Information System for Web-Based Management in OWO and Akure-Ala Forest Reserves, Nigeria

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Abstract
A forest web-based information management system is a great instrument in guaranteeing forests been managed in a sustainable way. Disagreeing with the development in technological advancement, the Forestry Department of Ondo State Ministry of Natural Resources has depend on on paper-based record keeping system to carry out its mandate to citizens, which undermines the efficiency and effectiveness of Justifiable Forest Management (SFM). In view of this, this study developed a forest web-based information system for forest management in Akure, Owo and Akure-Ala forest reserves to assist user access, bring up to date and retrieve forest information. This was accomplished by identifying the gaps in the current workflow of forest administration in study area. Data were acquired and processed by ArcGIS and QGIS software. Having georeferened digitized and classified, the digital maps were then exported to web in QGIS2Web plugin. A web site was created and hosted in order to have access to it anywhere, anytime and on any device, The developed system was then tested by the prospective users to confirm its' functionality, subsequently a questionnaire survey was conducted and processed the questionnaire data using SPSS software, the study showed that all 14 of the respondents who were carefully chosen using snowball technique established that the developed system provides a well-structured development of collecting, storing, updating and disseminating forest information.
***Keyword**s: Sustainable, WebGIS, Forest Information System.*

I. Introduction

Forests are important to all living beings, the environment in several ways than we can imagine. It not is not a tall tale to say we depend on forests for our survival, forests not only provide homes for animals and means of support for humans but also offer watershed protection, checking soil erosion and moderate climate change (Adekunle 2006), (Okunlola, and Akinyele, 2014). But disappointingly, we are not preserving them as much as it should which has led to the gradual disappearing in this Nation. Forests are storehouses of biodiversity as they provide habitats to various animal species. They are home to 80% of the world's terrestrial biodiversity (Adekunle et al 2008), (Onyekwelu, 2017).

Adekunle *et al*., (2008), simply put forest management as a process that involves the improvement and accomplishment of a plan incorporating all of the principles, practices and procedures necessary to care properly for the forest. It is not enough to just manage the forests, most importantly is the sustainable management of these forests to ensure that they not only meet our immediate needs but also that of future generations, which is the whole essence of sustainable management.

Unfortunately, forest reserves in Nigeria are not being managed well enough to meet our current needs let alone the needs of future generations. Unsustainable, unregulated and unauthorized harvesting of trees are the major problems faced in our forest reserves. In the study area, forest reserve records are still filed manually (Eugene, 2004). The manual filing system of keeping records is becoming inefficient, slow for updating, retrieving and storing information and its inability to carry out spatial and non-spatial analysis (Babalola *et al.,* 2011, Babalola and Uyi 2019). Therefore Information and Communication Technology (ICT) has come to play an essential role in proper record keeping and data management of forest reserves. An example of this is the use of Geographic Information System (GIS) in sustainable forest management (Longley et al 2005). GIS plan is an integral part of developing a sustainable forest management plan . Digital maps can be linked to relational databases that store spatial and attribute data of forest reserves (Alesheikh, *et al* 2002),

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(Kumar and Diwakar, (2015) and Designing and implementing a comprehensive GIS plan is the foundation for sound forest management decisions. However, there might has been other studies in GIS and forest management but more efficiently, this study, integrated a web-based information system application to house the GIS plan (Sonti, 2015), (Babalola et al 2016), (Alo *et al* 2014 and Babalola and Uyi 2019). This made a greater impact and change the status of forest management. This research therefore developed a web-based forest information system for providing; proper forest information collection, proper record keeping, storage, up to date information, dissemination platform and overall monitoring of forest activities, all for the primary purpose of sustainable forest management.

