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Development of A Qr Code System for Tree Species Identification

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ABSTRACT

Trees provide a wide range of benefits to humans and other living organisms. An accurate method tree species identification will improve their management and conservation. Also, tree identification and description are crucial for genetic study, biodiversity conservation, management and regeneration strategies. The conventional methods of tree identification are time-consuming and requires a high level of expertise, necessitating development of a more efficient tree identification means. In this research, a QR code system for tree identification was developed. Tree data were collected from campuses of two tertiary institutions in Akure, Nigeria: Federal University of Technology and Federal College of Agriculture. System design was built around a three-tier architectural model. PostgresSQL was used as the Database System, the lowest tier. The Middle tier is the Web Server, Apache HTTP Server. Php 8.1 was the scripting language that communicates with the database. For the Client tier, HTML, CSS and Javascript were used. The QR code generator was developed using PHP 8.1. The PHP script used a QR code library to generate the QR code image. The QR code is linked to the website database containing all tree species information. The generated QR codes were attached to trees, and when scanned, the website is automatically launched and the tree information is retrieved. A survey was conducted to get end-users' feedback within the study sites. The results obtained revealed that the QR codes are easy to use, and can make tree identification more interesting, thus increasing people's knowledge about trees and improving Trees management.

Keywords*— *Tree identification, QR code, Database, End user feedback, Urban Forest eco-tourism.

1. Introduction

In a typical rainforest, there are so many species of trees within a unit area. Research workers are agreed that tropical rainforests around the globe could habour between 100 and 300 different tree species within one hectare ([1]; [2] and [3]). Each species has diverse uses. The multiplicity of species in rainforests could explain why it can be daunting for the layman or tourist to interact with, identify and possibly understanding the uses of these tree species. Information and Communication Technology (ICT) has revolutionized many fields, including forestry. The ICT is used in forestry for variety of purposes such as monitoring the forest health, making information accessible to people and enabling public participation in forestry [4]. In addition, Remote Sensing and Geographic Information System (GIS) have been used over the years to provide valuable information for forest management and to map and analyze forest resources [5]. These tools have contributed to promoting sustainable forestry practices and ensuring the long-term health and productivity of forest ecosystems.

In this paper, the Quick Response (QR) Code was designed to store and provide information on some tropical rainforest tree species in South-Western Nigeria. A Quick Response (QR) code is a 2-dimensional matrix code designed to store large amount of encoded data, like text, url, etc. According to Reference [6], QR codes have high capacity for encoding data in small printout size, they are dirt and damage resistant, and can be read from any direction at 360 degrees. In addition, they are language-supported and can encode numeric data, alphanumeric characters, voices, and other binary information. They work independently of communication network or specific database, and can store large amount of information both vertically and horizontally.

Although it is a form of barcode, barcodes are 1-dimensional, while QR codes are 2-dimensional, and have higher storage capacity. They also have other advantages over the traditional barcode, like fast scanning, error-correction, varied types, omnidirectional readability, etc. [7]. They are also able to represent data systematically using two-dimensional shapes and symbols [8], represent more data per unit area, have error-protection formula, designed to keep data scannable and intact even if they get ripped, scratched or

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damaged, which makes them more suited for intense, fast-paced scanning applications.

In the landscape of innovative applications addressing the identification of plant species, several noteworthy platforms, such as Pl@ntNet, PictureThis, and iNaturalist, have emerged. While acknowledging the valuable contributions of these existing solutions, the rationale for the development and implementation of KnowYourTrees becomes evident when considering specific challenges and objectives.

Pl@ntNet, for instance, requires users to submit a set of four pictures depicting various parts of the plant for identification, necessitating subsequent uploading to the platform. In contrast, KnowYourTrees leverages the ubiquity of QR code scanning capabilities in devices, offering users the ability to access tree information swiftly and seamlessly while on the move. The emphasis on real-time, on-the-go access sets KnowYourTreess apart in terms of user convenience and immediacy.

