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Group photograph of Conference Participants at the opening ceremony

Environmental Management Conference 2011

Opening Address by the Vice- Chancellor, Prof. Oluwafemi Olaiya Balogun

It is my pleasure to welcome everyone to the University of Agriculture, Abeokuta, on this occasion of the first Environmental Management Conference to be organised by the College of Environmental Resources Management of the University.

Globally, the issue of the environment is no doubt a very serious one, and Nigeria is no exception. The reports of recent flooding in Lagos, Abeokuta and Ibadan due largely to reclamation of coastal areas, solid waste dump into water channels, lack of canals, and faulty urban planning, to mention a few, are still fresh in our memories. Also noteworthy are problems of industrial and domestic pollution of surface and groundwater, land degradation, loss of biodiversity, air and noise pollution, which are all very prominent in our environment.

Here in UNAAB, we realised quite early the need to study and assess the environment in all its ramifications. That is why UNAAB is the first University in Nigeria, right from inception, to have a College of Environmental Resources Management, where we consider issues relating to the environment, through the establishment of the Departments of Aquaculture and Fisheries Management, Forestry and Wildlife Management, Environmental Management and Toxicology and Water Resources Management and Agricultural Meteorology. It is therefore in order that the University is the host to the first edition of the Environmental Management Conference.
I have been informed that this conference is being co-sponsored by the Africa Geosciences Review, an International Journal of repute. Prof. Cornelius Kogbe, its founding Editor-in-Chief, is heartily welcome to UNAAB.

As scientists gather in this university in the next two to three days to present scholarly papers and reflect on the theme: 'Environmental Management in Coastal and Wetland Areas of Nigeria', I enjoin you to be proactive in your considerations as you formulate implementable environmental management policies. I wish you a very fruitful deliberation.

Finally, I want to seize this opportunity to urge you to take time out to look round our beautiful campus and visit Abeokuta city, taking cognisance of its historical sites like the popular Olumo rock and the traditional 'Adire' textile market at Itoku.

Thank you very much.

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VOLUME 2

CLIMATE CHANGE, HUMAN RESPONSES AND ADAPTATION

Impact of Climate Change on Groundwater Resources: An Example from Cross River State, Southeastern Nigeria

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Abstract

This paper presents least square equations for predicting some groundwater physical properties (static water level, total dissolved solids, groundwater temperature) in Cross River State, based on some climatic parameters (rain amount, air temperature). This was to assess the impact of future climate variability on the quantity and quality of groundwater in the study area. The results showed that irrespective of the geologic units and seasons, the static water level (SWL), groundwater temperature (GWT), pH and dissolved oxygen (DO) were in stable state conditions based on low standard deviation (SD) values. Secondly, in all the locations occupied, the amount of rainfall (RA) and air temperature (AT) showed significant correlations with SWL, GWT, pH, electrical conductivity (EC) and total dissolved solids (TDS). Predictive equations using climatic change indicators (RA, AT) and groundwater physical properties (SWL, GWT, TDS) were developed and used as a tool for monitoring the change in groundwater quantity and quality due to climate change. The fluctuations observed in groundwater properties (SWL, GWT) for the study period are attributed to the amount of rainfall and air temperature. The variation in TDS is due more to the influence of seawater and brine intrusion. The effect of geology was more or less insignificant. Hence generally, irrespective of the geology, with known amount of precipitation and air temperature, future changes in SWL, TDS and GWT can be predicted at least for limited management and environmental decisions in the study area.

Keywords Climatic change, temperature, rainfall, static water level, total dissolved solids

Introduction

The economic and social development of any community is influenced by the availability of good quantity and quality of water resources and its seasonal variability for drinking, domestic and agricultural purposes. The most noticeable impacts are generally related to alternation of wet and dry seasons. Several studies have shown that there is a strong relationship between atmospheric processes and the depth to water table and water quality. In Nigeria, studies have shown that the air temperature trend since 1901 shows increasing pattern. The mean air temperature in Nigeria between 1901 and 2005 was 26.6 ^{o}C while the temperature increase for

105 years was 1.1 ^{0}C. This is higher than the global mean temperature increase of 0.74 ^{0}C (Akpodiogaga-a & Odjugo, 2010; Spore 2008; IPCC, 2007). Also, rainfall trend in Nigeria between 1901 and 2005 shows general decline. According to Akpodiogaga-a & Odjugo (2010), within the period (1901-2005), rainfall amount in Nigeria dropped by 81 mm. Moreover, Odjugo (2005, 2007) also observed that the number of rainy days dropped by 53% in northeastern Nigeria and 14% in the Niger Delta coastal areas. Besides the short dry season, August Break is being experienced more in July as against it's normal occurrence in the month of August prior to the 1970s. This was attributed to major disruptions in climate patterns in Nigeria showing evidences of climatic change (Akpodiogaga-a & Odjugo, 2010).

One of the greatest impacts of climatic change is the alteration of hydrological cycle ranging from evaporation through precipitation, runoff and discharge (McGuire et al., 2002). According to Akpodiogaga-a & Odjugo (2010), the global warming and decreasing rainfall produce a minimal recharge of groundwater resources, wells, lakes and rivers in most parts of the world, especially in Africa, thereby creating water crisis. The resulting water crisis will create the tendency for concentrations of users around the limited sources of water. Under such conditions, there is increase possibility of additional contamination of limited resources of water and transmission of water borne diseases.

According to Vadillo (2005), climate change may alter the water quality by four ways: (1) increasing air temperature, (2) alteration of rainfall regime, with its changes in volume and velocity of flows to the aquifers, (3) atmospheric deposition of acid substances with an anthropic origin and (4) increase of CO_2 concentration of the air. Each one of these factors, and theirs interrelation, could vary in a drastic way the quantity and quality of the water resources. The increase of temperature of the air, even without changes of the rainfall, may increase the temperature of the water, and hence, a decrease in the concentration of dissolved O_2 and CO_2 (Gleick, 1987). In case of CO_2, this process could be masked by the increase of its concentration in the atmosphere. The decreasing concentration of O_2 has a direct consequence in the oxidation processes of contaminants. In regions with higher air temperatures, the natural biomass production (organic matter) will be enhanced. In a similar way with contamination episode with organic matter (landfill or sewage system leakage), this "extra" organic matter will need more oxygen to be degraded, so the net result will be less concentration of dissolved oxygen and a lost in the self cleaning capacity of the aquifers. Temperature is a master variable in all the chemical reactions, so any process in the soil will be affected if temperature increases, and this will have an associated change in the concentration of species and ions in water and an alteration of the hydrogen ions concentration (pH) in soil and water. Changes in volume and velocity of flows to the aquifers also have consequences in the quality of the water (Panagoulia and Dimou, 1996).

Stakeholders in Nigeria recently, have noted that climatic change will affect urban and rural water through unpredictable rainfall leading to inadequate recharge of aquifers and surface water, while quality and quantity of water resources will be impaired. As a prelude to management, they suggested the promotion of water reuse and recycling and efficient utilization of grey water (among others), in addition to incorporation of information about

current climate variability into water related management (Omotosho, 2011). Further, the Nigerian Meteorological Agency (NIMET), in its presentation of the 2011 seasonal rainfall prediction, predicted longer and early rainfall compared to 2010 and noted that the above normal rainfall predicted for 2011 would impact positively on the water resources of the various hydrological areas and its water related socio-economic activities (Igbokwe, 2011).

Short term climate variability or climatic fluctuations have been of great interest for a few years (Ropelewski & Jones, 1987; Lau & Shew, 1988; Moura, 1994). The importance lies in the applicability of the variability to agriculture, water resources and other social and economic activities. The present work is to develop statistical methodology to predict the future fluctuation of water quantity and quality of groundwater in Cross River State using available climatic data as input parameters. This is expected to guide the future impact of climate variability in the area, for at least, limited management of the resource.

Overview of Cross River State

Cross River State is very extensive, covering an area of approximately 23, 000 km^2. It has a population of 2.89 million people (2006 Population Census) and spans latitudes 4^o 49'-6^o 56' North and longitudes 7^o 49'-9^o 28 East (Figure 1). The mean annual rainfall varies from more than 3063 mm at Calabar in the south through 2018 mm at Ikom in the central part of the area to less than 1800 mm at Ogoja in the north (Edet et al., 1998). The rainfall patterns consist of alternating wet (April-October) and dry (November-March) periods. Temperatures are relatively high with mean annual temperature in the range of 30.1 ^{0}C at Ogoja to 22.4 ^{0}C at Calabar.

The main physical features of the area include highlands with elevations in excess of 400 m above sea level. These include the Obudu and the Oban massifs (Figure 1). By contrast, the low lands have elevations up to 350 m, decreasing southwards to a few meters near the coast: Cross River Plains and the Calabar Coastal Plains. From geological point of view, the area consists of Precambrian crystalline basement (Obudu plateau and Oban massif) and a sedimentary cover ranging in age from Cretaceous to Tertiary. The basement complexes consist predominantly of gneisses, schists, amphibolites, pegmatites, granites, granodiorites, diorites, tonalities etc. Cross River State is underlain by three sedimentary basins viz: Calabar Flank, Ikom-Mamfe Embayment and southern Benue Trough. The sedimentary Formations consists mostly of conglomerates, sandstones, shale, limestones, marls, clays, sands and silts. The hydrogeology is largely dependent on the lithology of the area. The major hydrogeological units are the crystalline basement; sandstone-siltstone-limestone-intrusive; shale-intrusive; shale; coastal plain sand and alluvium (Edet, 1993; Okereke et al., 1998).

Data Acquisition and Methods

Air temperature (AT), relative humidity (RH) and rainfall amount (RA) data from Calabar Airport, Ikom and Ogoja Meteorological Stations (Figure 1) were used. The stations are managed by the Nigerian Meteorological Agency (NIMET) and the data covered the period of study (January 2009-June 2010). A monitoring network of wells (Figure 2) meant to observe groundwater level and quality fluctuations was set up and implemented in 12 locations spanning different geologic

units within the study area. However, only 4 locations were used in this study due to nearness to the meteorological stations and geologic consideration. The monitored properties included groundwater level (SWL), electrical conductivity (EC), total dissolved solids (TDS), groundwater temperature (GWT), pH, Eh and dissolved oxygen (DO). A water level meter, a Hanna microprocessor EC/TDS meter model HI 8314, Hanna membrane pH meter model HI 8314, and Hanna DO meter model HI 9142, were used to measure the parameters.

Several statistical computations were made in order to determine the possibility of predicting groundwater physical properties (SWL, GWT, EC, TDS, pH, Eh, DO) from climatic properties (RA, AT). All the statistical analyses were made using software called STATISTICA (Pilz, 1993) and excel spread sheet. First a descriptive statistics (maximum, minimum, mean, median, standard deviation) for the climatic and water properties was made for all the locations and on the basis of the different lithologic units. To determine the background/threshold values, the cumulative frequency plots of the variables were made. This is expected to guide any further change in the water properties measured in the area.

To define the strength of the relationships, the correlation coefficient (r) between the climatic and groundwater physical properties was computed. The r measures the strength of relations between variables. A value of r close to ±1 means that the variables are strongly correlated, thus if the value of one variable is known, the value of the other variable can be predicted (Tanco & Kruse, 2001). A value of r that is very close to 0 means that the values are not linearly related. This method provides an estimate of the predictability of seasonal changes in groundwater physical properties. The computation of coefficient of correlation and linear regression are well documented (Wellmer, 1998).
To measure the relationship between the field and predicted data, the difference between the former and the later was computed and the 25% quartile, mean and 75% quartile determined. Using the two quartiles as a criterion, the data was divided into three parts. All the data in the first part correspond to below expected predicted values. The second part is within the expected predicted value and the last part corresponds to above the expected predicted values.

Results and Discussion

Climatic Framework of the Area

Monthly precipitation for the study period varied from 0.0 mm for the three meteorological stations to 611.30 mm at Calabar. The highest rainfall amount was recorded during the wet season. The air temperature ranged between 28.1^{0}C at Calabar in the south and 37.50^{0}C at Ogoja in the north. The relative humidity varied between 53% at Ogoja in the north and 92% at Calabar in the south. A summary of the climatic data for the 3 meteorological stations is presented in Table 2. The average annual precipitation for the period 1990-1995 (Fig. 2) shows that the rainfall amount decreases from Calabar in the south to Ogoja in the north, showing the normal precipitation pattern for the area. However, the reverse is the case for this study due to its short duration (see Table 2). A correlation analysis for the climatic data for the study period (Jan 2009-June 2010) indicates a decrease in amount of precipitation with increase in air

temperature, with correlation coefficient of -0.824, -0.719 and -0.833 for Calabar, Ikom and Ogoja respectively.

For the present work however, consideration is given to data obtained in August, September, October, December 2009 and February, March 2010. The air temperature and rain amount distribution for this period is presented in Figure 3. The climatic data showed that the temperature increased gradually from August 2009 (wet season), reaching a maximum in January 2010 (dry season) before decreasing again. The reverse was the case for the precipitation. The data showed that the temperature is fairly constant with standard deviation (SD) of 2.10 while the amount of precipitation is highly variable (SD = 205.74).

Threshold Values for Groundwater Properties

Cumulative frequency plots of constituents are useful to discriminate between background and affected values by certain factors such as seawater and anthropogenic contamination (Park et al., 2005; Lee and Song 2007). The physical properties of groundwater in the area generally showed abrupt increasing trends (Figure 5). The average of the lower and upper values at the point of break is considered as the threshold value for the parameter. Among the properties, some of them showed increasing value without any break. The threshold values are 3.94 m, 29.01^{o}C, 248.60µS/cm, 99.20ppm, 5.90, 99.77mV and 2.40mg/l for SWL, GWT, EC, TDS, pH, Eh and DO respectively.

Physical Properties of groundwater

Groundwater temperature

Figure 5 shows that throughout the study period, there was little variation in both air and water temperatures. The air temperature for the period under consideration varied between 28.10 ^{0}C at Calabar in the south to 36.0 ^{0}C at Ogoja in the north. The groundwater temperature varied from 27.8 ^{0}C at Ugep in the central part of the study area to 30.9 ^{0}C at Okpoma in the north near Ogoja. The maximum air temperature fluctuation is 7.9 ^{0}C, while for groundwater, the variation is 3.1^{0}C indicating lower fluctuations. The mean groundwater temperatures for the different monitored wells varied between 28.71 ^{0}C at Uyanga and 29.36 ^{0}C at Anantigha (Table 3) with higher values in the dry season (Table 4). The average air temperature (31.87±2.11^{o}C) is very close to the average groundwater temperature (29.21±0.75 ^{o}C). Such a similarity shows that the groundwater temperature is a reflection of the air temperature (Kazemi, 2004). For the entire study, the air and water temperatures were positively correlated with correlation coefficient of 0.442. The difference between these averages may be attributed to (i) the air temperature were not measured by the authors, and hence, there was no quality control and (ii) the meteorological stations were not very close to the groundwater monitoring wells (Figure 1).

Static water level

The SWL with respect to the ground surface for the chosen monitored wells, varied from 1.30 m at Okpoma in the wet season to a maximum of 5.85 m at the same location in the dry season (Table 4). The difference between the SWL for the dry and wet seasons were 1.37 m (Anantigha), 2.35 m (Uyanga), 1.75 m (Ugep), 0.75 m (Obubra) and 4.55 m (Okpoma). The

standard deviations for the sampled periods were 0.46, 0.91, 0.66, 0.29 and 1.92 respectively for the same locations, indicating low variability between different sample periods irrespective of the lithologic units.

Electrical conductivity (EC) and Total Dissolved Solids (TDS)

The EC for the groundwater samples varied between 53.8 and 872 µS/cm (mean 161.50±153.60 µS/cm) with higher value for the dry season relative to the wet season. The mean values for the different monitored locations varied from 89.06 µS/cm at Ugep in the central area to 314.04 µS/cm at Anantigha in the south. The high value at Anantigha is attributed to the influence of sea water. The TDS followed the same trend as the EC with mean values in the range of 44.47 ppm (Ugep) to 157.59 ppm (Anantigha). The correlation of EC and TDS was statistically significant at 95% confidence limit.

Hydrogen ion (pH) and redox potential (Eh)

The pH values ranged from 4.71 to 7.57 (mean 5.99±0.57), indicating insignificant variations throughout the entire period of study. The median value is 6.07. This may represent the dominant effect of humic acid from decomposing vegetation. The mean values for the different monitored wells ranged between 5.32 and 6.49 (Table 4). Seasonally, the pH values were higher in the dry season relative to the wet season

The Eh values ranged from 11–149 mV. The Eh values and characteristics showed inverse relationships compared to the pH. Lower values of Eh were recorded in the dry season and higher values in the wet season. According to Scheytt (1977), the redox potential is a potential that is caused by various redox reactions in groundwater. High Eh in wet season is attributed to the fact that infiltration water has a higher potential and more oxygen is dissolved in groundwater hence oxidation processes prevail leading to an increase of Eh in groundwater.

Dissolved Oxygen Contents (DO)

The oxygen content varied from 2.10 to 3.60 mg/l (Table 4) with higher values in the dry season (Tables 4). The oxygen contents results from oxygen usage and supply. The oxidation of organic substances and reduced inorganic substances leads to lower oxygen content in groundwater. A high content of oxygen infiltration water enriches the groundwater with oxygen (Matthess, 1994). Because most of the groundwater recharge takes place in the wet season and because the solubility of oxygen in warm water is lower than in cold water, higher contents of oxygen are measured in wet season (Scheyett, 1997; Joshi & Kocthyari, 2003). In this work, the reverse was obtained. This is attributed to high rate of reactions as noted in the Eh values (Edet & Worden, 2009).

Relationship between Lithology and Physical Properties of Groundwater

The SWL, GWT, pH, Eh and DO showed low variability for all the locations underlain by different lithologic units and all seasons based on low standard deviation values (Table 3). This indicates steady state conditions. The EC, TDS and Eh showed high variability for the different locations considering the different sample periods. The variation in EC and TDS is attributed to seawater influence during different seasons and tidal periods at Anantigha (Edet & Worden, 2009) and

brines at Okpoma (Tijani et al., 1996; Uma, 1998). The differences in SWL, oxygen supply and reaction rates are responsible for the variation in Eh.

Correlation between Climatic Parameters and Groundwater Properties

The correlation matrix for the different variables for different geologic locations is shown in Table 5. The data illustrate that for all the locations, correlation between RA and AT is statistically significant at 95% confidence level with r in the range -0.784 to -0.817. The correlation between RA and SWL was statistically high for three locations (Anantigha, Uyanga and Ugep) with r varying between -0.620 and -0.680. For the Okpoma location, the r was -0.399. The low r value is attributed to the fact that in the dry season, the monitored well was almost dry. The correlation between RA and GWT; EC and TDS were not statistically significant for all the locations. The AT was statistically highly correlated with SWL and GWT in all the locations. The correlation of AT and GWT was not significant at Okpoma. The correlation between AT with EC and TDS was statistically significantly correlated only at Ugep and Okpoma. Rain amount (RA) was correlated with pH (Anantigha, Okpoma) and AT correlated with pH (Ugep, Okpoma), Eh and DO (Okpoma). The variability in correlation is attributed mainly to the fact that the meteorological stations are not very close to the monitored wells as stated earlier (Fig 1).

Development of Predictive Least Square Equations

In developing predictive equation, least square equations in the form $y = mx + c$ (where y is the required groundwater property; x the input climatic parameter; m slope relating the groundwater property and the climatic parameter; c the intercept on the groundwater property or climate parameter of a line relating the two parameters) for the physical properties of groundwater from climatic parameters, three parameters were used as follows: static water level (SWL) based on statistically significant high positive correlation with rain amount (RA) and air temperature (AT); total Dissolved Solids (TDS) due to high variability at different geologic locations and seasons; and groundwater temperature (GWT) as an indicator of slight changes in climatic parameters

The predictive least square equations alongside the coefficients of variability and correlation are presented in Table 6. Using the prediction equations, the fluctuations in SWL, TDS and GWT were estimated for the different locations. Figure 7 shows the predicted and observed values for SWL, TDS and GWT fluctuations with RA and AT. A classification of the difference between the observed and predicted values (Fig. 8) showed that, based on a scheme (Table 7), at least 50% of the data generated was within expected predicted value. The difference between observed and predicted values showed high variability in respect of TDS compared to SWL and GWT (Table 8).

Conclusion

A simple model based on the least square equation was developed to predict the variations in static water level (SWL), total dissolved solids (TDS) and groundwater temperature (GWT) due to the variability of some climatic parameters. First, the correlation between the rain amount

(RA) and air temperature (AT) were established. The highest statistically significant correlation were found to be between the climatic parameters (RA, AT) and SWL, GWT and TDS.

The climatic parameters (RA, AT) were then used to estimate the variation of SWL, GWT and TDS. Good results were achieved when estimating SWL and GWT, but high variability was observed in the case of TDS.

In order to improve the ability of the equation as a better predictive tool, some other climatic parameters, such as relative humidity, evapotranspiration are recommended for inclusion, in addition to the fact that the meteorological stations should be as close as possible to the monitored wells.

Finally, the effect of geology was more or less insignificant. Hence, generally, irrespective of the geology, with known amount of precipitation and air temperature, future changes in SWL, TDS and GWT can be predicted at least for limited management and environmental decisions.

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Table 1**:** Location of monitored wells and meteorological stations including geological setting of Cross River State

Age	Basin	Formation	Hydrogeologic unit[a]	Location	Coordinates N	Coordinates E	Lithology	Remarks
Quaternary-Pliocene	Niger Delta	Benin	Coastal Plain Sands	Anantigha	4°55.088	8°18.945	Sand, clay	Monitored well
				Calabar Airport	4°58.433	8°21.067		Meteorological station
Campanian-Turonian	SE Benue Trough	Nkporo Shale	Shale					
Coniancian-Turonian	and	Amaseri Sandstone	Sandstone-Shale-intrusive	Ugep	5°47.750	8°04.447	Sandstone	Monitored well
Turonian-Cenomanian	Ikom-Mamfe Embayment	Ezillo Formation	Shale-Sandstone-Intrusives	Okpoma	6°35.971	8°38.486	Shale, basic intrusive	Monitored well
				Ogoja	6°38.699	8°46.661		Meteorological station
Cenomanian-Albian		Mamfe	Sandstone, arkosic, conglomeritic	Ikom	5°56.395	8°42.603		Meteorological station
Precambrian	Basement Complex	Oban massif	Basement	Uyanga	5°22.994	8°15.657	Granodiorite	Monitored well

[a]Edet (1993)

Table 2: Summary of climatic data for the study period from three meteorological stations at Calabar, Ikom and Ogoja

Year	Month	Location								
		AT °C			RA mm			RH %		
		Calabar	Ikom	Ogoja	Calabar	Ikom	Ogoja	Calabar	Ikom	Ogoja
	Aug	28.1	29.7	31.4	507.3	558.1	349.1	92.0	89.0	87.0
2009	Sept	29.7	30.2	31.5	273.9	283.3	336.9	89.0	87.0	85.0
	Oct	30.0	31.1	31.8	148.1	294.8	398.3	87.0	85.0	83.0
	Dec	33.0	33.7	35.9	0.0	0.0	0.0	84.0	78.0	76.0
	Feb	33.1	35.9	36.0	88.2	20.2	11.8	85.0	75.0	60.0
2010	Apr	33.1	34.9	34.4	130.4	166.0	411.6	83.0	77.0	75.0
	Jun	29.8	31.2	31.9	611.3	595.8	434.6	88.0	85.0	83.0
	Mean	30.97	32.39	33.27	251.31	274.03	277.47	86.86	82.29	78.43
	Median	30.00	31.20	31.90	148.10	283.30	349.10	87.00	85.00	83.00
Statistics	Min	28.10	29.70	31.40	0.00	0.00	0.00	83.00	75.00	60.00
	Max	33.10	35.90	36.00	611.30	595.80	434.60	92.00	89.00	87.00
	SD	2.06	2.43	2.09	227.55	236.62	188.64	3.13	5.50	9.27

Rain amount (RA), air temperature (AT) and relative humidity.

Table 3: Descriptive of groundwater physical properties

Area	Location	Geology	Statistics	SWL m	GWT °C	EC µS/cm	TDS ppm	pH	Eh mV	DO mg/l
			Mean	4.026	29.357	314.043	157.586	5.316	112.429	3.043
		Benin Formation	Med	4.150	29.400	221.500	110.800	5.320	107.000	3.000
	Anantigha	Niger Delta	Min	3.230	28.700	205.100	102.600	4.710	77.000	2.600
		Gravel, sand, silt, clay	Max	4.600	30.800	872.000	440.000	5.920	149.000	3.600
South			SD	0.461	0.766	246.543	124.781	0.424	28.401	0.341
			Mean	3.479	28.914	110.369	55.243	6.126	87.857	2.900
		Oban massif	Med	3.200	28.700	97.780	48.900	6.160	103.000	3.000
	Uyanga	Precambrian Basement	Min	2.300	28.200	81.400	40.600	5.180	48.000	2.300
		Granite, granodiorite, gneiss	Max	4.650	29.700	213.000	106.500	6.660	135.000	3.200
		schist	SD	0.508	45.815	22.896	0.460	31.793	0.327	2.700
			Mean	3.214	28.714	89.057	44.471	5.851	97.857	2.743
		Amaseri Sandstone	Med	2.950	28.600	98.300	49.100	5.680	118.000	2.800
Central	Ugep	Ikom-Mamfe Embayment	Min	2.300	27.800	53.800	26.800	5.600	66.000	2.100
		Sandstone, shale, intrusives	Max	4.050	29.500	111.200	55.600	6.200	121.000	3.200
			SD	0.664	0.593	21.772	10.947	0.258	27.052	0.450
			Mean	3.143	29.243	188.343	94.186	6.493	74.571	2.907
		Southern Benue Trough	Med	2.250	28.800	91.400	45.700	6.170	78.000	2.900
North	Okpoma	Nkporo Shale	Min	1.300	28.100	70.800	35.400	5.940	11.000	2.600
		Shale, intrusives	Max	5.850	30.900	507.000	254.000	7.570	110.000	3.300
			SD	1.917	0.983	171.315	85.731	0.595	36.864	0.259

Rain amount (RA), air temperature (AT), static water level (SWL), groundwater temperature (GWT), electrical conductivity (EC), total dissolved solids (TDS), pH, redox potential (Eh) and dissolved oxygen (DO).