Study Areas
       The study areas that were considered for this research are Akure Forest Reserve, Owo Forest Reserve and Akure-Ala Forest Reserve. The forest reserve is endowed with both indigenous and exotic species of trees like teak and gmelina. Also in Akure forest reserve is Queen Elizabeth's plot reserved for research purposes and some sections designated for cocoa and palm oil farming.
       Owo forest reserve is located in the lowland rainforest zone between latitudes 768991mN and 772720mN and longitudes 783614mE and 790965mE in the northern part of Ondo state, with a total land area of 241km^2. Ondo state is located in Southwest Nigeria. Owo forest reserve is endowed with teak and gmelina tree plantation.
       Ala Forest Reserve is also located in Akure North Local Government Area of Ondo State and it covers a total area of 199km^2. It lies between latitude 746566mN and 774301mN of the Equator and longitudes 721061mE and 739366mE of the Greenwich Meridian. Ala Forest Reserve is long and thin and a road runs straight through it from north to south. While the northern half has been taken over by teak and oil palm tree plantations, the southern half of the reserve has more teak plantations and natural forest.
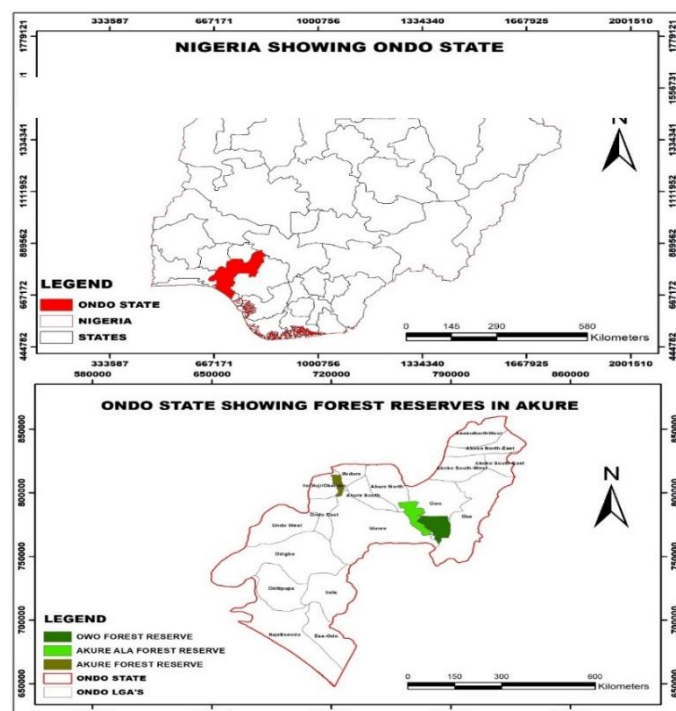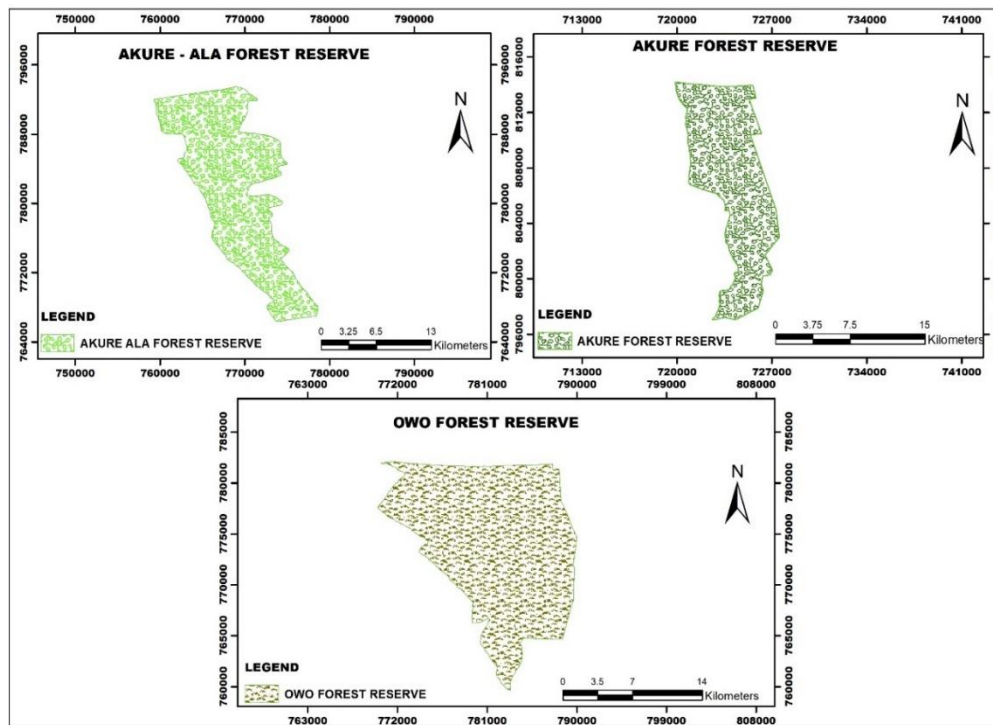

