PROMOTING INNOVATIVE RESEARCH IN FORESTRY SECTOR: PROSPECTS AND CHALLENGES

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DEVELOPMENT OF A LOCATION-ENABLED APPLICATION FOR THREATENED TREE SPECIES AT THE UNIVERSITY OF IBADAN, NIGERIA.

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ABSTRACT

Combining geospatial tools and data provision elements can greatly benefit threatened species management, particularly where location services are added. Therefore, this study was designed to develop a location-enabled mobile application for managing threatened trees within the University of Ibadan. The selection of threatened trees was based on the IUCN Red List. Threatened trees with a diameter at breast height of not less than 10cm within the University of Ibadan were identified to species level and wholly enumerated. The growth variables of each threatened tree were estimated, and each identified tree was georeferenced. Identified threatened trees were categorized based on their IUCN status, and the mean growth variables and the total number of trees, families and species per family were displayed. Icons on a map also represented identified trees to show their spatial. A data addition form was created, and the Google Firebase Real-time Database was used as a temporary repository of user-suggested data. A navigation system was also designed to navigate to threatened tree locations. A user-friendly mobile application called "UITTNav" was developed within the scope of this study. The application can be downloaded with the name "UITTNav" for free on the Google Play store without any restriction from June 2024. The application combines the ability to show where trees are, help users find their way to these trees, give detailed information about them, and allow users to suggest tree data. It will provide adequate location and tree data to manage threatened trees within the University of Ibadan.

Keywords: Threatened trees species, Mapbox SDK, Navigation System, and IUCN Red list

INTRODUCTION

Across the world's continents, 30% of trees are threatened with extinction, and well over 142 species have already been recorded as extinct in the wild. Unfortunately, these tree species' major threats are anthropogenic activities due to exploitation and climate change (Botanic Gardens Conservation International, 2021). Africa, including Nigeria, stands at the epicentre of this crisis, with the most threatened tree species reported by the Botanical Gardens Conservation International (Botanic Gardens Conservation International, 2021).

This high extinction rate can be attributed to an expansion of the human population (Gao *et al*., 2020). The human population, which is increasing at an alarming rate, is over-exploiting the environment at an alarming rate (Marselina and Prasetyo, 2023). Unfortunately, the degradation of the natural environment due to the human population explosion is affecting not only natural forests but also urban forests (Vogt, 2020). Nigeria is significantly burdened by overpopulation and is also experiencing this forest degradation (Adegbite *et al*., 2020).

Consequently, the management of urban forests in Nigeria is necessary. According to Usman *et al.* (2020), forest resources management using geospatial tools is highly indispensable for sustainable development. The availability of structural information also ensures the comprehensive management of forests. This is because this structural information can be used to estimate the actual and potential physical, biological, and social risks to species in the forest. (Ghorbanzadeh *et al*., 2019).

Beyond general urban forest management, accurate data on threatened trees can be used to demonstrate the importance of protecting these species, garnering support for conservation efforts (Barker, 2019). Additionally, combining elements of geospatial tools and data provision can greatly benefit threatened species management, particularly where location services are added (Dracott *et al*., 2019).

A location-enabled management application will combine elements of geospatial tools, data collection and location. It will provide benefits, including identification of target species, identification of seed sources, monitoring species population, and conservation planners (Fan *et al*., 2019). It can then be concluded that a real-time location-enabled forest application for threatened tree species can play a crucial role in managing and conserving threatened tree species in urban areas in Nigeria.

MATERIALS AND METHODS

Study Area

The study was carried out within the University of Ibadan campus. The University of Ibadan is the oldest in Nigeria. It is in the Northern part of Ibadan City, the capital of Oyo State in southwestern Nigeria (Oyekola *et al*., 2021). The coordinates of the University are longitudes 3°53′21″E to 3°54′26″E and latitude 7°25′58″N to 7°26′42″N. It is divided into different areas, including residential areas, administrative areas, parks and gardens, and academic areas (Agbaogun and Jimoh, 2021). The University of Ibadan is in the rainforest vegetation zone, characterized by dense and diverse plant life. (Oluwakayode *et al.*, 2020).

Collection of Tree Data for The Application

Data was collected by completely enumerating all the threatened trees within the University of Ibadan. A stratified sample technique (Hauglin *et al.*, 2021) was used to divide the University of Ibadan into administrative and academic, residential and conservation areas. The conservation area includes the botanical and zoological gardens. The following data was obtained for all the threatened trees encountered;

1. Coordinates of threatened trees,
2. Total Height (TH, m),
3. Merchantable Height (MH, m),
4. Diameter at Breast Height (DBH, cm),
5. Diameter at base (db, cm)
6. Diameter at middle (dm, cm)
7. Diameter at top (dt, cm).