Similarly, PictureThis, while a commendable plant identification system, primarily caters to gardening plants, leaving a gap in the identification of trees. KnowYourTrees addresses this specific niche by focusing exclusively on trees found in the open areas of universities, tailoring its functionality to meet the distinct needs of its target environment.

iNaturalist, a versatile platform facilitating the identification of plants and animals, operates on a collaborative model, enabling users to contribute observations for scientific research and conservation. KnowYourTrees, on the other hand, adopts a collaborative approach by partnering with institutions to collect and verify tree data. This ensures the accuracy and reliability of the information presented on the platform, with a particular emphasis on creating an inventory of tree species in higher educational institutions, particularly in Nigeria.

While recognizing the gamified platform Seek by iNaturalist as a potential avenue for future exploration, KnowYourTrees is positioned to evolve and integrate such features as resources become available. Notably, KnowYourTrees distinguishes itself by incorporating a manual verification process for information, surpassing direct linking to web-based content. This approach guarantees the accuracy and credibility of the data provided, a critical factor when dealing with educational institutions and research endeavors.

Furthermore, KnowYourTrees transcends mere identification, aspiring to offer users comprehensive insights into the uses of identified tree species. This commitment to providing additional information aligns with the platform's overarching goal of not only cataloging tree types but also contributing to the dissemination of knowledge regarding their practical applications. Importantly, this information is dynamic, with planned updates based on ongoing research discoveries pertaining to specific tree species, ensuring that KnowYourTrees remains a current and reliable resource.

2. Literature Review

Recently, the possibility of deploying the ICT in the identification of tree species is being explored. Reference [9] developed mobile plant tagging system for urban forest eco-tourism in Malaysia. The use of ICT will not only enhance the mode of identifying the trees, it will also provide quick and easy access to tree information, enhance interactive learning, make tree identification more engaging and in the long run, improve tree management and conservation. Barcodes are being used for easy and fast tree identification ([9]; [10]; [11]). The barcode system is the commonly used ICT technology in tree identification and tree information retrieval. With barcode system, people can obtain information about a tree quickly without having to depend on taxonomists or reference books. Reference [9] opined that the use of barcode has changed the way activities are being implemented, especially in tourism industry, since tourists do not have to depend on tour guide identify trees.

Reference [12] presented the concept of using QR codes, together with mobile devices for religious tourism by visitors in Mecca, Saudi Arabia. Reference [9] designed a Tree tagging system for improving the experience of visitors of Universiti Putra Malaysia's Sultan Idris Shah Forest Education Center, by assisting them to retrieve relevant information on available plant and trees, using their mobile devices. Currently, tree identification in the study area is through manual methods as there are no known ICT powered tree identification system. This manual method is time-consuming and requires some expertise in taxonomy, thus it is not accessible to the general public [13]. There is therefore, need to provide an ICT (QR code) tree identification system that is easy to use and understand and that will enhance tree identification for by the general public, which is the aim of this study.

3. Methodology

3.1. Study Area

The research was undertaken within two Nigerian's higher educational institutions located in Akure city, Nigeria. The aim is to expand the scope to include other parts of the city and Nigeria. The two institutions are: the Federal University of Technology, Akure (FUTA) and the Federal College of Agriculture, Akure (FECA), with both established to provide comprehensive education in the fields of agriculture and forestry. They are not only dedicated to academic pursuits but also serve as vibrant communities where learning plays a fundamental role in the lives of their students and faculty. The maps are shown in Figures 1 and 2.

3.2. Data Collection

The data for this study were collected from FECA and FUTA campuses. An initial survey was conducted to the two campuses, which was necessary to be acquainted with their conditions including road networks and distribution of trees. One crucial aspect of this survey was identifying specific areas where data collection would occur. Subsequently, the gathered information was subjected to a thorough analysis, carefully evaluating its viability, feasibility, and likelihood of successfully collecting the required data for the research.

Comprehensive information on each tree species (botanical name, common name, family name, etc) was acquired with the assistance of an experienced taxonomist. Simultaneously, supplementary information on the uses,

distribution, habitat, and other relevant aspects were also sourced from existing literature and other sources. The amalgamation of data from field observations and literature was the foundation for constructing a robust and extensive database. The database was specifically designed to accommodate the requirements of the QR code system, ensuring that it encompasses a wealth of information that users can readily access.