Figure 1. Map of the study areas

Figure 2: Map of the forest reserves of interest

II. Material and Methods

This research was carried out for the purpose of developing a web-based forest information system for sustainable forest management in Ondo State forest reserves. The forest reserves chosen for this research are; Akure, Owo and Akure-Ala forest reserves. Reconnaissance was first carried out which aided in deciding the type of data that would be required. Data was acquired from Ondo State Forest Department, Ministry of Natural Resources. Spatial data and non-spatial data were used which includes; layout maps, other forest administrative records and questionnaire data. Information extracted from the raw datasets were then processed using ArcGIS and QGIS software which involved georeferencing and digitizing, after which the system was developed. Fanon, et al (2016), the system development which involved web application development, database design and web server was exported to web using the QGIS2Web plugin. The use of questionnaire survey was deployed for system testing and validation.

A Personal Computer (Intel® Core™ i3-5005U CPU @ 2.00GHz, 4GB RAM memory, 64-bit Operating System, x64-based processor) and HP LaserJet Printer are the hardware used. While the software are: ArcGIS, QGIS, QGIS2Web, OpenLayers library, Notepad++ and SPSS.

Data Processing

The data processing involved the preparation of information from the raw data obtained from the questionnaires and datasets. ArcGIS and QGIS are the software of choice for this research. They were chosen because; they are most suitable for achieving the aim of this research, for contribution to knowledge and also based on familiarity with the workability of the software. The digital image was georeferenced in ArcGIS using the UTM coordinates of the significant boundary points of the forest reserve. Afterwards, it was digitized and shapefiles were created to show the forest compartments, enclaves, Queen Elizabeth's plot and other relevant features. The digital map was then transferred to QGIS for further processing. In summary, this process involved careful digitizing of the scanned images and inputting the attributes of the features in the images being digitized using ArcGIS

The questionnaire data entry and analysis was carried out with the use of SPSS software. SPSS is short for Statistical Package for the Social Sciences. It is a very simple but accurate and well-known software program which helps in the extraction of actionable insights from data. There are a handful of statistical methods that can be leveraged in SPSS, including: Descriptive statistics was the method of analysis used in this research. Data from the questionnaire was systematically extracted, categorized and coded to suit the data entry technique in SPSS. The questionnaire utilized closed ended questions and therefore the coding procedure was adopted for the purpose of extracting quantitative data. Afterwards, data was then fed into the SPSS software in order to get accurate results and precise analysis of the results, the result of which is a statistical output to be interpreted. Tables and bar charts were used to interpret the output to give better understanding of the results.

System Development
The system development for this web based GIS consisted of database design, web application development and web server.

Database Design
The database designed the basis of the functionality of the forest information system . These include; Web map creation, forest information recovery and spatial analysis. The Entity Relationship Diagram is shown in figure 3 below. While the forest compartment attributes are shown in table 1 below.
The database design comprised of the following:

