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Development of Geospatial Database for Oluwa Forest Reserve

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Abstract
This study was undertaken to develop geospatial database for Oluwa forest reserve using Geographic Information System (GIS). This database was designed to incorporate relevant spatial and non-spatial information collected on the reserve which can be used for management purposes. In order to ensure that suitable and necessary information were included in the database, a user's need assessment was carried out and copies of checklist were administered to the staff of Ondo State Afforestation Project (OSAP), who are the primary managers of the reserve. Highlighted information need included information on the forest comprising of plantation and natural forest, nursery, sawmill, staff, and forest dwelling communities within the reserve. In addition, satellite imagery of the area was downloaded from Google Earth and topographic map were obtained for the purpose of map production. Geographic coordinates were also taken using the Global Positioning System (GPS) during the fieldwork as well as relevant pictures. The primary data obtained during the fieldwork, alongside the secondary data were subjected to descriptive statistical analysis using Microsoft Excel software for onward use in the Database Management System (DBMS). ArcView 3.2a, the GIS Software used as the DBMS, was used to produce thematic maps of vegetation, forest dwelling communities, road networks and river body. All non-spatial information obtained for each thematic feature were incorporated into the information system as attribute data. A database for Oluwa forest reserve which included information on forest, nursery, sawmill, staff and forest communities was developed. The study shows that GIS is a powerful tool that is not only useful for map production but also for developing database.

Keywords: Forest Reserve, Geographic Information System, Database, Forest Management.

Introduction

Information is important to the management and development of any resources (Mishra, *et al*. 2015). This is also true for forest resources. Information management and monitoring systems are instrumental for effective policies, planning, and valuation of forest resources, prioritizing interventions, efficient investments, and engendering accountability in the forest sector (World Bank 2008; Dau *et al*. 2015). Relevant forest information that is periodically and systematically collected can enable effective implementation of policies, inform decision making, and guide management (Fardusi *et al.*, 2017). However, it was observed that despite the increasing awareness of the importance of information in planning for sustainable forestry development, most developing countries, Nigeria inclusive, still do not have adequate information about forestry sector (FAO 1999; Mahdavi 2006; Poker and MacDicken 2016). This makes it difficult to adequately plan and work towards the sustainable management of the resources. Inadequate information on forests and weak monitoring capacity have resulted in poor forest policies, planning and management (Murty 2008; Wegi and Obsinet, 2019).

Baseline data and information on environmental issues (forest reserves included) in Nigeria are inadequate and, where in existence, data cannot be accessed by researchers and other end users (USAID 2008; WARIMA 2010; Nageswara-Rao *et al.* 2012). The paper format, which is used in most cases to store information about forest reserves, have either been destroyed or misplaced and those that are still in the right condition are archaic. Fardusi *et al*. (2017) noted that successful forest management demands that critical information be available and made accessible to critical management operators on timely basis. One of the effective ways of obtaining, storing information and making the information readily available to end-users is through the use of Geographic Information System (GIS) technology to create a geospatial database. Geospatial database is a database that combines information on location (geographic coordinates) of an object and their corresponding attribute/characteristics (Stock and Guesgen, 2016). Geographic Information System and related technologies provide foresters with powerful tools for record keeping, analysis and decision making (Tereşneu *et al.* 2016; Mukete, *et al*. 2017; Picchio *et al*. 2018). In order to ensure the sustainability and effective management of forest resources therefore, it is pertinent to obtain relevant up-to-date information on forest reserves in the country.

Oluwa forest reserve is of particular interest for the study because it is one of the most popular forest reserves in Nigeria and it is of obviously significance for biological conservation (Esievoadje 2019). The main objective of this study therefore was to create a geospatial database for Oluwa forest reserve.

Study Area

Oluwa forest reserve is located between latitudes 6°38' and 6°59'N and longitudes 4° 23' and 4° 46'E as shown in Figure 1. Oni River forms the western boundary of the reserve while Ominla River borders it on the eastern side. Shasha forest reserve bounds it on the north while Benin-Lagos expressway cuts through the southern part of the reserve (Onyekwelu, 2001). The reserve consists of both natural forest and Plantations. The natural forest is a tropical rainforest and it is characterized by emergent trees with multiple canopies and lianas (Orimoogunje, 2014). Tropical hardwood trees found in the natural forest are *Triplochiton scleroxylon, Lophira alata, Terminalia ivorensis, Brachystegia nigerica, Antiaris africana,* while plantation species include *Gmelina arborea, Pinus caribaea and Tectona grandis.*