3.3. Database Structure

The data requirements for the tree information database included tree species name, family, local name, description, and uses. Data sources, such as photographs and tree position coordinates, were also used to complement the tree information. However, the coordinate feature is yet to be uploaded on the platform. The database schema was designed to organize the data efficiently. The schema consisted of multiple tables, including a "Trees" Table to store tree-specific information and an "Images" Table to store associated photographs. Relationships between Tables were established using primary and foreign keys to ensure data integrity.

The "Trees" Table structure was determined from the information collected from field observation and literature. Each data item was captured on the Table and assigned a Primary Key. Other attributes of the data items captured were data name, data type, data length, and column constraints, which are specific rules that the data must follow. For example, "not-null" ensures that the column cannot be empty. The constraint also identifies the Unique Primary Key. Table 1 shows the Table Structure of the Tree Database.

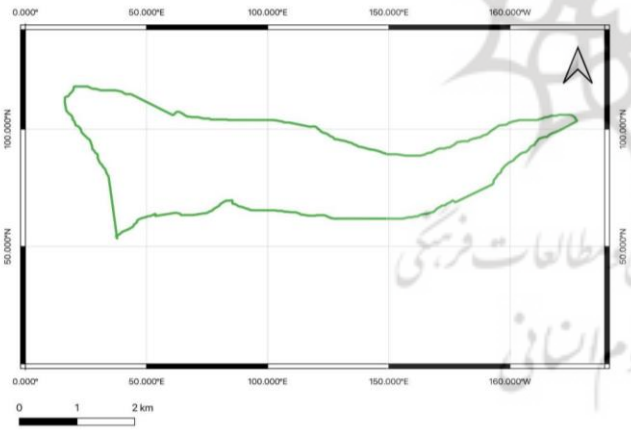

Figure. 1. The Map of the Federal College of Agriculture, Akure

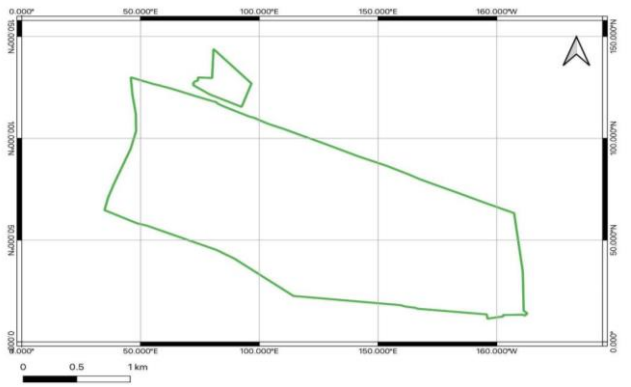

Figure. 2. The Map of Federal University of Technology, Akure

The Images Table was designed to store associated photographs of each tree species. The structure is shown on Table 2.

3.4. System Architecture

The system is a Web Application that takes input in two ways, direct search of the Database from the User Interface, using the tree name, and/or scanning the QR code pasted on a tree using either a QR Reader or a Smartphone camera. The direct search or scanned QR code launches the scripting program that retrieves all information on a specific tree from the database, and displays them on the screen. The system architecture is shown in Figure 3. The flowchart that clearly depicts the flow of the system is shown in Figure 4.

4. Results - System Development

4.1. QR Code Generation

The QR codes were generated using PHP 8.1. Data such as URLs, tree information, and other alphanumeric data were encoded into the QR codes. A QR code library was utilized by the PHP script to generate the QR code image. The PHP script received user input to specify the size and format of the QR code. Examples of the QR code generated for Azadirachta indica and Acacia auriculiformis trees found at the study area are shown in Figures 5 and 6.

Table 1. Tree Table Structure

Column	*Datatype*	*Length*	*Constraint*
Tree_id	serial	8	Primary Key
Common Name	Varchar	30	Unique, Not null
Family Name	Varchar	30	Not null
Specie Name	Varchar	30	Not null
Location	Varchar	30	Not null
Tree Uses	Varchar	200	Not null
Distribution	Varchar	100	Not null
Other Information	Varchar	200	Not null

Table 2. Image Table Structure

Column	*Datatype*	*Length*	*Constraint*
Tree_id	Serial	8	Primary Key
Tree Image	Bytea	200	Unique, not null