* User needs analysis
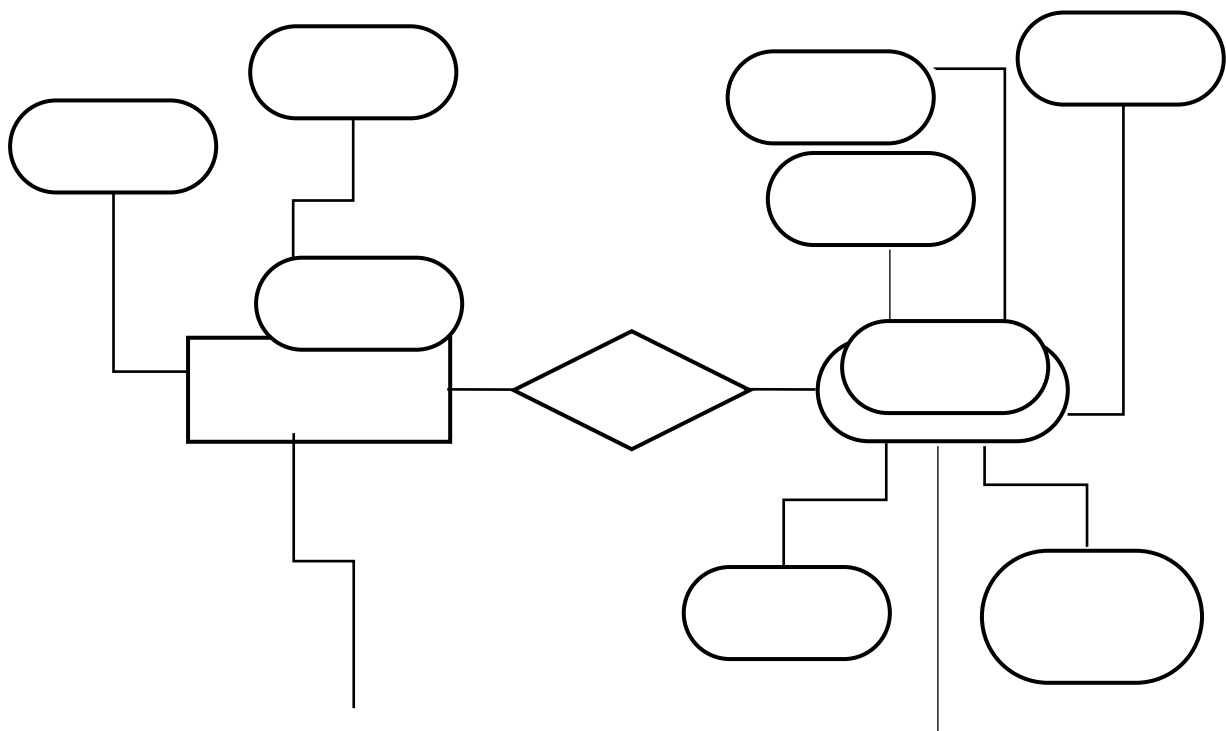* Conceptual model
* Logical model
* Physical design

Figure 3. Entity-Relationship Diagram of the Forest Information System Database

Table 1. Representation of Compartment Attribute

Unique ID	Area	Tree Type	Age	Allocation	Date Harvested
Akf1	88.38066971480	Teak	Overgirth	No	MM/YY
Akf2	94.29206302430	Gmelina	Undergirth	No	MM/YY
Akf3	89.00296532900	Gmelina	Overgirth	Yes	MM/YY
AkAF1	34.76625508340	Teak	Undergirth	No	MM/YY
AkAF2	69.36447388090	Teak	Overgirth	Yes	MM/YY
AkAF3	85.51734476440	Teak	Undergirth	No	MM/YY
OwoF1	72.17354282190	Teak	Overgirth	No	MM/YY
OwoF2	47.18236113760	Gmelina	Overgirth	No	MM/YY
OwoF3	27.29830414640	Teak	Overgirth	Yes	MM/YY

Web Application Development
All compartments of the three forest reserves were merged to form one shapefile. This was done by merging the vector layers using the vector data management tool. After merging all three forest reserve compartments, data classification was carried out on the merged compartments for ease of access, to ensure data is searchable and retrievable. The design/visual representation of data was equally carried out to ensure effective visual communication. The compartments were categorized based on allocation where allocated and non-allocated compartments were assigned specific colours to distinguish the features in order to differentiate

between areas that have been allocated and areas that have not been allocated. Plate 1 below shows the developed maps of the forest compartments before exporting to web.

GIS users are not typically web programmers. It therefore presents a challenge when there is need to create a web map that is of the same quality as a map created in GIS environment. However, this has been made easy with the help of tools that translate maps in QGIS to web maps. An example of such tool is the QGis2Web plugin. The QGis2Web plugin provides an easy way to distribute and visualize QGIS work as a web map using OpenLayers or LeafLet without having to build the web application from scratch. This system was therefore designed using QGis2Web by exporting the functionalities in QGIS to web as an html page.

