. These conditions ensure that the automated pump system operates efficiently, maintaining the optimal humidity temperature and soil moisture levels for enhanced plant growth and health.

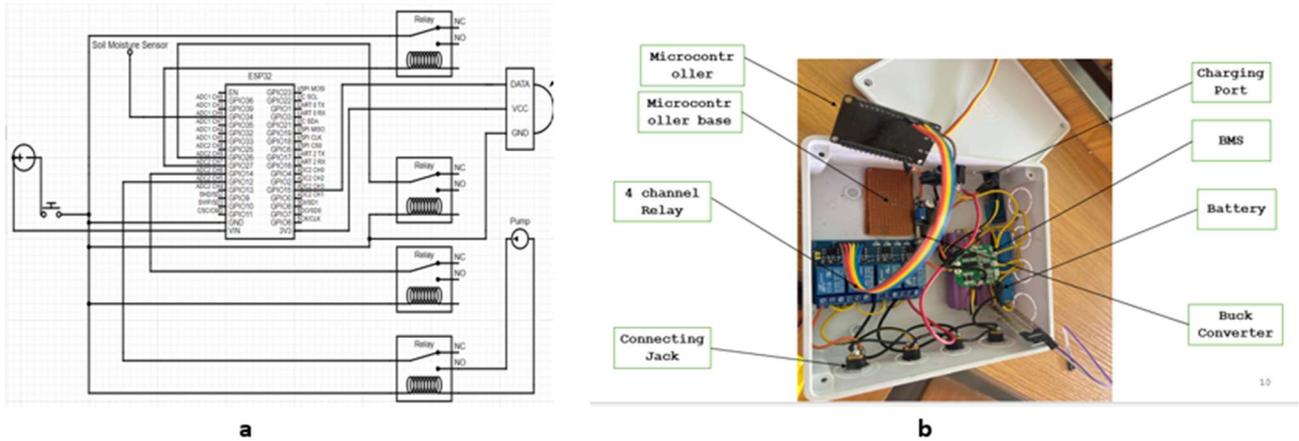


Figure 3: a) Circuit Diagram showing connection of components b) Components after coupling

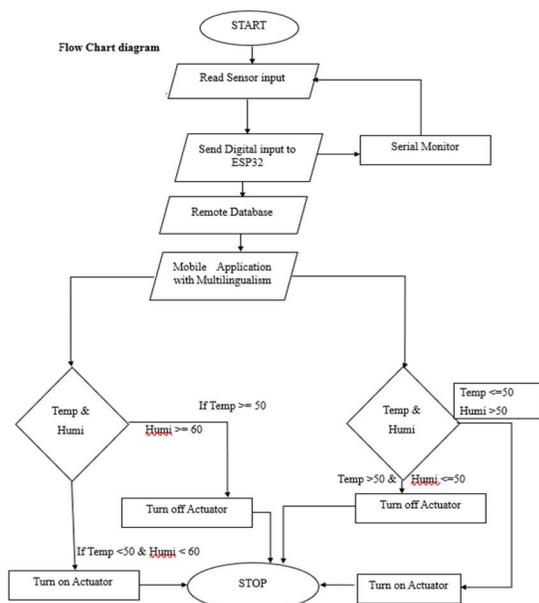


Figure 3.14: Flowchart

Figure 4 System Flowchart

C. Hardware and Mobile App Integration

To connect the developed mobile application to the smart irrigation system, an Arduino Independent Development Environment (IDE) was used as the interfacing module. A Wi-Fi SSID "mobile router" and password are provided respectively. This enabled the microcontroller to be interfaced (handshake) with the Internet connectivity and ensured live data was sent over the Firebase remote database system. Figure 5 shows how each argument was assigned to the SSID and password parameters in the process of interfacing the developed mobile App with a laboratory-scale smart irrigation system.

```

1  #if defined(ESP32)
2  #include <WiFi.h>
3  #elif defined(ESP8266)
4  #include <ESP8266WiFi.h>
5  #endif
6  #include <Firebase_ESP_Client.h>
7  #include <addons/TokenHelper.h>
8  #include <DHT.h> // Include the DHT sensor library
9
10 // Define DHT sensor parameters
11 #define DHTPIN 15
12 #define DHTTYPE DHT11
13
14 // Define WiFi credentials
15 #define WIFI_SSID "MTN_4G_48489D"
16
17 #define WIFI_PASSWORD "5B0486D7"
    
```