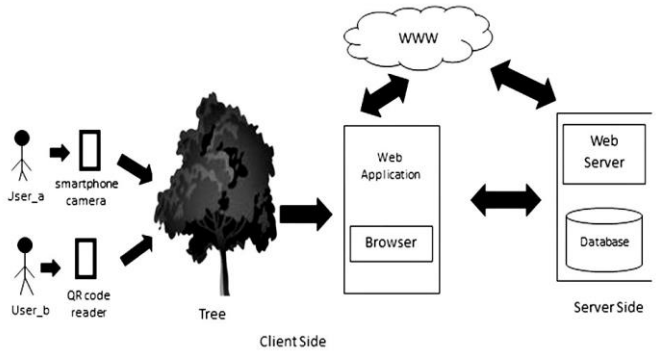

Figure. 3. The System Architecture

4.2. QR Code Translation

The QR code feature was smoothly integrated into an HTML (HyperText Markup Language) page, providing users by securing the connection between the user and the server using Secure Sockets Layer (SSL)/Transport Layer Security (TLS). This ensures a safe environment for user interactions. The overall focus was on reinforcing security through SSL/TLS without engaging in specific testing processes, aiming to create a secure browsing experience for users.

4.3. Interface Design

A user-friendly interface was designed to enable users easily access tree information. The platform included a search functionality that queried the database using either the scanned QR code or direct search using a tree name or part of it.

4.4. The Homepage

The Homepage (https://tech4forest.org/) was designed using HTML, CSS (Cascading Style Sheets), and JavaScript, which are used to build components for websites or web applications. The primary objective was to present information in a user-friendly and visually appealing format [14]. A screenshot of the Homepage is shown on Figure 7.

When a user scans the QR code on a tree species, the website is launched, and detailed information on the name (common and botanical), description and uses of the species is displayed on the website. Figure 8 is the screenshot of the information displayed when the QR code on Azadirachta indica was scanned.

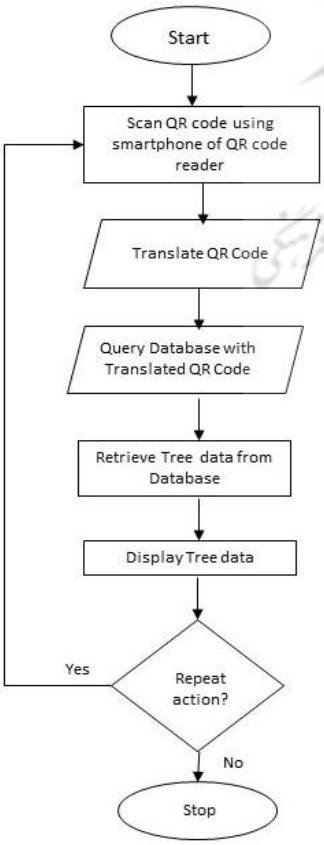

Figure. 4. System Flowchart

4.5. Back-end

The back end, also known as the server-side, plays a crucial role in website functionality. It handles tasks behind the scenes, such as storing and organizing data, and ensures the seamless operation of the client-side. The back-end communicates with the front end, exchanging information and delivering it to be displayed as a web page. The back-end is basically made up of the server, the application and the database, and it is responsible for the storage and handling of data. PostgreSQL is the database management system employed in this research, due to its reliability, security, stability, and scalability.