QGis2Web exports the spatial data to GeoJSON format which can be accessible using a web browser. It also creates a functional WebGIS application using OpenLayers. On exporting the QGIS file to web format, a directory was created containing the index.html page and sub directories. This web page contains the spatial data and WebGIS functionalities needed to visualize the map online. With the click of a button, information about each compartment will automatically be displayed. Plate 2 below shows information display in the web maps.
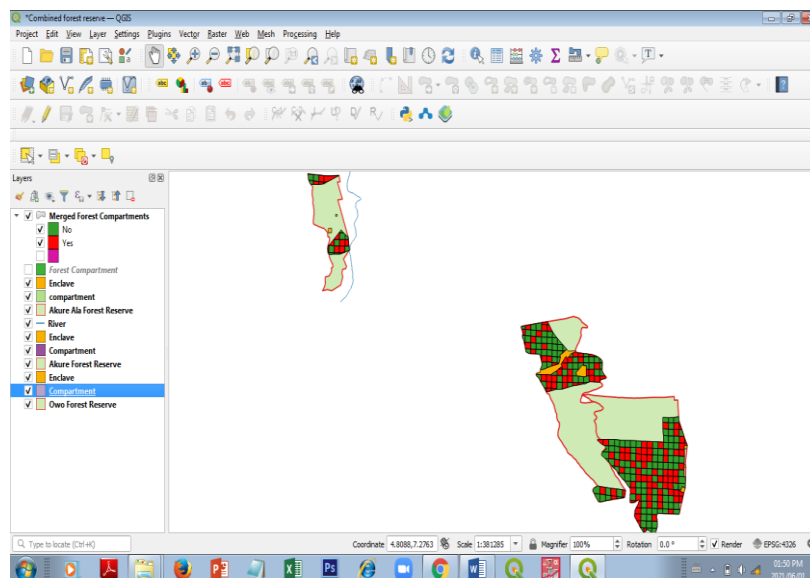

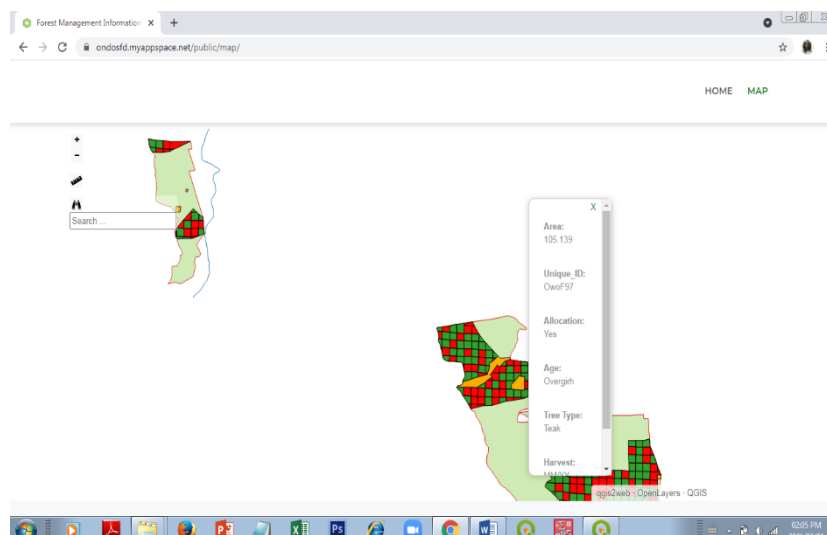Plate 1. Developed maps of forest compartments

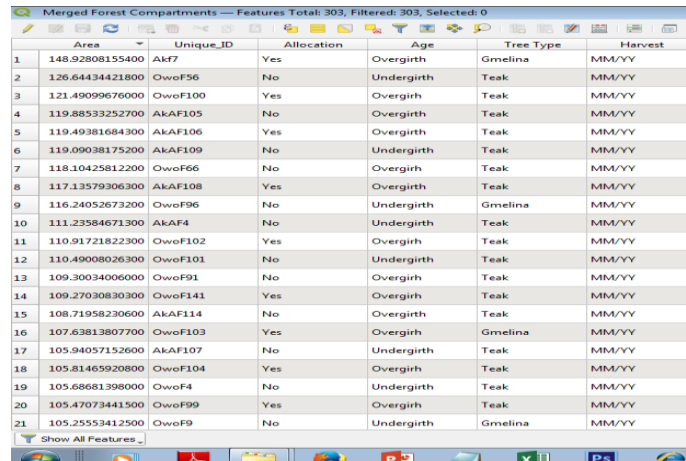**Plate 2.** Web maps showing information display

Web Server

For the purpose of this research, the hardware web server is a personal computer that stores the web server software and the website's component files; while the software includes an HTTP (Hypertext Transfer Protocol) server that responds to client requests made over the World Wide Web. The key function of a web server is to display website content which is done by storing, processing and delivering webpages to users.