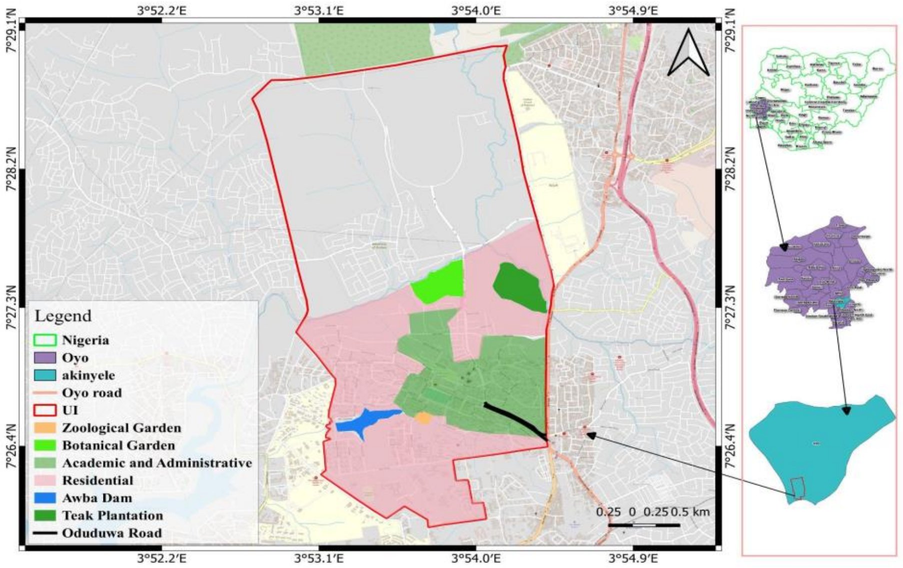

Figure 1.: Map of The University of Ibadan.

The coordinates of each tree were taken using Mapinr, a mobile GIS application (Naharudin *et al.*, 2016). The height was taken using a Haga Altimeter. At the same time, the diameter at the top and middle was measured using a Spiegel Relaskop, and the diameter at breast height and base was measured using diameter tapes. The diameter at breast height measurement of forked trees and other atypical trees followed the standard convention for these measurements. Tree family names were also obtained from the literature.

The measured diameter at breast height in centimetres was used to calculate the basal area (BA) of individual trees as per Elledge and Barlow (2020).

$BA(m^2) = \pi \times DBH$… Equation I

Where BA = basal area; DBH = diameter at breast height (1.3 m) and π *= 3.142.*

The stem volume was estimated using Newton's formula, as per Elledge and Barlow (2020). The stem volume of individual trees was calculated as

$V(m^3) = \pi H \left[\frac{Db^2+4Dm^2+Dt^2}{24}\right]$… Equation II

V = Volume(m^2*), H = stem height (m), Db = Diameter at the base, Dm = Diameter at the middle, Dt = Diameter at the top and* π *= 3.142.*

The slenderness coefficient was estimated using the formula below, as per Hanum *et al.* (2021).

$SC = \frac{H}{DBH}$… Equation III

Where: SC = tree slenderness coefficient, H = tree height (m) and DBH = diameter at breast height (m)

Development of The Mobile Application
The mobile application was developed using Kotlin in Android Studio (Dimitrijevic *et al.*, 2023).

Back End

Mapbox SDK was initialized in the Android application by setting up the required dependencies. After all necessary dependencies were added, a Mapbox Secret Access Token and a Public Access Token were generated from the Mapbox official website. Following the installation guide on the Mapbox website, the secret access token was added to the "gradle. properties" file of the project as "MAPBOX_DOWNLOADS_TOKEN= secret access token", and the public access token was added to the "string.xml" resource file of the project as "<string name="mapbox_access_token">public access token</string>." The maven repository was also added to the "settings. gradle" file. After this, the application was built, and the necessary services were downloaded.

The routing and navigation logic was implemented on the backend. It involved handling route requests, managing route updates, and monitoring the user's progress along the route. Route request call-backs and route progress observers were also set up.

Real-time updates for location and route progress were established. It included managing user location data, matching it to the road, and updating the route progress based on the user's location. It also involved ensuring that voice instructions were generated at the right moments.