Figure 5 Wi-Fi Connectivity Setup

D. Step-by-Step Operation of the System

The operation of the developed multilingual mobile App with the smart irrigation system is a step-by-step process involving login and Authentication, Language selection, multilingual data presentation, and Real-time data acquisition and control.

1) Log-in and Authentication

From the screen of an Android mobile device, the user clicks on the icon named Flutter application as shown in Figure 6a. When this is done, the welcome page is displayed in a default English language as shown in Figure 6b. If the user is a first-time, there is a need to register by clicking on the register icon and filling in the appropriate credentials such as name, email, and password. After this, he can log in by providing the registered credentials. This is referred to as the process of authentication in order to screen off illegitimate users of the developed App. When an existing user logs in, he is directed to a welcome page as shown in Figure 6c with the message "Welcome back, we have missed you".

2) Language Selection stage

After signing in, the language interface is displayed. This is where users can select their preferred language by clicking on an icon in the top right corner of the interface as shown in Figures 7a and b. Once this is done, different languages are displayed including English, Hausa, Yoruba, French, Igbo. Figure 8 is an illustration of the smart irrigation App applied to three indigenous languages of Hausa, Yoruba and Igbo. For this study, only three of the languages are translated and activated for use. Once the user selects a particular language for instance Yoruba, the information formally displayed on the interface in English language shown in Figure 9a is changed to Hausa, Yoruba, and Igbo languages based on the user’s desire as shown in Figure 9b to 9d. This gives users the liberty to access and operate irrigation systems using the multi-lingual mobile App in the languages of their choice rather than the conventional English language.



Figure 6: a) screen of an Android mobile device
 b) App home interface in English language
 c) welcome page for existing users

3.) Language Translation

In order to present the App interface developed in English Language in the Nigerian indigenous languages of Hausa,

Yoruba, and Igbo languages, translation has to be carried out. The translation to the indigenous languages was performed by experts in the field of linguistics and individuals who have a good command of both written and spoken English as well as the desired indigenous language. Table 1 shows the words in English and their literal translation in Hausa, Yoruba, and Igbo languages as well as the icons (graphics) displayed on the mobile app and their functions or meanings. This is to enhance the user's understanding of the indigenous languages and to enhance the user-friendliness of the developed multi-lingual app. The translated words were programmed into the App from the back end to produce the front-end multi-lingual interfaces that users can relate to as shown in Figures 9b to 9d.

4) Multilingual Data presentation

From Figure 10, it can be observed that the usability of the mobile app has increased to three users rather than on the English version. This is due to the translation from the English language to include three other Nigerian languages.

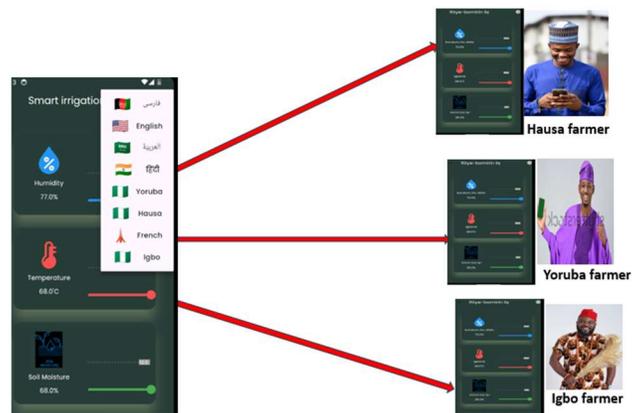
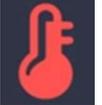