The web application stored in the local host was easily transferred online using File Transfer Protocol (FTP). However for on-the-go accessibility, a domain name was created and hosted on a third party webhosting server to enable access anywhere, anytime, on any device and with any browser, provided there is internet availability.

III. Discussion of Results

Spatial Database of Forest Compartments

A good database is fundamental to any organisation. This is because the database stores all relevant details and is capable of managing large amount of data. The benefits of a good database are numerous, ranging from improved efficiency to multi-access. The spatial databases of the forest reserves were designed for the purpose of easy access, storage and update of forest information. Plate 3 below is the spatial database of the merged forest compartments.

	Area	Unique_ID	Allocation	Age	Tree Type	Harvest
1	148.92808155400	Akf7	Yes	Overgirth	Gmelina	MM/YY
2	126.64434421800	OwoF56	No	Undergirth	Teak	MM/YY
3	121.49099676000	OwoF100	Yes	Overgirth	Teak	MM/YY
4	119.88533252700	AkAF105	No	Overgirth	Teak	MM/YY
5	119.49381684300	AkAF106	Yes	Overgirth	Teak	MM/YY
6	119.09038175200	AkAF109	No	Undergirth	Teak	MM/YY
7	118.10425812200	OwoF66	No	Overgirh	Teak	MM/YY
8	117.13579306300	AkAF108	Yes	Overgirth	Teak	MM/YY
9	116.24052673200	OwoF96	No	Undergirth	Gmelina	MM/YY
10	111.23584671300	AkAF4	No	Undergirth	Teak	MM/YY
11	110.91721822300	OwoF102	Yes	Overgirh	Teak	MM/YY
12	110.49008026300	OwoF101	No	Undergirth	Teak	MM/YY
13	109.30034006000	OwoF91	No	Overgirh	Teak	MM/YY
14	109.27030830300	OwoF141	Yes	Overgirth	Teak	MM/YY
15	108.71958230600	AkAF114	No	Overgirth	Teak	MM/YY
16	107.63813807700	OwoF103	Yes	Overgirh	Gmelina	MM/YY
17	105.94057152600	AkAF107	No	Undergirth	Teak	MM/YY
18	105.81465920800	OwoF104	Yes	Overgirh	Teak	MM/YY
19	105.68681398000	OwoF4	No	Undergirth	Teak	MM/YY
20	105.47073441500	OwoF99	Yes	Overgirh	Teak	MM/YY
21	105.25553412500	OwoF9	No	Undergirth	Gmelina	MM/YY

Plate 3. Spatial database of the Forest Compartments

A Web-Based GIS application

A web-based system is an application that is accessed via Hypertext Transfer Protocol (HTTP). The developed Forest Information System Application (FISA) is a web-based GIS application that is run in a web browser. The host server for the web-based system is a local server that can be accessed via the internet. The importance of a web based GIS application are: easy installation and maintenance, multiuse, increased efficiency, accessible anywhere and anytime, easy data sharing, greater availability of information, etc. Plate 4 below shows the home page of the web application, while plate 5 shows the about page of the web application.
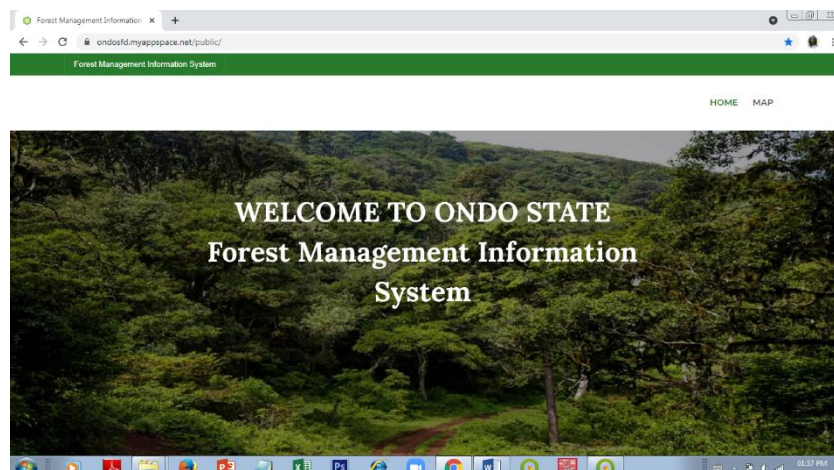