Google Firebase Real-time Database was used to accommodate the storage of tree data. Authentication and security rules were configured to ensure controlled data access. A data submission mechanism was developed in the frontend, facilitating the real-time transfer of tree data to the backend. The backend was configured to accept incoming tree data in a structured format and store it within the Google Firebase Real-time Database. An appropriate database schema was set up to manage tree data effectively.

Front End

An Android Studio project and Kotlin activities were created. MapView was integrated and configured to display the map.

Mapbox SDK was used for the navigation aspect. Location permission requests were implemented and handled to ensure the application could access the device's GPS. Mapbox's routing API was used to calculate routes based on user input. Logic was implemented to accept source and destination coordinates and make route requests. The computed route was displayed on the map using appropriate styling. The turn-by-turn navigation feature was then implemented. Mapbox's voice guidance was also used to provide spoken directions to the user at each turn. Controls were added for muting/unmuting voice instructions and displaying upcoming manoeuvres. Map interactions like pinch-to-zoom and map re-centring were also implemented.

An activity that included collapsible buttons representing vulnerable, threatened, endangered, and critically endangered trees was created to display tree data. Each one of these buttons was designed to expand to reveal 3 buttons each — Spatial Distribution, Mean Growth Variables and Number. Each one of these buttons leads to separate activities. In the Spatial Distribution activity, Mapbox Mapview was configured and integrated into the activity's layout. It includes UI elements such as buttons for user location zoom and a space to display tree characteristics via alert dialogues.

In the Spatial Distribution activity, a "tree data class" defines the structure of tree characteristics, which includes attributes like tree total height, merchantable height, Volume, slenderness coefficient, diameter at the top, diameter at the middle, diameter at the base, diameter at breast height, Volume, etc. was developed. A Tree Data list that houses the objects of the tree data class was also created. In the Number activities, the total number of trees per IUCN classification was displayed, and in the Mean Growth Variable Activities, the mean of each growth variable estimated was displayed.

To handle annotations in the Spatial Distribution activity, "add annotations to map" was implemented. A point annotation manager was created by iterating through the Tree Data List, and a "click listener" was added for annotations. Tree data lookup was done through the "getTreeDataForAnnotation" method to find tree data for a clicked annotation based on coordinates. Tree information was then added to the alert dialogue when clicked. A copy button was added to copy tree coordinates to the clipboard, and a close button was added to close the alert dialogue box.

In the Spatial Distribution activity, Mapbox was configured to enable the display of the user's location on the map using the default location puck icon. A button that allows users to zoom to their present location on the map was implemented. A different activity was created for users to suggest threatened tree data. The form layout was constructed with fields for tree image, total height, diameter at the top, diameter at the base, diameter at the middle, diameter at breast height, location, and coordinates. A functionality for automatically capturing tree coordinates when users double-click on the form coordinate field was also implemented. A button was added to submit the form data to the backend database for real-time storage.

The front and backend components were thoroughly tested to identify and rectify any issues. The Android application was deployed with the integrated map functionality and the linked backend database.

RESULTS

A mobile application called "UITTNav" was developed within the scope of this study (Figure 2.). It aims to provide a user-friendly management system for trees within the University of Ibadan. The application can be downloaded with the name "UITTNav" for free on the Google Play Store without any restriction from June 2024. The application opens into a main menu that has 5 buttons.

i. "Getting Started" button,
ii. "Start Navigation" button,
iii. "View Tree Data" button,
iv. "Add Tree Data" button
v. "Tree Database" button.

On selecting the Getting Started button, the user is directed to a page where the user's guide for the application is obtained. The Start Navigation button directs the user to the navigation system designed within this study's scope. This navigation system can navigate to an address or a tree coordinate. It uses the GPS coordinates provided by the user's device and provides a turn-by-turn navigation service with voice navigation.

The View Tree Data button directs the user to a page with collapsible buttons for the categories of threatened trees, according to IUCN: Vulnerable, Endangered, and Critically Endangered. It enables users to view data on trees of their preferred conservation status. Each of these collapsible buttons expands on click to show 3 additional buttons: Spatial Distribution, Number and Mean Growth Variable.

The Spatial distribution button has a map view, and a tree annotation represents each tree under the selected IUCN status. A popup containing the tree information comes up when clicking on each annotation. It includes the Species, diameter at breast height, diameter at base, diameter at middle, diameter at top, total height, merchantable height, tree volume, slenderness coefficient, basal area, IUCN status, longitude, latitude, location, area of identification and date of data collection. This popup includes a "close" and "copy" buttons. The copy button copies the tree's searchable code, which can be used within the navigation system in UITTNav or any other navigation application. At the base of the page is a "Zoom to My Location" button that allows users to see threatened trees close to them.