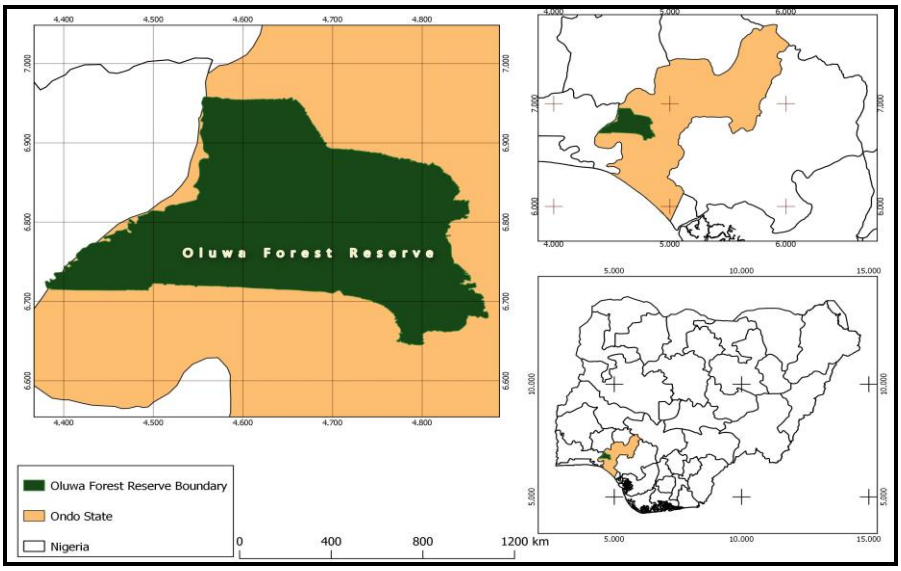

Figure 1: Map of Ondo State Showing Oluwa Forest Reserve

Data Collection

Designing and Administration of User Need Assessment Checklist

A user's need assessment checklist was designed in order to determine the appropriate data to be collected. This was to ensure the information that was included in the database management system meet the needs of the prospective user. Copies of the designed checklist were administered to the primary managers of the reserve staff of Ondo State Afforestation Project (OSAP) as recommended by Asopa and Beye (1997), Rajaraman (2011) and Ryan (2011). Data requirements as elicited from the checklist were categorised into non-spatial and spatial data.

Spatial Data Acquisition

Spatial data are data which are directly or indirectly referenced to a location on the surface of the earth, they are graphical representations of natural and human features on the earth surface. Some of the spatial data used for the study were satellite imageries, topographic map, administrative maps and geographic coordinates taken during field work. They were used to produce geo-referenced map of the reserve. An Enhanced Thematic Mapper (ETM) Landsat imagery covering Oluwa Forest Reserve was obtained, while the Topographic map of the reserve was acquired from the Federal Surveys department in Lagos State, Nigeria. While the satellite imagery showed a better and more recent view of the reserve, the topographic map showed the boundary of the reserve. Ground-truthing survey was carried out. This involves a field exercise to confirm on ground, some of the features shown on the satellite imagery. This is essential for an accurate assessment of the classification of features on the satellite imagery. More so, geographic coordinates of all locations visited during the fieldwork were taken and recorded using Global Positioning System (GPS).

Non-Spatial Data Acquisition

Non-spatial data, also refer to as attribute data, are characteristics of the natural and human features. The non-spatial data used for the study included both primary and secondary data. The secondary data were obtained from the Ondo State Afforestation Project and previous studies on the area. Some of the secondary data obtained included: historical information about the reserve *e.g.,*

year of establishment, original size of the area gazetted for the reserve *etc* personnel information *e.g*., number of professional, technical, uniform and support staff information on Land use and the basic attributes of the various units of land information on nursery management, information on sawmill management.

Primary data were obtained for forest dwelling communities and forest cover. Twenty-four communities were identified with the aid of satellite imagery and Odigbo Local Government administrative map. Questionnaire were administered to key-informants within each community. In addition, data were also collected in the different age series of the exotic plantation (*Gmelina arborea*, *Tectona grandis* and *Pinus Caribaea*) and the natural forest. There were twenty-one (21) age series of *Gmelina arborea*, seven (7) age series of *Tectona grandis* and five (5) of *Pinus Caribaea* within the reserve. Three temporary sample plot sizes of 20 m by 20 m were laid in four selected age series in the *Gmelina arborea*, *Tectona grandis* and *Pinus Caribaea* plantation (selected at 5-age interval). All trees within the sample plots were measured Tree variable that were measured included: diameter at breast height (*Dbh*), diameter at the base (*Db*), diameter at the middle (*Dm*), diameter at the top (*Dt*) and total height (*h*). Measurements obtained were used in computing the stem volume, basal area, number of stems per plot and diameter distribution. Relevant pictures were also taken in locations that were visited.

Data Analysis

Stem volume estimation

The stem volume was estimated using the Newton's formula for volume estimation (Equation 1).

$$V = \frac{\pi}{24} h\,(Db^2 + 4Dm^2 + Dt^2) \quad \text{(Eqn. 1)}$$

Where V= Volume (m^3), h=height (m), Db=Diameter at the base, Dm=Diameter at the middle, Dt= Diameter at the top, π= 3.142 (Constant)

The total volume for each of the sample plots was obtained by the summing up the volumes of individual trees within the plot while mean volume for the plots was obtained by dividing the total volume obtained by the number of sample plots. Stem volume per hectare was estimated by multiplying mean volume per plot with the number of 20 by 20 m plots in a hectare (25).

Basal Area Estimation

The basal area of each tree in each plot was estimated using the formula given in Equation 2.

$$BA = \frac{\pi D^2}{4} \quad \text{(Eqn. 2)}$$

Where BA= Basal Area (m^2), π= 3.142, D= Diameter at Breast height (m)

The total basal area for each of the sample plots was obtained by the summing up the BA of all trees in the plot while mean BA for the plot was obtained by dividing the total BA by the number of sample plots. Basal area per hectare was estimated by multiplying mean BA per plot with the number of 20 by 20 m plots in a hectare (25).