Figure. 5. QR code generated for Azadirachta indica

Figure. 6. QR code generated for Acacia auriculiformis

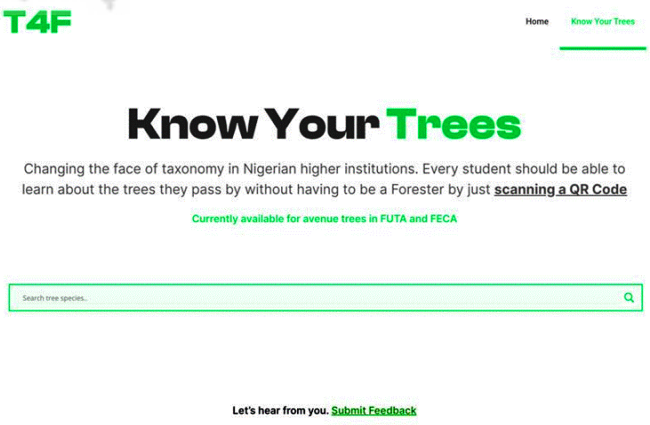

Figure. 7. Homepage of the Website developed for this study

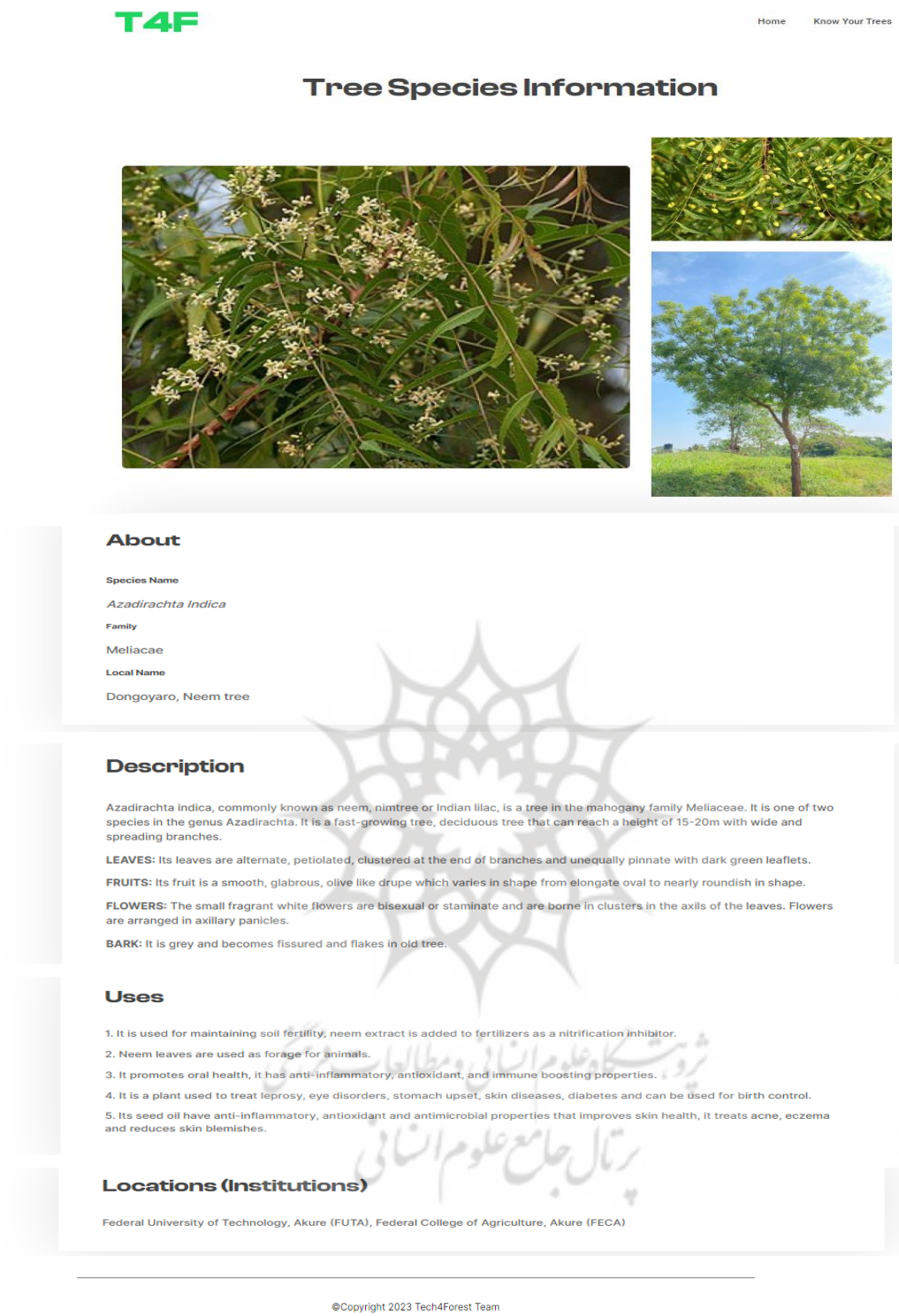

Figure. 8. displayed information on Azadirachta indica

Each tree species was assigned a unique ID number, a reference for generating a corresponding link. These links, when accessed, redirect users to specific pages containing information about the tree species of interest. When a user scans the QR code attached to a tree using their mobile devices, a link would appear on their mobile QR code scanner application. Clicking on the link would direct them to the relevant tree species information page. The QR code feature was implemented using the PHP QR code library. The PHP QR code library is a popular open-source library that provides functionality for generating QR codes using PHP. QR codes, are two-dimensional barcodes scanned by smartphones and other devices equipped with QR code scanning capabilities. They are commonly used to store information such as URLs, text, contact details, or other data that can be easily decoded by scanning the code.

The PHP QR code library simplifies the process of generating QR codes dynamically within PHP applications. It

offers a range of features and options for customizing the appearance and content of the QR codes. With this library, developers can easily integrate QR code generation into their web apps.

A relational database management system (DBMS) was selected for this study. The choice was based on performance, scalability, security, and the availability of features required for spatial data support and geolocation capabilities. Optimization strategies, including content caching to alleviate server load and enhance response times, along with the implementation of lazy loading to defer the loading of specific elements until required, were employed to improve the efficiency of data retrieval and storage. PostgreSQL is the Relational Database System used to store the Trees data collected. PostgreSQL is an innovative, enterprise-class, and open-source relational database system that combines both SQL (relational) and JSON (non-relational) querying. PostgreSQL is used as a primary database for lots of web applications, mobile applications and analytics applications [15].