Table 4**:** Seasonal variation of climatic parameters and physical properties of groundwater

Season	Statistics	RA mm	AT °C	SWL m	GWT °C	EC µS/cm	TDS ppm	pH	Eh mV	DO mg/l
	Mean	20.03	34.23	4.34	29.39	166.11	83.19	6.10	86.50	2.96
	Median	5.90	33.70	4.28	29.60	102.85	51.70	6.08	91.50	3.05
Dry	Min	0.00	33.00	3.15	27.80	53.80	26.80	4.91	11.00	2.30
	Max	88.20	36.00	5.80	30.80	507.00	254.00	7.57	143.00	3.60
	SD	34.40	1.36	0.77	1.02	133.31	66.74	0.77	37.54	0.43
	Mean	366.63	31.25	3.50	29.13	159.66	79.94	5.95	94.08	2.88
	Median	349.10	31.20	3.23	29.20	100.80	50.40	5.94	103.00	2.90
Wet	Min	130.40	28.10	1.30	28.20	62.40	31.00	4.71	45.00	2.10
	Max	611.30	34.90	5.85	30.90	872.00	440.00	6.71	149.00	3.30
	SD	156.34	1.83	1.21	0.63	163.55	82.49	0.48	28.54	0.29

Explanations as in Table 3

Table 5: Correlation matrix between climatic parameters and groundwater properties for the different monitored locations

		RA	AT	SWL	GWT	EC	TDS	pH	Eh	DO
	RA	1.000								
	AT	-0.784	1.000							
	SWL	-0.664	0.865	1.000						
	GWT	-0.237	0.528	0.426	1.000					
Ananthiga	EC	-0.274	0.471	0.575	0.168	1.000				
	TDS	-0.273	0.471	0.574	0.169	1.000	1.000			
	pH	0.674	-0.242	-0.236	-0.022	0.169	0.169	1.000		
	Eh	-0.439	-0.012	0.003	-0.257	-0.258	-0.259	-0.934	1.000	
	DO	-0.084	-0.034	-0.311	0.570	-0.088	-0.087	-0.191	0.070	1.000
	RA	1.000								
	AT	-0.784	1.000							
	SWL	-0.620	0.953	1.000						
	GWT	-0.547	0.497	0.572	1.000					
Uyanga	EC	0.097	-0.363	-0.363	0.330	1.000				
	TDS	0.095	-0.361	-0.361	0.334	1.000	1.000			
	pH	-0.007	0.382	0.475	-0.186	-0.934	-0.934	1.000		
	Eh	-0.053	-0.483	-0.664	-0.047	0.698	0.697	-0.880	1.000	
	DO	0.229	-0.057	-0.137	-0.593	-0.234	-0.240	0.207	-0.053	1.000
	RA	1.000								
	AT	-0.787	1.000							
	SWL	-0.680	0.938	1.000						
	GWT	0.057	0.199	0.315	1.000					
Ugep	EC	0.635	-0.841	-0.833	-0.652	1.000				
	TDS	0.634	-0.841	-0.833	-0.652	1.000	1.000			
	pH	-0.028	0.602	0.561	0.419	-0.612	-0.613	1.000		
	Eh	0.056	-0.626	-0.559	-0.369	0.592	0.593	-0.993	1.000	
	DO	-0.146	0.154	0.374	-0.271	0.021	0.020	-0.069	0.120	1.000
	RA	1.000								
	AT	-0.817	1.000							
	SWL	-0.399	0.795	1.000						
	GWT	0.221	-0.135	0.049	1.000					
Okpoma	EC	-0.519	0.789	0.946	0.183	1.000				
	TDS	-0.520	0.789	0.945	0.184	1.000	1.000			
	pH	-0.793	0.946	0.839	0.080	0.911	0.911	1.000		
	Eh	0.452	-0.765	-0.872	-0.410	-0.937	-0.937	-0.883	1.000	
	DO	-0.852	0.588	0.232	-0.018	0.396	0.399	0.652	-0.318	1.000

Explanations as in Table 3

Table 6: Predictive least square equations for groundwater physical properties

Location	y	m	x	c	r^2	r
Anantigha	SWL	-0.001	RA	3.894	0.423	0.650
	GWT	-0.003		30.065	0.482	0.694
	TDS	-0.060		109.260	0.587	0.766
	SWL	0.148	AT	-0.927	0.842	0.918
	GWT	0.399		16.958	0.684	0.827
	TDS	37.007		-1005.100	0.799	0.894
Uyanga	SWL	0.014	RA	2.831	0.795	0.892
	GWT	-0.002		29.729	0.885	0.941
	TDS	0.097		39.981	0.787	0.887
	SWL	0.740	AT	-18.647	0.576	0.759
	GWT	0.195		22.845	0.581	0.762
	TDS	23.398		-630.910	0.662	0.814
Ugep	SWL	-0.003	RA	3.824	0.422	0.650
	GWT	-0.003		30.419	0.435	0.659
	TDS	-0.633		404.730	0.508	0.713
	SWL	0.663	AT	-18.259	0.587	0.766
	GWT	0.438		15.469	0.737	0.858
	TDS	66.862		-1985.400	0.700	0.837
Okpoma	SWL	-0.009	RA	5.601	0.726	0.852
	GWT	-0.004		30.487	0.781	0.883
	TDS	-0.455		242.720	0.718	0.847
	SWL	0.434	AT	-9.879	0.519	0.721
	GWT	0.313		19.462	0.678	0.823
	TDS	26.623		-702.300	0.538	0.733

Table 7: Evaluation scale for the predicted values

SWL	TDS	GWT	Remarks
< -0.34	< -7.6	< -0.66	Below expected
- 0.34 to 0.49	- 7.60 to 5.33	- 0.66 to 0.22	Expected
> 0.49	> 5.33	> 0.22	Above expected

Table 8: Descriptive statistics for the difference between observed and predicted values of SWL, TDS and GWT

Statistics	ΔSWL	ΔTDS	ΔGWT
Mean	0.141	2.051	-0.370
Median	0.040	-0.519	-0.299
Minimum	-1.606	-146.570	-4.400
Maximum	3.247	166.841	2.204
Lower Quartile	-0.335	-7.603	-0.660
Upper Quartile	0.448	5.330	0.220
Range	0.783	12.934	0.879
Std.Dev.	0.767	41.300	1.282

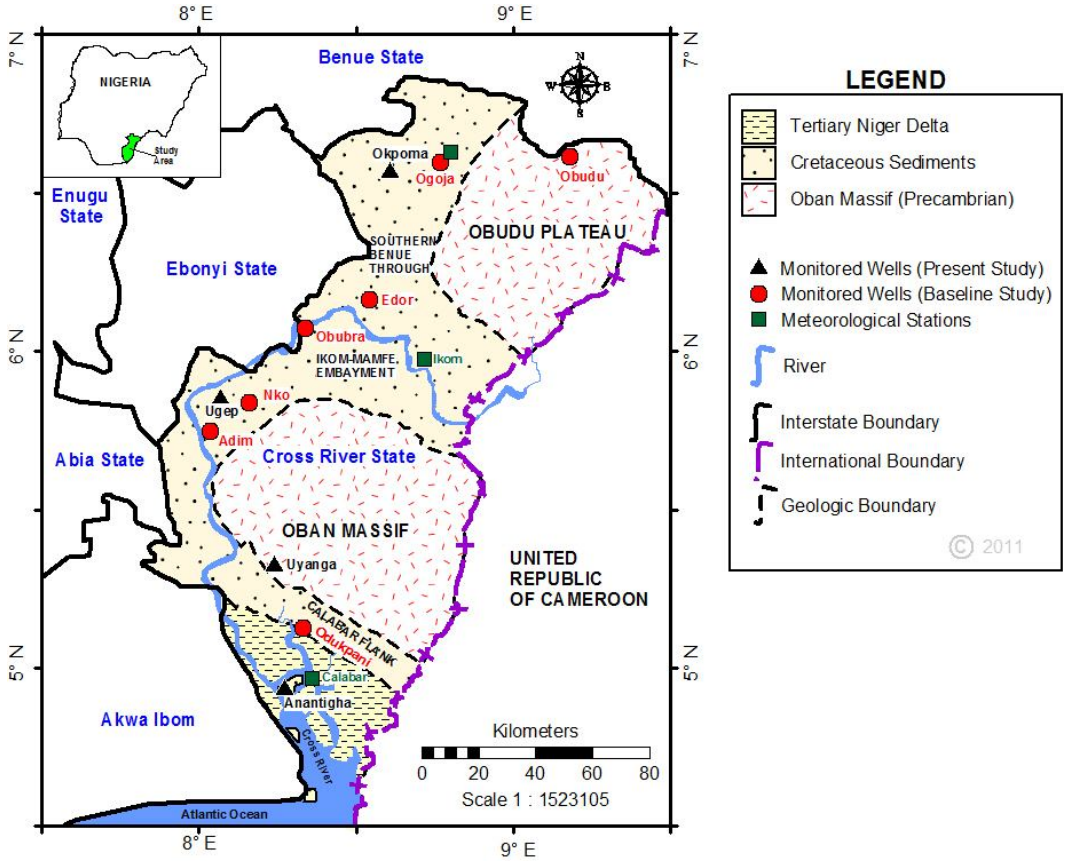


Fig. 1**:** Location of Monitored wells and Meteorological stations

Fig. 2: Typical monitored well at Ugep

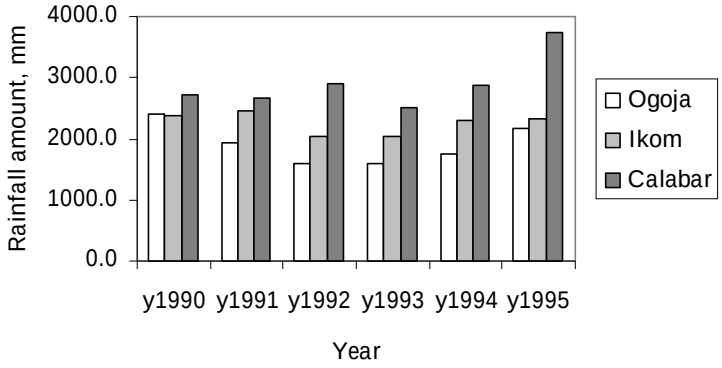


Fig. 3: Average annual rainfall for Calabar, Ikom and Ogoja for the year 1990-1995.

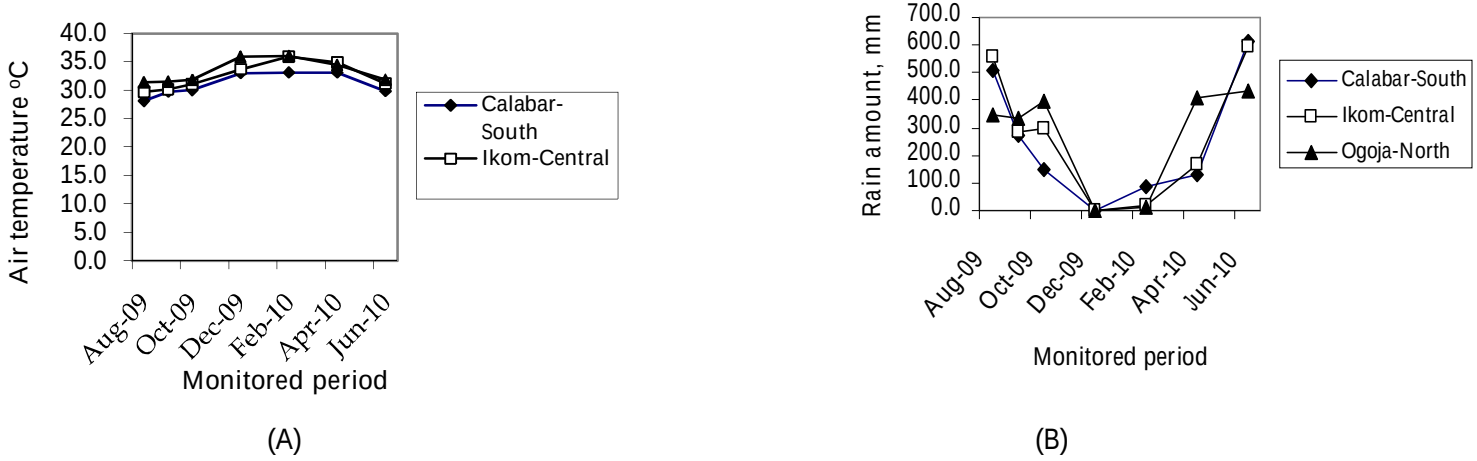


Fig. 4: Variation of air temperature and rainfall amount for the study period

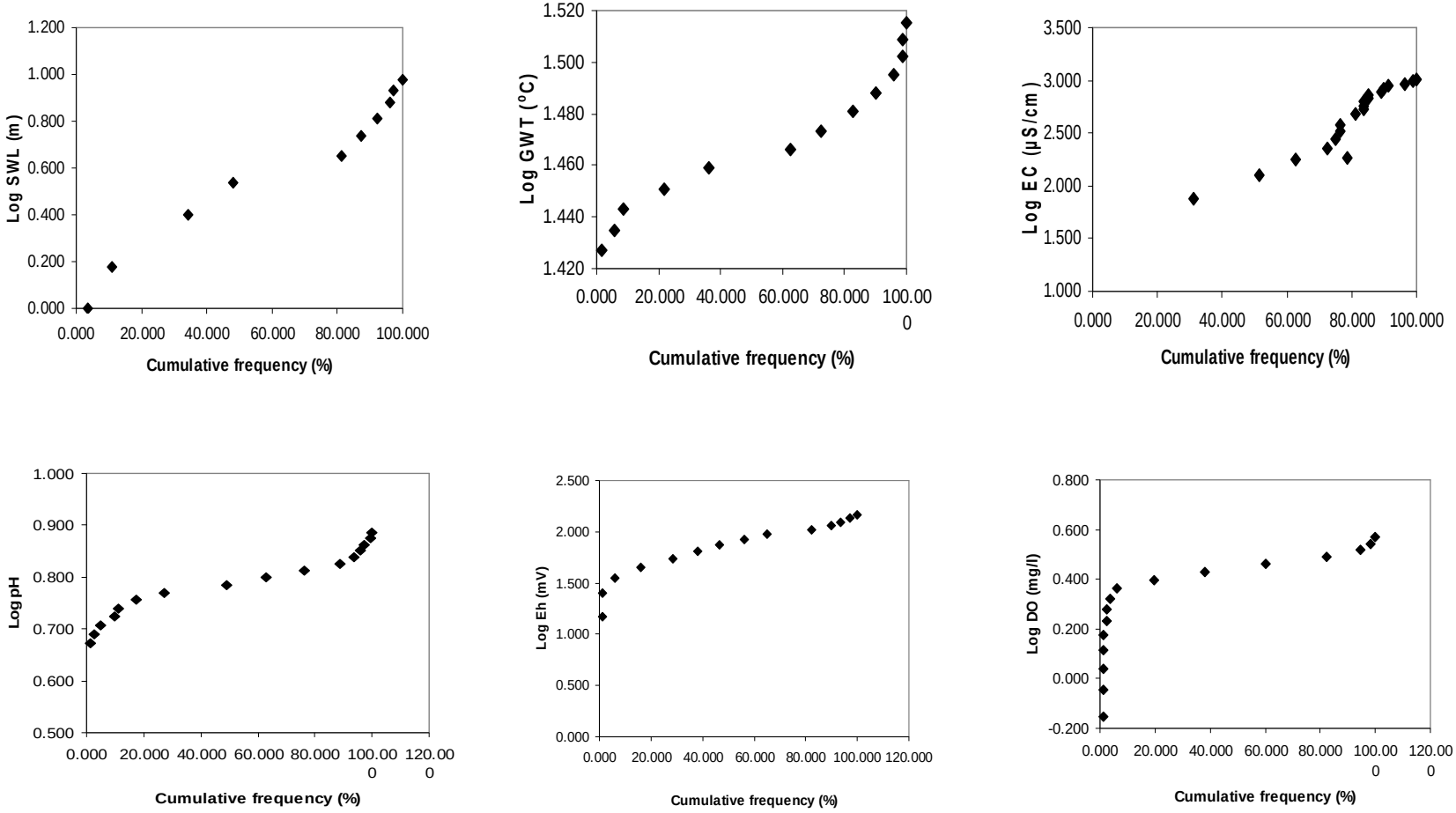


Fig. 5: Cumulative frequency plots for some physical parameters of groundwater.

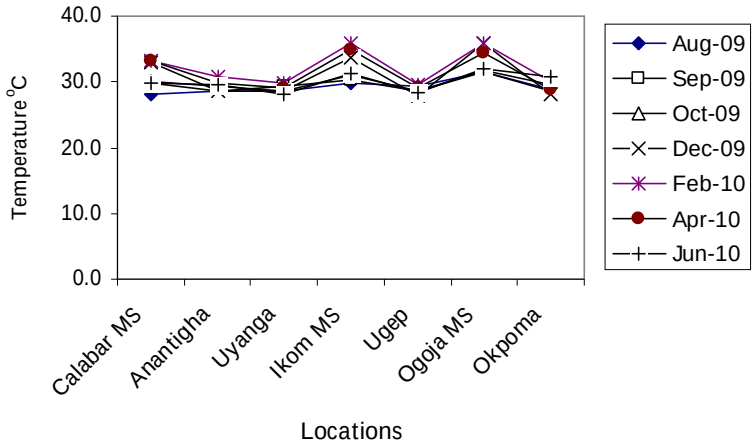
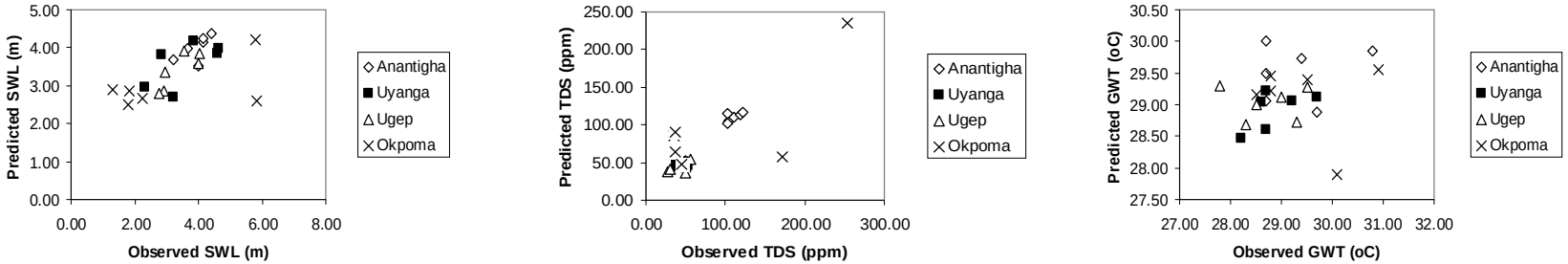
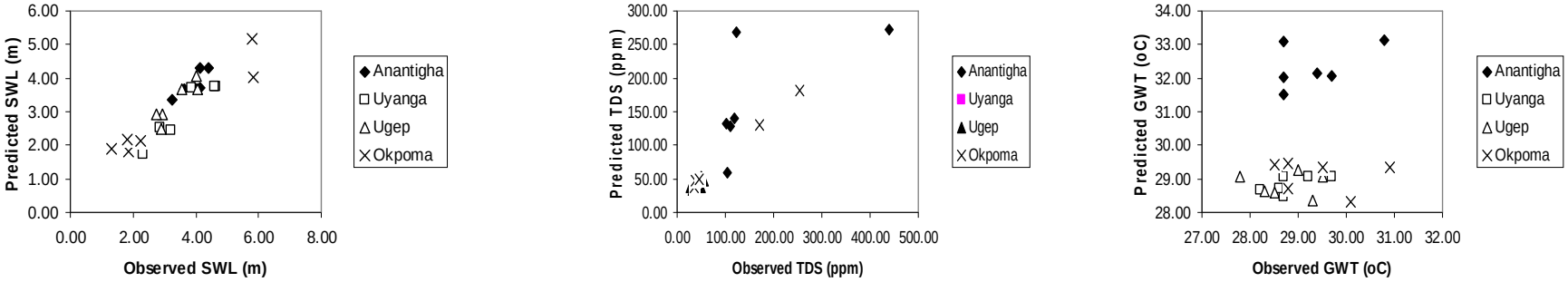


Fig. 6: Comparison of air and groundwater temperatures (MS-Meteorological stations)



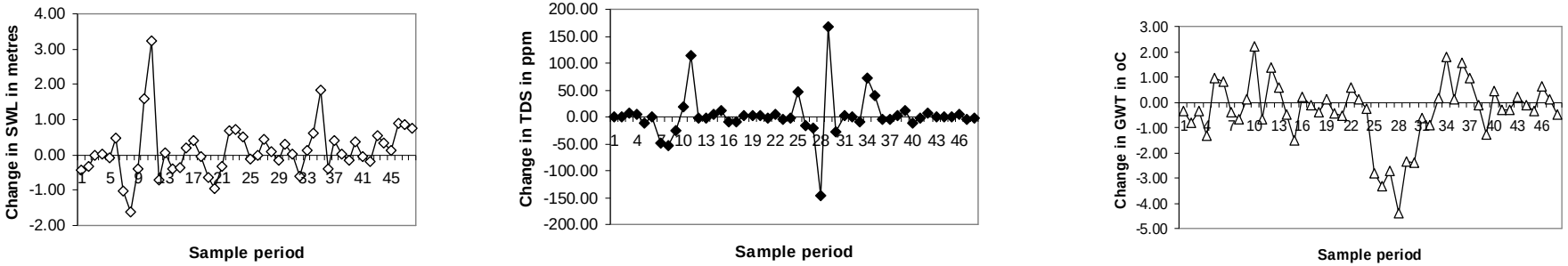
(A) (B) (C)

Fig. 7a: The Plot of observed and predicted values for (A) static water levels (B) TDS and (C) Groundwater temperature, GWT for the different sample periods based on correlation with rain amount. The sample periods were August, September, October, December 2009 and February, March 2010.



(A) (B) (C)

Fig 7b: The Plot of observed and predicted values for (A) static water levels (B) TDS and (C) Groundwater temperature, GWT for the different sample periods based on correlation with air temperature. The sample periods were August, September, October, December 2009 and February, March 2010.



(A) (B) (C)

Fig. 8: Computed differences between the observed and predicted values of groundwater properties for (A) Static water level (B) Total dissolved solids and (C) Groundwater temperature

Indigenous Efforts by African Farmers in Ensuring Sustainability in Agricultural Productivity in the Face of Changing Climate

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Abstract

The study focused on the impact of climate change on African agriculture and how farmers around Africa have been coping through various indigenous mitigation and adaptation measures they adopt in ensuring sustainability in agricultural productivity. Indigenous methods such as traditional irrigation system, water harvesting and storage methods, soil moisture storage techniques, traditional soil protection techniques such as digging compost-filled planting pits which hold water, helping deep-rooted vegetables grow; building up grass and rock barriers around crops to protect them from soil erosion; and cultivating manure in septic tanks to use as fertilizer, intercropping trees with food crops and so on have responded well in the past to changing climatic conditions. The success of any mitigation cum adaptation strategies would rely not only on the traditional small-scale farming techniques; therefore there is urgent need to revive more traditional farming practices and combine them with modern scientific discoveries to help mitigate and adapt to climate changes.

Keywords: Mitigation, Adaptation, Indigenous, Climate change, Agriculture, Farmers, Africa

Introduction

Climate change is one of the most serious environmental threat to human beings as it adversely affect agricultural productivity (Zlervogel, 2006). The impact of climate change is global but the impact is mainly felt by the developing countries most especially Africa due to their low level of coping capabilities (Nwafor, 2007 and Jagtap, 2007). Jones and Thornton, (2002) projected that crop yield in Africa may fall by 10-20% by 2050 or even up to 50% due to climate change because African agriculture is predominantly rain-fed and hence depend solely on weather. The elements of climatic change that affects agricultural productivity includes prolonged drought, thunderstorms, flooding of crops fields, erosion of fertile soil, land slides and falling of tender crops by wind (Magadza, 2000). IPCC (2007) reported that there have been noticeable impacts of climate change on plant production, insect, disease and weed dynamics. Moreover, rising atmospheric CO_2 concentration, higher temperatures, changes in annual and seasonal

precipitation patterns and the frequency of extreme events are the usual features of climate change phenomenon (Brussel 2009). Mark et al. (2008) observed that seasonal changes in rainfall and temperature, which are features of climate change could impact agro-climatic conditions, altering growing seasons, planting and harvesting calendars, water availability, pest, weed and disease populations; these characteristics will affect the volume, quality, quantity, stability of food production and the natural environment in which agriculture takes place. Khanal (2009) also noted that heat stress might affect the whole physiological development, maturation and finally reduce the yield of cultivated crop.

Studies show that climate change will have positive effects on livestock productivity because Livestock are sensitive to temperature, the combination of high temperature and high humidity cause greater stress and discomfort in livestock, and thus a larger loss in productivity. Changes in climate are expected to have significant impacts on ecosystem function (Backlund et al. 2008). Equally, changes in land use and management associated with agriculture are also likely to affect the ecosystem services associated with agricultural lands, such as the regulation of water quantity and quality and the global carbon cycle and conservation of biodiversity. Warmer climate with elevated CO_2 levels would increase pest and disease pressure and thus result in greater use of pesticides (Hatfield et al. 2008). Increased use of pesticides would be expected to have adverse effects on ecosystem services such as water quality, pollination and biodiversity. This study therefore looked into the various indigenous adaptation efforts by African farmers in ensuring sustainability in agricultural productivity in the face of varying climatic conditions. The various indigenous measures for each of the countries described in this paper is therefore to stimulate farmers to learn from one another's approaches, and to develop further their own adaptation strategies.

Indigenous Adaptation Measures in African Countries

Indigenous knowledge has been defined as institutionalized local knowledge that has been built upon and passed on from one generation to the other by word of mouth (Osunade, 1994; Warren 1992). It is the basis for local-level decision-making in many rural communities. Indigenous knowledge has value not only for the culture in which it evolves, but also for scientists and planners striving to improve conditions in rural localities (Mundy and Compton 1991). The knowledge set is influenced by the previous generations' observations and experiment and provides an inherent connection to one's surroundings and environment (Adesina et al, 1999). Therefore Indigenous Knowledge is not transferable but provides relationship that connect people directly to their environments and the changes that occur within it, including climate change (Woodley 1991).

As reported by Anselm (2011), adaptation helps farmers achieve their food, income and livelihood security objectives in the face of changing climatic and socio-economic conditions including climatic variability, extreme weather conditions such as droughts and floods and volatile short term changes in local and large-scale markets (Kandlinkar and Risbey, 2000). Farmers can reduce the potential damage by making tactical response to these changes.

According to Brussel (2009) adaptive measures to climatic change in agriculture range from technological solutions to adjustments in farm management or structures and to political changes such as adaptation plans.

Adaptation and Coping Strategies in Tanzania

Nsema et al, (2009) in their research on strengthening local agricultural innovation systems to adapt to climate change in Tanzania found out that negative impacts of climate change in Tanzania include decreasing crop production, increasing pests and diseases and abandoning of certain crops, in particular maize. Other factors which are not climate related have been mentioned to be introduction of new plant seeds which carry pests and diseases. Livestock production has also been adversely affected because of diminishing water and pasture and increasing pests and diseases particularly tick borne diseases. This is also attributed by lack of proper livestock diseases control such as dips. The production of both crops and livestock are more severely impacted.

In response to the reported changes in Climate Change in Tanzania, Nsema et al, (2009) reported that there has been a change in planting dates, change in crop varieties: Introduction of improved varieties e.g. maize hybrids. Cultivation on valley bottoms for production of vegetables. It was predicted that harvests will be less due to further decline in soil fertility. Hence the farmers resorted to plan ahead by expanding crop production, increasing livestock, improved access to subsidized fertilizer, having improved access and terms for credit, increasing business activities. Strategies for improving agricultural production included increase area of cultivation; buy more fertile for their children; increase number of livestock; diversify the crops and try to have own source of water for irrigation. In some areas the strategies for the future included early field preparation, zero grazing of cattle, Non-farm activities making of clay pots, planting milulu for basket weaving, planting trees (Pines for timber, mivengi for water sources conservation) and besides restrict river banks/valley bottom cultivation, prohibition of wildfires/bushfires and introduce tower gardening and water harvesting (Nsema et al, 2009).

Nsema et al, (2009) further reported that in adapting to drought, local communities have responded in different ways by planting drought tolerant crops such as millet and sorghum, timing of farm operations, early planting and harvest of rain water, growing drought tolerant crops, planting high yielding varieties etc. Farmers have reverted to growing traditional crops varieties that are considered to be both drought and disease resistant, for example, millet and sorghum. In addition, some farmers are increasingly being engaged in the cultivation of other pests/diseases resistant crops such as pigeon peas as an alternative to growing beans. Small-scale irrigation is practiced in narrow river valleys, and can be seen as a potential coping strategy to climate change.

Migration is among the local adaptation strategies, The study by Yanda and Mung'ong'o, (1999) indicated that migration is an important adaptation strategy in times of climate change or

environmental degradation in some parts of Tanzania. People are migrating to cultivate in some places considered to be relatively more fertile.