Diameter Class Distribution and Number of Stem per Plot

The Dbh obtained for each of the trees in each plot was used in classifying the trees into different diameter classes. In addition, the number of stems per plot was generated from the inventory.

The results obtained from all the analyses were sorted and arranged into Microsoft Excel Spreadsheet. They were then saved in dBase IV file format for onward use in ArcView 3.2a.

Map Preparation

Arcview 3.2a was used for the map production. The preparation of the GIS map involves a number of procedure such as geo-referencing, digitizing, map overlaying, importation of tables from Excel spreadsheet into the database, hotlinking and map presentation. Geo-referencing entails adding geographic information (that is, longitude and the latitude) to their respective location on a scanned map to place them in their appropriate location in a real world. Digitizing is the process of converting spatial data on a map into a digital format. It involves manually tracing out features of interest from the base map. The topographic map's boundary was digitized by manually tracing out the boundary of Oluwa Forest Reserve shown on it (Figure 2). The geo-referenced boundary theme was superimposed on the satellite imagery in order to get the boundary of the reserve on the imagery (Figure 3). Thereafter, features of interest in the satellite imagery were also digitized (Figure 4). The map that was produced was a thematic map with each layer representing different features on the reserve. The layers that were represented on the map included the vegetation classification, road network, water bodies, administrative area and the communities within the reserve. The vegetation types were represented by polygons, the road network by lines, the communities by dots, the water bodies by lines.

The attribute data of each feature, which had been saved as dBaseIV file and imported into ArcView 3.2a environment, were also linked to each of the theme (Figure 5). In addition, pictures that were taken in the location visited within the study area were linked to their corresponding locations on the geo-referenced map using

the hot link icon. The hot link icon helps to create a link between the features on the map and pictures of the feature taken (Figure 6). The geo-referenced map was then produced.