Figures 9 and 10 show screen shots of the process of storing tree data into the database.

4.6. Update of Information on the Portal

A content management system (CMS) was integrated into the backend of the system to facilitate efficient information management. Within this CMS framework, users are assigned the role of an editor, granting them access privileges to the underlying database. This enables users to actively update and manage information seamlessly, enhancing the overall flexibility and control of the content management process. A screenshot of the Information Update Portal is shown in Figure 11.

4.7. Assessment of End Users' Feedback

The objective of the end user appraisal was to gather valuable feedback from individuals utilizing the QR code system developed in this study. This feedback focused on content, user-friendliness, usefulness, and overall acceptance of the QR code technology. By actively involving end users in the appraisal process, the aim was to mitigate the risk of developing an ineffective QR code system that fails to meet the diverse needs of its users.

A sample of ten (10) staff members and fifteen (15) students was randomly selected from FECA and FUTA campuses, respectively to conduct the appraisal. These selected end users were instructed to scan the printed QR codes attached to different tree species using their mobile phones. Their experiences and perceptions of using the QR code system for tree identification were sought, allowing for a comprehensive understanding of user satisfaction.

The End Users' Appraisal was developed in parallel with the QR code system, ensuring that after scanning each QR code, a user-friendly interface was automatically displayed, allowing participants to provide feedback and rate their level of satisfaction. The web application subsequently analyzed the collected feedback, facilitating the identification of areas for improvement. By incorporating these insights, continuous enhancements were made to optimize the QR code system's effectiveness and efficiency for accurately identifying tree species.

Though a high percentage (80 - 84%) of the respondent have previously used QR code system, most of them (96 - 100%) have never used the system for tree species identification (Table 3). Between 84 and 92% of the respondents indicated that they found the QR code very easy to use for tree identification, with the remaining (8 - 16%)