Figure 8: smart Irrigation mobile App in three indigenous languages



Figure 7: a) language selection menu,
 b) language displayed for selection

Table 1 Comparison of the different Indigenous Apps and functions of their icons

Icon	Function	English	Hausa	Yoruba	Igbo
	To display the amount of water vapour in the air	Humidity	Tawali'u	Kurukuru inu afefe	iru mmiri
	To display the intensity of heat present in a substance or object	Temperature	Yanayin zafi	Igbona	okpomoku
	To display the water content of the soil	Soil moisture	Tawali'u Danshi na kasa	irinmi inu ile	Oḳuku Ala",

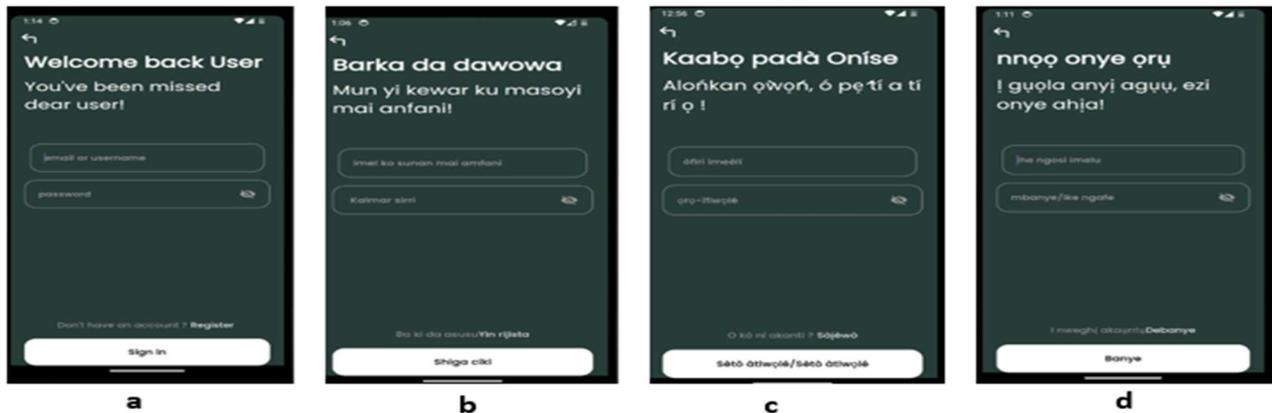


Figure 9 Front-end display of sensor readings in a) English language b) Hausa language c) Yoruba language d) Igbo language

III. RESULTS AND DISCUSSION

The developed device was used under different conditions including the data acquisition test, remote control test, and comparison with contemporary smart irrigation systems with the Blynk mobile Application.

A.) Data Acquisition Test

The experiment was performed to allow the soil moisture sensor and digital humidity and temperature sensors to acquire appropriate data from soil samples and the environment respectively. Figures 10a and b show the humidity in blue, temperature in red, and soil moisture in green colours. It should be noted that the Graphical User Interface (GUI) values displayed as shown in Figures 10a and b in the English language can also be displayed in Hausa, Yoruba, or Igbo languages depending on the user's preference. In Figure 10a, the sensor's interface was displayed but not yet activated. The moment the user connects (activates) the appropriate sensors, measured values of the different parameters under consideration are obtained and are shown as indicated in the graph in Figure 10b. Apart from environmental condition monitoring, the user is also able to initiate an irrigation system remotely over the Internet as in Ogidan and Afia, (2019) and in a study by Edodi et al., (2022). In Ogidan and Afia, (2019), an Android mobile device was used to control irrigation

process from remote locations while in the case of Edodi et al., (2022), the solar/battery power and water in reserve were monitored over the Internet using a mobile Android device. This is accomplished by toggling the "irrigation ON" and terminating it using the "irrigation OFF" menu shown in Figure 10a.