Adaptation to Climate Change in Malawi

The SOER (1998) report indicates that in the last three decades, Malawi has experienced significant variability and unpredictability in seasonal rainfall. The agriculture, water, forestry, fisheries and wildlife sectors are greatly affected by these drought events. The SOER (1998) further reported that agriculture and livestock sectors are directly affected by drought, water shortages, resulting from drought or inter seasonal rainfall shortages, and have significant impact on other sectors as well. However, temperature was very high implying that evaporation rate was high too. For this reason it is suggested that farmers in this area should practice agroforestry in which annual crops grow together on the same piece of land with trees, thereby reducing evapo-transpiration and improving infiltration.

Adaptation in Kenya

In Kibera, Nairobi, the largest slum in Kenya, more than 1,000 women farmers are growing "vertical" gardens in sacks full of dirt poked with holes, feeding their families and communities. These sacks have the potential to feed thousands of city dwellers while also providing a sustainable and easy-to-maintain source of income for urban farmers. Pastoralists in South Africa and Kenya are preserving indigenous varieties of livestock that are adapted to the heat and drought of local conditions.

As reported by Isaiah (2011), that the Use of Agro-biodiversity by Indigenous and Traditional Agricultural Communities in Adapting to Climate Change in eastern Kenya which is mostly semi-arid, receiving only erratic rainfall with long spells of drought that can last as long as three years, involve employing permaculture, a traditional farming method where different types of crops ranging from vines to fruits trees are grown together as a strategy to cope with erratic weather. Also from his findings to survive this long-standing dryness which could potentially be aggravated by climate change, the farmers resulted to grow here include perennials such as indigenous fruits which cope well in erratic weather; important legumes such as pigeon pea, lablab, climbing bean (ngelenge) and creeping forms of cowpeas (ndamba) which have been successfully cultivated in these tough conditions for generations.

Burkina Faso

In Burkina Faso, farmers have resisted desertification and rehabilitated degraded land through planting trees in the fields and around villages. They also use traditional water harvesting and storage methods, and soil moisture storage techniques such as zai-pits (Aly and Hamado 2005). A zai-pit is a square hole 60 centimetres deep and 60 by 60 cm wide, sunk into dry, sandy soil. It is filled with compost manure mixed with topsoil. When, the mixture of compost and topsoil is saturated say with rain water (or by irrigation), it is able to retain moisture for several days - whereas the sandy soil that surrounds it dries out again almost immediately.

The people have resulted to some agricultural activities to extend traditional soil protection techniques, Methods such as digging “Zai” pits – compost-filled planting pits which hold water, helping deep-rooted vegetables grow; building up grass and rock barriers around crops to protect them from soil erosion; and cultivating manure in septic tanks to use as fertilizer. But to enable crops to survive erratic rains, many more farmers need access to high-yield, quick-growing seeds (Aly and Hamado, 2005).

Sahel Region of Africa

Allowing trees to grow and shade fields has helped boost yields for farmers across the Sahel. Farmers in the western Sahel have resorted to growing trees. They mix trees and crops, a practice they have named "farmer-managed natural regeneration," or FMNR, and that is known generally as agro-forestry, this brings a range of benefits. The trees' shade and bulk offer crops relief from the overwhelming heat and gusting winds. Indigenous knowledge has been directly applied in the Sahel in climate change mitigation through emission reduction, Carbon sequestration and carbon substitution. In the area of adaptation, indigenous knowledge systems have been applied in weather forecasting, vulnerability assessment and implementation of adaptation strategies. Local farmers in the Sahel have been known to conserve Carbon in soils through the use of zero tilling practices in cultivation, mulching and other soil management techniques (Schafer 1989; Osunade 1994). Natural mulches moderate soil temperatures and extremes, suppress diseases and harmful pests, and conserve soil moisture. Before the advent of chemical fertilizers, local farmers largely depended on organic farming, which also is capable of reducing GHG emissions. It is widely recognized that forests play an important role in the global carbon cycle by sequestering and storing Carbon (Karjalainen et al. 1994; Stainback and Alavalapati 2002).

Local farmers are known to have practiced the fallow system of cultivation, which encouraged the development of forests. Agroforestry is another practice that has been very effective in carbon sequestration. It is a system that tries to find some balance in the raising of food crops and forests (Adesina et al. 1999; Floyd 1969). Agroforestry techniques can be perfected to cope with the new conditions that are anticipated under a drier condition and a higher population density, they lead to an increase in the amount of organic matter in the soil thereby improving agricultural productivity and reducing the pressure exerted on forests.

In the Sahel, local farmers have developed several adaptation measures that have enabled them to reduce their vulnerability to climate variability and extremes. One important step in reducing the vulnerability of a climatic hazard is the development of an early warning system for the prediction or forecast of the event (Ajibade and Shokemi 2003). These farmers have developed intricate systems of gathering, prediction, interpretation and decision-making in relation to weather. Adaptation strategies that are applied among the pastoralists include the use of emergency fodder in times of droughts, multi-species composition of herds to survive climate extremes, and culling of weak livestock for food during periods of drought. During drought periods, pastoralists and agro-pastoralists change from cattle (Bos) to sheep (Capra) and goat

(Capra) husbandry as the feed requirements of the later is less than the former (Oba, 1997). Pastoralists' nomadic mobility reduces the pressure on low carrying capacity grazing areas /through the circular movement from the dry northern areas to the wetter southern areas of the Sahel.

Uganda

Uganda's Developing Innovations in School Cultivation (DISC) program is integrating indigenous vegetable gardens, nutrition information, and food preparation into school curriculum to teach children how to grow local crop varieties that will help combat food shortages and revitalize the country's culinary traditions. An estimated 33 percent of African children currently face hunger and malnutrition, which could affect some 42 million children by 2025. School nutrition programs that don't simply feed children, but also inspire and teach them to become the farmers of the future, are a huge step toward improving food security.

Madagascar

In Madagascar, the agricultural sector employs over 70% of the population, low productivity coupled with land tenure insecurity and strong demographic growth have led to over exploitation of lands, decline soil quality and desertification; thereby making food security on the Island be under threat. Agro-ecological techniques which involves protecting soil with a perennial green cover which restores soil fertility,increase yield and reduces irrigation has been put to practice. The method requires no labour, no fertilizer and helps reduce Co_2 emissions by fixing Co_2 in the soil.

South Africa

In a survey by Archer et al, (2008) on Farming on the edge' in arid western South Africa the impacts described by the farmers includes severe drought, observed drought stress in their tea crops, mostly in the form of diminished yield. In addition, weather conditions contributed to increased frequency of potholes in roads, complicating transport, tick infestation that affected livestock and their poor conditions due to direct result of the pattern of weather events. Farmers were able to respond by stock reduction and dipping. Insufficient rain period adversely affected off-farm work opportunities. Farmers have been coping by providing supplemental feed to the livestocks. All farms surveyed reported climate-related heat stress to livestock, livestock water shortages (related to rainfall, without supplemental irrigation), and climate-related increases in pests and pathogens (affecting rooibos and stock) (Archer, 2008). uncertainty in the timing of agricultural activities as a direct result of late starts to the winter rainfall season and increased frequency of dry spells during the season. With regard to rooibos, adaptation strategies undertaken by all farms included: changes in ground preparation and tea harvesting times; wind erosion prevention measures (retaining bushed strips in lands, or planting of wind breaks, which reduced loss of tea due to wind); and water conservation measures.

Furthermore Archer et al, (2008) reported that the farmers resorted to using as a basis their

local knowledge about managing climate risk, conserving biodiversity and conserving soil and water. These were not new activities; they comprised existing activities and strategies. Windbreaks continued to be planted because wind increases tea loss, using indigenous vegetation planted in rows angled (to prevent soil build-up against the barrier) to the direction of the dominant drying wind, Vegetation was removed, to aid water conservation. Lastly, alternative income sources continued to be developed, including eco-tourism initiatives, and the collection of indigenous medicinal plants and seeds.

Nigeria

Enete and Amusa (2010) reported that unusual early rains that are not sustained, erratic rainfall, delay in the onset of rain, long period of dry season, less rainfall, long period of harmattan and higher temperature, heavy winds, drought and decreasing soil moisture have been on the increase. thunderstorm, heat waves, desertification and loss of forest resources have shown no change, while floods, heavy rainfall and soil erosion have been decreasing and early rains that are not sustained, erratic rainfall, delay in the onset of rain, long period of dry season, thunderstorms, heavy winds, intense heat wave and so on. This was also the same trend for pests, diseases, weeds and signals of land degradation such as declining soil fertility and drying up of streams/rivers such are the case with southeastern Nigeria in the face of varying climate. Science in Africa (2007) observed that the effects of these extreme weather events and uncertainties in the onset of rainy season on agriculture are particularly more pronounced in the developing world.

Crop yields in the Sudan-Sahel zone of northern Nigeria are strongly and positively influenced by rainfall and evaporation as major climatic parameters affecting crop yields. This is so because soil moisture, which is often regarded as the single most important parameter in determining crop yields in semi-arid environments, can be coarsely derived from a relationship between rainfall and evaporation (Baier, 1977; Kowal and Kassam, 1978). However, According to Enete and Amusan, (2010) the main cause of poor yields is attributed to drought, poor soils, pest and diseases. The declining yields were blamed on the uncertain rainfall pattern since the Sahelian drought of the 1970s. Loss of seeds due to droughts and migration were some of the factors mentioned for the overall decrease in levels of production in spite of moderate rainfalls in some years. In adjusting to drought, the farmers employed cropping mixtures during drought, for example, they usually substitute early millet for sorghum, they also plant cassava and quick-maturing cowpea in the FADAMAs (wetlands) with no normal cropping mixtures during drought.

Areas cultivated during drought reduced often due to lack of seeds and labour - the young and able men migrate to cities in drought years leaving farm work to aged ones. Their livestock also suffer as a result of drought since the growing season could not receive adequate rainfall and could not get water from nearby wells and earth-dams to water their crops. However, availability of water in the earth-dams depended on sufficient rain falling at the beginning of the season, otherwise the little water collected may be lost completely through seepage and intense evaporation.

Other places like Bangladesh as reported by Isaiah, (2011) that in drought prone regions of Bangladesh, the resilience of traditional homestead gardens is strengthened through inter-cropping of fruit trees with vegetables, small scale irrigation and organic fertilizers. In the flood-affected regions, floating gardens have been created for cultivation of mixed traditional crops, red amaranth and kohlrabi. Therefore he concluded that local agrobiodiversity could be the basis for integration of adaptation and protection of indigenous peoples' rights .

Conclusion

The foregoing has highlighted the various indigenous measures adopted by some African countries in combating the menace of climate change on their agricultural systems. Effective adaptation strategies will require reliable scientific data on the nature of climate change and on its potential impact, though some of the indigenous ways in which the farmers have been adapting have been highlighted but the success of any adaptation strategies would not rely only on the traditional small-scale farming techniques but also in conjunction with modern knowledge on climate change adaptation such as climate forecasting and long-term climate change projection. The various indigenous measures for each of the countries described in this write up is therefore to stimulate farmers to learn from one another's approaches, and to develop further their own adaptation strategies.

Recommendation

1. It is recommended that for low potential areas that are highly vulnerable to climate change, significant investments will be needed to maintain agricultural production and the general community livelihoods. Achieving the above would need increased understanding of climate change and socio-economic dynamics of particular locations which will aid in the pursuit of longer term policies on adaptation.
2. Improving the knowledge and skills of extension service personnel about climate change and adapted management strategies, increasing extension-farmer ratio, and making the extension services more accessible to farmers.
3. Government policies should therefore ensure that terms for credit in the banks are flexible to enhance farmers' access to affordable credit, which will increase their ability and flexibility to change crop and soil management strategies in response to climate change
4. Provision of incentives for farmers by the African government and Stakeholders to avoid deforestation through intensified production on existing land.
5. There is need for crop and livelihood diversification in addition to the adoption of high yielding crop varieties and intensive agricultural production.
6. Formulation of strategies by institutions and organizations that will enhance the capacity to adapt to climate change within natural and agricultural systems.
7. Indigenous knowledge and practices should be integrated into formal climate change mitigation and adaptation strategies for continuous process of innovation.

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Modelling Arable Crop Farmers' Decisions on Climate Change and Adaptation Strategies: A Multinomial Logit Analysis in Ogun State

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Abstract

Climate and rural farmers' resource allocation behaviour are primary determinants of agricultural productivity in Nigeria. Hence, knowledge of the rural farmers about climate change is important in order to offer adaptation practices that mitigate its adverse effects. This study, thus, investigated issues on climate change adaptation strategies among arable crop farmers in Ogun State. It utilized primary data collected from 150 arable crop farmers selected across Ogun State through a multistage sampling technique. The data were obtained through administration of questionnaire designed to elicit information on socio- economic characteristics, production activities, as well as adaptation behaviours of the respondents to climate change. The multinomial logit regression model was used to capture choice probabilities across the various options of climate change adaptation strategies. The study result revealed that most (81.08%) of the arable crop farmers were males, majority (69.6%) had no more than primary school education, with an average farming experience of 24 years. Furthermore, 22.97 percent of the respondents did not take up any adaptation strategy, while the remaining either targeted rains to plant (45.95%), used multiple strategies (12.16%), good soil conservation techniques (10.81%), or wetland farming (8.11%). The multinomial logit analysis result showed that household size ($p<0.05$), gender ($p<0.10$), years of residence in a community ($p<0.05$), educational level ($p<0.10$), frequency of extension contact ($p<0.01$), access to agricultural credit, and income from secondary occupation ($p<0.05$) are all important in explaining the choice of climate change adaptation strategies taken up by the arable crop farmers in Ogun State.

Keywords: Decision Making, Climate Change Adaptation Strategies, Arable Crop, Multinomial Logit.

Introduction

Agriculture places heavy burden on the environment in the process of providing humanity with food and fibre, while climate is the primary determinant of agricultural productivity. Studies indicate that Africa's agriculture is negatively affected by climate change (Pearce *et al*. 1996;

McCarthy *et. al* 2001). Given the fundamental role of agriculture in human welfare, concern has been expressed by federal agencies and others regarding the potential effects of climate change on agricultural productivity. Interest in this issue has motivated a substantial body of research on climate change and agriculture over the past decade (Lobell *et al*, 2008; Wolfe *et al*, 2005; Fischer *et al*, 2002). Climate change is expected to influence crop and livestock production, hydrologic balances, input supplies and other components of agricultural systems. However, the nature of these biophysical effects and the human responses to them are complex and uncertain.

Adaptation to climate change refers to adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities (IPCC, 2001). Common adaptation methods in agriculture include: use of new crop varieties and livestock species that are more suited to drier conditions, irrigation, crop diversification, mixed crop livestock farming systems and changing planting dates (Bradshaw *et al*., 2004; Kurukulasuriya and Mendelsohn, 2006; Nhemachena and Hassan, 2007).

Climate change according to IPCC, 2001 (Intergovernmental Panel on Climate Change) can be defined as the change in the state of the climate that can be identified using statistical data by changes in the mean and variability of climate properties that has persisted for an extended period, typically decades or longer. It also refers to any change in climate over time, whether due to natural variability or as a result of human activity. This usage however differs from that in the United Nations Framework Convention on Climate Change (UNFCC), where climate change refers to a change of climate that is attributed directly or indirectly to human activity that alters the composition of global atmosphere and that is, in addition to natural climate variability observed over comparable time period. (Currents, 2008).

Climate change is expected to exacerbate Africa's struggles with strained water resources and food security. Rising global temperatures are expected to increase flooding in coastal areas, cause declines in agricultural production, threaten biodiversity and the productivity of natural resources, increase the range of vector-borne and waterborne diseases, and exacerbate desertification; thus, they have a disproportionately adverse impact on Africa's agriculture-based economy (Mendelsohn *et al.* 2000). To make matters worse, Africa has a low adaptive capacity due to its dependence on rain fed agriculture, low levels of human and physical capital, and poor infrastructure. Of the first wave of studies on the effects of climate change on economic variables, most estimated the predicted loss of income from climate change through crop simulation experiments. The next generation of studies - Ricardian studies (such as by Mendelsohn and Dinar, 1994; 2003) and hedonic studies sought to capture adaptations to climate change by exploiting cross-sectional variance in climate and land prices. However, looking at how land rents change with climate misses an important part of the impact of climate change. Climate change is expected to cause an increase in drastic weather events and

this, in combination with households employing costly risk-coping strategies, is likely to increase the probability of income shocks having an even larger impact on the poor.

It is evidenced that climate change will have a strong impact on Nigeria-particularly in the areas of agriculture; land use, energy, biodiversity, health and water resources. Nigeria, like all the countries of Sub-Saharan Africa, is highly vulnerable to the impacts of Climate Change (IPCC 2007; NEST 2004). It was also, noted that Nigeria specifically ought to be concerned by climate change because of the country's high vulnerability due to its long (800km) coastline that is prone to sea-level rise and the risk of fierce storms.

In addition, almost two-third of Nigeria's land cover is prone to drought and desertification. Its water resources are under threat which will affect energy sources (like the Kainji and Shiroro dams). Moreover, rain-fed agriculture practiced and fishing activities on which two-third of the Nigerian population depend primarily for foods and livelihoods, are also under serious threat, just as the high population pressures of 140 million people surviving on the physical environment through various activities within an area of 923,000 square kilometres (IPCC 2007; NEST 2004).

Food crop farmers in south west Nigeria provide the bulk of arable crops that are consumed locally, so also, major food crop supplies to other regions in the country. The local farmers are experiencing climate change even though they have not considered its deeper implications. This is evidenced in the late arrival of rain, the drying-up of stream and small rivers that usually flow year-round, the seasonal shifting of the "Mango rains" and of the fruiting period in the Southern part of Oyo State (Ogbomosho), and the gradual disappearance of flood-recession cropping in riverine areas of Ondo state are among the effects of climate disturbances in some communities of South-Western Nigeria (BNRCC, 2008).

To approach the issue appropriately, one must take into account local communities' understanding of climate change, since they perceive climate as having a strong spiritual, emotional, and physical dimension. It is therefore assumed that these communities have an inborn, adaptive knowledge from which to draw and survive in high-stress ecological and socio-economic conditions. Thus, the human response is critical to understanding and estimating the effects of climate change on production and food supply for ease of adaptation. Accounting for these adaptations and adjustments is necessary in order to estimate climate change mitigations and responses.

Climate Change Impacts on Agriculture

Increased intensity and frequency of storms, drought and flooding, altered hydrological cycles and precipitation variance have implications for future food availability. The potential impacts on rain fed agriculture *vis-à-vis* irrigated systems are still not well understood. The developing world already contends with chronic food problems, and Climate change presents yet another significant challenge to be met. While overall food production may not be threatened, those

least able to cope will likely bear additional adverse impacts (WRI, 2005). The estimate for Africa is that 25 to 42 percent of species habitats could be lost, affecting both food and non-food crops. Habitat change is already underway in some areas, leading to species range shifts, changes in plant diversity which includes indigenous foods and plant-based medicines (McClean, Colin *et al*., 2005).

In developing countries, 11 percent of arable land could be affected by climate change, including a reduction of cereal production in up to 65 countries, and about 16 percent of agricultural GDP (FAO Committee on Food Security, Report of 31st Session, 2005). According to FAO, 2007, changes in ocean circulation patterns, such as the Atlantic conveyer belt, may affect fish populations and the aquatic food web as species seek conditions suitable for their lifecycle. Higher ocean acidity (resulting from carbon dioxide absorption from the atmosphere) could affect the marine environment through deficiency in calcium carbonate, affecting shelled organisms and coral reefs.

In sub Saharan Africa, including Nigeria, agriculture is the principal source of food, fibre, livelihood and foreign exchange earnings. (Badiane and Delgado, 1995). It contributes about 52% of the GDP, generates more than 85% of the foreign exchange earnings and employs about 80% of the population. Despite its high contribution to the overall economy, agriculture is characterized by its environmental, behavioural, and policy aspects, and environmental problems of agriculture largely stems from intensive human activities with the use of natural resources. This sector is also challenged by multitudes of factors of which climate related disasters like drought and flood, which often causes famine, are the major ones. Trade-offs between food security and the environment is what is being practiced in most developing countries. There are strong indications and ready evidence that the agricultural and food system as well as the rural areas across the world are experiencing major climatic changes (Apata, 2009; IPCC, 2007). This change has drastically reduced soil fertility and led to poor agricultural outputs particularly in Sub-Saharan Africa.

Climate change is widely recognised and accepted as a reality and that it poses serious challenges with far reaching social, political, economic and environmental consequences, particularly in most vulnerable countries. It is one of the biggest threats facing mankind today and it seriously impacts on the lives of more than 10% of the world's population every year. By 2030, the annual death toll from climate change is expected to reach half a million people a year and the figure is expected to reach 660 million by 2050, making it the biggest emerging humanitarian challenge in the world. Nevertheless, climate change is hardly known by many people including people in decision-making positions and those responsible for resource allocation, hence the low level of activities to address the problem. A majority of the world's population does not have the capacity to cope with the impact of climate change without suffering a potentially irreversible loss of wellbeing and risk of loss of life (Mujere, 2009).

Africa is generally acknowledged to be the continent most vulnerable to climate change. West Africa is one of the most vulnerable to the vagaries of the climate, as the scope of the impacts of climate variability over the last three or four decades has shown (IPCC, 2007). Recent food

crises in countries such as Nigeria are reminders of the continuing vulnerability of the region to the vicissitudes of climatic conditions. This is in large measure due to weak institutional capacity, limited engagement in environmental and adaptation issues, and a lack of validation of local knowledge (SPORE, 2008; BNRCC, 2008; Royal Society, 2005; Adams *et al*, 1998). Accordingly, there is the need to gain as much information as possible, and learn the positions of rural farmers and their needs, about what they know about climate change, in order to offer adaptation practices that meet these needs.

Much of the Niger-delta wetland areas of Nigeria are now endangered due to climate variability, as witnessed by the significant reduction of their size in recent years. The maximum flooded area of the inner Niger Delta, which is the second largest wetland area in Africa, has dropped from approximately 37,000 km^2 in the early 1950s to 15,000 km^2 in 1990, coupled with what the environmental degradation of crude-oil exploration has done to Niger-delta wetlands areas (BNRCC, 2008).

Recent research has focused on regional and national assessments of the potential effects of climate change on agriculture (Lobell, *et al*, 2008; Hassan and Nhemachem, 2008; Fischer *et al*, 2002). These efforts have, for the most part, treated each region or nation in isolation and do not integrate (i.e. combined biophysical and economic) assessment of the potential effects of climate change on proletariat agriculture but mostly focus on world agriculture (ODI, 2007; Segerson and Dixon, 1998). Consequently, this research intends to investigate the effects of climate change at the grassroots by considering the determinants of the communities' adaptation to changes in climate. This is important because sustainability of agricultural production depends largely on actions of farmers and their ability to make decisions given the level of knowledge and information available to them.

Methodology

Description of the Study Area

The study area is Ogun State. Ogun State is one of the 36 states of the Federal Republic of Nigeria. It was carved out of the defunct Western State on the 3rd day of February, 1976, and it has total land area of 16,409.26sq.km. The estimated population is 3, 728, 098 according to Nigerian 2006 National Census release (Federal Republic of Nigeria, FRN, 2009). The climate of Ogun State follows a tropical pattern with the raining season starting about March and ending in November, followed by dry season. The mean annual rainfall varies from 128mm in the southern parts of the state to 105mm in the northern areas. The average monthly temperature ranges from 23°C in July to 32°C in February. The northern part of the State is mainly of derived Savannah vegetation, while the Central part falls in the rain forest belt. The southern part of the State has mangrove swamp.

The geographical landscape of the State comprises extensive fertile soil suitable for agriculture, and savannah land in the north western part of the State, suitable for cattle rearing. There are also vast forest reserves, rivers, lagoons, rocks, mineral deposits and an oceanfront. The rivers

in the state provide veritable opportunities for farmers' to access the potentials of dry season as well as fadama farming.

The state capital is Abeokuta, which is about 100km north of Lagos, Nigeria's business capital. The state is made up of 20 Local Government Areas. The majority of the people of the state belongs to the Yoruba ethnic group of south-west Nigeria, and they are mainly Egba, Yewa, Egun, Awori, Ijebu , Remo, Ikale, and Ilaje. The greater proportion of the state lies in the tropical rain forest zone with a sizeable feature of guinea savannah in the far northern area of the state. The main occupation of the people of the state is farming, which is largely subsistence in scale.

The state is known to have a virile Agricultural Extension Programme which comprises of four agricultural zones identified by OGADEP as Abeokuta, Ilaro, Ijebu and Ikenne. Each zone is divided into blocks, as shown in Table 2, and each block into circles or cells and each of these is anchored by a Village Extension Agent (VEA) who oversees the activities of farmers in his coverage area, while a Block Extension Agent (BEA) anchors a block by overseeing activities of farmers in the coverage area.

Table 1: Zonal Structure of OGADEP, Ogun State.

Zones	Blocks
Abeokuta	Ilugun, Opeji, Ilewo, Olorunda, Wasinmi and Ifo.
Ilaro	Imeko, Sawonjo, Ado-Odo and Oke-Odan.
Ijebu-Ode	Ibiade, Ijebu-Ife, Ala, Ijebu-Igbo, Ago-Iwoye and Isoyin.
Ikenne	Isara, Simawa, Obafemi and Someke

Source: OGADEP, 1996.

Data Types, Sources and Sampling Technique

This study was based on primary data. The primary data were obtained through administration of structured questionnaire on arable crop farmers in the study area. Data collected included the arable crop farmers' socio economic and production characteristics, actual adaptation strategies adopted by the respondents' as well as barriers to adaptation faced in the study area. The sample size used for this study was 150 arable crop farmers. Multi-stage sampling technique was used to select arable crop farmers from whom data were generated for this study. The first stage of sampling involved a random selection of two zones from the four OGADEP zones. Abeokuta and Ikenne zones were selected in this respect. The second stage involved a random selection of 50 percent of the total number of blocks in both Abeokuta and Ikenne zones, resulting in the selection of three blocks from Abeokuta zone, and two blocks from Ikenne zone using list of blocks in the zones as the sampling frame. The third stage involved a random selection of three cells from each of the selected five blocks in each zone using the list of cells obtainable from OGADEP as the sampling frame. The fourth stage involved a random selection of 10 arable crop farmers from each of the selected cells thereby giving a total number of 150 respondents.

The sampling procedure for this study is summarized in Table 2.

Table 2: Sampling Procedure for the study

STAGE	PROCEDURE	REMARKS
1.	Random selection of two zones from the four OGADEP zones.	Sampling frame was list of all the four OGADEP agricultural zones.
2.	Proportion random selection of half of the total number of blocks within each selected zone.	Sampling frame was list of all blocks under the OGADEP agricultural zones selected.
3.	Simple random selection of three cells each from the above selected blocks.	Sampling frame was list of all cells under the five OGADEP agricultural blocks selected.
4.	Simple random selection of 10 respondents from each of the cells selected above	List of all arable crop farmers under each cell obtainable from OGADEP was the sampling frame.

Analytical Techniques

Descriptive and Multinomial Logit regression model was used to analyse the collected data. The advantage of the multinomial logit is that it permits the analysis of decisions across more than two categories, allowing the determination of choice probabilities for different categories of climate change adaptation. This approach is more appropriate than the probit or logit models that have been conventionally used. The decision of whether or not to use any adaptation option could fall under the general framework of utility and profit maximization. Consider a rational farmer who seeks to maximize the present value of expected benefits of production over a specified time horizon, and must choose among a set of *J* adaptation options. The farmer *i* decide to use *j* adaptation option if the perceived benefit from option *j* is greater than the utility from other options (say, *k*) depicted as:

$$U_{ij}\,(\theta'_j X_i + \varepsilon_j) > U_{ik}\,(\theta'_k X_k + \varepsilon_k) \quad \ldots\ldots (1)$$

where j is not equal to k, U_{ij} and U_{ik} are the perceived utility by farmer *i* of adaptation options *j* and *k,* respectively; and ε_j and ε_k are the error terms.