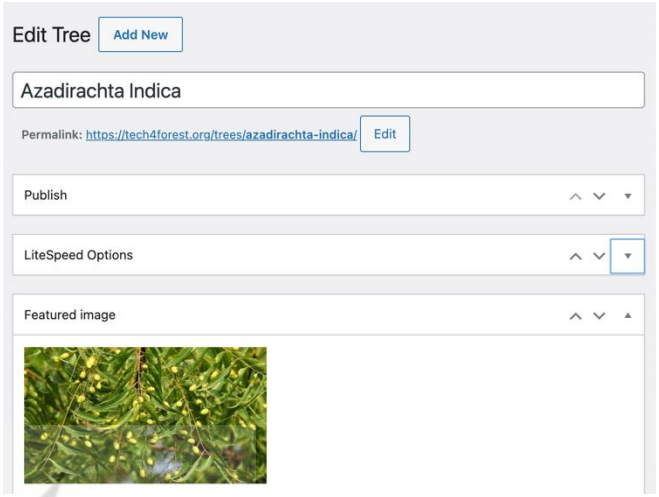

Figure. 9. Entry of Azadirachta indica data into the database

Figure. 10. Entry of botanical, family and common names of tree species

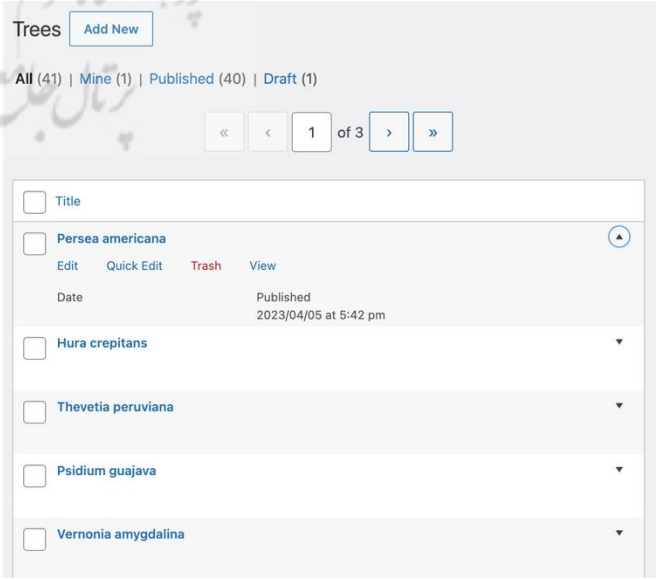

Figure. 11. Information update portal

opining that they found it somewhat easy to use. All respondents believe that the QR code system generated in this study improved their accuracy of tree identification, made tree identification very easy, improved their learning experiences in tree identification and made tree identification very interesting and engaging (Table 3).

5. Discussion

Since inception a little more than twenty years ago, QR codes have been used for virtually everything, from shopping, simple school assignments to intricate machine regulation and intercommunication processes. The use itself is examined in several ways, primarily as a simplified method of providing information and advertising, a teaching tool, a marketing component, or simply as an opportunity to investigate information storage systems [7]. Only recently is the QR code system being deployed to natural resources management such as Eco-tourism, Forestry, Horticulture, etc. ([6]; [8])

The Tree QR code system developed in this study makes it easy to identify different tree species. This is accomplished by simply scanning the QR code on a tree with a mobile device, which then links the user to the website showing detailed information about the species. This method reduces the high cost and time associated with the manual process of identifying trees and obtaining information about them. Given good and fast internet connectivity, the response time is about five seconds, indicating a fast and reliable method of accessing information about the tree species. Reference [6] had earlier observed that the manual method of tree identification could be tedious as it requires the user to search through books, pamphlets or flyers to assess the necessary information on a tree species, which aligns with our opinion. In some cases, the assistance of an experienced taxonomist our tour guide is necessary to identify a tree under the manual method, which is totally eliminated with QR code system. Urban forest eco-tourists in Malaysia use barcode to obtain information about trees quickly and easily without having to depend on tour guides, taxonomists or reference books [6]. Our QR code system can serve similar purpose if deployed on trees in cities in Nigeria.

The tree information provided on the website created for this study gives the user accurate information about specific the tree species, the benefits the tree provides to humans, their uses, importance, among others. This will influence the user's perception in conservation of trees and encourage their interest in tree planting [7]. Using the QR code system, people can get information about a tree quickly without having to depend on taxonomists or reference books. This also has a significant impact on the tourism industry, since tourists do not have to depend on tour guide to identify and know trees.

Our view is in agreement with that of [8], that when properly deployed, the QR code will be a useful tool for tree identification and will provide the following benefits to end users:

- quick and easy access to tree information by simply scanning the QR code using mobile devices. Tree information can be accessed within five seconds after scanning the QR code;
- enhance interactive learning and make tree identification more engaging. The information provided by the system can be used to learn more about trees and its habitat;
- provide accurate and up-to-date information about tree species;
- provide accurate means of differentiating between tree species that look similar;

The feedback provided by end users revealed a very high level of satisfaction with our QR codes by the public. All respondents believe that the QR code system generated in this study improved their skills and accuracy of tree identification, made tree identification very easy, improved their learning experiences in tree identification and made tree identification very interesting and engaging (Table 3). This unanimous agreement by end users is an indication of its reliability, effectiveness, user-friendliness and easy to use nature of the QR code system generated in this study. With this positive end user assessment, the QR codes can be deployed for use by the general public in cities with similar ecological characteristics as Akure, Nigeria.