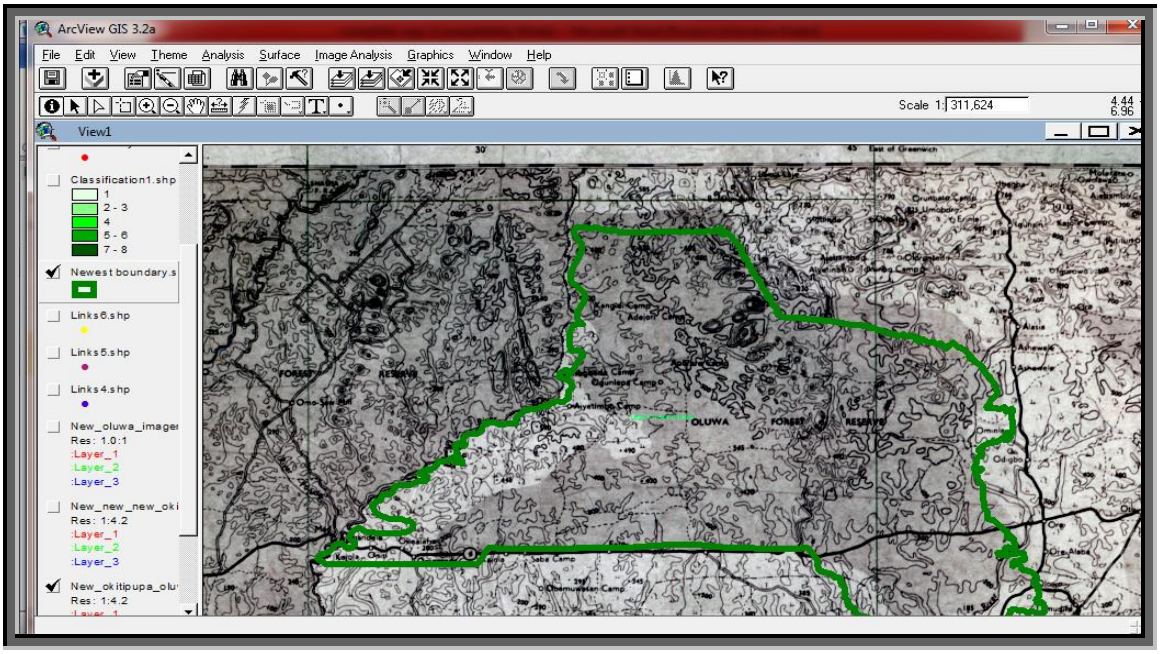

Figure 2: Screenshot showing the digitized boundary of Oluwa Forest Reserve

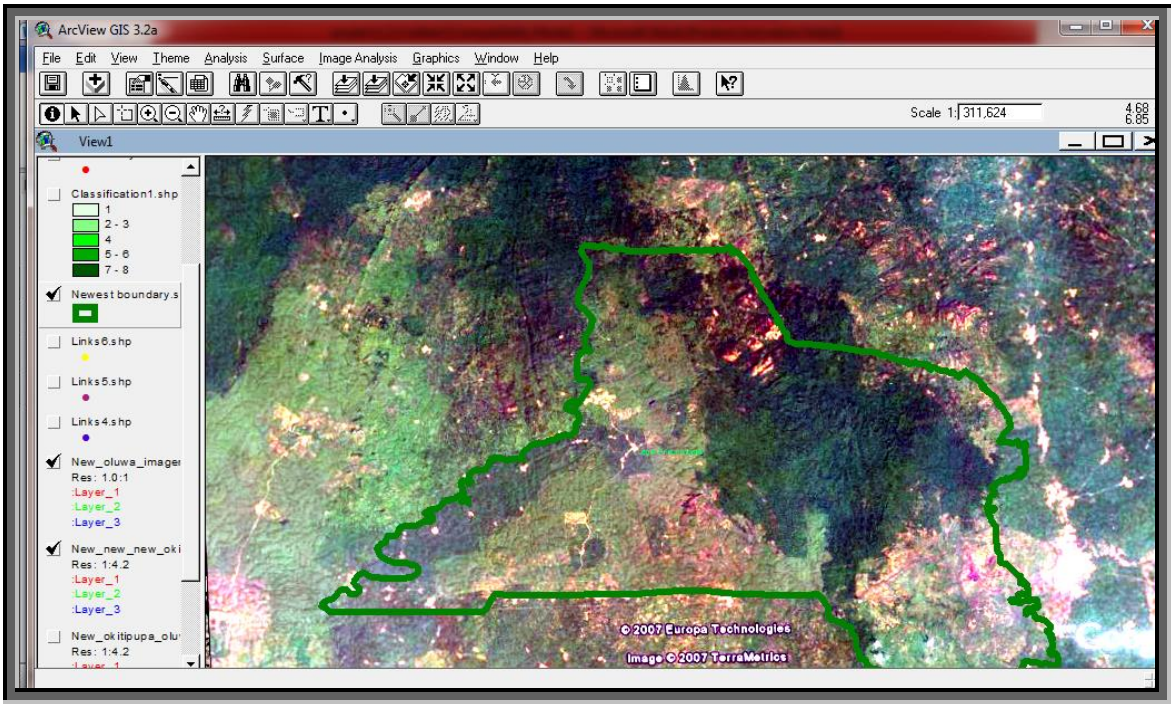

Figure 3: Screenshot of the Geo-referenced Satellite Imagery of Oluwa with the superimposed boundary

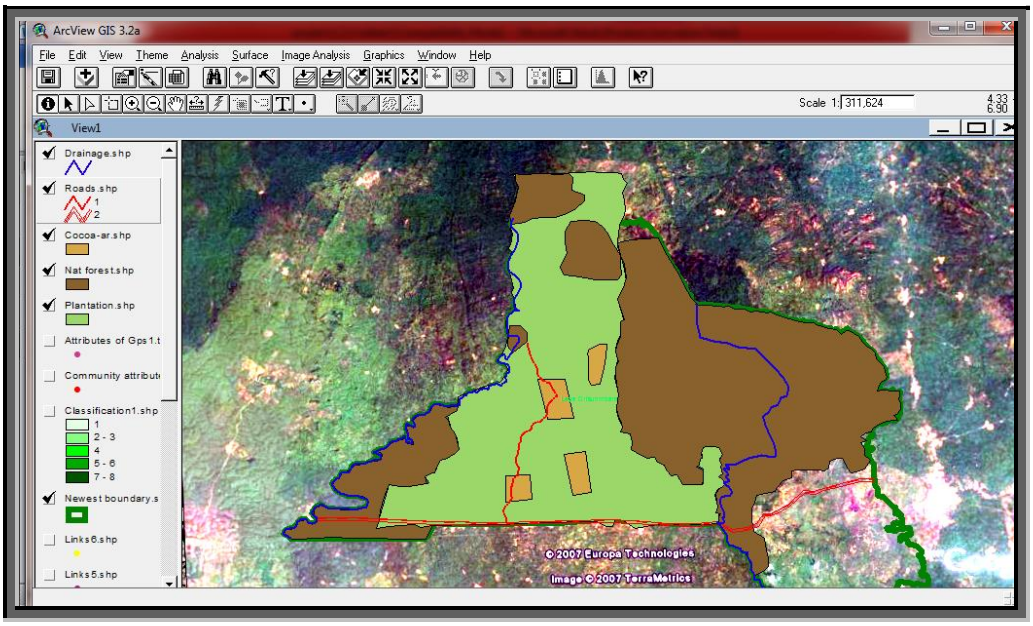

Figure 4: Screenshot showing some of the digitized features on the Satellite Imagery