Under the revealed preference assumption that the farmer practices an adaptation option that generates net benefits and does not practice an adaptation option otherwise, we can relate the observable discrete choice of practice to the unobservable (latent) continuous net benefit variable as:

$$Y_{ij} = 1 \text{ if } U_{ij} > 0, \text{ and } Y_{ij} = 0 \text{ if } U_{ij} < 0.$$

In this formulation, Y is a dichotomous dependent variable taking the value of 1 when the farmer chooses an adaptation option in question and 0 otherwise. The probability that farmer *i* will choose adaptation option *j* among the set of adaptation options could be defined as follows:

$$P(Y=1/X) = P\,(U_{ij} > U_{ik})/\,X \quad \ldots\ldots (2)$$

$$= P [(\beta'_j X_i + \varepsilon_i - \beta'_k X_i - \varepsilon_k) > 0 / X]$$
$$= P [(\beta'_j - \beta'_k) X_i + \varepsilon_j - \varepsilon_k) > 0 / X]$$
$$= P (\beta^* X_i + \varepsilon^* > 0 / X) = F (\beta^* X_i)$$

In this analysis, the five categories considered are given below:

1. Good Soil Conservation Techniques.
2. Irrigation/Drainage/Wetland farming.
3. Targeting rains to plant.
4. Multiple strategies.
5. No Adaptation, (reference category)

To estimate this model there is need to normalize on one category, which is referred to as the "reference state." In this analysis, the last category (No Adaptation) is the "reference state." The reference category for the multinomial logit analysis was no adaptation.

ε* is a random disturbance term,
β* is a vector of unknown parameters that can be interpreted as the net influence of the vector of explanatory variables influencing adaptation,
$X_{is\ are}$ the explanatory variables, and they included the following
X_1 = Farming experience in years
X_2 = Educational level
X_3 = Age in years
X_4 = Household size
X_5 = Years of residence in a community
X_6 = Secondary occupation income in naira
X_7 = Frequency of extension contact
X_8 = gender
X_9 = Marital status
X_{10} = Religion
X_{11} = Land size
X_{12} = Access to credit, and
F (β*X$_i$) is the cumulative distribution of ε* evaluated at **β*X$_i$**.

The Multinomial logit model is thus specified according to Green, 2003 as:

$$P_{ij} = \text{prob}(Y = 1) = \frac{e^{x'\beta}}{1 + \sum_{J=1}^{j} e^{x'\beta}} \quad \text{.....} \quad (3)$$

j= 1…..n

where **β** is a vector of parameters that satisfy $\ln (P_{ij}/P_{ik}) = X' (\beta_j - \beta_k)$ (Greene, 2003).

Unbiased and consistent parameters estimates of the MNL model in Equation 13 require the assumption of independence of irrelevant alternatives (IIA) to hold. Specifically, the IIA assumption requires that the likelihood of a household's using a certain adaptation measure needs to be independent of other alternative adaptive measures used by the same household. Thus, the IIA assumption involves the independence and homoscedastic disturbance terms of the adaptation model in Equation 3. The validity of the IIA assumption is based on the fact that if a choice set is irrelevant, eliminating a choice or choice sets from the model altogether will not change parameter estimates systematically. Differentiating Equation 3 with respect to each explanatory variable provides marginal effects of the explanatory variables given as

$$\partial p_j / \partial x_k = Pj \left[\beta_{kj} - \sum_{J=1}^{j-1} P_j \beta_{jk} \right] \quad \ldots\ldots (4)$$

Results and Discussion

Distribution of Respondents by Personal Characteristics

Age is generally believed to be an important factor in farming activities. This is because younger farmers are believed to commit more energy into production activities, while older ones are likely to be more experienced which may also impact positively on their productivity. As shown in the Table 3, majority, (79.70%) of the respondents are economically active, with age between 31-60years, with the mean being 45.7years, indicating that they are mainly in the active age group.

With regards to gender of surveyed respondents, 81.08 percent of the respondents are males, while only 18.92 percent of the respondents are females showing that there are more male arable crop farmers in the study area than their female counterparts. From the table below, the sampled respondents are mostly married (86.49%), while 6.76 percent of them are single, 2.70 percent are divorced, while 4.05 percent are widowed. Christians constitute the majority of the respondents (60.81%), as against Islam which is (37.16%), while traditional worshippers constitute 2.03% of the respondents.

In terms of educational level, 36.49% of the respondents have no formal education, 2.07% had adult literacy training, while a reasonable percentage of the respondents, (30.41%) are educated up to the primary school level, and 19.59% up to secondary school level, while 3.38% of the respondents have vocational/technical education. Only 7.43 percent of the respondents have tertiary education.

From Table 3, about 43.92% of the sampled respondents have secondary occupation, while the remaining 56.08% do not have. The secondary occupation included mainly artisanship, trading, carpentry, hunting, cattle rearing, among others. In terms of extension contact, 86.49% of the sampled respondents have access to extension contact, while the remaining 13.51% do not have. Out of this, 86.49%, majority (72.3%) of the respondents had up to twelve times of

extension contact in the last production season, while the mean contact frequency is 11times in the last production season. This shows that access of arable crop farmers to extension services across the study area is above average, but there is still the need for service intensification on the areas with lack of access in order to educate the farmers on innovation capable of improving their productivity.

For credit access, only 17.57percent of the respondents had access to credit facilities, while the remaining 82.43percent of the sampled respondents do not have access, this may limit the ability of the farmers in the latter category to expand their scale of production. This lack of access to credit facilities may be due to low literacy level of farmers, high interest rates being charged by financial institutions, and other bureaucratic bottlenecks which always characterize loan acquisition and disbursement in this country.

The distribution of respondents by household size is also shown in Table 3. From the table, about 15.54 percent of the surveyed respondents have household size of between 1 and 4 members, 52.03 percent have household size of between 5 and 9 members, and 27.07 percent have household size of between 10 and 14 members, while 4.73 percent have above 15persons as household size. The mean household size for the sampled respondents is approximately 8 persons, implying that other members of the household can provide labour in agricultural production. This could however lead to the use of child labour at the expense of formal education.

It is obvious from the Table 3 that 65.54percent of the respondent cultivated less than 1ha of farmland, 10.81percent cultivated between 1.101ha and 1.5 ha of farmland, 13.51percent cultivated between 1.501ha and 2.0 ha of farmland. In all, 89.86 percent of the sampled respondents' cultivated up to 2ha, thus corroborating the true picture of the subsistence nature of arable crop farming in Nigeria. About 10.13percent of respondents cultivated greater or equal to 2.5 ha of farmland, showing that the bulk of the food crop producers operate on a small-scale. The mean land size cultivated by the respondents' is approximately 1ha. The table also revealed that the predominant crop types grown by the arable crop farmers was maize, followed by cassava and vegetables, while other crop types grown included rice melon and pepper, indicating that they are truly arable crop farmers.

Table 3: Description of Respondents by Personal Characteristics

Personal Characteristics		Frequency	Percentage	Mean
Age (years)				
	30 or less	20	13.51	
	31 – 40	26	17.57	
	41 – 50	48	32.43	47.5
	51 – 60	44	29.73	
	Above 60	10	6.76	
Gender				
	Male	120	81.08	
	Female	28	18.92	
Marital Status				
	Married	128	86.49	
	Single	10	6.76	
	Divorced	4	2.70	
	Widow	6	4.05	
Religion				
	Islam	55	37.16	
	Christianity	90	60.81	
	Traditional worshipper	3	2.03	
Educational level				
	No formal education	54	36.49	
	Adult Literacy Training	4	2.70	
	Primary education	45	30.41	
	Secondary education	29	19.59	
	Technical/Vocational education	5	3.38	
	Tertiary education	11	7.43	
Farming experience group				
	20 or less	73	49.32	
	21-30	44	29.73	
	31-40	21	14.19	23.5
	41-50	9	6.08	
	above 51	1	0.68	
Secondary occupation income group				
	0 or less	90	60.81	
	5000-20000	30	20.27	
	21000-40000	16	10.81	
	41000-80000	5	3.38	26,387
	81000-150000	3	2.03	
	150000-400000	2	1.35	
	401000 and above	2	1.35	

Contact frequency group				
	0 or less	20	13.51	
	1-6	40	27.03	
	7-12	47	31.76	10.89
	13-18	11	7.43	
	19-25	20	13.51	
	above 25	10	6.76	
Household size group				
	1-4	23	15.54	
	5-9	77	52.03	8.1
	10-14	41	27.70	
	above 15	7	4.73	
Land size group				
	0.5 ha or less	47	31.76	
	0.501- 1 ha	50	33.78	
	1.01 - 1.5 ha	16	10.81	1.11
	1.501 - 2 ha	20	13.51	
	2.01 - 2.5 ha	2	1.35	
	Above 2.5 ha	13	8.78	
Crop types grown				
	Vegetables	51	34.5	
	Cassava	123	83.1	
	Cocoyam	133	89.9	
	Pepper/Tomato/Okra	15	10.2	
	Yam	10	6.8	
	Garden egg/Potato/Beans	3	2.0	
	Rice	20	13.5	
	Melon	14	9.5	

Source: Field survey, 2010.

Distribution of Respondents by Adaptation Strategies to Climate Change

As indicated in figure 1, targeting rains to plant (resulting to either early or late planting) is the most commonly used (45.95%) method of adaptation. Use of irrigation coupled with construction of proper drainage channels as well as wetland farming is the least practiced (8.11%) adaptation strategy among the major adaptation methods identified among arable crop farmers interviewed for the study. More use of targeting rains to plant as an adaptation strategy could be attributed to the inherent nature of peasant farmers as they rely on natural weather conditions. Also, the limited use of irrigation coupled with construction of proper drainage channels as well as wetland farming could be attributed to low level of capital as an

important input in production and restricted access to wetlands for farming activities. Moreover, 10.81 percent of the respondents adopt good soil conservation techniques such as planting cover crops, mulching, as well as re-supplying of missing seedlings. Nevertheless, 12.16 percent of the respondents engaged in multiple strategies such as the combination of Good Soil conservation techniques with Targeting rains to plant, as well as Irrigation/Drainage/Wetland farming. 22.97 percent of the surveyed farmers reported that they have not taken any adaptation strategies indicated on the figure 1 due to many reasons.

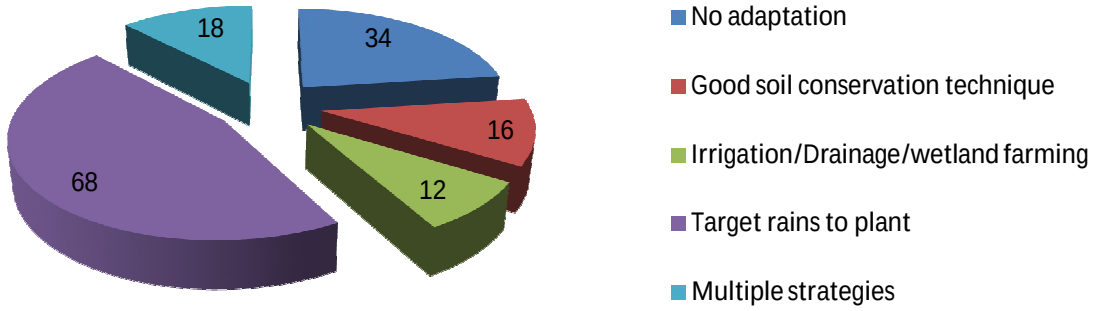

Figure 1: Distribution of respondents by adaptation strategies to climate change

Source: Field Survey, 2010.

Determinants of Arable Crop Farmers' Decisions on Climate Change Adaptation Strategies

Multinomial Logit model was used in this study to estimate the determinants of respondents' adaptation behavior to climate change in the study area. There were about eight actual adaptation strategies being practiced by the sampled respondents in the study area. These are:

1. Good cultural practices such as mulching and re supplying of seedlings.
2. Planting cover crops.
3. Irrigation of farmland.
4. Construction of proper drainage channels.
5. Wetland/ Fadama farming.
6. Targeting rainfall to plant, leading to either early or late planting.
7. Praying for God's intervention.
8. No adaptation.

The highlighted strategies above failed to produce satisfactory results in terms of the significance level of the parameters estimates. The model was thus restructured by grouping closely related choices together in the same category. Good cultural practices and planting of cover crops were grouped in the same category labelled as "Good Soil Conservation Techniques", while Irrigation of farmland, Construction of proper drainage channels and wetland farming were grouped and labelled as "Irrigation/Drainage/Wetland farming" category. The third category is "Targeting rains to plant", followed by "Multiple strategies"

category which is a series of combination of the first three categories. Lastly, the fifth category is a combination of Praying for God's intervention and No Adaptation, and it is labelled "No Adaptation". Accordingly, the choice set in the restructured Multinomial Logit model included the following adaptation options:

1. Good Soil Conservation Techniques.
2. Irrigation/Drainage/Wetland farming.
3. Targeting rains to plant.
4. Multiple strategies.
5. No Adaptation

In this analysis, the last category (No Adaptation) is the "reference state." The reference category for the multinomial logit analysis was no adaptation, and the result is presented in the Table 4. The result revealed that explanatory variables in the model significantly explain the determinants of adaptation behaviour of respondents to climate change in the study area. The Chi-square value of 117.76 associated with the log likelihood ratio was significant ($p<0.01$) suggesting strong explanatory power of the model.

The study found out that household size is a significant ($p<0.05$) but negative, implying that an increase in household size will decrease the probability of respondents' choosing good soil conservation techniques such as good cultural practices and planting cover crops as an adaptation option. Also, the odds of choosing good soil conservation adaptation option as opposed to not adapting at all is 0.70 (70 percent) per unit decrease in household size.

The coefficient of number of years of residence in a community is also significant ($p<0.05$) and positive both for "Good soil conservation techniques" and "Irrigation/Drainage/Wetland farming", implying that an increase in this variable will increase the probability that the respondents will choose each of these adaptation options respectively. This is because with increase in the years of residence of an individual in the community, there is higher possibility of an individual having access to more social capital in the community, thus aiding his ability to adopt new innovations to improve his farming activities and livelihood in general. In the same vein, the odds of adopting each of these strategies by the respondents compared to not adopting at all are 1.08 and 1.09 respectively for each of the adaptation strategies mentioned above.

Moreover, coefficient of Income from secondary occupation was also found to be significant ($p<0.05$) and positive for the adaptation strategy of good soil conservation technique, implying that a change in income from secondary occupation will likely cause an increase in the respondents behaviour to choosing this adaptation strategy. This is because wealthier households are likely to be willing to adapt by investing in good soil conservation techniques. This follows the view of Knowler and Bradshaw, (2007) that the adoption of agricultural technologies requires sufficient financial well- being. Thus, expanding smallholder farmers' access to off-farm sources of income increases the probability that they will invest in farming

activities. The associated odd of respondents adopting this strategy compared to the reference category for each unit increase in income from secondary occupation is 1.00.

Coefficient of Educational level of respondent was also found to be significant ($p<0.10$) and positive for strategies of Irrigation/Drainage/Wetland farming and Multiple Strategies, implying that an increase in this variable will increase the likelihood of sampled respondents choosing these strategies, with associated odd values of 1.78 and 2.17 respectively . Generally, higher level of education is believed to be associated with access to information on improved technologies and productivity consequences as evidenced from various sources indicates that there is a positive relationship between the education level of the household head and the adoption of improved technologies and adaptation to climate change (Maddison, 2006). Therefore, farmers with higher levels of education are more likely to better adapt to climate change by taking up multiple strategies.

Furthermore, the coefficient of frequency of extension contact was found to be significant and positive, for strategies of good soil conservation techniques ($p<0.01$), targeting rains to plant ($p<0.01$), and for multiple strategies ($p<0.05$) implying that an increase in this variable will increase the likelihood of sampled respondents choosing these strategies respectively. The associated odd values of choosing the strategies by respondents as opposed to not adapting at all are 1.16, 1.14, and 1.12 respectively. With these in mind, farmers who have access to extension services are more likely to be aware of changing climatic conditions (confirmed by the probit models, above) and to have Knowledge of the various management practices that they can use to adapt to changes in climatic condition.

In terms of credit access, the result revealed that this variable is significantly ($p<0.10$) and positively affecting adaptation behaviours of respondent to good soil conservation techniques, with an associated odd value of 5.21 per unit increase in access to credit facility. From the table, an increase in the number of respondents having credit access will increase the likelihood of adaptation. This is true because poverty or lack of financial resources is one of the main constraints to adjustment to climate change. In this study also, a large percentage of the respondent cited lack of financial resources as the main constraint or barrier to adaptation.

In terms of Religion, the result revealed that this variable is in favour of respondents practicing Islam. Religion is significant ($p<0.10$), and positively affecting adaptation behaviours of respondent to taking Multiple Adaptation Strategies with an associated odd value of 4.41 per unit increase in this variable.

In terms of gender, the result revealed that this variable is in favour of the males. Gender is significant ($p<0.10$) and negatively affecting adaptation behaviours of respondent to Irrigation/Drainage/Wetland farming as well as Targeting Rains to plant, each with associated odd values of 0.10 and 0.28 respectively per unit increase in number of male respondents. From the table, an increase in number of male respondents will decrease the likelihood of taking up these adaptation options.

Table 4: Determinants of adaptation behavior of respondents

Variables	Good soil conservation technique		Irrigation/Drainage/Wetland farming		Targeting Rains to plant		Multiple Strategies	
	Parameter	Odd-ratio	Parameter	Odd-ratio	Parameter	Odd-ratio	Parameter	Odd-ratio
Intercept	-21.98 (6942.07)	-	-4.25 (6277.93)	-	29.99 (3731.61)	-	-23.09 6528.41)	-
Farming Experience in years	-0.04 (0.05)	0.96	0.09 (0.07)	1.09	-0.02 (0.04)	0.98	-0.02 (0.05)	0.98
Educational Level	0.08 (0.31)	1.08	0.57* (0.44)	1.78	0.14 (0.21)	1.15	0.77** * (0.31)	2.17
Age	0.05 (0.06)	1.05	-0.02 (0.06)	0.98	0.00 (0.03)	1.00	0.03 (0.04)	1.03
Household size	-0.35** (0.17)	0.70	-0.32 (0.18)	0.72	-0.12 (0.09)	0.88	-0.17 (0.12)	0.84
Years of residence	0.07** (0.03)	1.08	0.09** (0.05)	1.09	0.03 (0.02)	1.03	0.03 (0.03)	1.04
Secondary occupation income	0.00** (0.00)	1.00	0.00 (0.00)	1.00	0.00 (0.00)	1.00	0.00 (0.00)	1.00
Extension contact frequency	0.15*** (0.06)	1.16	-0.06 (0.09)	0.94	0.13** * (0.05)	1.14	0.12** (0.06)	1.12
Respondent is a Male	-0.60 (1.34)	0.55	-2.30* (1.45)	0.10	-1.28* (0.86)	0.28	-0.49 (1.13)	0.61
Respondent is a Female	0.00 -	-	0.00 -	-	0.00 -	-	0.00 -	-
Respondent is Married	1.36 (3934.40)	3.89	-15.15 (2941.33)	0.00	-14.58 (2941.33)	0.00	1.79 (5142.36)	5.98
Respondent is Single	2.65 (3934.40)	14.10	-14.38 (2941.33)	0.00	-13.53 (2941.33)	0.00	1.61 (5142.36)	5.00
Respondent is Divorced	1.75 (3934.40)	5.73	-31.79 (4387.86)	0.00	-15.59 (2941.33)	0.00	2.59 (5142.36)	13.31
Respondent is Widowed	0.00 -	-	0.00 -	-	0.00 -	-	0.00 -	-
Respondent is a Muslim	0.09 (4049.14)	0.92	-0.70 (3862.53)	0.50	-15.24 (2296.42)	0.00	1.48* (0.78)	4.41
Respondent is a Christian	0.17 (4049.14)	1.18	-1.45 (3862.53)	0.23	-16.12 (2296.42)	0.00	-0.12 (0.00)	0.88
Respondent is a Traditional worshipper	0.00 -	-	0.00 -	-	0.00 -	-	0.00 -	-
Land size of 1ha or less	12.86 (4039.47)	384785.82	20.92 (3980.19)	1219116463.91	0.78 (1.59)	2.17	17.51 (4021.98)	4032836 9.50
Land size of 1.01 to 1.5 ha	17.91	59722836	17.27	31727484.63	1.38	3.99	17.30	3263840

	(4039.47)	.13	(3980.19)		(1.42)		(4021.98)	5.51
Land size of 1.501 to 2 ha	17.60 (4039.47)	43947663 .81	18.41 (3980.19)	98786329.21	2.02 (1.50)	7.53	17.14 (4021.98)	2782799 5.26
Land size of 2.01 to 2.5 ha	18.97 (4039.47)	17314048 4.39	19.08 (3980.19)	193586592.25	1.83 (1.67)	6.25	2.58 (4391.45)	13.19
Land size of above 2.5 ha	0.00 -	-	0.00 -	-	0.00 -	-	0.00 -	-
Credit Access	1.65* (1.01)	5.21	-0.26 (1.54)	0.77	0.62 (0.77)	1.85	1.01 (1.02)	2.74
No Credit Access	0.00 -	-	0.00 -	-	0.00 -	-	0.00 -	-

Standard errors are in parenthesis
**** Coefficients significant at 1%*
*** Coefficient significant at 5%*
** Coefficient significant at 10%*
*Chi square of Log likelihood=117.76****
Source: Computed from Survey Data; 2010.

Conclusion and Recommendations

The multinomial logit result highlighted that household size and gender in favour of the males are negatively influencing adaptation behaviours of respondents to climate change. While years of residence in a community, educational level, frequency of extension contact, access to agricultural credit, married respondents, and income from secondary occupation are having positive influence adaptation behaviours of respondents to climate change. It is therefore recommended that:

- Policies from government and other stakeholders should ensure that farmers have access to sufficient credit to increase their ability and flexibility to change production strategies in response to the forecasted climate conditions. There should also be investment on yield increasing technology packages to increase farm income.
- Also, there should be encouragement of informal social net works among farmers and in our rural communities as it has the potentials of increasing social capital useful for adaptation.
- Lastly, farmers should be encouraged to acquire formal education as it has the likelihood of increasing the possibility of taking up adaptation strategies. Also, there should be increased access to extension services to educate farmers more, and disseminate useful agricultural innovations that will improve living standards of the farmers.

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ENVIRONMENTAL POLICY, LEGISLATION AND IMPLEMENTATION

Environmental Sustainability Management Systems and Regulations

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Abstract

Business activities have significant potential for generating impacts on the environment as a result of their environmental aspects. Businesses also tend to locate in areas of dense population in an attempt to maximize resources, which are true for Lagos state and other coastal cities in Nigeria. Population growth thus makes the case for the natural environment very compelling, but the growing population needs to change its habits if it wants to be sustainable.

It is possible that Governments can be caught up in an outmoded mindset that sees conflicts between profitability and sustainability, but this does not have to be the case. Recognizing and resolving government's environmental aspirations, social responsibilities and business development is possible through an integrated management system.

A similar single sustainability management system derived from ISO 9001 quality management system and ISO 14001 environmental management system audit programs was created by BMT Group UK in 2009, which was accredited in 2010. This paper summarizes the essentials of their contribution to growing environmental management challenges.

The generic qualities of both standards properly implemented and embedded in a communication concept based methodology would move environmental performance from a compliance and measurement activity to one that adds value to business which directly or indirectly engages it stakeholders, address socio-economic needs and promote environmental stewardship.

Key words: Business Activities, Population, Sustainability, Social Responsibility, Compliance.

Introduction

A strong majority of us express concern about the environment and believe that at least some (if not immediate and drastic) action must be taken to address environmental problems, yet only less than 20% regard themselves as active participants in such efforts *(Dunlap & Saad, 2001).* We have always altered our physical environment in order to survive, but the pace and scale of current environmental changes knows no precedent. The longer we wait, the worse the problems become, making solutions seem more and more difficult and the gamble we take on technological solutions seems more and more irrational.

The concept of sustainable development in environmental management which was introduced in 1987 by the World Commission for Environment and Development (WCED), known as the *Brundtland Report* has come a long way in trying to shape our future as humans on earth vis-à-vis our responsibility to the environment. This could be truer in coastland and wetland areas as a result of the complexity of environmental interrelationships. The news is bad and it continues to get worse. In any event, it is becoming clear to most of us that we cannot continue on our present course. The process of exponential growth is deceptive because it starts off slowly but quickly and steadily accelerates. It occurs when a quantity increases by a fixed percentage of the whole, meaning that it will double after certain interval rather than grow incrementally.

Visualizing the Scope of Environmental Stewardship

Coastal cities like Lagos and its ever growing population do have extreme impacts on ocean ecosystems. The global trend of rural-urban migration, which is quite evident in places like Port Harcourt and other coastal cities in Nigeria tend to put tremendous strain on the hydrological cycle. These intricacies could not be more evident in wetland regions. Wetlands are transitional areas between land and marine areas providing breeding and nursery areas for thousands of species, but most importantly for humans. If the complex balance of the environment is anything to go by, then we could just be scratching the surface of our impacts on wetland regions.

Interestingly, the solution or solutions to the problem of environmental degradation still eludes the majority of us. This is evident in the constant divide by scientists and nations on how best to combat this ever creeping and perceived eminent danger that threatens the survival of the human race.
This paper however focuses on the effect of population increase and land use management with respect to governmental environmental policies and sustainable business practices as they relate to environmental management.

Presently, current proposed solutions have been nonetheless grossly inadequate, partly because private and public institutions are approaching environmental issues differently, or according to their individual convictions. For example,

I. Governments are more inclined to be worried about economic developments than caring for a disappearing wetland region;
II. Environmentalist are concerned with past and present crimes, such as, mining operations, emissions from automobiles, use of pesticides, waste production etc. while the rest of us are just plain scared of the impacted balance of nature and the unknown.

According to the United Nations Development Program's (UNDP) Human Development Report 2007/2008 (UNDP 2007) and the recent Global Monitoring Report (World Bank and IMF 2008), as well as other literature within the last decade or so, on economic growth and the environment, has shown that environmental sustainability could be consistent with sustained economic growth if certain conditions are met. But one cannot but ignore the handling of 'Social Equity' by governments as seen everyday in the news media. We see nations advertising

their respective countries on international media telling people to come visit, on the basis of their economic development. On the other hand, it seems most nations tend to owe a lot of money! Where is the logic in all these?

Current Situation of the Environmental Global Governance

Economic stagnation is almost always associated with government policy failures, such as misallocation of public revenues, and failure to promote the development of certain basic institutions. A lot of these policy failures, by and large could be attributed to ignorance and the total loss of social responsibility currently being exhibited in the political systems the world over. The amounts or level of riches of special interest groups and elites are now variables or indicators used for measuring countries economic growth. So, if countries like the United States of America that is on the forefront of sustainable environmental and economic developments (social-entity effect) are currently in debt to a whooping tune of 14 trillion dollars with China, and other creditors holding just over 4 trillion dollars, that is 30 percent of the total sum. Hence, who does the US government owe the rest to? The answer would be the business community.

On the up side, we have seen an ever increasing participation from committed professionals and scientist in the environmental sectors and other facets of the cooperate world. Large bodies of scholarly analysis now exist in academia; environmental policies and scientific research have been enacted by governments the world over. However, as humans, we have been known to always alter our physical environment in a bid to survive; and giving the steady population increase amongst other things, the rate and scale of these environmental changes are nothing short of frightening. The current situation has become too complicated and cumbersome to get a grip on by a small group of scientists.