S/N	*Statement*	*FUTA Campus*					*FECA Campus*				
		Yes	*No*	*Very easy*	*Somewhat easy*	*Difficult*	*Yes*	*No*	*Very easy*	*Somewhat easy*	*Difficult*
1.	Have you ever used a QR code system before	84	16	0	0	0	80	20	0	0	80
2.	Have you ever used a QR code system for tree identification before?	0	100	0	0	0	4	96	0	0	96
3.	How easy was it to use this QR code for tree identification?	0	0	84	16	0	0	0	92	8	0
4.	Do you think this QR code can improve the accuracy of tree identification?	100	0	0	0	0	100	0	0	0	100
5.	Do you think this QR code system can improve your learning experience in tree identification?	100	0	0	0	0	100	0	0	0	100
6.	Do you think this QR code system can make tree identification more interesting	100	0	0	0	0	100	0	0	0	100

Nevertheless, the QR code system for tree identification is poised with some limitation, which should be overcome for maximum functionality. Prominent among these limitations are:

- Tagged QR code can deteriorate, fade, or become damaged over time, resulting in illegibility and thereby making it challenging to access the information they harbor;
- lack of or poor internet connectivity poses great challenges while trying to scan the QR codes, as the process of using the QR code and obtaining the desired tree information requires good and strong internet access ([7]; [8]);
- bsence of smartphone, scanning device or mobile device with a QR code scanner can impede the ability to use the QR code system.

6. Conclusion

The development of a QR code system for tree identification is a useful and practical tool that can increase knowledge and understanding of trees, improve the management of trees, and make it easy for foresters and non-foresters to identify trees using a smartphone or other appropriate mobile devices. The QR code system is linked to a database which provides accurate and precise information about tree species through a website, which facilitates learning and identification. When compared to conventional methods of tree identification which can be expensive and time consuming, the QR code system provides a cost-effective, quick and efficient approach to identify different tree species. This method saves time and effort for both foresters and non-foresters. The Tree QR code system is a valuable tool for easy tree identification, and it can facilitate conservation and education initiatives. The positive end user assessment is an indication that the QR codes developed in the study can be deployed for use by the general public in cities with similar ecological characteristics as Akure, Nigeria.

In the trajectory of future developments, KnowYourTrees envisions an expansion of its capabilities through the acquisition of resources and the deepening of collaborative efforts. As a prospective avenue for advancement, the platform intends to leverage the amassed data from diverse institutions to train Neural Networks. This strategic approach is aimed at addressing inherent challenges within taxonomy, augmenting the system's analytical capacities. It is noteworthy that, as of the present, KnowYourTrees does not operate as an Artificial Intelligence-driven system.

Furthermore, in the pursuit of heightened accessibility and user engagement, a future objective is to enable individuals to query the platform's database effectively. This involves facilitating searches for specific tree species and concurrently providing information on the higher educational institutions in Nigeria where these identified tree species can be located. This envisioned enhancement aligns with KnowYourTrees' overarching goal of offering comprehensive botanical insights while also fostering geographical specificity, contributing to a more nuanced understanding of tree distributions within educational landscapes. As the platform advances, such refinements will fortify its utility as an authoritative resource for botanical inquiries within the academic milieu in Nigeria.

Declarations

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Authors' contributions

BO: Study design, interpretation of the results, drafting the manuscript, revision of the manuscript.

GA: Acquisition of data, interpretation of the results, statistical analysis

FE: Acquisition of data, interpretation of the results, statistical analysis

MA: Study design, interpretation of the results

IA: Acquisition of data, interpretation of the results, statistical analysis

JO: Study design, drafting the manuscript;

Conflict of interest

The authors declare that no conflicts of interest exist.

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