Shape	ID	Name of co	Local gove	Lat	Long	Year of es	Founder	Number of	Average ac
Point	1	Ayetevere	Odigbo Lo	6.775070	4.554810	1913	Pa A. Makinde	245	
Point	2	Ogunilepa	Odigbo Lo	6.847100	4.620600	1920	Mr Famakinwa	90	
Point	3	Kajola Om	Odigbo Lo	6.724970	4.510270	1870	Baale Samuel Akinj	500	
Point	4	Sakoto1	Odigbo Lo	6.774020	4.497320	1954	Sakoto	85	
Point	5	Ayetembo	Odigbo Lo	6.828700	4.559390	1940	Mr Alo	50	
Point	6	Imorun	Odigbo Lo	6.819440	4.585440	1912	Mr Iyega	50	
Point	7	Kangidi c	Odigbo Lo	6.896800	4.575740	1942	Baba Kangidi	30	
Point	8	Lege Oni	Odigbo Lo	6.824433	4.591000	1912	Joshua Akinmola	200	
Point	9	Oloibon	Odigbo Lo	6.766580	4.431610	1942	Mr Falekulo	100	
Point	10	Bolorundu	Odigbo Lo	6.828660	4.553100	1940	Balogun Akekuni, C	120	
Point	11	Lisagbede	Odigbo Lo	6.848340	4.556760	1910	Mr Ogunikasi	20	
Point	12	Ayetoro	Okitipupa	6.723140	4.535490	1914	Chief Okunoye	200	
Point	13	Temidire	Odigbo Lo	6.769090	4.457690	1966	Chief Adekunle Ade	100	
Point	14	Sakoto2	Odigbo Lo	6.782650	4.515970	1914	Mr Muhammed Lawal	40	
Point	15	Ikuntu	Odigbo Lo	6.812983	4.581983	1914	Mr Ajeturmobi	40	
Point	16	Masole	Odigbo Lo	6.816440	4.582630	1950	Mr Akinpemi Akinto	120	
Point	17	Onipetesi	Okitipupa	6.724510	4.549090	1960	Micheal Ogunmakin	102	
Point	18	Ajebambo	Odigbo Lo	6.752540	4.435450	1913	High Chief Sasere	135	
Point	19	Oniparaga	Odigbo Lo	6.722520	4.453090	1914	Adetokunbo, Emmanu	350	
Point	20	Olorunted	Okitipupa	6.724770	4.525520	1918	Mr Obasemo	50	
Point	21	Obadore	Odigbo Lo	6.812410	4.519790	1982	Mr Moses Oguntusi	500	
Point	22	Jagodo	Odigbo Lo	6.780750	4.480840	1940	Chief Ekuesan	360	
Point	23	Adejoni c	Odigbo Lo	6.889740	4.636510	1910	Pa Adesanlu	100	
Point	24	Osotosho	Okitipupa	6.722770	4.649710	1914	Pa Osotosho	150	

Figure 5: Screen shot of imported attribute data

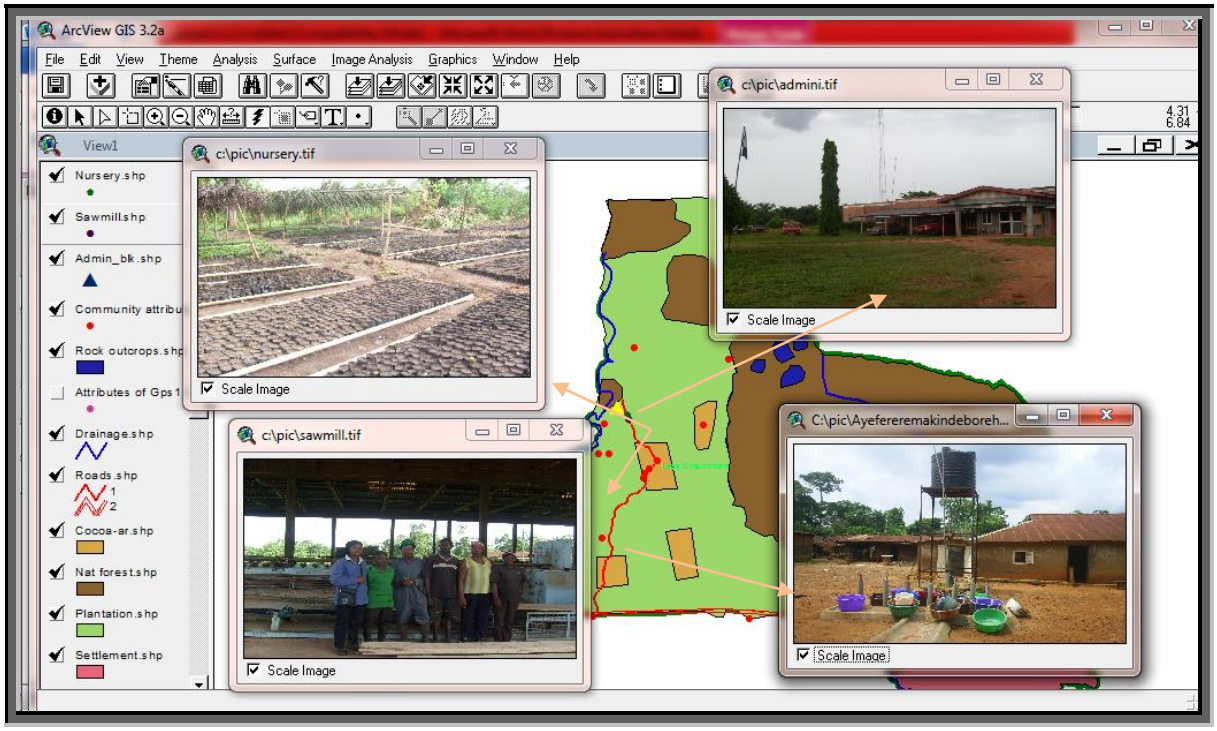

Figure 6: Screenshot showing hotlinked pictures

Results

Historical and Staff Information

The information obtained from the study revealed that Oluwa forest reserve was gazetted and published in the Nigeria gazette No. 74 of November 21, 1918. The Ondo State Afforestation Project (OSAP) is situated within the reserve. The afforestation project which spanned between 1974 and 1996, was part of a long term goal which was expected to yield about 200m^3/ha of pulpwood and 100m^3/ha of sawn wood over a time span of 15years. The plantations were meant to supply pulpwood to Iwopin paper mill. The paper mill project failed and consequently, the plantations have outgrown the rotation age of 12 years for pulpwood and are no longer suitable for pulp and paper production. As a result of this, the plantations are currently being managed for timber production. There are three major exotic species plantation within the reserve. They are *Gmelina arborea*, *Tectona grandis* and *Pinus caribeae* with *Gmelina arborea* being the dominant species.