One of the greatest misconceptions that have ever been propagated is that of the meaning of the word environment! The environment does not only imply coastal and wetland regions, pollution and endangered species coral reef destruction, deforestation, to mention a few; it is more of an integrated system than a global economy which is adversely impacted by human activities. The inefficient patterns of goods and services consumptions and the equally biased population distribution configuration are putting additional pressure on the current already over stretched natural resources.

Considering what has been done so far by all parties involved, is still a far cry from the current situation we now find ourselves in. The word climate change which has been loosely thrown around should about now be taken more seriously! We are at this time seeing monumental frequencies in “acts of God”. The present information and data on environmental issues have by no means translated to better knowledge or efficiency. This could be attributed to their lack of connectivity or contradictory nature, giving rise to a challenge in sustainable governance and methodological challenges.

A Complementary Approach to Promoting Environmental Sustainability

If the Gaia hypothesis by *James Lovelock 1970* (An active, adaptive control process, able to maintain the Earth in overall Balance) is anything to go by, then a leaf should be borrowed from nature. The key word here is balance! Earth science recognizes four spheres, the lithosphere, the hydrosphere, the atmosphere and the biosphere which are linked in a complex web of sustainability. This could also be said for a civil society and governments. There are obviously complex inter-linkages existing between the environment and the human society or in other words, governance, economic policies and the environment. What has been achieved so far seems to be disjointed, and approached individually with lots of emphasis on bias and prejudice across the board. It appears that the global agenda on environmental sustainability did not arise as a result of actual impacts on people; but rather forged from top to bottom by international watch dogs of the environment, which has nonetheless translated into gigantic disparities in the degree of public awareness and support.

A more coherent understanding between the economy and the environment thus seems a better approach towards sustainability. Management systems that could quantify trends and impacts in environmental degradation; impact policy changes and communicate awareness to the civil society as delineated by the Commission on Sustainable Development (CSD) in Agenda 21, of the 1992 Rio Earth Summit. But what these groups mainly translate to, in lack of a proper phrase, is "the general populace".

Businesses and the Environmental Psychology of the Civil Society

To put it simply,

I. The business community has been making huge profits as a result of the boost in the world's population and the advancement in social networking.
II. Business has now embedded itself with the politics of governments that any meaningful decisions on reaching a variable environmental sustainability could not exist in isolation, that is, without economic sustainability.
III. Our social and behavioral psychic has also been greatly affected by businesses through our dependence on consumables.

An Integrated Management System:

A simple management system created from two similar but different management systems would achieve positive economic growth along with environmental sustainability and social environmental stewardship, one that will touch every structural dimension of human endeavor, such as, material and energy flow, as well as ethical, aesthetic and cultural values. The transition towards sustainability is enormous and a process of social, cultural and technological innovation.

Integrating an International Standard Organization (ISO) 14001 and International Standard Organization (ISO) 9001management principles, as a single management system would enable

the vast majority of the sustainable society develop a more habitual sense of sustainability through a low cost information dissemination system.
ISO 14001 is part of an international standard for environmental management with a set of interrelated elements used to establish policies and organizational objectives in companies. The standard amongst other things, measures the results of an organization's management of its environmental aspects against the organization's policy, environmental objectives, targets and performance requirements.

While ISO 9001 is part of the ISO 9000 series, concerned with quality management and meeting customer quality requirements. The two standards are known as generic management system standards because they are not specific to a particular organization or sector, whether it is business, public administration, or a government department. This Sustainable Management Environmental System (SMES) will contribute to the conservation and regeneration of the social and capital demand that has come to dominate our current way of life. The system would enable;

I. Government review environmental regulations and policies that would give more incentives to businesses, hereby promoting necessary communication through these companies, environmental awareness to further develop peoples understanding of the consequences of their actions on the environment.
II. By adapting SMES, business in turn would be practicing lean management. That is to say, adopting environmental procurement practices in their raw material consumption purchases hereby reducing waste, improve resource efficiency, provide cost savings and enhance corporate image and provide added value by helping stimulate markets for environmentally preferred goods and service
III. The environmental sustainability awareness that is being feed into this social learning process of our versatile human nature, will empower communities with a sense of initiative, collaboration and belief in its ability to find a sustainable way of living which would in-turn translate back to governments in form of leadership and continuity. Thus, civil societies can help build a political will for a new approach to development that integrates environmental and social goals. In turn, governments would direct attention towards concrete and direct methods of environmental sustainability.

By comparison to other innovative ways of trying to solve our environmental dilemma, the proposed solution ideally focuses on behavioral technology to try and change people's perception towards understanding our environmental problems through education and change in attitudes. In reality, the SMES methodology is a product and service-based system which addresses the problem of global environmental degradation through an already existing social and cultural framework of the society (meaning; governments, businesses, and stakeholders) in their respective regions. The complexity of our world is an issue that makes developing an all encompassing environmental management system a difficult if not an impossible task.
For instance, the cumulative pollution effects on ocean ecosystems in Nigeria, as a result of social ignorance and lack of concern for the environment from the consumption of everyday product could result to an unprecedented change in certain environmental conditions in

Canada. As such, the sustainable management environmental system tries to engage the socio-economic and environmental processes that define our existence.

Conclusion

In this paper we have seen that the challenges and solutions to environmental management are like strands in a mass of knotted string. The natural climatic regulation and chemical interactions that exist between the earth's spheres result in an intricate network that affects the rise and fall of natural processes and biodiversity which is especially more intense in coastland and wetland areas. But the balance of nature has been nature's way of sustainability since the beginning of time.

The argument presented in the design of the sustainable environmental management system, has simply borrowed a leaf from nature. It is based on the concept of creating a balance between institutions and human social activities through corporate technological innovation and communication from a bottom-up initiative (where life-sustaining processes of the environment should be perceived as a common concern for us all) that would inevitably lead to a diverse sustainable society. A system consisting of two already well tested management standards (ISO 9001 and ISO 14001) currently been employed in their respective realms of the society, namely; economic and environmental development.

Environmental interrelationships are nothing but very complex, everything seems to be connected to everything else, the uneven distribution in urbanization does not appear to be helping matters, however, there have been efforts by national and international legislation leading to the control of environmental degradation, but how well informed about the magnitude of the problem is the ordinary man on the street?

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Sustainability Reporting in the Nigerian Oil and Gas Sector

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Abstract

This paper assesses sustainability reporting in the Nigerian Oil and Gas sector. Content analysis was used on data sourced from the annual reports of selected oil companies to identify the extent to which their reporting has been in line with global best practices. The study found an arbitrary and incompatible sustainability reporting indicators among all the sampled companies and therefore recommends the introduction of sustainability reporting framework in line with global best practices in the Nigerian Oil and Gas sector.

Keywords: Sustainability reporting, oil and gas companies, corporate social responsibility, disclosure, multinationals.

Introduction

Conventional financial reporting has been premised on the notion that, although a number of identifiable user group exist, the primary concerns of financial statements are shareholders, prospective investors and financial intermediaries (FEE, 2000). Friedman (1962) claimed that the only responsibility of business is to make profits and traditional financial statements principally report on shareholders at the detriment of other stakeholders.

In the past decade however, there has been a consistent concern that traditional financial reports do not adequately represent the multiple dimensions of corporate value today (Simnet, Vanstraelen & China, 2009). This pressure has further been exacerbated by the recent global financial crisis with its profound consequences on accounting and auditing. This has resulted in a search for both new financial metrics and additional non-financial measures of value/performance (Stewart 1999; Skveiby, 1997), and a call for better corporate governance, transparency and accountability as traditional financial statement do not provide a full measure of business performance and shareholder value creation.

During the past 40 years, pressures from a variety of sources have come to bear on the business community on their responsibility towards all of its stakeholders, environment and the society in which it operates (Sihotang & Effendi, 2010; Dilling, 2010), hence, the need for an

interdisciplinary reporting that reflects a simultaneous integration of economic, environmental and social factors into corporate behavior with the aim of sustaining resources for future generation (Eppel, 1999 as quoted by Quick, 2008). Sustainability reporting has emerged in an attempt to respond to the demands for interdisciplinary reporting. While there is no single globally accepted definition of sustainability reporting, Elkington (1997) stated that "the term sustainability reporting or "triple bottom-line" in its narrowest term is a framework for measuring and reporting corporate performance against economic, social and environmental parameters while in its broadest term, it is the whole set of values, issues and processes that companies must address in order to minimize any harm resulting from their activities and to create economic, social and environmental values and the three lines represent society, economy and the environments. Although, sustainability reporting has yet to reach a generally accepted standard of financial reporting and is still largely a voluntary exercise in many countries of the world, however, this is changing with mandatory requirements being introduced in countries such as France, Germany, South Africa (ACCA, 2005; SIRAN, 2008).

Nigeria should not be an exception in the introduction of sustainability reporting in the business community with particular reference to the oil and gas sector in view of its role in economic development of the nation. The oil and gas sector is the backbone and mainstay of Nigeria's economy, accounting for over 95% of her foreign exchange earnings, 40% of her GDP and 85% of the Federal Government's collectible revenue (Uwakonye, Osho & Anucha, 2006). The major oil producing companies are Shell Petroleum Development Company of Nigeria Ltd., Mobil Producing Nigeria Unlimited, Chevron Nig. Ltd., Nigerian Agip Oil Company Ltd., Elf Petroleum Nig. Ltd., and Texaco Overseas Petroleum Company of Nigeria Unlimited. These multinationals participate in the petroleum industry in joint ventures with Nigeria National Petroleum Corporation (NNPC), as operators/contractors in the Nigeria deep water under production sharing contracts (PSC) which did not address the triple bottom line aspect of sustainability reporting and in one instance under a service contract with NNPC. All of the crude oil in Nigeria comes from numerous small producing fields, located in the swamps of the Niger Delta, however, the multinationals have had to contend with a number of issues including lack of transparency, environmental degradation, insensitivity to stakeholders concern and have continually been targets of community unrest and public criticisms.

Consequently, the objective of this paper is to carry out a critical assessment of the current level of sustainability reporting through content analysis with a view of recommending a framework in line with international best practices. The analysis is based on the multinational oil and gas companies whose operations have a very strong impact on the environment.

Sustainability Reporting Best Practices

Several reporting standards exist as guidelines for reporting sustainability. These standards are as follows:

- Global reporting initiative sustainability reporting guideline developed by Global Reporting Initiative in 2006.

- Oil and Gas Industry Guidance on Voluntary Sustainability Reporting developed by American Petroleum Initiative (API) and the International Petroleum Industry Environmental Conservation Association (IPIECA).
- Organization for Economic Cooperation and Development Guidelines for Multinational Enterprises developed by Organization for Economic Cooperation and Development (OECD).
- Environmental Management (ISO 14001, EMAS)
- Greenhouse Gas Protocol developed by World Business Council for Sustainable Development (WBCSD) and World Resources Institute (WRI).
- Global Compact and United Nation Norms developed by the United Nations.
- AA 1000 for auditing and assurance process developed by Accountability, an international membership organization.
- Social Accountability 8000 developed by Social Accountability International, an independent organization consisting of business, non-governmental organizations, trade unions and others.

Among other standards, the GRI G3 Sustainability reporting guidelines and the API/IPIECA oil and gas industry guidance on voluntary sustainability reporting are the most widely accepted reporting standard for oil and gas industries.

Methodology

The primary purpose of this paper is to carry out an assessment of the current level of sustainability reporting in line with international best practices. The study focused on the six major oil and gas multinationals operating in Nigeria. Data were sourced through content analysis of annual reports (global and local), stand-alone sustainability reporting and other triple line-reporting publications.

The Global Reporting Initiative and the IPIECA oil and gas industry guidance on voluntary sustainability reporting served as the basis for the development of an evaluation method. While the two studies outlined above applied an extensive range of evaluation criteria, this study will only use limited criteria deemed relevant within the Nigerian context. The description of the evaluation criteria are as shown in Table 1.

The following scaling ratings were applied in assessing the degree of reporting in the sample companies.

	Rating/Score
✓ Issue not reported at all	0
✓ Issue reported locally but in general terms	1
✓ Issue reported locally and in specific terms	2
✓ Issue reported globally with no specific mention of Nigeria	3
✓ Issue reported globally and with specific mention of Nigeria	4
✓ Issue reported in both global and local reports	5

Discussion

Criterion 1: Organizational Profile, Strategy, Report and Governance

All surveyed multinationals fared well under the above criterion with the exception of Governance. Most multinationals reported extensively on their profile, strategy and reporting parameters. On the issue of strategy, while multinationals established a relationship between companies' strategies and sustainability in their global reports, such was not reported at the local level. 50% of the sampled companies described key impacts risks and opportunities at both local and global levels, the other 50% only reported same issues only on the global scene. On the issue of the Reporting parameters, multinationals only described their reporting cycle both locally and globally but failed to mention the contact person at the local level and their policies with regards to seeking external assurance for the report.

However, in the reporting of governance structure, all companies reported globally but their Nigerian affiliates did not report on key issues like list of stakeholders group, approaches and frequency of engagement; basis for identification and selection of stakeholders with whom to engage as well as key topics and concerns raised and how the organization responded to them.

Criterion 2: Economic Performance Indicators

All surveyed companies reported extensively on their economic performance indicators in both local and global reports but failed on their responsibilities to mention in their local reports policies and / or advocacy programmes for the promotion of transparency of payments to host government. Over the years, the multinationals have been accused by other stakeholders of a lack of transparency in their dealings with the Nigerian government. These criticisms, inter alia, culminated to the introduction of Nigeria Extractive Industries Transparency Initiatives (NEITI) which was meant to promote transparency in the activities of the multinationals in their dealing with the Federal Government. As at the time of carrying out this research, the said initiatives remained non-operative.

Criterion 3: Environmental Performance Indicators

All surveyed companies reported environmental performance Indicators in general terms in their global reports but their local affiliates did not make any report on their environmental performance. On spills and discharges, multinationals in their local reports failed to mention the number and volume of hydrocarbon spiloled and present in regulated discharges to a water environment.

On the issue of wastes and residual materials, teere was no report on the quantity of hazardous and non-hazardous wastes disposed toxic releases and the total quantity of materials recycled, re-used or reclaimed that would otherwise have been considered as wastes.

On emissions issues, international best practices require that individual quantities of emissions by type, total volume of hydrocarbon gsa both vented and flared to the atmosphere and annual

emissions of greenhouse gases reported as total co2 equivalent be appropriately accounted for. This requirement was not adhered to by multinationals in their local reports.

On resource usage, the multinationals only reported the implementation and coverage of an Environmental management system in both local and global reports while the Quantity of primary energy and fresh water consumed in their operations were only reported globally.
On Biodiversity, companies failed to report locally their operations in area of high biodiversity, the impact of their operations on biodiversity and their strategies for managing the impact on biodiversity associate with their activities despite reporting same in their global reports.

Criterion 4: Health and Safety Performance Indicators
While multinationals operations in Nigeria stated the existence and implementation of an occupational health and safety management system, they failed to describe in specific terms the participation of employees in health dialogues, the existence of programmes to understand the general health risks affecting the local force and a description of a system for reporting occupational injuries unto total injury rate, total illness rate, lost time injury rate and fatality rate.

Criterion 5: Social Responsibility Performance Indicators
Multinationals in their local reports failed on their Social Responsibility performance Indicators. In respect of Hunan Rights, there was neither policies and / or procedure for addressing human rights nor employees training on the issue of human right. There was no report on the number of incidents of discrimination and violation involving rights indigenous people and action taken (if any).

In terms of employment practices, while multinationals reported on the availability of a policy for preventing discrimination among employees, there was no programme to gauge employees' satisfaction. On the issue of the community, there were no description of processes engaged and address the needs of indigenous communities, resettlement and land rights of impacted communities, management of the positive and negative impacts on communities in areas affected by core business activities, the total number of legal actions against the companies were not reported although the companies made provision for contingent liabilities (for issues like fines, non compliance with laws and court cases) in their local reports

Conclusion

(i) The study found out significant variations in sustainability reporting disclosures with no support by any known local regulation.
(ii) While multinationals reported extensively in line with global best practices in their global reports, their local affiliates did not report locally on the same issue
(iii) Multinationals also differed in their mode of reporting which resulted in a lack of comparison from one company to another.
(iv) Multinationals operating in Nigeria fared badly in their Environmental and Social

reporting indicators which may partly explain the upsurge in criticism and unrest that characterized their operations in the last decade.

Recommendations

Since multinationals operating in the Nigerian Oil and Gas sector have not been adhering to international best practices on the issue of sustainability reporting, this paper recommends a mandatory localized sustainability reporting framework in line with international best practices as practiced in countries like France, Germany and South Africa for companies operating in the Oil and Gas sector of the economy in view of the criticality of the sector to the economic well-being of the Nigerian State.

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Table 1: Description of Sustainability Reporting indicators and Assessment/Ratings

S/No	Code	Indicators	Multinational Oil/Gas Companies Assessment/Ratings					
Criterion 1: Organizational Profile, Strategy, & Governance								
Organizational Profile			A	B	C	D	E	F
1.	OR1	Name of organization, primary brand, product and /or service						
2.	OR2	Countries in which the organization's operations are located and its headquarters						
3.	OR3	Market served (including geographic breakdown, sector served and types of customers).						
4.	OR4	Significant changes during the reporting period regarding size, structure and ownership.						
Organizational Strategy								
5.	OR5	Statement from CEO about relevance of sustainability to organization and its strategy.						
6.	OR6	Description of key impacts, risks and opportunities.						
Report Parameters			A	B	C	D	E	F
7.	OR7	Reporting period (e.g. calendar year) and cycle.						
8.	OR8	Contact person(s) for the report including e-mail and web addresses.						
9.	OR9	Boundaries of the report (countries/divisions/ leased facilities /joint venture) and specific limitation on boundary of reports						

10.	OR10	Policy and current practices with regard to seeking external assurance for the report.						
Governance			A	B	C	D	E	F
11.	OR11	Governance structure of the organization, including major committees under the board of directors that are responsible for setting strategy or organizational oversight.						
12.	OR12	Mechanism for shareholders and employees to provide recommendations or direction to the highest governance body.						
13.	OR 13	Internally developed statements of mission or value, code of conducts and principles relevant to economic, environmental, and social performance and the status of their implementation.						
14.	OR14	Procedure of the highest governance body for overseeing the organization's identification and management of economic, environmental, and social performance, including relevant risks and opportunities, and adherence or compliance with internationally agreed standards, codes of conduct and principles.						
15.	OR15	Process for evaluating the highest governance body's own performance, particularly with respect to economic, environmental and social performance.						

16.	OR16	Externally developed economics, environmental, and social charters, or other initiatives to which the organization subscribes or endorses.						
17.	OR17	List of stakeholder groups engaged by the organizations.						
18.	OR18	Approaches to stakeholder engagement, including frequency of engagement by type and by stakeholder group.						
19.	OR19	Key topics and concerns that have been raised through stakeholder engagement and how the organization has responded to those key topics and concerns, including through its reporting.						
20.	OR20	Basis for identification and selection of stakeholders with whom to engage.						
<u>Criterion 2: Economic Performance Indicators</u>								
Shareholders			A	B	C	D	E	F
21.	EC1	Dividend paid plus share repurchases (if applicable)						
Government			A	B	C	D	E	F
22.	EC2	Globally aggregated annual amount of income tax expenses.						
23.	EC3	Polices or advocacy programmes for the promotion of transparency of payments to host governments.						
		Employees	A	B	C	D	E	F
24.	EC4	Total employees payroll and benefits for the current reporting period.						

25.	EC 5	Organization's defined benefit plan obligations for employees procedure for local hiring and proportion of senior management hired from the local community at locations of significant operation.						
Supplier and Contractors			A	B	C	D	E	F
26.	EC 6	Total capital expenditures.						
Lenders and Holders of Debt Securities			A	B	C	D	E	F
27.	EC7	Interest paid to lenders and holders of the company's debt securities in the reporting period.						
Criterion 3: Environmental Performance Indicators								
Spills and Discharges			A	B	C	D	E	F
28.	EN 1	Number and volume of hydrocarbon liquid spills greater than 1 barrel that reach the environment.						
29.	EN 2	Quantities of hydrocarbons present in controlled or regulated discharges to a water environment (both inland waterways or to the sea).						
30.	EN 3	Quantities of permitted or controlled discharges of chemicals or materials other than hydrocarbons.						
31.	EN 4	Significant non-hydrocarbon spills and accidental releases from operational upsets.						
Wastes and Residual Materials			A	B	C	D	E	F
32.	EN 5	Quantity of regulated hazardous wastes disposed.						
33.	EN 6	Quantity of non-hazardous waste disposed.						

34.	EN 7	Total quantity of materials recycled, reused or reclaimed that would otherwise have been considered harzadous or non-hazardous wastes.						
35.	EN 8	Toxic Releases						
Emissions			A	B	C	D	E	F
36.	EN 8	Annual emissions of greenhouse gases reported as total CO_2 equivalent and as individual species, from facilities managed and /or owned by the company.						
37.	EN 9	Total mass or volume of hydrocarbon gas both vented and flared to the atmosphere from operations and reported separately.						
38.	EN10	Individual quantities of omissions by type released to the atmosphere from oil and natural gas operations during routine and non-routine processing.						
Resource Use			A	B	C	D	E	F
39.	EN11	Quantity of primary energy consumed in oil and natural gas operations including the primary energy that is generated on site or imported.						
40.	EN12	Fresh water consumed in oil and gas operations where availability is a significant issue.						
41.	EN13	Initiatives to develop produce or use alternative or renewable energy sources.						
42.	EN14	Implementation and coverage of an Environmental management system.						
Biodiversity			A	B	C	D	E	F

43.	EN15	Location and size of land owned, leased, managed in or adjacent to, protected areas and areas of high biodiversity value outside protected areas.						
44.	EN16	Description of significant impacts of activities, products, and services on biodiversity in protected areas and areas of high biodiversity value outside protected areas.						
45.	EN17	Habitats protected or restored.						
46.	EN18	Strategies, current actions, and future plans for managing impacts on biodiversity associated with activities in terrestrial, fresh water and marine environments.						
47.	EN19	National conservation list species with habitats in areas affected by operations by level of extinction risk.						
Criterion 4: Health and Safety Performance Indicators								
48.	HE 1	Implementation and coverage of an occupational health and safety management system.						
49.	HE 2	Participation of employees in safety and health dialogues.						
50.	HE 3	Existence of programmes and practices to understand the general health risks and experiences affecting the local workforce.						
51.	HE 4	Description of a system for recording occupational injuries and illness and reporting them as total injury rate, total illness rates, lost time injury rate and fatality rates.						
Criterion 5: Social Responsibility Performance Indicators								

Human Rights			A	B	C	D	E	F
52.	SR 1	Policies/Procedures to address human rights broadly, as relevant to operations including implementation progress.						
53.	SR 2	Total hours of employees training on issues of human rights relevant to operations.						
54.	SR 3	Total number of incidents of discrimination and actions taken.						
55.	SR 4	Total number of incidents of violations involving rights of indigenous people and actions taken.						
Business Ethics			A	B	C	D	E	F
56.	SR 5	Policies and/or procedures for addressing bribery and corruption.						
57.	SR 6	Policies and/or procedures for managing political contributions, political lobbying and advocacy.						
Employment Practice			A	B	C	D	E	F
58.	SR 7	Policy and/or procedure preventing discrimination among employees in operations, including a description of equal opportunity practices.						
59.	SR 8.	Description of programmes to gauge employee satisfaction.						
60.	SR 9.	Total workforce by employment type, contract and region.						
61.	SR 10	Average hours of training per year per employee category.						

62.	SR 11	Policies and/or procedures for hiring and training local employees within a country/region, including at senior levels.						
Community and Society			A	B	C	D	E	F
63.	SR 12	Processes for assessing and managing positive and negative impacts on communities in areas affected by core business activities.						
64.	SR 13	Amount of social investment including policies and procedures for making the social investment.						
65.	SR 14	Description of processes to engage with and address the needs of indigenous communities.						
66.	SR 15	Policies and/or procedures to address resettlement and land rights of impacted communities.						
67.	SR 16	Percentage and total number of business units analysed for risks related to corruption.						
68.	SR 17	Action taken in response to incidents of corruption.						
69.	SR 18	Public policy positions and participation in public policy development and lobbying.						
70.	SR 19	Total value of financial and in-kind contributions to political parties, politicians and related institutions.						
71.	SR 20	Total number of legal actions for anti-competitive behavior, antitrust and monopoly practices and their outcomes.						
72.	SR 21	Monetary value of significant fines and total number of non-monetary sanctions for non-compliance with laws and regulations.						

Source: GRI, 2006; API/IPIECA, 2005

The following scaling ratings were applied in assessing the degree of reporting in the sample companies.