B.) Remote Control Test

Tests were performed to ascertain the network coverage of the developed device under Wi-Fi and Internet networks. The laboratory-scale smart irrigation system was kept at a specific location while the operating distances of the mobile app were varied using the Wi-Fi and Internet networks (Ogidan and Afia, 2019; Edodi et al., 2022). Figures 11 and 12 are the results of the respective distance covered with an optimal distance of 10 m (5th sample) for Wi-Fi after which the signal strength fell considerably. The Internet network maintained a consistently strong network with an experimental maximum distance of 420 m (22nd sample).

C) Comparison with contemporary mobile Application

An evaluation was done by comparing the developed Flutter-based multilingual mobile App for smart irrigation systems (Github, 2025) in comparison with the contemporary Blynk App (Ogidan and Afia, 2019; Edodi et al., 2022). Table 2 presents the report of the comparison of smart irrigation

systems with a multilingual mobile App in comparison with contemporary smart irrigation systems with the Blynk mobile application.

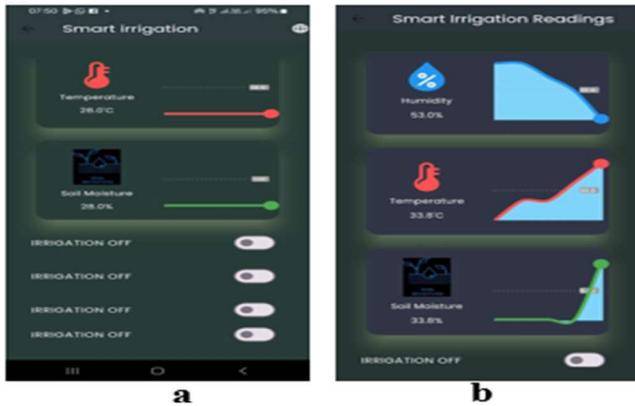


Figure 10: a) Sensor interface not yet activated, b) Activated sensor interface with measured values for Soil moisture, temperature, and humidity displayed on the English mobile App Wi-Fi

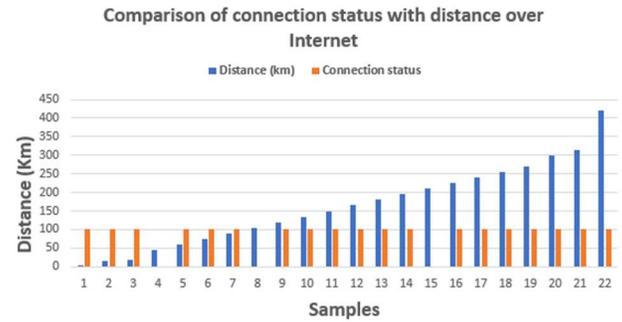


Figure 11: Network coverage under the Internet

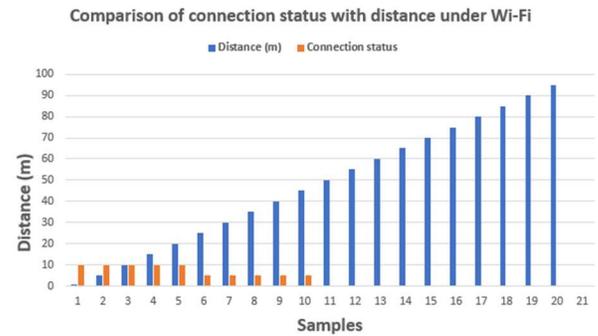


Figure 12: Network coverage under Wi-Fi

Table 2: Developed smart irrigation system with a multilingual mobile App in comparison with the contemporary Blynk mobile App (Ogidan and Afia, 2019; Edodi et al., 2022).