The bio-data obtained from OSAP shows that there are only ten (10) permanent staff managing the reserve. This was attributed to lack of funding. The permanent staff consist of three professional staff, one technical staff and six uniform staff. Asides from the permanent staff, there are about fifty-five ad hoc staff. These are staff managing the day to day running of the forest reserve.

Information on Nursery and Sawmill Management

The information obtained from OSAP revealed that the nursery was established in 1974 when the afforestation project began. Seedlings raised within the nursery included *Tectona grandis*, *Gmelina arborea*, *Masonia altissima* and *Terminalia superba*. More so, the information gathered shows that the nursery had been moved from its original location to a new location because of proximity to a water body. This was due to unavailability of fund to replace spoilt nursery maintenance gadget. The information obtained from the sawmill shows that there are different types of sophisticated machine used for the different operations at the sawmill (Table 1).

Table 1: Information on the Wood Utilization Unit of Oluwa Forest Reserve

Type of Machine Used	Wood Species Utilized	Type of Wood Product	Problem encountered
Vertical Bandsaw	*Gmelina arborea*	Planks	Low Customer Patronage
VQ72sternner, VQ54 Sternner and VQ48 Sternner	*Tectona grandis*	Furniture	Underfunding
Forester Multiple Edger and Cross Cutting Machine	*Triplochiton scleroxylon*	Upholstery	Bad Access Road
Fiat Hitachin Payloader For Log Loading	*Ceiba pentandra*		Lack of Power Supply
Four Side Planner	*Pterygota sp*		
Circular Sawing Machine	*Erythrophlem ivorense*		
Sanding Machine	*Sterculia sp*		
Spraying Machine	*Terminalia superba*		
	Terminalia ivorensis		

Information on Communities within the Reserve

A total of twenty-four communities were identified in the study area. The results showed that the communities were established between 1870 and 1982 as shown on Table 2. The oldest of all the community was Kajola Omiowi which was established in 1870, while the newest of all the communities was Obadore founded in 1982. About 54% of the communities were already in existence before Oluwa was gazetted as a forest reserve.

The population ranges from about 200 to 9000 people. The community with the lowest population was Lisagbede with a total population of about 200 people, while Kajola Omiowi has the highest population of about 9000 people. The average population is about 2500. Omotosho Community which had the highest population is situated along the road, while Kangidi Camp (lowest population estimate) is located in the interior of the forest reserve.

In addition, the result of the gender distribution in the communities shows that the female gender has a higher population than their male counterparts. The female has an average population of 62% while the male is about 38%. Farming was the major occupation in most of the communities.

Information on Plantations within the Reserve

The information obtained from OSAP shows that a total of about 20,719 ha of planted forest was established between 1974 and 1996. *Gmelina arborea* accounted for about 88% of the total area established while Teak accounted for only 6%. *Pinus caribaea*, *Nauclea diderrichii* and *Terminalia sp* accounted for about 1%, 4% and 1% respectively (Table 3).

In addition, the estimated volume per hectare obtained for *Gmelina arborea* for the years 1974, 1980, 1983, 1985 were 164.86m^3, 152.56 m^3, 440.1 m^3 and 335.76 m^3 respectively, while the average number of stems obtained for the years were 275, 475, 525 and 350 respectively. For *Pinus caribaea*, an estimated volume of 492.4m^3, 396.14 m^3, and 419.63 m^3 were obtained for the years 1993, 1994 and 1996 respectively. The average numbers of stems for the years were 312, 250 and 568 respectively. Details on diameter class distribution are as shown in Table 4.

Oluwa Forest GIS Map

The total area of the reserve was about 82,940 ha. The plantation accounted for about 19,824 ha of the total area while the natural forest was about 21,793 ha. The estimated size of the cocoa could not be ascertained because of its poor visibility on the imagery used. However, the ones that were identified totaled about 2219.075 ha (Figure 7).