	Rating/Score
✓ Issue not reported at all	0
✓ Issue reported locally but in general terms	1
✓ Issue reported locally and in specific terms	2
✓ Issue reported globally with no specific mention of Nigeria	3
✓ Issue reported globally and with specific mention of Nigeria	4
✓ Issue reported in both global and local reports	5

Table 2: Results of Assessment/Ratings of the six multinationals operating in the Sector

S/No	**Code**	**Indicators**	**Multinational Oil/Gas Companies Assessment/Ratings**					
Criterion 1: Organizational Profile, Strategy, & Governance								
Organizational Profile			A	B	C	D	E	F
1.	OR1	Name of organization, primary brand, product and /or service	5	5	5	5	5	5
2.	OR2	Countries in which the organization's operations are located and its headquarters	5	5	5	5	5	5
3.	OR3	Market served (including geographic breakdown, sector served and types of customers).	5	5	5	5	5	5
4.	OR4	Significant changes during the reporting period regarding size, structure and ownership.	5	5	5	5	5	5
Organizational Strategy								
5.	OR5	Statement from CEO about relevance of sustainability to organization and its strategy.	3	3	3	3	3	3
6.	OR6	Description of key impacts, risks and opportunities.	3	5	3	5	3	5
Report Parameters								
7.	OR7	Reporting period (e.g. calendar year) and cycle.	5	5	5	5	5	5

8.	OR8	Contact person(s) for the report including e-mail and web addresses.	3	3	3	3	3	3
9.	OR9	Boundaries of the report (countries/divisions/ leased facilities /joint venture) and specific limitation on boundary of reports	3	5	5	5	3	3
10.	OR10	Policy and current practices with regard to seeking external assurance for the report.	3	3	3	3	3	3
Governance								
11.	OR11	Governance structure of the organization, including major committees under the board of directors that are responsible for setting strategy or organizational oversight.	5	5	5	5	5	5
12.	OR12	Mechanism for shareholders and employees to provide recommendations or direction to the highest governance body.	5	5	5	5	5	5
13.	OR 13	Internally developed statements of mission or value, code of conducts and principles relevant to economic, environmental, and social performance and the status of their implementation.	5	5	5	5	5	5
14.	OR14	Procedure of the highest governance body for overseeing the organization's identification and management of economic, environmental, and social performance, including relevant risks and opportunities, and adherence or compliance with internationally agreed standards, codes of conduct and principles.	3	3	3	3	3	3

15.	OR15	Process for evaluating the highest governance body's own performance, particularly with respect to economic, environmental and social performance.	3	3	3	3	3	3
16.	OR16	Externally developed economics, environmental, and social charters, or other initiatives to which the organization subscribes or endorses.	3	3	3	3	3	3
17.	OR17	List of stakeholder groups engaged by the organizations.	3	0	3	3	0	3
18.	OR18	Approaches to stakeholder engagement, including frequency of engagement by type and by stakeholder group.	3	3	0	0	3	3
19.	OR19	Key topics and concerns that have been raised through stakeholder engagement and how the organization has responded to those key topics and concerns, including through its reporting.	0	0	3	3	0	3
20.	OR20	Basis for identification and selection of stakeholders with whom to engage.	0	0	0	3	0	0
Criterion 2: Economic Performance Indicators								
Shareholders			A	B	C	D	E	F
21.	EC1	Dividend paid plus share repurchases (if applicable)	5	5	5	5	5	5
Government								
22.	EC2	Globally aggregated annual amount of income tax expenses.	5	5	5	5	5	5
23.	EC3	Polices or advocacy programmes for the promotion of transparency of payments to host governments.	3	3	3	3	3	3
		Employees						

24.	EC4	Total employees payroll and benefits for the current reporting period.	5	5	5	5	5	5
25.	EC 5	Organization's defined benefit plan obligations for employees procedure for local hiring and proportion of senior management hired from the local community at locations of significant operation.	5	5	5	5	5	5
Supplier and Contractors								
26.	EC 6	Total capital expenditures.	5	5	5	5	5	5
Lenders and Holders of Debt Securities								
27.	EC7	Interest paid to lenders and holders of the company's debt securities in the reporting period.	5	5	5	5	5	5
Criterion 3: Environmental Performance Indicators								
Spills and Discharges			A	B	C	D	E	F
28.	EN 1	Number and volume of hydrocarbon liquid spills greater than 1 barrel that reach the environment.	3	3	3	3	3	3
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30.	EN 3	Quantities of permitted or controlled discharges of chemicals or materials other than hydrocarbons.	3	3	3	3	3	3
31.	EN 4	Significant non-hydrocarbon spills and accidental releases from operational upsets.	3	3	3	3	3	3
Wastes and Residual Materials								
32.	EN 5	Quantity of regulated hazardous wastes disposed.	3	3	3	3	3	3

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34.	EN 7	Total quantity of materials recycled, reused or reclaimed that would otherwise have been considered hazardous or non-hazardous wastes.	3	3	3	3	3	3
35.	EN 8	Toxic Releases	0	0	0	0	0	3
Emissions								
36.	EN 8	Annual emissions of greenhouse gases reported as total CO_2 equivalent and as individual species, from facilities managed and /or owned by the company.	3	3	3	3	3	3
37.	EN 9	Total mass or volume of hydrocarbon gas both vented and flared to the atmosphere from operations and reported separately.	3	3	3	3	3	3
38.	EN10	Individual quantities of emissions by type released to the atmosphere from oil and natural gas operations during routine and non-routine processing.	3	3	3	3	3	3
Resource Use			A	B	C	D	E	F
39.	EN11	Quantity of primary energy consumed in oil and natural gas operations including the primary energy that is generated on site or imported.	3	3	3	3	3	3
40.	EN12	Fresh water consumed in oil and gas operations where availability is a significant issue.	3	3	3	3	3	3
41.	EN13	Initiatives to develop produce or use alternative or renewable energy sources.	5	5	5	5	5	5
42.	EN14	Implementation and coverage of an Environmental management system.	5	5	5	5	5	5
Biodiversity			A	B	C	D	E	F

43.	EN15	Location and size of land owned, leased, managed in or adjacent to, protected areas and areas of high biodiversity value outside protected areas.	3	3	3	3	3	3
44.	EN16	Description of significant impacts of activities, products, and services on biodiversity in protected areas and areas of high biodiversity value outside protected areas.	3	3	3	3	3	0
45.	EN17	Habitats protected or restored.	3	3	3	3	3	3
46.	EN18	Strategies, current actions, and future plans for managing impacts on biodiversity associated with activities in terrestrial, fresh water and marine environments.	3	0	0	3	3	0
47.	EN19	National conservation list species with habitats in areas affected by operations by level of extinction risk.	3	3	0	3	3	0
Criterion 4: Health and Safety Performance Indicators								
48.	HE 1	Implementation and coverage of an occupational health and safety management system.	5	5	5	5	5	5
49.	HE 2	Participation of employees in safety and health dialogues.	3	3	3	3	3	3
50.	HE 3	Existence of programmes and practices to understand the general health risks and experiences affecting the local workforce.	0	0	0	0	0	0
51.	HE 4	Description of a system for recording occupational injuries and illness and reporting them as total injury rate, total illness rates, lost time injury rate and fatality rates.	3	3	3	3	3	3
Criterion 5: Social Responsibility Performance Indicators								

Human Rights			A	B	C	D	E	F
52.	SR 1	Policies/Procedures to address human rights broadly, as relevant to operations including implementation progress.	0	0	0	0	0	0
53.	SR 2	Total hours of employees training on issues of human rights relevant to operations.	0	0	0	0	0	0
54.	SR 3	Total number of incidents of discrimination and actions taken.	0	0	0	0	0	0
55.	SR 4	Total number of incidents of violations involving rights of indigenous people and actions taken.	0	0	0	0	0	0
Business Ethics			A	B	C	D	E	F
56.	SR 5	Policies and/or procedures for addressing bribery and corruption.	0	0	0	0	0	0
57.	SR 6	Policies and/or procedures for managing political contributions, political lobbying and advocacy.	3	3	3	3	3	3
Employment Practice								
58.	SR 7	Policy and/or procedure preventing discrimination among employees in operations, including a description of equal opportunity practices.	5	5	5	5	5	5
59.	SR 8.	Description of programmes to gauge employee satisfaction.	0	0	0	0	0	0
60.	SR 9.	Total workforce by employment type, contract and region.	5	5	5	5	5	5
61.	SR 10	Average hours of training per year per employee category.	5	5	3	3	5	5

62.	SR 11	Policies and/or procedures for hiring and training local employees within a country/region, including at senior levels.	5	5	5	5	5	5
Community and Society								
63.	SR 12	Processes for assessing and managing positive and negative impacts on communities in areas affected by core business activities.	3	3	3	3	3	3
64.	SR 13	Amount of social investment including policies and procedures for making the social investment.	5	5	5	5	5	5
65.	SR 14	Description of processes to engage with and address the needs of indigenous communities.	0	0	0	0	0	0
66.	SR 15	Policies and/or procedures to address resettlement and land rights of impacted communities.	0	0	0	0	0	0
67.	SR 16	Percentage and total number of business units analysed for risks related to corruption.	3	0	0	3	3	0
68.	SR 17	Action taken in response to incidents of corruption.	0	0	0	3	0	3
69.	SR 18	Public policy positions and participation in public policy development and lobbying.	3	3	3	3	3	3
70.	SR 19	Total value of financial and in-kind contributions to political parties, politicians and related institutions.	5	5	5	5	5	5
71.	SR 20	Total number of legal actions for anti-competitive behavior, antitrust and monopoly practices and their outcomes.	3	3	3	3	3	3
72.	SR 21	Monetary value of significant fines and total number of non-monetary sanctions for non-compliance with laws and regulations.	5	5	5	5	5	5

Source: GRI, 2006; API/IPIECA, 2005

ENVIRONMENTAL, SOCIO-ECONOMIC AND HEALTH IMPACT ASSESSMENT

Assessment of the Economic Value of Selected Wetlands in Southwest, Nigeria

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Abstract

This study assessed the economic value of the Eleyele, Eriti, and Lagos Lagoon wetlands in Oyo, Ogun and Lagos States (Nigeria) respectively. The study was based on primary data collected on livelihood activities of 160 wetland users that were drawn in a multistage sampling process. The data were obtained by administration of questionnaire that was designed to elicit information on the respondents' socio-economic characteristics and livelihood activities around the wetlands. The wetland users' willingness to pay (WTP) for utilization of the wetlands was also assessed by Contingent Valuation method based on an iterative bidding game process. The data were analysed by descriptive and budgetary techniques as well as Tobit regression analysis. The study revealed that the most prevalent economic activities around the wetlands include crop farming and fishing. Most (71.8%) of the operators of these livelihood activities were males, majority (58.8%) of which had no more than primary school education. Budgetary analysis showed that the Net Factor Income (NFI) per ha per year, which is the economic value of the wetland when used for crop farming, was ₦349,024 for Eleyele wetland, ₦239,694 for Eriti wetland, ₦263,699 and ₦175,633 for Badagry and Epe wetlands respectively. In terms of fishing, the economic value per year of Eleyele wetland's water body was estimated to be ₦32, 341,920 while that of Epe wetland was ₦1, 486,974,024. Eriti. The average WTP was ₦8,050.42, and was significantly ($p<0.05$) higher among fisherfolks (₦11,967.57/year) and crop farmers (₦8,370.40). The Tobit regression analysis result showed that the WTP for wetland utilisation is significantly ($p<0.05$) higher among female-folks than their male counterparts and those in the urban area vis-a- vis their rural counterparts. The study therefore concludes that wetlands are not wastelands but of economic importance to various users and thus recommends that the government should put in place measures to reduce wetland destruction as this leads to significant income losses to members of farm households.

Keywords: Wetlands, economic value, willingness to pay, southwest Nigeria

Introduction

Wetlands, according to Carter (1981) are land transitional between terrestrial and aquatic systems where the water level is usually at or near the surface or the land is covered by shallow

water. They cover 6% of the world's land surface and contain about 12% of the global carbon pool, playing an important role in the global carbon cycle [International Panel on Climate Change (IPCC), 1996]. They constitute some of the most important and threatened ecosystems in the world (IPCC, 1996). Wetlands in Nigeria cover an extensive area (13,000 km^2) and support a wide range of economic activities that sustain significant proportion of communities around it [Nigeria Environmental Study/Action Team (NEST), 1991].

Wetlands are important especially for the biological, hydrological, economic, socio-cultural and aesthetic roles they play in the environment. Terer *et al* (2004) observed that in the world over, rivers, lakes, seas, oceans and the plants and animals associated with them are important to every culture on earth and form an explicit or implicit part of the religious and cultural heritage of almost all human cultures. Their rich physical and biological resources are exploited for food, water, medicinal plants, fuel wood, materials for building and handcrafts (Terer *et al,* 2004).

Interactions among wetland characteristics, structure and processes result in the performance of functions, which are not of economic nature but provide a flow of goods and services which are valued by society. Wetlands provide populations with numerous goods and services that have a significant economic value, not only to the local population living in its periphery, but also to communities living outside the wetland area. Examples of valuable wetland goods are fish, reeds and papyrus, birds and wild animals and fresh water. The staple diet of 3 billion people, half the world's population, is rice, which grows in wetlands in many parts of the world (Schuyt and Brander, 2004). In addition, wetlands provide a nursery habitat for many commercially important fish species that are harvested outside the wetland. Tejuoso, (2006) reported that each wetland is composed of a number of physical, biological and chemical components such as soils, water, plants and animal species, and nutrients which yields benefits, which are of direct use value to humans. Many wetlands are being directly exploited to support human livelihoods. Processes among and within these wetland components allow the wetland to perform certain functions such as flood control, shoreline stabilization, water purification, and general products such as wildlife, fisheries and forest resources. In addition, there are ecosystem scale attributes such as biological diversity and cultural uniqueness/heritage that have value, either because they induce certain uses, or because they are valued themselves.

Ecosystems have limited resilience and have a carrying capacity, which is the maximum stress that it is capable of absorbing without changing into a vastly different state. Secondly, biodiversity provides the ecosystem with its functional properties and resilience (Hulme, 2005). Thus, due to its carrying capacity and biodiversity, ecosystems change and evolve continually.
One of the world's most important natural resource is consumed in an unsustainable manner to the extent that their continuous existence may not be guaranteed for the future generations (Barbier *et al.*, 1997). The situation is not different in Nigeria as one of its most important wetland, the Hadejia-Nguru Wetlands in Jigawa and Yobe states respectively, have shrunk by as much as two-thirds in the past 30-40 years because of diversions from dams, irrigation developments and drought. Fisheries, farming and wildlife are all impacted by these hydrological changes (Idris, 2008). As people increasingly reclaim wetlands or distort the

ecosystem balance, coupled with population increase, such problems are bound to worsen because the people may not be aware of the effect of their activities on the agro-ecological value of the wetland. Nevertheless, wetlands can be sustainably exploited if the dynamics of the local institutions that influence accumulation and consumption of livelihood assets are well understood and harnessed appropriately, because conversion of wetlands is influenced by households' asset position and shocks which, under an appropriate and sustainable management regime, can generate a flow of useful functions such as nutrient purification, ground water buffering and biodiversity (Gren *et al.,* 1994*)*. The life support systems that are inherent within the wetland ecosystems can provide a wide range of valuable functions to society if they are used in a sustainable manner, for example, by incorporating the primary users in the management of the wetlands within the context of societal livelihoods and local institutions (Folke, 1991).

People increasingly reclaim wetlands for construction purposes (houses, industries roads) and also to sustain livelihood, thus, the wetland resource is degrading at a very fast rate. The inability to place a monetary value on wetland has been identified as one of the reasons why both public and government do not value the wetland . Hence, there is a need to quantify the value of wetlands in order to come up with strategies for income generation, food security and environmental sustainability. Against the above background, the study is assesses the economic value of Eleyele, Eriti and Lagos Lagoon wetlands respectively in Oyo, Ogun and Lagos States located in Southwest Nigeria.

The specific objectives are to:

- describe the prevalence of the various types of livelihood activities around the selected wetlands ;
- describe and compare socioeconomic characteristics of the wetland users;
- determine the wetland users' willingness to pay for sustainable utilisation of the selected wetlands and the determinants; and
- estimate the economic value of each of the selected wetlands for agricultural uses.

Materials and Methodology

The study was carried out in communities around and/or within Eleyele, Eriti, and Lagos Lagoon wetlands in Oyo, Ogun and Lagos States, in the Southwest rainforest zones of Nigeria. The Eleyele wetland is located in Ido Local Government Area (LGA) of Oyo State. The city lies between latitudes 07°22'30" N and 07°25'50" and longitudes 003°2'00" E to 003°55'50" E, at an altitude of approximately 1500 m above sea level. The climate of the area is influenced by Tropical Maritime and Tropical Continental air masses. The mean annual rainfall is 1413 mm, while the mean annual temperature ranges from 22.5^{o}C to 31.4^{o}C. The Eleyele wetland passes through Awatan, Apete, Ijokodo, Olopomewa and Eleyele.

Eriti wetland is located in Obafemi Owode LGA of Ogun State. It lies between latitude 7.73^{0} and longitude 5.79^{0} with an elevation of 459 m, with temperature ranging between 24°C to 30^{0}C during the dry and raining seasons respectively. Eriti vegetation is mainly Guinea and derived

savanna. Eriti is mainly a farm community and it is popularly known as the home of vegetables, as the farmers there cultivate more of leafy and fruit vegetables.

Lagos Lagoon wetland stretches from Epe LGA to Badagry LGA in Lagos state. The Lagos lagoon is fed by several rivers, the most important of which are, the Yewa, Ogun, Ona/Ibu, Oshun, Shasha and Oni.

This study was based on primary data collected by personal administration of a questionnaire /interview schedule from individuals that have their livelihood activities around the wetlands in the study areas. The questionnaire included questions on various socio-economic parameters such as age, gender, educational status, occupation, farm size, land ownership, organizational participation, involvement in farm activities, participation in decision making, access and rights on wetland resources, livelihood patterns, as well as production costs and returns.
The study respondents were selected by multi-stage sampling technique. The main goal of the selection was to ensure that communities where various types of wetland related livelihood activities – farming, fishing, sand mining, wetland resource collection, etc are represented in the sample.

The data collected were analysed by a combination of descriptive statistics, budgetary techniques, Contingent valuation method (CVM), Sensitivity Analysis and Tobit regression model.

Descriptive statistics
Descriptive statistics such as mean, frequencies and percentages, crosstabs, tables were used to describe the socio-economic characteristics of the respondents. It was also used to explain the livelihood pattern of the respondents.

Budgetary analysis
Budgetary techniques were used to estimate the costs and returns as well as the Net Wetland Income (NWI) associated with various livelihood activities found around the wetlands. The NWI, which is a measure of the economic value associated with wetland uses, is defined as follows:

$$NWI = GFI - NWTC \quad (1)$$

where,

GFI = is the Gross Farm Income, which is the total value of farm outputs including those sold, consumed at home and/or given out;

TNWC = is the Total Non-Water Cost of production, including the cost of all the variable and fixed inputs employed in production except that of the wetland water, land and associated resources.

Contingent valuation method (CVM)

Contingent valuation method was used to determine willingness to pay for preserving the wetland. Respondents were presented with various conservation plans in order to elicit their willingness to pay for conservation. The CVM was achieved using the following steps:

1. The respondents were asked questions on their socio-economic characteristics and livelihood activities around the wetland.
2. The respondents were thereafter, educated on various use pattern that destroy the wetlands, and the need to put in place appropriate strategies/measures to ensure sustainable use of the wetland. They were then presented the following hypothetical wetland preservation plans:
   i. Establishment of a waste reclining plant and general waste management measure.
   ii. Timely removal of all water weeds which posed problems, most especially for the fishermen and sand miners.
   iii. Improving the aesthetic quality of the wetland;
3. The respondents were then asked, by iterative bidding process, the maximum percentage of their wetland related income they were willing to pay to continue to use the wetland. The actual value of each respondent's willingness to pay (WTP) for sustainable wetland utilisation was computed as follows:

   WTP (₦) = %WTP x Gross Wetland Income (2)

Sensitivity analysis

In order to reduce the biases associated with CVM , such as payment vehicle and hypothetical bias, a sensitivity analysis was carried out by enquiring about the wetland users desired improvement as well as their preferred payment vehicle. They were then educated about the fact that fund expended to achieve the desired change will not be available for satisfying other needs and therefore, the decision to pay should be considered carefully.

Tobit Regression Model

The relationship between the respondents expressed WTP for a continuous utilisation of the wetland and its hypothesised determinants were analysed within the framework of a Tobit regression model. The model is specified as follows:

$WTP_i^* = X_i \beta + \varepsilon_i$ (3)

where,

$\varepsilon_i \sim N(0, \sigma^2)$.

β is the vector parameters being estimated

WTP^* is a latent variable that is observed for a reported WTP values greater than 0 and censored otherwise.

The observed WTP_i is defined by:

$WTP_i = WTP^*$, if $WTP^* > 0$

$WTP_i = 0$, if $WTP^* \leq 0$

X_i = is a vector of hypothesised explanatory variables, including

X_1 = the main livelihood activity of the respondent, decomposed into four dummy variables:
- X_{11} for farming; it takes the value 1 if the reference person is a farmer and 0 otherwise. This was dropped during estimation, with farmers used as the reference group.
- X_{12} for fishing ; it takes the value 1 if the reference person is a fisher and 0 otherwise
- X_{13} for natural resource collection; it takes the value 1 if the person is a natural resource collector and 0 if otherwise. Natural resource collectors are people who collect sand, leaves, firewood etc around the wetland resourceX_{14} for service rendering; it takes the value 1 if the reference person is rendering services and 0 if other wise

X_2 = Gender of the respondents (1 if female and 0 if male)
X_3 = Age of respondents (years)
X_4 = Wetland Income (Naira)
X_5 = Income from non-wetland livelihood activities (Naira)
X_6 = Education of respondents in years
X_7 = Distance of respondents' resident from the wetland in kilometers
X_8 = Frequency of visit to wetland site (no of times per week)
X_9 = Locality of the wetland which consist of three dummies including
- X_{91} for rural; it takes the value 1 if the wetland is in a rural area, and 0 if otherwise
- X_{92} for suburban; it takes the value 1 if the wetland is located in a suburban area, and 0 if otherwiseX_{93} for urban; it takes the value 1 if the wetland is in an urban area, and 0 if otherwise

The model was estimated by the Tobit regression procedure in SHAZAM econometric software (Windows Professional Edition), with the default lower limit of zero imposed in estimation.

Results and Discussion

The wetland communities considered in this study were classified into three: rural, sub-urban and urban communities bearing in mind the fact that uses to which wetlands may be put could vary from one type of locality to another depending on population density. The classification follows official definitions in Nigeria, which requires that a community be considered as urban if its population is at least 20,000 and/or if it is located within a State or Local Government headquarter town/city (Shittu, 2008). Areas considered rural were, however, those with a population of less than 3000 people (Okali, *et al.*, 2001; Lanjouw and Lanjouw, 2001), while those considered as sub-urban were those located in urban fringes (peri-urban communities) with population typically between 3,000 and 20,000.

Personal Characteristics of Respondents

Table 1 summarises the personal characteristics of individuals involved in the pursuit of livelihood activities around the selected wetlands by locality type. As shown on the table, majority (92.4%) of these individuals were married, with an average age of 45years. The youth

(30years or younger) constituted less than a fifth (17.4%) of those pursuing livelihood activities around the wetlands, just as the women-folks (28.2%) were out-numbered by their male counterparts (71.8%).

In terms of formal education, results on Table 1 show that the people pursing livelihood activities around the wetlands were predominantly primary school (43.5%) or secondary school (29.0%) leavers. Only a few (11.2%) were educated up to the tertiary school level. Most (66.4%) of the livelihood operators had crop farming as their main occupation, with 14.5% having artisanal fishing as their main occupation. The prevalence of fisher-folks was higher on rural wetlands (21.9%) than what obtains in other wetland localities.

A typical wetland livelihood operator's household was made up of six (6) members with households in the rural area having five (5) members while their counterparts in the urban area had household size of 7. This, however, is contrary to *a-priori* expectations, but may be a result of rural-urban migration, with some members of the rural households having migrated to urban centres.

Table 1 also shows that the respondents live very close to the wetland (i.e. within 1km radius of the wetland). This implies that they both reside and have livelihood pursuit around the wetland. Also, they incur little or no transport cost in order to access the wetland. In addition, the respondents have spent about 20 years around the wetland. Since they are long time settlers, this is likely to affect the value they place on the wetland, given their likely emotional attachment to it. The value they place on the wetland may be very high.

Livelihood Activities around the Wetlands

One of the key objectives of this study was to identify the various types and mix of livelihood activities that are taking place around wetlands in the study area. Table 2 summarises the distribution of livelihood operators found around the selected wetlands by the mix of livelihood activities they were engaged in and locality types. As shown on Table 2, the main types of livelihood activities identified around the wetlands were crop farming (mostly fruit and/or leafy vegetable production), fishing, natural resource collection (sand mining, water collection, leaf collection, snail collection etc) and services (trading, hotel and bar services, transportation, boat making and mending) .

The most prevalent single enterprise wetland related livelihood pursuit was farming (69.5%), with most of the other types of enterprises embarked upon in conjunction with crop farming or jointly with other types of livelihood pursuit. Fishing was predominantly combined with farming and/or natural resource collections, with only a few (2.3%) having fishing as their only activity. Resource collection was common only in the rural area, though involving a negligible proportion (1.4%) of the wetland operators. This is possible because the rural people are closer to nature while service-rendering is more in the urban areas (14.7%) than the rural area (1.4%). One feature of the livelihood of the people who live in wetland areas is that their livelihood is essentially wetland related and based around the cultivation of crops such as vegetables, rice,

cassava, fruity vegetables and harvesting of aquatic resources such as fish. People living in wetland areas undertake a wide range of activities as part of their livelihood strategies. For instance, some of the respondents combine farming and fishing (7.6%), farming and resource collection (4.6%), with some of them involved in all the activities. These findings agree with those of Groot *et al* (2006) and Bikangaga (2007), which had noted that, with dramatic seasonal changes in water levels, livelihood strategies in wetland areas tends to change according to periods of floods and periods of less water.

Willingness to Pay For, and Economic Value of Wetlands

The main theme of this study was to estimate the economic value of the respective wetlands in Southwest Nigeria. The wetlands were valued using the Net Factor Income (NFI) and WTP methods. The results are summarised on Table 3.

As shown on Table 3, economic value of Eleyele wetland was estimated to be ₦349,024.28/ha/year for crop farming and ₦269, 516.11/fisherman/year for fishing. Epe wetland was worth ₦75,633.42/ha/year and ₦303,588.00/fisherman/year for crop farming and fishing respectively. Income from the collection of natural resources such as sand, leaves, snail etc as well as income from service rendering around the wetland was estimated to be N23,3218/person/year and ₦192,312/person/year for Epe wetland while that of Eriti was ₦48,804/person/year for each of the activity.

Contingent valuation was used in this study to determine willingness to pay for preservation of wetland. It is expected that livelihood pursuers in wetland areas should be willing to pay for wetland preservation because, in doing so they are sustaining their livelihood indirectly as preservation prevents the wetland land resource from degrading thereby preventing its users from losing their means of livelihood. The mean willingness to pay for wetland preservation per year was ₦3102.13 for wetland users in Eleyele, ₦6,620.84 for users in Epe, while that of wetland users in Badagry and Eriti were ₦8372.69 and ₦10252.98 respectively. WTP was higher among fishermen (₦11,967.57/year) and crop farmers (₦8370.40/year) than their natural resource collectors (₦3025.30) and service rendering (₦3556.66/year) counterparts. The mean WTP for preservation of a wetland in southwest Nigeria was ₦8050.42.

Factors Affecting Willingness to Pay For Wetland Preservation

Table 4 shows the estimated Tobit regression model which was used to determine factors that influence how much respondents in the study area were willing to pay for wetland utilization of the wetland. Education (years) has an influence on how much individuals having livelihood pursuit around wetlands are willing to pay for its preservation as the coefficient of education is significant at $P<0.05$ but negative. This means that the higher the educational level, the lower the willingness to pay. This may be because individuals with high education may find less-reliance on seeking livelihood around the wetland in relation to white –collared jobs elsewhere. The coefficient of income from other activities like civil service, transport services, tailoring, etc. was significant at $P<0.01$ and positive. This means that those involved in other activities other than wetland activities are willing to pay more. This implies that the value they attach to the

wetland goes beyond the use value and probably involves other values, such as option and existence value. Fisher men are willing to pay more than crop farmers. This could be as a result of the fact that they earn their income directly exploring the wetland and further improvements may lead to increase in income thereby sustaining their livelihood.

The coefficient for urban dummy was significant at $P<0.05$ and positive. This implies that operating around urban wetlands has an influence on how much they pay for wetland preservation. People in the urban areas are willing to pay more for wetland preservation than their rural area counterpart. It could be because there are other activities around the urban wetlands such as hotel services, boat making, trading which served as a source of income other than agriculture. But the willingness to pay of those in the sub-urban area was less than that of their rural counterparts as the coefficient was significant and negative.

Conclusion and Recommendations

First, the study revealed that wetlands are actually not wastelands but serves as a source of income for people that have livelihood activities such as farmers, fishers, resource collectors and those rendering services around it. If properly put to use, wetlands will help to an extent to solve the problem of food insecurity and poverty as it serves as a source of food and income.
Second, the main activity around any typical wetland is crop farming and majority of the people having livelihood around wetlands have little or no formal education. The implication of this is that livelihood pursuers may be dependent on their old practices since, they lack the ability to learn new methods that will enable them optimize the use of the wetland and maximize profit.
The study therefore concludes that wetlands are of economic importance to various user and efforts should be made to preserve the wetlands so as to sustain the livelihood of the users.
The findings of this study has revealed that there is need to educate people more about the value of wetlands and also the need to preserve them for livelihood sustainability. Based on these, the study therefore recommends the following:

- Individuals, government and NGOs should put in place measures to reduce wetland destruction, as it leads to significant income losses to members of farm households.
- Efforts should be made to create awareness about the true value of wetlands, the services they provide to people, as well as their importance for the maintenance of biological diversity.
- Farmers should be encouraged to cultivate more of fruity vegetable around wetlands as these will optimize the use of land and also maximize profit.