The Number button directs the user to a page displaying the number of trees, species, and family in the IUCN status within the University of Ibadan. The Mean Growth Variable button leads to a page where the mean diameter at breast height, mean diameter at the base, mean diameter at the middle, mean diameter at the top, mean total height, mean merchantable height, mean tree volume, mean slenderness coefficient and mean basal area of all the trees within the selected IUCN status in the University of Ibadan are displayed.

UITTNav allows users to suggest data for addition. It is done under the Add Tree Data segment. A form is displayed on selecting the "Add Tree Data" button. This form includes fields like tree image, the user's name, tree species, tree growth variable, area of identification, tree location and tree coordinates. Some of these fields can be left empty. However, tree species, coordination and exact tree location were compulsory; the form cannot be submitted unless filled. An asterisk in front of the field name differentiates these mandatory fields.

The form has a coordinate collection function that automatically updates the user's coordinate when the user double-clicks the empty field. It also has an in-app image-capturing function that works after granting the application permission to use the phone camera. Captured images can be accepted or rejected and can even be changed.

Two things are likely to occur when selecting the submit button. If one or more compulsory fields have not been filled out, the form remains on the screen, and a toast that says, "Tree Species, Tree Coordinates and Exact Tree Location are compulsory fields. Please fill them out" is displayed on the screen. A new page with 2 buttons (Submit Now and Edit First) pops up if all compulsories were filled. If Edit First is selected, the user is returned to the filled form, and a toast that says, "Make necessary edits before submitting" is displayed. If Submit Now is selected, the form is sent to a real-time database, and the user will see a toast on the screen that says, "Data saved." The user is then automatically returned to the application menu.

On clicking the Tree Database button, a page showing all the data in the application in tabular form is displayed. This data includes the Species, diameter at breast height, diameter at base, diameter at middle, diameter at top, total height, merchantable height, tree volume, slenderness coefficient, basal area, IUCN status, longitude, latitude, location, area of identification and date of data collection. This page also shows the total number of filtered trees and the total number of trees recorded in the application. The data in this table can be filtered by species, location, and IUCN status by typing it into the required field and selecting the search icon. All the data in the table can also be displayed after filtering by selecting the eye icon beside the search icon.