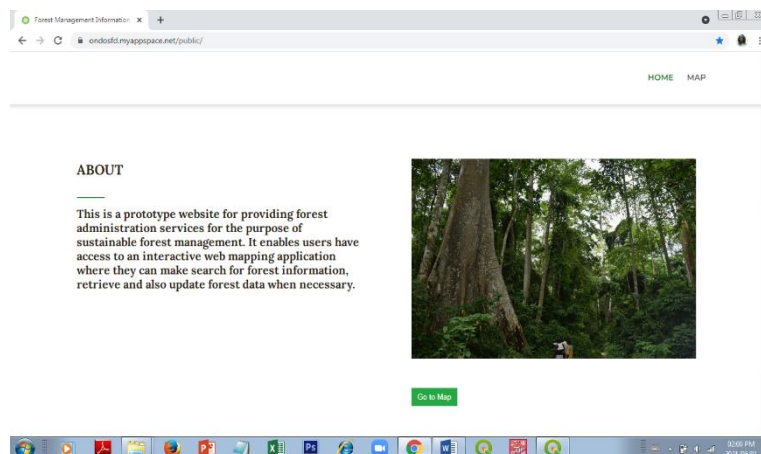Plate 4. Home page of web-based application

Plate 5. About page of web application

Functionalities of the Web Based GIS Application
The web-based Forest Management Information System provides ease of data storage, access and data management.
The developed system has several capabilities such as:
a.   Zoom in and out: used to improve the view of the web map.
b.   Pan: to easily navigation on the map.
c.   Feature information: by clicking on any part of the map, information about the map feature is displayed as shown in Plate 3.16.
d.   Distance measurement: Users can measure distance between compartments or other features as shown in Plate 3.17.
Search feature: Users can easily carry out layer search on the map using the unique ID of the compartment. See Plate 3.18.

Questionnaire Result, Analysis and System Testing
The web application was made live online and the users who were given the URL could have access to the Forest Management Information System from any location and on any device connected to the internet. Prospective users who are the staff of Ondo state forest department were given the URL and asked to visit the website in order to test the functionality of the web application. After the web application had been tested, questionnaires were issued to them to fill and make recommendations to the developed system.
On testing the developed system, the proficiencies and limitations of the system were validated. The participants comprised of 14 staff and 100% of the questionnaires were returned and there were no missing values.

Summary of System Testing and Validation
Generally, all the respondents were of the opinion that the system possibly will add great significance to the running of forest management in study area, stating that the system provides a platform that appears to be precisely what desirable. 100% of the respondents expressed their satisfaction with the developed system and made recommendations where necessary. Table 2 below shows a summary of the participants' response after testing the system.

Table 2. Summary of the system testing response

Test	Average
Web map loaded quickly	2
Easily navigate the web map	2
Navigation/links functioned correctly	1
All compartments were shown	1
Compartments displayed necessary information	1
Web application contains all relevant forest data	1
Web app provides better record keeping	1
Efficient means of forest management	1
Web map will help in detecting & predicting deforestation	2
Supports sustainable forest management	1
Good graphics design	2
Web map works on different computers	2
Web map works on different browsers	1

Data update and retrieval was done with ease	1

Point values of 1 to 5 were assigned to each response. The numbers 1 to 5 represents strongly agree, agree, neutral, disagree and strongly disagree respectively.

IV. Conclusion

The primary aim of this research is to develop a web-based forest information system for sustainable forest management in Owo/Akure Ala forest reserves. The motivation for this study arises from the need to provide an efficient platform that supports sustainable forest management as opposed to the current paper-based method of record keeping and forest administration in Ondo State Forest Department. The main functionalities of this study offers, online visualization, search feature, measurement of distance on map, update and retrieval of information and report generation. The system offers an efficient flow of forest information within the Ministry ensuring there is a well-structured process of collecting, storing, updating and disseminating forest information. The benefit of this web application system are numerous, ranging from up-to-date information on forest activities to ease of data access, retrieval and exchange. The developed system was tested to validate its' functionality and efficiency over the present workflow in Ondo State forest administration. The result of the system testing showed that the web application will be very instrumental in the sustainable management of the forest reserves, which will consequently help reduce illegal activities, enhance transparency in the use of forest resources, aid harvest planning, enable quick decision-making to facilitate and enhance analysis for forest use planning and also serve as a tool for improving public service.

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