Table 2: Information on communities within Oluwa Forest Reserve

S/N	COMMUNITY	LAT	LONG	YEAR	NUM	AVPH	POP. EST.	M (%)	F (%)	SP	MO
1	Ayeferere Makinde	6.775070	4.554810	1913	245	8	1960	30	70	Linear	Farming
2	Ogunlepa	6.847100	4.620600	1920	90	15	1350	35	65	Nucleated	
3	Kajola Omiowi	6.724970	4.510270	1870	500	18	9000	40	60	Scattered	
4	Sakoto1	6.774020	4.497320	1954	85	10	850	30	70	Scattered	Farming
5	Ayetimbo	6.828700	4.559390	1940	50	15	750	40	60	Linear	Farming
6	Imorun	6.819440	4.585440	1912	50	10	500	40	60	Scattered	Farming
7	Kangidi camp	6.896800	4.575740	1942	30	10	300	35	65	Scattered	Farming
8	Legee Orisunmbare	6.824433	4.591000	1912	200	15	3000	40	60	Scattered	
9	Oloibon	6.766580	4.431610	1942	100	15	1500	35	65	Nucleated	Farming
10	Bolorunduro	6.828660	4.553100	1940	120	25	3000	40	60	Linear	Farming
11	Lisagbede	6.848340	4.556760	1910	20	10	200	45	55	Linear	Farming
12	Ayetoro	6.723140	4.535490	1914	200	10	2000	30	70	Scattered	
13	Temidire	6.769090	4.457690	1966	100	30	3000	50	50	Nucleated	
14	Sakoto2	6.782650	4.515970	1914	40	10	400	35	65	Linear	Farming
15	Ilu-tuntun	6.812983	4.581983	1914	40	10	400	25	75	Linear	Farming
16	Masole	6.816440	4.582630	1950	120	15	1800	36	64	Nucleated	
17	Onipetesi	6.724510	4.549090	1960	102	20	2040	40	60	Nucleated	Farming
18	Ajebambo	6.752540	4.435450	1913	135	10	1350	35	65	Nucleated	
19	Oniparaga	6.722520	4.453090	1914	350	20	7000	35	65	Scattered	
20	Oloruntedo	6.724770	4.525520	1918	50	20	1000	35	65	Nucleated	
21	Obadore	6.812410	4.519790	1982	500	10	5000	35	65	Nucleated	Farming
22	Jagiodo	6.780750	4.480840	1940	360	10	3600	40	60	Nucleated	
23	Adejori camp	6.889740	4.636510	1910	100	30	3000	45	55	Nucleated	Farming
24	Omotosho	6.722770	4.649710	1914	150	25	3750	40	60	Nucleated	Farming

** L.G.A = Local Government Area, LAT = Latitude, LONG = Longitude, YEAR = Year Founded *****NUM = Number of housing unit, AVPH = Average number of persons per housing unit. The population was estimated by multiply the average number of persons per housing unit by the number of housing units in the community M=Male F=Female S.P.= Settlement Pattern M.O=Major Occupation*

Table 3: Forest Plantation Established in Oluwa Forest Reserve

Year	Exotic Species			Indigenous Species		Total per Year
	Gmelina arborea **(Size in ha)**	***Tectona grandis*** **(Size in ha)**	***Pinus caribaea*** **(Size in ha)**	***Nauclea diderrichii*** **(Size in ha)**	***Terminalia sp*** **(Size in ha)**	**(Size in ha)**
1974	450.00	-	-	-	-	450.00
1976	545.00	-	-	-	-	545.00
1977	1,160.00	-	-	-	-	1,160.00
1978	914.00	-	-	-	-	914.00
1979	985.00	-	-	-	-	985.00
1980	1,145.00	-	-	-	-	1,145.00
1981	1,062.00	-	-	-	-	1,062.00
1982	1,554.00	-	-	-	-	1,554.00
1983	636.00	-	-	-	-	636.00
1984	1,879.00	-	-	-	-	1,879.00
1985	1,060.00	-	-	-	-	1,060.00
1986	820.00	-	-	-	-	820.00
1987	-	-	-	-	-	
1988	200.00	-	-	-	-	200.00
1989	500.00	-	55.00	-	5.00	560.00
1990	1,000.00	50.00	50.00	-	30.00	1,130.00
1991	1,150.00	50.00	70.00	-	50.00	1,320.00
1992	500.00	50.00	25.00	-	90.00	665.00
1993	250.00	100.00	-	-	64.00	414.00
1994	1,015.00	285.00	-	-	-	1,300.00
1995	741.00	350.00	-	468.00	-	1,559.00
1996	819.00	350.00	4.00	184.60	-	1,358.00
Total	**18,385.40**	**1,235.00**	**204.00**	**652.60**	**239.00**	**20,716**

Table 4: Result obtained from the Inventory carried out in Selected Plantation Stands in Oluwa Forest Reserve

S/N	Tree Species	Year Planted	*AV/ha (m^3/ha)	AV Stem per ha	Diameter Classes							Planting Spacing
					0-10cm	10.1-20cm	20.1-30cm	30.1-40cm	40.1-50cm	50.1-60cm	60.1-70cm	
1	*Gmelina arborea*	1974	164.86	350	0	9	24	11	1	0	0	2.5m X 3m
2	*Gmelina arborea*	1980	152.56	275	1	4	9	7	1	0	0	2.5m X 3m
3	*Gmelina arborea*	1982	440.1	475	5	7	8	14	0	3	1	2.5m X 3m
4	*Gmelina arborea*	1985	335.76	525	1	18	31	15	0	0	0	2.5m X 3m
5	*Tectona grandis*	1991	264.224	675	6	67	51	13	1	1	0	3m X 3m
6	*Tectona grandis*	1989	198.32	600	10	57	42	13	0	0	0	3m X 3m
7	*Tectona grandis*	1993	175.59	600	15	69	45	6	0	0	0	3m X 3m
8	*Pinus caribaea*	1993	492.43	312	0	5	3	26	25	11	0	3m X 3m
9	*Pinus caribaea*	1994	396.14	250	1	14	30	26	22	10	0	3m X 3m
10	*Pinus caribaea*	1996	419.63	568	1	62	78	35	9	0	0	3m X 3m