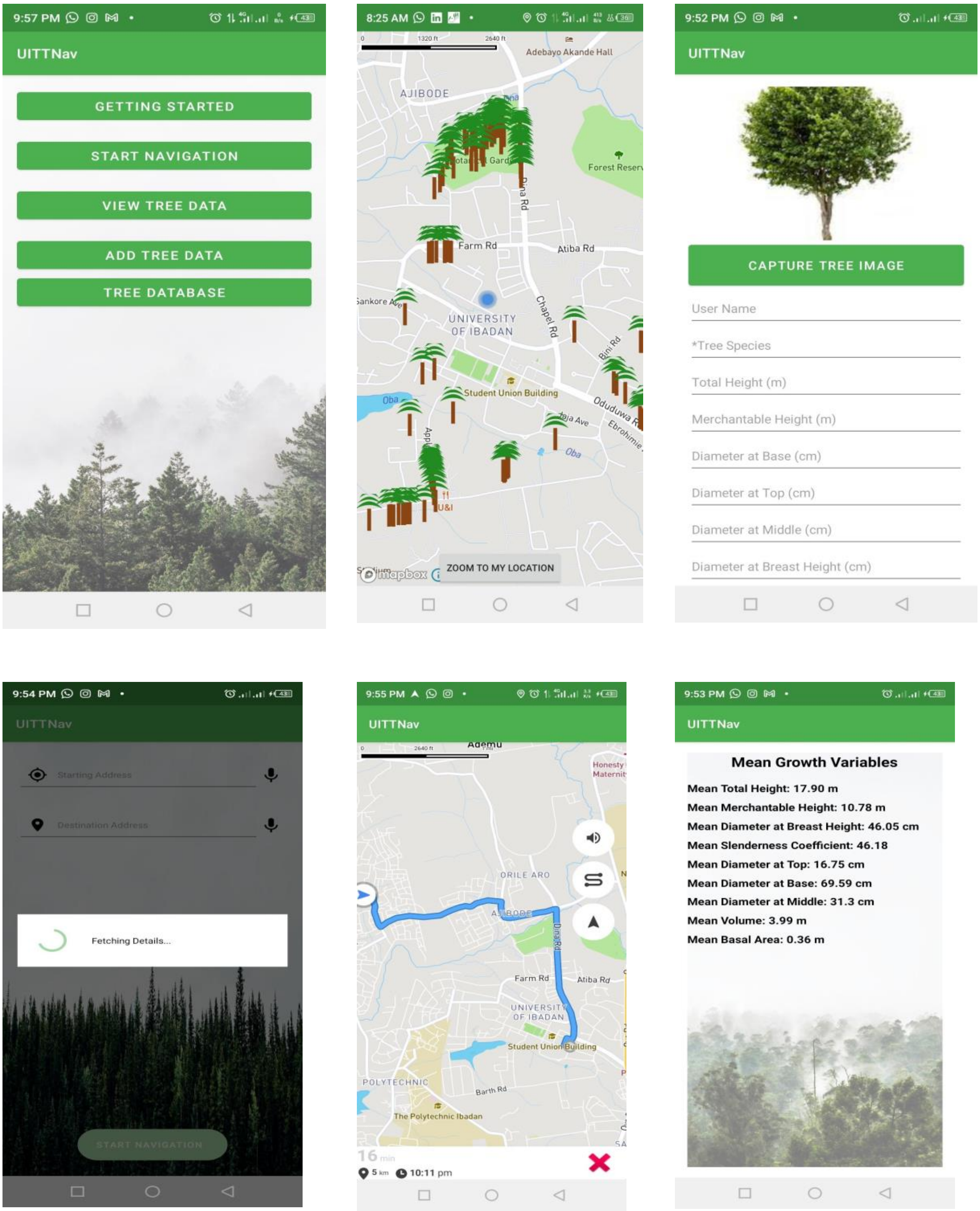

Figure 2: Screenshots from UITTNAV

DISCUSSION

Accurately identifying threatened trees is essential for quantifying current biodiversity crises and prioritizing conservation efforts (Silva *et al.*, 2022). UITTNav was created to combine location data of threatened trees, turn-by-turn navigation to the specific location of these trees, as well as the collection and display of growth characteristics of each threatened tree within the University of Ibadan in a single application for easy management of these threatened trees. At its current state of development, UITTNav allows users to have ready access to inventory and location data of threatened trees. It also allows users to suggest the addition of tree data.

However, a significant concern is the duration of data accuracy within the application. Many studies have addressed the issue of the accuracy of tree inventory data over time. Maltamo *et al.* (2021) found that data updated 5-years before was just as accurate as new inventory data. This suggests that data within the application remains accurate for at least five years after data collection. Another concern in the application is the Google Firebase integration used for storing submitted data. Google Firebase is a database commonly used for applications due to its real-time capabilities and developer-friendly environment (Khafid and Putri, 2020). It has been used successfully in various applications such as hydroponic farming monitoring systems (Megantoro *et al*., 2022), user complaint support systems (Fitriastuti *et al.*, 2022), fault detection in power line transmission (Goswami and Agrawal, 2020), cloud computing optimization analysis (Semma *et al.*, 2023), among others.

As regards the navigation system, at the current state of its development, the navigation system in UITTNav provides a suitable way for its users to move to the location of threatened trees. It was done using services provided by MapBox. However, it was noticed during testing that while the navigation system automatically makes the user's current location the starting address, it sometimes adjusts the user's location once the navigation view opens up to give a more accurate estimate.

Also, the navigation system does not fetch the user's address once there is no internet connectivity. It makes it unsuitable for situations where connectivity is poor. However, since it was meant for the University of Ibadan, which is in an urban area, this does not pose much of a challenge.

CONCLUSION AND RECOMMENDATIONS

This study has led to development of an application that can help manage trees within the University of Ibadan. During this study, it was discovered that the University of Ibadan is home to many threatened species. Unfortunately, these trees are poorly managed, and no record exists. These species are also unevenly distributed among the academic, residential, and protected areas.

This study, therefore, recommends that the management of threatened trees within the University of Ibadan be made a priority. Trees within the University of Ibadan should be well protected from vandalism, and unauthorized harvesting of any forest resource within the University should be banned. Regular monitoring of threatened trees within the University of Ibadan and a regular inventory of threatened trees should also be promoted to assist in managing these threatened trees. Lastly, the management of trees within the University of Ibadan should follow a management plan.

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