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Table 1: Distribution of wetland livelihood operators by personal characteristics and locality type

Description	Locality type			**All**
	Rural	**Sub-urban**	**Urban**	**Respondents**
Mean Age (years)	43	47	48	45
Mean household size	5	6	7	6
Mean distance from home to wetland (km)	0.8	0.3	0.9	0.8
Mean years spent around wetland	20	22	21	20
Gender				
Female	29(39.7%)	3(12.5%)	5(14.7%)	37(28.2%)
Male	44(60.3%)	21(87.5%)	29(85.3%)	94(71.8%)
Marital status				
Married	66(90.4%)	24(100.0%)	31(91.2%)	121(92.4%)
Single	2(2.7%)	0(0.0%)	2(5.9%)	4(3.1%)
Widow(er)	5(6.8%)	0(0.0%)	1(2.9%)	6(4.6%)
Education level				
None	14(19.2%)	3(12.5%)	3(8.8%)	20(15.3%)
Primary	31(42.2%)	14(58.4%)	12(35.3%)	57(43.5%)
Secondary	18(24.6%)	6(25.0%)	14(41.2%)	38(29.0%)
Tertiary	10(13.7%)	1(4.2%)	5(14.7%)	16(11.2%)

Source: Data from field survey 2010

Table 2: Distribution of livelihood enterprise operators by mix of livelihood activities and locality

Activities	Locality			**Total**
	Rural	**Sub-urban**	**Urban**	
Farming	48(65.8%)	20(83.3%)	23(67.6%)	91(69.5%)
Fishing	1(1.4%)	2(8.3%)	0(0.0%)	3(2.3%)
Resource collection	1(1.4%)	0(0.0%)	0(0.0%)	1(0.8%)
Service rendering	1(1.4%)	0(0.0%)	5(14.7%)	6(4.6%)
Farming and fishing	7(9.6%)	1(4.2%)	2(5.9%)	10(7.6%)
Farming and resource collection	6(8.2%)	0(0.0%)	0(0.0%)	6(4.6%)
Farming and services rendering	3(4.1%)	0(0.0%)	1(2.9%)	4(3.1%)
Farming, fishing and resource collection	1(1.4%)	1(4.2%)	0(0.0%)	2(1.5%)
Farming, fishing and service rendering	3(4.1%)	0(0.0%)	0(0.0%)	3(2.3%)
Fishing, resource collection and services rendering	1(1.4%)	0(0.0%)	1(2.9%)	2(1.5%)
All activities	1(1.4%)	0(0.0%)	2(5.9%)	3(2.3%)

Source: Data from field survey 2010

Table 3: Economic value and willingness to pay for of wetland

	Net Wetland Income				**Mean WTP (₦/Operator /year)**
	Eleyele	**Epe**	**Eriti**	**Badagry**	
Enterprise					
Crop farming (N/Ha/Year)	349,024.28	75, 633.42	239, 694.26	2636, 98.82	8370.40
Fishing (N/fisherman/Year)	269,516.11	303,588.00	-	-	11967.57
Resource collection (N/person/Year	-	233,218	48,804	-	3025.30
Service rendering (N/	**-**	192,312	48,804	-	3556.66
Mean WTP by location (₦/year)	3,102.13	6,620.84	10,252.98	8, 372.69	
Overall Average WTP (N/person/year)					**8,050.42**

Source: Data from field survey 2010

Table 4: Estimated Tobit regressions for willingness to pay for wetland utilization

Explanatory variable	Estimated coefficient	T-Ratio	Marginal effect
Constant	18.637	3.9761	
Age	-0.10743	-1.5181	-0.80121E-1
Female	1.7305	0.82860	1.29061
Education	-0.54198**	-1.9773	-0.40421
income(Wetland)	-0.20137E-04	-1.5906	-1.50182E-05
Income(other s)	0.30246E-04***	2.8766	2.25557E-05
Frequency of visit	0.30019	1.0658	0.22388
Distance	0.25463	0.43231	0.18990
Fishing	12.065***	2.8209	8.99808
Resource collection	2.5643	0.38089	1.91245
Services	-2.9141	-0.78375	-2.17334
Urban	4.2698**	2.0263	3.18442
Sub-urban	-6.2940**	-2.5180	-4.69407
Log –Likelihood Function	-807.42358		
Predicted F(I)	0.7458		
Squared correlation	0.41047		

Note: ***, ** ***and*** * ***indicate the associated coefficient was significant at 1%, 5% and 10% level respectively***

Source: Data from field survey 2010.

Public Willingness to Pay for Ecosystem Service Functions of a Peri-urban Forest In Abeokuta, Ogun State, Nigeria

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Abstract

The willingness to pay (WTP) format contingent valuation method (CVM) was adopted to elicit monetary values from some respondents in Arakanga forest reserve (AFR) (a peri- urban forest) in Abeokuta. This was to provide monetary estimates of the ecosystem service functions of the reserve. The respondents were randomly selected from both the neighbours and non-neighbours of the reserve. Data were collected with the aid of structured and pre- tested questionnaire administered interpersonally to the respondents. The questionnaire were 200 in number i.e 100 administered to each category of respondents. A total of 92 respondents (46%) were willing to pay money ranging from ₦100 to ₦1, 000 monthly. The modal value was ₦100 with the highest percentage of response (56.5%). An individual mean monthly WTP of ₦165.22 was recorded in the entire study area. This resulted into an aggregate of ₦15, 301,245.59 and ₦33, 263,577.38 minimum and maximum values respectively. These amounts represented the monthly monetary values of the ecosystem services functions of AFR .Income and household sizes are some of the socio-economic factors by which the monetary values of ecosystem services of AFR can be predicted as revealed by the multiple regression analysis. It can be concluded from this study that the respondents valued the reserve so highly to the extent that they are willing to contribute a part of their income to ensure the continued existence of the reserve.

Keywords: Ecosystem service functions, willingness to pay, peri -urban forest.

Introduction

The forests have been hitherto valued as a land bank rather than a valuable resource providing essential goods and services for livelihood generation. According to MEA (2005), the benefits derived from the forest are collectively referred to as ecosystem service functions (ES). The ES have been categorized into Provisioning services e.g. food, freshwater, fuel wood, fibre and medicine); Regulating services e.g. climate, water disease regulation and e.g. educational, aesthetic, cultural heritage values, recreation and tourism.

The loss of the forest ecosystem, and by implication its services, has been due to some drivers such s climate change, pollution, over- exploitation, land – use change and urbanization. It has been found out that 60% of ecosystem services assessed globally are either degraded or being used unsustainably (MEA 2005). The forest resources of Nigeria in general and Ogun State in particular are not excluded from these global assessment shortcomings. This situation can be attributed to lack of insufficient incentives for land owners to protect forest ecosystem and its services as they may receive little or no benefits from them. Economist often classify most forest ecosystem services as public goods, i.e. goods that are non- rivalrous and non-excludable in consumption (Coull and Valatin ,2008). The implication of this is that consumption of the goods by one individual does not reduce the amount available for consumption by others and no one can be excluded from using those goods. Putting a value (especially monetary values) on a good such as the forest ecosystem can help to provide an incentive for people to produce and conserve it. This is because the current economic crisis is leading to pressure on government budgets and on the budgets available to maintain existing forest reserve, especially the Arakanga forest reserve in Ogun State. This problem can be tackled through information on the monetary values of forest ecosystem services .These information are presently lacking, and where available, are always scanty and many a times inaccessible . Hence, the relevance of this study, which attempts to ascribe monetary value to the ecosystem services provided by Arakanga forest reserve situated in the peri -urban area of Abeokuta, Ogun State.

Various approaches have been used to attach monetary values to non–market goods and services of the forest by economists (White and Lovett 1999). They include revealed and stated preference methods. The revealed preference methods are based on how individual actually behaved in a real market situation while the stated preference methods are based on how individuals say they will behave under hypothetical market situation. Prominent among the stated preference method is the Contingent Valuation method (CVM) which is a means of quantifying public preference and willingness-to–pay (WTP) for forest goods and services or willingness to accept compensation for losing access to the forest goods and services. .There methods have been employed by researchers (Adekunle 2005; Adekunle and Sanni, 2009; Adekunle *et al*, 2008; Tkac, 1998; and Popoola and Ajewole, 2002) to ascribe monetary values to forest goods and services. This study therefore investigated public willingness–to–pay for the ecosystem services of a peri–urban forest with Arakanga forest reserve (AFR) as a focus .The information provided will assist landowners and users to make informed decisions and plausible trade-offs on forest reserves investment.

Study Area

This study was carried out in Arakanga forest reserve. It is one of the 9 forest reserves in Ogun State with a land area of about 2.39 km^2. The reserve is predominantly of high forest and savannah vegetation. It is situated at the border between Abeokuta North and Opeji ward of Odeda local government area. AFR is a peri–urban forest as described by Konijnendijk *et al*.(2004). A peri-urban forest reserve has been described as trees and forest resources outside, but close to urban areas, because they are major contributors of goods and services to urban society (Konijnendijk *et .al*. 2004). AFR is close to Abeokuta city, hence the description of Abeokuta is relevant in this study.

Abeokuta is the capital of Ogun State and the traditional home of the Egba's. It is divided into Abeokuta North and South local Government Areas. The Egba's have been traditionally divided into four, namely Egba Ake, Oke- ona, Gbagura and Owu. Three types of religion are widely practiced by the people. They are Christianity, Islam and traditional religion. The Christians predominates.

Geographically, Abeokuta lies on a latitude $7^0$15N and longitude $3^0$25E. The town is about 81 km southwest of Ibadan, Oyo State capital and 106 km north of Lagos, former Nigeria capital city. Abeokuta lies at an altitude of about 157m above sea level amidst isolated outcrop of natural formation of granite rocks which give the town's landscape its undulating characteristics. The ancient and historic 'Olumo Rock' is a popular tourist and holiday resort in the town. It is about 17,228 m above sea level and is located in the central part of the town. Itoku Market, popular for traditional 'Adire' cloth, is located close to the Olumo rock.

Abeokuta has a humid weather with an average temperature of about 27.4^0C and an annual rainfall of 128 cm in the southern part of the city to 105 cm in the northern part. The Ogun river transverses the town from the south to the western parts. The population of Abeokuta North and South Local Government area has been estimated to be 451,607 people (NPC, 2006).The town is a nerve centre of commercial activities such as banking, cloth weaving and dyeing, trading and carving. Both modern and traditional agriculture are widely practiced in the town. Some of the prominent agricultural products include maize, cassava, yam and livestock. The town is also an educational center with educational institutions providing formal education up to university level.

Materials and Methods

Data Collection

The multistage sampling procedure was adopted in the study. The area was stratified into 2 categories i.e. Neighborhood and Non–neighborhood. Areas that are within 1 km radius was classified as Neighborhood while those that are situated at more than 1 km radius were Non–neighborhood. In each category, four (4) settlements were randomly selected for sampling as summarized in the Table 1.

The main instrument of data collection was a structured and pretested questionnaire. The questionnaires were 200 in number and were administered interpersonally to 25 respondents in each of the settlements as shown in Table 1. The questionnaire was in two parts. Part A was made to address the socio- economic characteristics of the respondents while Part B dealt with the contingent valuation survey. The payment card system was used to elicit WTP values for ecosystem services from the respondents.

Table 1: Sampling Design

Category	Settlements	No of respondents	Total
Neighbourhood	Abe igi Asela Ayo Bus Stop Quarry	25 25 25 25	100
Non – Neighbourhood	Iberekodo Mokola Elega Ajitadun	25 25 25 25	100
Total		100	200

Data Analysis

Data gathered from the interview were encoded in Microsoft Excel program and processed using Statistical Package for Social Science (SPSS). Descriptive statistical tools such as frequencies, percentage, mean and mode was used to summarize the variables of interest. Multiple linear regression was used to find out some of the socio-economic factors by which WTP for ecosystem services can be determined and predicted.

The model specifications are as follows:

$$WTP = f(X_1+X_2+X_3+\ldots\ldots\ldots X_n+e) \quad (1)$$

where

WTP = Willingness to pay
X_1 = Age
X_2 = Income
X_3 = Educational level
X_4 = Sex
X_5 = Household size
X_6 = Marital status
X_7 = Native
X_8 = Year of residence
e = error term

Three functional forms were tried in order to choose the one with the best performance.

$$\text{Linear :} \quad WTP = b_o + b_1 X_{1+} b_2 X_{1\ +} - - - - - - - - b_8 X_{8+} Ed \quad (2)$$

$$\text{Semi log:} \quad WTP = L_n b_o + b_1 LnX_1 + b_2 LnX_2 + \ldots\ldots\ldots\ldots b_8 LnX_8 + LnEd \quad (3)$$

$$\text{Double Log:} \quad LnWTP = Lnb_o + b_1 Ln\ b_1 X_1 + b_2 LnX_2 + b_8 Ln\ X_8 + LnEd \quad (4)$$

where

b_o = constant

$b_1 b_2 ... b_6$ = Regression coefficient for WTP
Ed = Residual or error term
Ln = Natural logarithm

Results and Discussion

Percentage distribution of respondents on WTP for Ecosystem services of AFR

The distribution of respondents on WTP for Ecosystem services are summarized in Table 2. According to the table, 46% of the total respondents were willing to pay for ES. This percentage ranges from57% for the Neighborhood to 35% for the Non-Neighborhood. The large percentage of respondents on willingness to pay recorded among the Neighborhood could be because of their proximity to the reserve and because they benefit more from the services provided by the forest.

Distribution of responses on WTP values for ecosystem services function

The respondents are willing to pay amounts ranging from ₦100 - ₦1000 (Table 3). Both the respondents from Neighborhood and Non–neighborhood has ₦100 as their modal elicited value having recorded 52.6% and 62.9% responses respectively. This is in line with Ajewole (2002) and Adekunle *etal.* (2008). This result could be attributed to the fact that most of the respondents are low income earners and also because people are in most cases averse to paying for public goods and services such as the forest.

Table 2 : Percentage Distribution of Respondents on Willingness to pay for Conservation of Arakanga Reserve

Category		Yes	No	Total
Neighbourhood	No	57	43	100
	%	57	43	100
Non- Neighbourhood	No	35	65	100
	%	35	65	100
Total	No	92	108	200
	%	46	54	100

Table 3: Percentage Distribution of Respondent on Elicited Values of Individuals WTP (in Naira ₦) for ecosystem services

Category		₦ 100	₦ 200	₦ 500	₦ 1000	Total
Neighborhood	No	30	32	4	1	57
	%	52.6	38.6	7.02	2.04	100
Non- Neighborhood	No	22	13	-	-	35
	%	62.9	37.1	-	-	100
Total	No	52	35	4	1	92
	%	56.5	38.0	4.35	1.09	100

Mean monthly WTP for Ecosystem services in the study area across different socio- economic strata

The monthly mean WTP for ES in the study area across different socio –economic strata are summarized in Table 4. It can be observed from the Table that WTP for ecosystem services is not gender biased as there was a small difference between WTP by males (₦164.7) and WTP by females (₦153.4) . This could be because the benefits derived from the forest is not gender biased, as both males and females could be observed accessing the reserve for different ES benefits. However, these findings are not in line with Adekunle *et al*. (2008) which recorded a larger mean WTP values among male respondents in UNAAB urban community. As expected, the highest WTP values (₦94.8) was observed among the active working age group. This group must have realized that they need to plough part of their incomes back into the reserve for ES sustainability.

In the same vein, highest mean of WTP was elicited from the married respondents. This is an indication that WTP for ecosystem services can be transferred to their generations. As expected, the mean WTP skewed towards respondents in the high income brackets. Specifically, the highest amount of ₦132.5 was elicited from those earning between ₦20,000 and ₦50,000 monthly . These results agreed with Adekunle *et.al.* (2008). The low WTP values elicited from low income earners is expected. For instance, people are always reluctant, especially low income earners, to pay for forest goods and services. This is because of their characteristic nature and attitude towards public properties. Educational status for instance, up to tertiary level, could play a significant role in peoples WTP for ES as found in this study. For instance, respondents with postgraduate education, though few, had the highest mean monthly WTP (₦200). This is an indication that formal education could enhance people willingness to contribute for the sustenance of forest ecosystem services.

Table 4: Summary of Mean Willingness to Pay Across Different Socio –Economic Strata

GENDER	**Average Willingness to pay (₦)**		
	Neighborhood	**Non-Neighborhood**	**Pooled**
Male	**184.4**	**145.0**	**164.7**
Female	**180**	**126.7**	**153.4**
AGE (years)			
15-24	55.6	85.7	70.7
25-34	92.9	48.3	70.6
35-44	115.2	35.7	75.5
45-54	142.9	46.7	94.8
55 and above	-	-	-
Marital status			
Single	71.4	117.7	94.6
Married	116.7	155.6	136.2
Income level(₦)monthly			
1,000-10,000	80.9	36.8	58.9
10,000-20,000	56.52	25	40.8
20,000-50,000	182.14	82.8	132.5
50,000 and above	100	100	100
Educational level			
No formal	57.14	-	57.1
Primary	86.9	19.3	53.1
Secondary	86.1	43.9	65
Tertiary	157.7	95.8	126.8
Postgraduate	200	-	200

Mean and Aggregate Estimates of WTP values for forest Ecosystem services

The total monthly WTP ranged from ₦2,800 for Non-neighbourhood to ₦10,400 for Neighbourhood, with a mean monthly WTP of ₦165.22 for the ecosystem services (Table 5). This resulted into a monthly aggregate estimate value for forest ecosystem service function ranging from ₦15, 301, 245.59 to ₦33, 263, 577.38. These values represent the monetary estimates of ecosystem services of AFR. The management implications of these findings are that apart from values in use, forests has value in exchange. Hence, the forests, especially AFR, should no longer be viewed as a mere land bank which can be cleared for food crop farming. For example, the monetary estimates of economic benefits of ES of Hoge Veluwe Forest in Netherlands, was thrice the per hectare value generated by a nearby agricultural land (Heins, 2011). This finding is also in line with that of Ajewole (2002) who recorded an aggregate estimates value of between 155.5 and 240.9 million naira as the money residents of Ibadan (Nigeria) are willing to pay for environmental services of urban forests.

Mode and time of payment

Direct taxation and voluntary donations were the preferred mode of payments for the ES of the AFR. Both suggestions recorded 37% of the response from the respondents as shown in Table 7. The study further revealed that 48% of the respondents would want to pay the elicited values every week. This could be because majority of the respondents are non -government workers. They were notably artisans who earn their incomes daily or weekly.

Suggested Management strategies for the existing reserve

About 24.2% of the respondents would want non- forestry or non- forest related activities prohibited from AFR as a management strategy. This is to ensure a continued existence of the forest reserve.

Results of multiple regression analysis

The summary of multiple regression analysis to determine the socio-economic factors contributing to the monetary values of ecosystem services showed that double log has the best performance having recorded the highest coefficient of determination (R^2) of 12.8% The respondents income and household size had significant influence, at 5% and 10% respectively, on the amount the respondents are willing to pay for ecosystem services. This is an indication that WTP for ES can be determined and predicted through the income and household sizes of the residents.

Table 5 : Estimated monetary values of Ecosystem services in the study area

Category	No of respondents	Total WTP(₦)	Mean WTP(₦)
Neighborhood	57	10,400	182.46
Non-Neighborhood	35	2,800	80
Total	92	15,200	165.22

Table 6 : Means and Aggregate Estimate Values of Forest Ecosystem services of Abeokuta

No of respondents	Total WTP(₦)	Mean WTP(₦)	Population	Minimum Aggregate(₦)	Maximum Aggregate(₦)
92	15,200	165.22	201,329	15,301,245.59	33,263,577.38

Table 7: Mode and Time of Payment

Mode of Payment	Neighborhood		Non- Neighborhood		Total	
	Frequency	%	Frequency	%	Frequency	%
Direct Taxation	15	26.3	18	31.6	34	37
Conservation/Maintenance Levy	18	31.6	6	17.1	24	26.1
Voluntary Donation	24	42.1	10	28.6	34	37
Total	57	100	35	100	92	100
Weekly	30	52.6	14	40	44	47.8
Monthly	17	29.8	8	22.9	25	27.2
Yearly	10	17.5	13	37.1	23	25
Total	57	100	35	100	92	100

Table 8: Percentage distribution of Respondents on Management Strategies for AFR

Category		Disallow non-forestry use	Physical barrier	Education	Recreation activities	Managed by private org	Encourage production NTFP	Use of forest guards	Total
Neighborhood	No	23	16	19	5	18	7	12	100
	%	23	16	19	5	18	7	12	100
Non-Neighborhood	No	9	3	4	1	3	5	7	32
	%	28.1	9.4	12.5	3.1	9.4	15.6	21.9	100
Total	No	32	19	23	6	21	12	9	132
	%	24.2	14.4	17.4	4.5	15.9	9.1	6.8	100

Table 9: Regression results for the estimation of factors that determine WTP for forest trees ecosystem services for the entire study area

Regression	Bo	X_1 Age	X_2 Income	X_3 Educational Level	X_4 Sex	X_5 Household size	X_6 Marital status	X_7 Native	X_8 Year of residence	R^2	Adj. R^2	Sig. F
Linear	2.141 (1.771)	0.016 (0.721)	-2.606E-5** (-2.288)	-0.054 (-1.446)	-0.192 (-0.783)	-0.126* (-1.920)	0.578 (1.169)	0.378 (1.464)	-0.013 (0.513)	0.125	0.089	3.425
Semi-Log	0.464 (0.999)	0.008 (0.932)	-8.739E-6* (-2.000)	-0.017 (-1.227)	-0.089 (-0.948)	0.048* (1.890)	0.219 (1.155)	0.140 (1.411)	-0.006 (-0.594)	0.116	0.078	3.119
Double-Log	1.032 (1.167)	0.303 (0.973)	-0.170** (-2.254)	-0.175 (-1.042)	-0.114 (-0.844)	0. 402** (2.363)	0.377 (1.303)	0.213 (1.499)	-0.076 (-1. 028)	0.128	0.091	3.491

***** Represents sig. at 5%, * sig. at 10% , Figure in parenthesis are t –values.***

Conclusion

The study has shown that with appropriate economic tools, monetary values can be attached to non- market forest goods and services. There is need to engage in a meaningful dialogue with urban residents about forest and choices they can make to benefit themselves, as well as forest and ecosystem functions. Participatory forest management strategies are suggested for the sustainable utilization of forest resources. Forest managers and decision makers should embrace and emphasize the concept of Total Economic Valuation (TEV) of the forest. This is because the concept of forest valuation in the contemporary world is not measured only by the value of timber or by the value of forest products that have direct market prices. Regulations, land acquisitions, conservation easements and tax incentives are some of the conservation approaches that can protect and conserve the nation forests and grasslands.

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Environmental Sensitivity Indexing of Lagos Shorelines

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Abstract

Environmental Sensitivity Indexing (ESI) mapping of Atlas Cove, Lagos, Nigeria was carried out with the objective of producing an Environmental Analysis Index map of the shorelines. The study integrated methodologies developed by National Oceanic and Atmospheric Administration (NOAA) and Nigerian Oil Producing Trade Sector (OPTS). The result of the assessment was validated by comparison with the ESI standards in Nigeria. Nine ESI types were found in the area namely; ESI 1b, 2a, 2b 3a, 4a, 6b, 9b, 9c, and 10a. Animal biodiversities such as shorebirds (*Tringaly poleucos* and *Charadrinning marginatus*), sea turtles (*Dermocellys spp*) and white crabs (*Occipoda africana*) were more prominent on the western shores. Spearman's Correlation coefficient (r) value of -0.6 was obtained for the association between number of socioeconomic features and biological species along the shores. The result shows that a cause and effect exists between biological productivity and anthropogenic activities along the shorelines. The study ranked Mangrove swamps, creeks and fresh water swamp highest with ESI values of 10a. Margalef's index also shows that the same areas are the most sensitive with respect to species richness. The database developed from the study provides baseline information on the biophysical and socio-cultural condition of the environment and can serve as good decision support system for coastal managers.

Key words: ESI, Oil spill, GIS, Atlas-cove

Introduction

Atlas cove coastal environment in Lagos is undergoing progressive degradation from pipeline spills since the construction of the 64 million litre Nigerian National Petroleum Corporation (NNPC) oil depot in 1981. Oil pollution resulting from faulty petroleum facilities in the area is so unremitting that repeated loss of lives and ecological devastation has been recorded. In addition, this environment and the adjoining sea, fall within Oil Prospecting License blocks (OPL306, OPL311 and OPL 454). The implication is that the Atlas cove coastal environment is vulnerable to both inland and off shore oil spill disasters.

Environmental/ecological degradation from oil spill results in gradual erosion of biodiversity pools and species; which incidentally forms the basis for the survival of the human species. Prevention of such disasters through rapid and precise response action is not negotiable (Fabiyi, 2002a). Comprehensive information on the sensitivity levels of each category of a susceptible environment is an important requirement for effective oil spill disaster management. Regrettably, the ESI documents that could support the development of good and robust oil spill contingency plans for the study area are not available.

In Nigeria, ESI mapping began (Gundlach et al., 1981) as attempts by oil and gas operators to characterize the environment in their respective areas of operation by providing detailed and consistent source of information as a critical tool in oil spill response. Although nuances exist between versions of sensitivity maps from zone to zone, the basic principles of the mapping have remained constant.

This paper is a Nigerian example of ESI calculation. The paper adopted a modified Oil Producing Trade Sector protocol (OPTS, 2001) and National Oceanic Atmospheric Administration (NOAA, 1996) methodology respectively for ESI mapping of the study area. The methodology derived from the integration of the two techniques was designed to correspond to the available data at the time of the project. A new technique for validating shoreline sensitivity was added in Margalef's Species richness computation.

Study Area

The study area is geographically described by latitudes 6^0 22' 33" and 6^0 26' 39" and by longitudes 3^0 32' 00 and 3^0 45' 00. The area lie south west of Lagos city; overlooks the Bight of Benin (Atlantic Ocean) and is enmeshed with a net work of tortuous creeks and other water bodies (Figure 1). It has a variety of shore types ranging from marine to fine grained sand beaches. The area is part of the Oil Prospecting License (OPL) blocks, and the presence of the 64 million litre Nigerian National Petroleum Company (NNPC) depot with series of oil pipelines/flow stations makes it highly vulnerable to risk of oil spill.