*AV = Average and ha = hectare

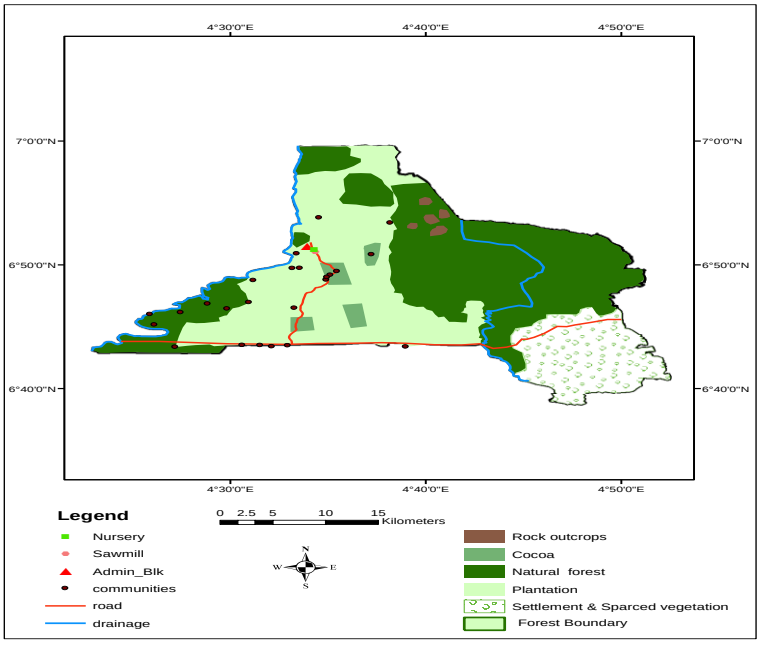

Figure 7: Map of Oluwa Forest Reserve

Discussion

Information on Staff

The information obtained on the management staff of Oluwa forest reserve shows that there are only three professional, one technical and six uniform staff assigned for the management of the reserve. This was attributed to lack of funding. This confirms the argument by Usman and Adefalu (2010) that one of the problems facing biodiversity conservation in Nigeria is inadequate funding of institutions, programmes and other conservation activities. These ten permanent staff's duties included the management of the plantation, nursery, natural forest and sawmill, all of which are located within the reserve. This number is grossly inadequate for the effective management of the forest reserve. This further buttressed the point raised by Usman and Adefalu (2010) and Ahmed and Oruonye (2017) that the country lacks the political will to employ and engage well-trained foresters, forest biologists and other conservation experts capable of successfully managing the country's forest and wildlife resources. USAID (2008) stated that the problem is severe in areas protected by state governments, as seen in the case of Oluwa forest reserve. The information on staff is very useful in the effective management of the reserve, because knowing what is on ground helps in making planning towards achieving better results in the future. Having such information can help in raising the awareness on the need to employ more trained and qualified staff in achieving the sustainable management of the reserve.

Information on Communities within the Reserve

Communities within Oluwa forest reserve are major stakeholders to be considered when taking any policy decision about the reserve. This is because to achieve a conservation level for sustained production of goods and services, the rural communities should actively participate in the control, management and utilization of forest resources in the reserves (Jallah *et al.* 2017; Wambugu *et al*. 2017; Kurniawan 2018; Sukardi *et al*. 2019). This can only be based on full understanding of the need for conservation and the negative impact of environmental degradation. A mutual dialogue between the people and the Government is the main instrument by which common interest can be accommodated on public land (Nurrochmat, *et al*. 2019). Such information will include their location, population and other attributes. Information on gender distribution is also vital, if community participatory forest management approach is considered.

GIS Map and database

The result from the map production shows the flexibility of GIS in producing different types of maps of interest. GIS makes it possible to produce different types of maps from a single database. Maps that were produced from the database developed included the maps of plantation, community, natural forest, water body, road network, *etc*. The implication of this is that maps can be generated for different uses. In addition, the database can also be used to produce updated maps. With GIS, the forest cover maps can be easily updated on a constant basis thereby providing forest managers with an important tool which can be used for decision and planning purposes (Bikuvienė and Tiškutė-Memgaudienė, 2016). Moreover, the efficient data storage and displaying facilities provided in GIS, as well as its powerful analytical power, are necessary in solving modern forest management problems (Ruben and Juan, 2018).

Conclusion

This study produced a comprehensive database of Oluwa forest reserve, which can be used for the purpose of planning and policy making for sustainable forest management. The flexibility of the database in producing different types of map is an added advantage, especially for planning, that requires a wide range of data. Research work should be intensified in collecting relevant data that borders on the management of other forest reserves in Nigeria so as to develop a solid database which will serve as a basis for present and future planning and policy formulation. This is very necessary in achieving sustainable management. More so, forest manager should take advantage of GIS technology to collect, store, analyze

and present relevant information on the management of the forest reserves.

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