Features	Developed multilingual App	Ogidan and Afia, (2019)	Edodi et al., (2022)
English language	Yes	Yes	Yes
Hausa language	Yes	No	No
Yoruba language	Yes	No	No
Igbo language	Yes	No	No
Backup power	Yes	No	Yes
Remote control	Yes	Yes	Yes
Real-time monitoring	Yes	Yes	Yes

D.) Discussion of Results

The choice of the indigenous languages of Hausa, Yoruba, and Igbo would ensure that the developed device is made available to many Nigerian farmers. In terms of data acquisition, the developed device was able to make measured sensor values such as temperature, humidity, and soil moisture of the environment (Sumithra et al., 2024) available to users in English and the three indigenous languages in real-time as shown in Figure 10a and b. The user is also able to initiate irrigation systems on his mobile phone from a remote location using the developed mobile App. This is in line with similar studies (Ogidan and Afia, 2019, Edodi et al., 2022; Singh et al., 2023b).

In the case of Figure 11, the experiment over the Internet, the network connection was stable for most of the cases under consideration up to a distance of 420 km, however, there were some occasions such as 45 km, 105 km, and 210 km in which the network failed. These are locations in which the network of the subscribed service provider is not available or could be

considered very weak. This is a common phenomenon in Nigeria especially as people travel from one location to the other. The experiment performed over the Wi-Fi connection as reported in Figure 12 revealed that the network was stable until it reached a critical distance of 45 m. Beyond this distance, it was no longer stable. Overall, the Internet network, though more expensive than Wi-Fi because users will need to purchase data for network access, could be used in any part of the country to operate the developed device provided Internet connectivity is available. In the case of a Wi-Fi network, its low cost is an advantage for low-income farmers whose farms are within the Wi-Fi reach to leverage the technology for convenience, improved farm management, and enhanced crop yield.

Reports from Table 2 show that the developed device and its accompanying multilingual App are able to perform real-time monitoring and remote control of the irrigation process as we have (Ogidan and Afia, 2019; Edodi et al., 2022). This is similar to the work of (Lorvanleuang & Zhao, 2018). It,

however, outlines the superiority of the developed smart irrigation system with a multilingual mobile App over contemporary studies revealing that in case of (Ogidan and Afia, 2019; Edodi et al., 2022), the user can only operate it English language whereas in the developed system, the user can choose a desired languages be it English, Hausa, Yoruba or Igbo language based on their preferences. Figures 7a and b displays the icon through which language selection can be done. The significance of this is that more people can benefit from the use of the device thus increasing its market acceptability and enhance commercialization. This also means more farmers would be able to benefit from the use of the device and the benefits it offers.

Based on the performance evaluation shown in Figures 11 and 12, farmers would be allowed to choose between Wi-Fi and Internet connectivity based on their needs in terms of budget and coverage area thus providing a very flexible user plan for the developed App. The success of the indigenous language translation illustrated in Table 2 and Figures 7a and b allowing farmers to select their preferred language of choice will be motivation to extend the capability of the developed multilingual mobile App to include other Nigerian and African languages.

IV. CONCLUSION

In this research, a multilingual mobile App was developed and tested over the Wi-Fi and Internet connectivity. Performance evaluation revealed the Wi-Fi network was stable up to 45 m, beyond which stability declined. The Internet connection remained stable up to 420 km except at certain weak or unavailable coverage points (45 km, 105 km, 210 km). Due to this result, farmers would be able to make informed decisions between Wi-Fi and Internet connectivity based on their needs in terms of budget and coverage area. This would provide very flexible user plan for the developed App in irrigation management. The success of the indigenous language translation from English allowing farmers to select their preferred language of choice is a major initiative to extend the capabilities of smart irrigation system by making it accessible and adaptable to indigenous users. Future work would include extending the App translation to more African languages to reach a greater number of farming communities.

AUTHOR CONTRIBUTIONS

O. K. Ogidan: Conceptualization; O.O. Fadeyibi: Data curation; O.O. Fadeyibi: Formal analysis; Funding acquisition; O.O. Fadeyibi: Investigation; O. K. Ogidan: Methodology; O. K. Ogidan: Project administration; Resources; O.O. Fadeyibi: Software; O. K. Ogidan: Supervision; Validation; Visualization; O. K. Ogidan & O.O. Fadeyibi: Writing - original draft; O. K. Ogidan: Writing - review & editing.

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