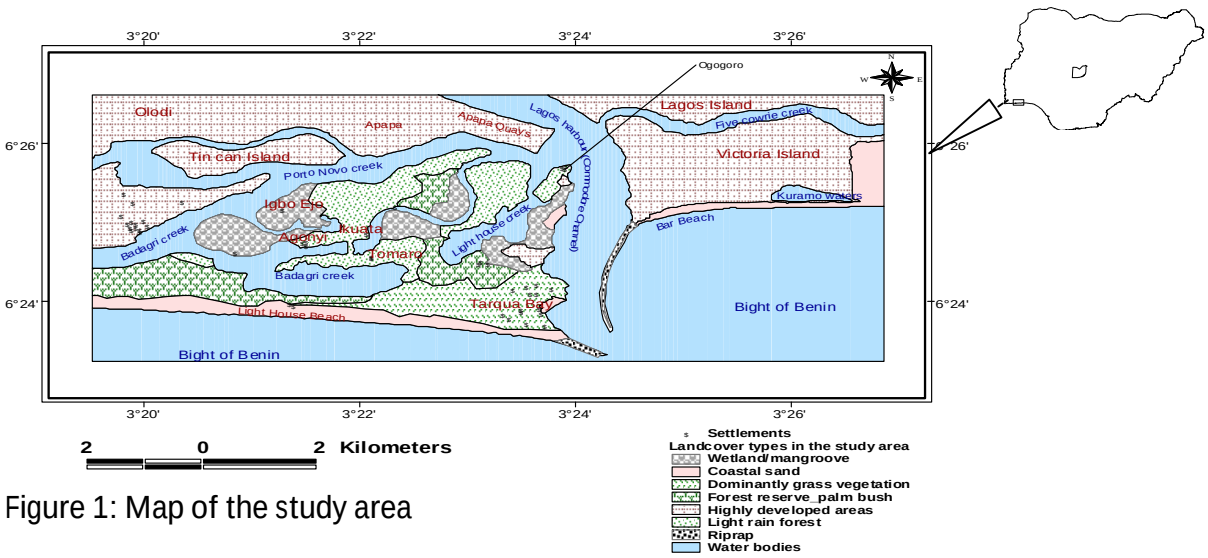

Figure 1: Map of the study area

Materials and Methods

The Topographical and NNPC facility map were digitized at scale of 1:20000. An overlay of the two digitized map was performed to produce the Digital Base Map (DBM) of the area. The DBM was updated with an Ikonos image acquired for December 2005. Field site logistic plan was then developed to determine requirement and date for field work, types of primary data to be collected, location of data collection and data size. Stations were created at interval of 400m along the shoreline and in each of the stations; data were collected in-situ as indicated in Figure 1

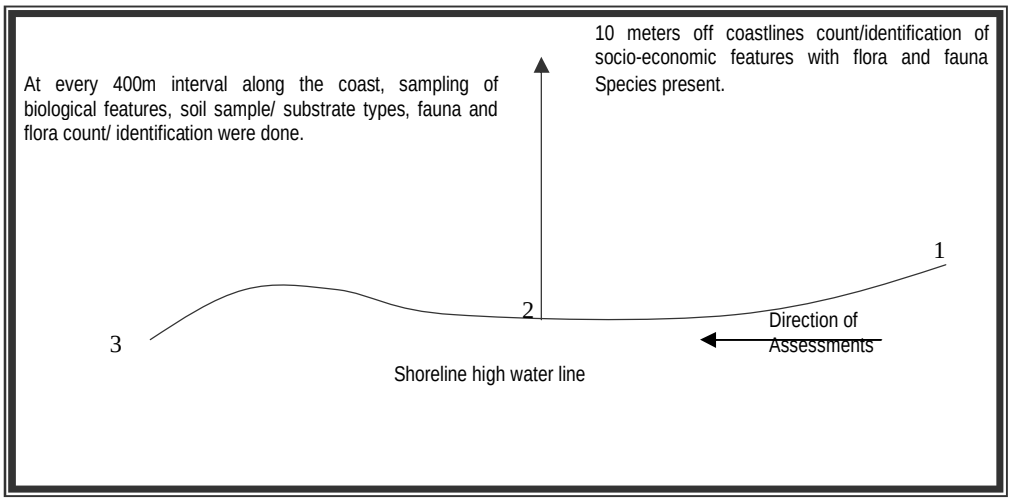

Figure 2: Rapid shoreline assessment plan

The data gathered in-situ was used to build up a relational database for the shorelines on the Updated Digital Base Map (UDBM) to derive the Level 1 GIS map (L1GM). Results of the rapid assessment from (field notes and observations) along the shorelines were compared with the standard ESI look-up table prepared for Nigerian shorelines by the OPTS for validation. The shore types were classified into sensitivity ranks on a scale of 1 to 10 based on the original index of Gundlach and Hayes (1978) for Nigeria. The shorelines were later colour coded using ArcView 3.2 colour palette customizations.

Rules for Sensitivity Determination

The results of the rapid assessment along the shorelines were compared with the standard ESI validation table (Table 1).

Table 1: Standard ESI validation table for shorelines

ESI	Shore Type	Dominant Sediment type and slope	*Slope*	Exposure
1a	Exposed rocky shores or banks	Rocky = boulders (>256 mm) Banks = marked by scarping, clays and mud (<0.625 mm) are common	*Moderate-High*	*Moderate-High*
1b	Exposed sea walls and solid man-made structures	Vary from Boulders and cobbles (> 64 mm) to sand bags, solid concrete, sheet pile or wood	*Moderate-High*	*Moderate-High*
2a	Un-vegetated/Eroding bank	Silt and clay (<0.0625 mm)	*Very low slope*	*Moderate*
2b	Exposed wave-cut platform	Bedrock or boulders (> 256 mm)	*Low slope backed by bluff or cliff*	*Moderate-High*
2c	Rocky shoals, bedrock ledges	Bedrock or boulders (> 256 mm)	*Low slope*	*Moderate-High*
3a	Fine sand beach	Fine sand (0.0625 – 2.0 mm)	*Low slope,(< 5^o)*	*Low-High*
3b	Scarps or steep slope in sand	Sand = 0.0625 – 2.0 mm	*Marked by scarp or steep slope*	*Moderate-High*
4a	Medium to coarse sand beach	Grain size = 0.25 – 2.0 mm	*Low to moderate*	*Moderate-High*
5	Mixed sand and gravel beach, bar or bank	Grain size = 1 – 64 mm	*Low to moderate slope (8-15^o)*	*Moderate-High*
6a	Gravel beach or bar	Grain size < 2mm, Moderate	*Steep slope (10 – 20^o)*	*Moderate-High*
6b	Riprap	Boulders (>256 mm)	*Moderate to steep slope (>20^o)*	*Moderate-High*
7	Exposed tidal flat	Coarse sand – mud (< 2mm)	*Low slope (3^o)*	*Low – moderate*
8a	Vegetated steeply sloping bluff	Soils (sand - mud)(<1mm), boulders (>256mm)	*Moderate to steep slope (>15^o)*	*Low*
8b	Sheltered Riprap	Boulders (>256 mm)	*Moderate to steep slope (>20^o)*	*Low*
8c	Sheltered rocky shore or scarp	Bed rock or boulders (>256mm)	*Moderate to steep slope (>15^o)*	*Low*
9a	Sheltered tidal flat or sand mud	Medium sand-mud (<0.5mm)	*Low slope (3^o)*	*Low*
9b	Vegetated low bank	Soils [sand to mud(1mm)]	*Low to moderate slope (20^o)*	*Low*
10a	Mangrove Nympa palm	Mud (0.625mm) Vegetation will indicate shore type	*Low slope (3^o)*	*Low*
10b	Fresh water swamp		*Low slope (3^o)*	*Low*
10c	Marsh		*Low slope (3^o)*	*Low*

Source: OPTS (2001)

Results

The observations along the shores of Atlas cove which guides in understanding the potential behavior of oil slick at the shores and the ESI types to which each shoreline belongs are shown in Table 2. From Lagos harbour to Tarqua bay and light house beaches, the grain sizes are finer (0.0625 – 0.25mm) than those of the Bar beach and Kuramo beach in Victoria Island (medium sized grain 0.25-2.0mm) (Table 3). The creeks and the mangroves substrates however have the finest grain size (0.0625mm). Along the west and east moles heavy quarried rocks were placed as shoreline fortification, the largest in terms of substrate size (>256mm) (Table 3).

With respect to shore slope and exposure to wave energy, the ranking is similar to sediment grain size. The deepest slope (0.75%) and the highest exposure to sea wave energy were observed along the west and east moles where the substrate size are also largest. The flattest slope (10%) also corresponds to the Light house and Tarqua Bay shores with the finest substrate size. The observed trend is typical of the geomorphology of Nigerian coastlines (Gundlach et al 2001, Noshkarhe et al 2001)

Table 2: Physiographic characteristics of the shorelines

hore location	Dominant substrate type (mm)	Shore description	Slope	Exposure to wave energy
Victoria island (Kuramo)	Grain size = 0.25 – 2.0	Medium to coarse sandy beach	0.15	High
Victoria island (bar beach)	Grain size = 0.25 – 2.0	Medium to coarse sandy beach	0.15	Very High
Light house beach	Fine sand = (0.0625 – 0.25)	Fine sandy beach	0.10	High
Tarqua bay beach	Fine sand = (0.0625 – 0.25)	Fine sandy beach	0.10	Moderate
East mole v/I side	Boulders (> 256)	Rip rap	0.75	Very high
East mole (Lagos harbour)	Boulders (> 256)	Rip rap	0.75	Very high
West mole (Lag harbour)	Boulders (> 256)	Rip rap	0.75	Very high
West mole (light house)	Boulders (> 256)	Rip rap	0.75	Very high
Lagos harbour(V/I side)	Solid concretes	Sea walls/solid man-made structures	--	Moderate
Lagos harbour (Atlascove)	Fine sand = (0.0625 – 0.25)	Fine sandy beach	0.20	Moderate
Badagri creek (water)	Sand-mud (< 0.0625)	Brackish/fresh water swamp	--	--
Light house creek	Sand-mud (< 0.0625)	Brackish/fresh water swamp	--	--
Five cowry creek	Sand-mud (< 0.0625)	Brackish/fresh water swamp	--	--
Porto-Novo creek	Sand-mud (< 0.0625)	Brackish/fresh water swamp	--	--
Badagri creek fringes	Sandy loam Soil (0.0625–0.25)	Sheltered Veg low banks	0.20	Low
Five cowry creek fringes	Sandy loam Soil (0.0625–0.25)	Sheltered Veg low banks	0.20	Low
Porto-Novo creek	Sandy loam Soil (0.0625–0.25)	Sheltered Veg low banks	0.20	Low
Light house fringe	Sandy loam Soil (0.0625–0.25)	Sheltered Veg low banks	0.20	Low
Ogogoro, Kuata, Tomaro, Tarqua bay	Sandy loam Soil (0.0625–0.25)	Huts along shorelines	0.20	Low
Mangrove (via Ogogoro)	Grain size = 0.25 – 2.0	Mangrove	0.15	Low
Mangrove (Via NNPC)	Grain size = 0.25 – 2.0	Mangrove	0.15	Low
Mangrove (Tarqua bay)	Grain size = 0.25 – 2.0	Mangrove	0.15	Low
Mangrove (L.H. cork)	Grain size = 0.25 – 2.0	Mangrove	0.15	Low
Mangrove (Badagri crk)	Grain size = 0.25 – 2.0	Mangrove	0.15	Low
Mangrove(Badagri crk)	Grain size = 0.25 – 2.0	Mangrove	0.15	Low
Mangrove	Grain size = 0.25 – 2.0	Mangrove	0.15	Low
Igbo Ejo swamp	Sand-mud (< 0.0625)	Brackish water swamp	--	--

Source: Adapted from Gundlach *et al* 2001

The information in Table 3 revealed 9 ESI types in the study area. The information is made more explicit in Table 3. ESI type 1b (Sea walls/solid man-made structures), 2a (Un-vegetated or Eroding bank), 2b (Exposed wave cut platform), 3a (Fine sand beaches), 4a (Medium to coarse sand beach), 6b (Riprap), 9b (Sheltered vegetated low banks), 9c (Huts along shorelines) and 10a are Mangrove/swamps. The relative proportions of each shoreline categories reveals that sheltered vegetated low banks are the most prominent with almost 40% presence. The observed is perhaps an indication of the overall sensitivity of the entire area.

Table 3: Shoreline by categories

ESI	Shore types	Location	Total length (km)	Percentage of entire shoreline
1b	Sea walls/solid man-made structures)	Eastern side of Lagos harbour, Apapa quays, part of five cowrie creek, Tin can island port and NNPC Depot	19.53	23.5
2a	Un-vegetated or Eroding bank	Bar-beach end of Victoria island.	2.46	3.0
2b	Exposed wave cut	Badagri creek near Kuata village.	0.056	0.1
3a	Fine sand beaches	Tarqua bay light house and western side of Lagos harbour	12.28	14.8
6b		West and Eastern Lagos harbour	8.74	10.5
9b	Sheltered Vegetated low banks	Found along all creeks occurring along upper reaches of creeks embayment.	31.03	37.3
9c	Huts or settlements along shorelines	Ogogoro, Kuata and Tomaro villages.	1.44	1.7
10a	Mangroves/swamps	Around NNPC Depot	5.77	6.9

In Table 4 the distribution of socio-economic and biological features along the shorelines are presented. Table 5 reveals the richness of each shoreline with respect to biodiversity. The Table also gives insight to geographical targeting of protective or containment actions. From the results in Table 5 it appears there is a relationship between the distribution of socio-economic features and biological productivity of the shorelines.

Table 4: Biological and socioeconomic features per shore locations

Location	ESI type	Socio economic features	Biota.
Victoria island beach (Kuramo)	4a	1	6
Victoria island (bar beach)	2a	1	-
Light house beach	3a	-	23
Tarqua-bay beach	3a	1	6
East mole V/Island	6b	1	25
East mole (Lagos harbour)	6b	-	22
West mole (Lagos harbour)	6b	-	25
West mole (light house beach)	6b	-	17
Lagos harbour (V/Island)	1b	9	5
Lagos harbour (Atlas cove side)	3a	3	26
Badagri creek (water)	10c	-	10
Light house creek	10c	-	10
Five-cowrie creek	10c	-	10
Porto-Novo creek	10c	-	10
Badagri creek fringes	9b	2	17
Five-cowrie creek fringes	9b		15
Porto-Novo creek	9b	5	21
Light house fringe	9b	-	27
Mangrove (via Ogogoro village)	10a	-	23
Mangrove (Via NNPC depot)	10a	-	22
Mangrove (Tarqua bay)	10a	-	27
Mangrove (Light house crk)	10a	-	26
Mangrove (Badagri crk upper)	10a	-	22
Mangrove(Badagri crk)	10a	-	27
Igbo Ejo swamp	10c	-	25

ESI map

Figure 3 is the composite of the information in Tables 1 and 2. The information was utilized to depict the relative shore sensitivity on the Initial ESI map. The color codes used presents the entire coastline environment according to relative sensitivity. Warm tones depict high sensitivities and cooler tones, lower sensitivities. The map presents most of the shoreline in warm colours relative to the proportions of the map in cooler colours. The cooler tones are seen to be generally contiguous with the ocean front. The location of more sensitive shores is identifiable. Human settlements located along shorelines at Tarqua Bay, Ogogoro and Tomaro were coded orange. The named shores exhibits extensive vegetation that requires saturated soils for growth and reproduction and are assigned ESI 9c. The mangrove and wetlands (assigned ESI 10a) were coded red.

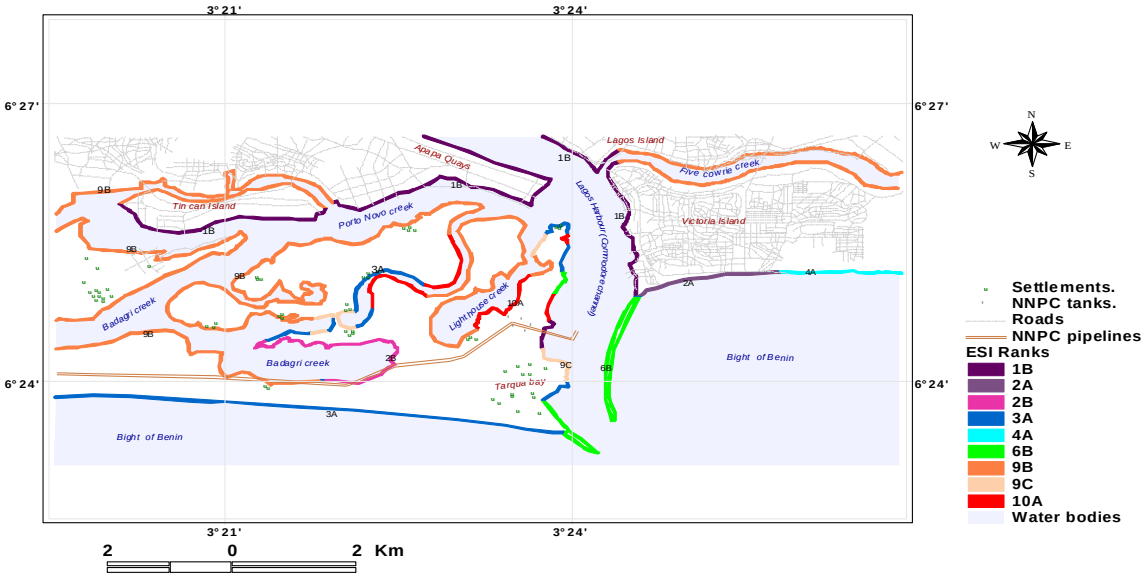

Figure 3: Atlas cove Shoreline sensitivity

Figure 4 is the overall ESI map which contains the positions and symbols of important features in the environment. The map reveals the location of socio-economic features and sensitive biological resources that may be affected by oil spill.

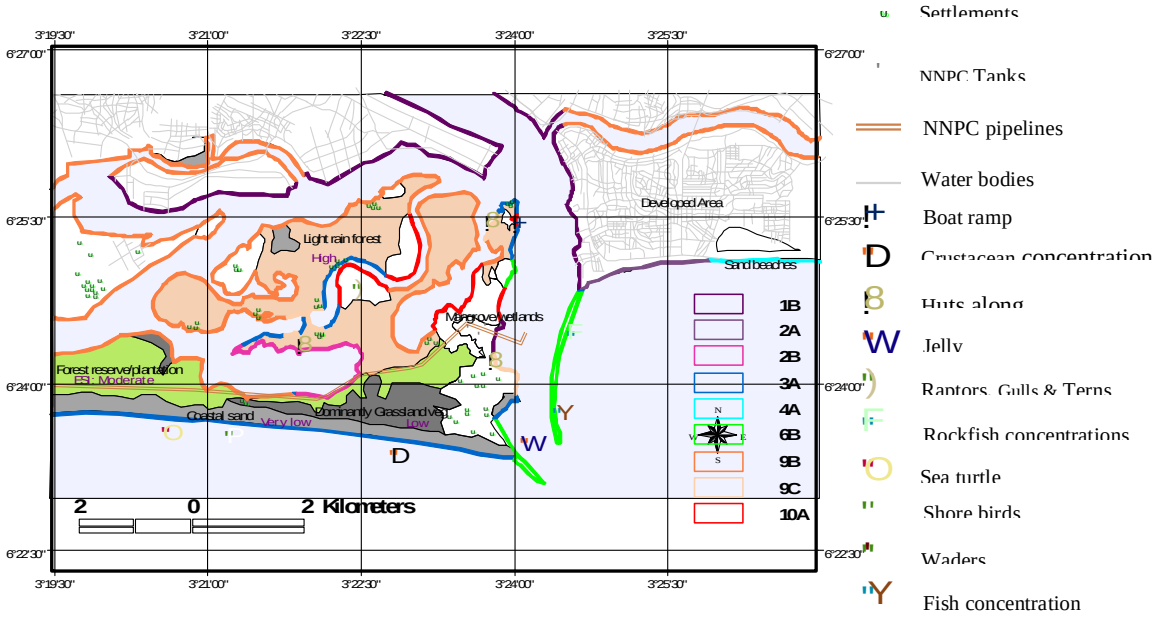

Figure.4: ESI Map of Atlas cove

Discussion

To distil the complexities of shorelines into biodiversity distribution pattern and proportion of shore types alone will lead to gross simplification and the underlying assessment becomes unavoidably subjective. Looking at the importance attached to individual issues in ESI mapping, it was essential to dwell on the physical attributes of each shorelines. Dwelling on the physical attributes lent some accuracy to prediction of the behaviour of oil and possibly guided in recommending the best clean up method. A complementary profile on the physical attributes of the shorelines and relative biological productivity contains shore information that borders on coastal dynamics and sensitivity.

Impact of oil may not be so severe along the solid man-made structures since it is made of hard impregnable sea walls and pilings exposed to direct wave action. Any oil deposited on these sea walls or solid man-made structures will be rapidly removed from exposed faces. Although oil persistence on any specific shoreline is related to the incoming wave energy, which for most of these shore type is relatively weak compared to the ocean wave. The most resistant oil on solid man-made structures would only remain as patchy bands, which can easily be recovered at or above the high water line. However to prevent leaching of the oil from the structures, high pressure spraying with dispersant may be required to remove oil from the solid man-made structures. Clean up crews should make sure they recover all released oil.

At the bar beach in Victoria Island, any oil slick from the sea will easily get to the shore with high wave action but it is also most likely to be washed away in a short time. The situation at the Light house and Tarqua bay resort beaches will be different. Here the oil may be buried by sand within the first few weeks since they are accreting beaches. It is important to note that during small spills, oil will most likely concentrate in bands along swash line of sandy beaches. Maximum penetration of oil into fine grain sand will be less than 15cm. While penetration into

coarse grain sand can reach 25cm, burial of oiled layers by clean sand within the first few weeks after the spill will be limited usually to less than 30cm whereas burial up to 60cm on coarse grain is possible. If the oil is stranded on shore at the beginning of an accretion period, such as after a storm, the deepest burial will occur but much of the oil will be removed during the next storm. Heavy accumulations of residual oil can form tar mats. However biological impacts are likely to be low except when the beaches are being used for nesting and foraging.

However, because of the heavy recreational use of the beaches in the area, an extensive clean up efforts to remove as much of the oil as possible may be required. Victoria Island beach has a very high exposure to wave energy, which could explain its eroding nature. Sand removal should therefore be kept to a minimum to avoid further erosion problems. The use of heavy equipments for oiled sediments do lead to removal of excessive amount of sand therefore manual clean up may be preferable. Mixing oil into deeper sediments and contamination of adjacent clean areas should be prevented. If possible cleanup crews should wait for all the oil to come offshore prior to the removal of oiled sediments.

Rip raps are generally exposed to very high wave energy. Deep penetration of oil between boulders is likely where the riprap is placed at the water line especially on the East mole on Victoria Island side of the commodore channel. Oil may readily adhere to the rough rock surfaces and if not quickly removed, it may cause chronic leaching until the oil hardens into an asphalt deposit. When the oil is fresh and liquid, high pressure spraying and or water flooding may be effective making sure to recover all released oil. Heavy and weathered oil will be more difficult to remove. As such it may require scraping and or hot-water spraying. If the oiling is beyond was can be put under control, it may be necessary to replace heavily oiled riprap. If oil should adhere to the rough surfaces of the heavy boulders, it may result in chronic leaching until it hardens to an asphalt deposit on impermeable surfaces. Fresh oil could be removed by pressure spraying. Weathered oil may be more difficult to remove by ordinary pressure spraying or water flooding. Removal of weathered oil may require water spraying, scraping or even complete removal of the rip rap in case it is heavily oiled.

Sheltered vegetated low banks (ESI 9b) were found almost along the banks of all creeks colonized by terrestrial plants that grow in aerated soils. The vegetated low banks occur prominently along the upper reach of creeks and their embankments. In the event of spillage, oil will adhere to any vegetation along the water line. Very heavy accumulations will be trapped along shoreline irregularities and pool in any surface depressions. Response staff should therefore note that all free oil must be removed by vacuum or low pressure flushing. If it is necessary to remove the contaminated vegetation it should be done only when confirmed necessary and under close supervision.

The mangroves, creeks and brackish water swamp ranked highest with scores of 10a, 10c and 10c respectively. Similar studies (Gundlach *et al* 2001) in the Niger Delta region of Nigeria support the fact that mangroves and wetlands are about the most sensitive in terms of impact of oil spill on biodiversity in shore line. Oiling would impact heavily on the area since it would be difficult to clean easily and several life forms would be affected. The mangroves and wetlands

have low exposure to wave energy but since the slope is a gentle one, slight tidal increase will get oil on to it. Moreover, the NNPC pipeline right of way passes directly through part of the mangroves. The NNPC pipes for many points along its length have been mutilated by vandals and it is beyond mere conjecture to say it will be a big threat to the ecosystem of the entire area in the very near future. Oil would adhere to vegetation and if not quickly removed may smother and kill the animals. Heavy oil accumulations will be trapped in irregularities and depressions hence, the use of vacuum, low pressure flushing should be considered.

Where Huts, houses are located along shoreline (ESI 9C), boom should be put in place before the oil slick arrives because of the high value placed on human habitats. In cases of contamination, detergent or dispersant options should be considered.

From the ESI map for the shorelines, two ready source of oil spill pollution are depicted. One is the NNPC depot that appears centrally located in the area. The other is the Ocean, which could be a ready source of pollution coming from tankers accidents or drift from the off shore wells of Ondo, Ogun and Lagos States, if and when they begin to mine the recently discovered oil deposit.

Conclusion

The established Environmental Sensitivity Index Mapping of Atlas cove Lagos shorelines is expected to improve the information and preparedness of coastline managers in their effort at protecting Nigerian shorelines from major oil or chemical disasters. The safest means of protecting the Atlas cove shorelines from marine spill therefore is to place a boom at the entrance of the Lagos channel while curtailing the oil from getting to very sensitive areas like Kuramo end of Victoria Island beach and the light house beach respectively. Response agencies like National Oil Spill Detection and Response Agency (NOSDRA) and National Emergency Management Agency (NEMA), and Nigerian Environmental Study Team (NEST) among others should take note of important and sensitive areas like the light house beach. The beach provide habitat for shore birds and rare species sea turtles. The Atlas cove environment is vulnerable but highly sensitive to oil spill.

The data gathered in this study is expected to be managed by a robust information management system, which would guarantee update in real time and help in decision support with respect to rapid response in future. From this study, GIS-supported Environmental Sensitivity Index mapping has proved very useful in this regard. GIS will remain one of the most important tools in contingency planning and rapid response to oil spill. The ESI maps will also sometimes find wider usage in areas such as coastal resource inventory/assessments, Environmental Risk Assessment, coastal and recreational planning, Environmental Impact Assessments and Baseline Environmental Studies.

The ecosystem's sensitivity level while still imperfectly understood has perhaps being the most critical aspect of the pollution debate. Ecological aspect of the environment need be given serious consideration in studies of this nature. The emphasis given to the issues of species extinction and environmental resources protection appear to a large extent yet unfruitful

probably because previous studies in Nigeria placed emphasis on human use/socio-economic features rather than the ecosystem as a whole. To put priority on human use, resources may be important but it should be noted that genes species and organisms are the product of over 3 billion years of evolution and they are the basis for the survival of the human species. Therefore, earth's resources ought not to be put in jeopardy at the instance of human socio-economic features. There is therefore the need to incorporate biodiversity into Environmental Sensitivity Indexing as shown in the present study.

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Role of Women in Fisheries in Coastal Wetland Areas of Ogun State, Southwest Nigeria

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Abstract

Fish is an essential source of animal protein and a primary supplier of essential polyunsaturated fatty acids specifically omega 3 and 6 fatty acids. Increase in population has placed high demand on fish products. Fish production has not been able to meet demand thereby creating a wide gap between demand and supply. Various efforts, such as introduction and encouragement of aquaculture, have been made to bridge the gap but to no avail. However, recognition of the role and empowerment of women in fisheries would go a long way to reduce, if not bridge the gap. Policy makers most often over-look women participation in making fish products readily available to consumers. Fish contribution from coastal wetlands to overall fish production can be improved through capacity building of women in fisheries. Introduction of new technologies, training, improved transport system and health services can boost fish production and enhance socio-economic status of the women fisher folk.

Key words: Women, fish, fish production, fisher folk, coastal wetlands.

Introduction

Fisheries sector is an important source of food and livelihood for many people around the world. Fish provides a vital source of protein and cash income for many families in the developing countries. About 200 million people throughout the world are estimated to depend on fish for all or part of their incomes (Akpaniteaku *et. al* 2005). Women play important role in fisheries and in maintaining households and communities. Although fish production is traditionally considered as masculine enterprise, women's role in fisheries is complementary and crucial. One of the most important commodity handled by women is fish (Akpaniteaku *et. al;* 2005). In coastal wetland communities, women are deeply involved in artisanal fisheries activities. These activities include unloading of fish from landing canoes, fish marketing and processing (Cochrane *et. al;* 2009); which basically form the link between production and consumption.

Traditionally, women are obliged to take care of the family in terms of feeding, clothing schooling, health care (Nauen, 1989) and some other domestic chores like cooking, cleaning, fetching of water and firewood. These primary responsibilities are often combined with crop

farming to support the family. Income-generating opportunities depend on local needs and circumstances and also on the ingenuity of the women in tapping them (Madhu, 1989). Families depend mainly on free fish supplied by the women of the household who are engaged in fish marketing (Adeyemo, 1983). Policy makers usually overlook the significant role women play in fisheries production and there is not enough information on women involvement in artisanal fisheries in the study area. The aim of this study is to highlight the relevance and contributions of women in the coastal wetland area of Ogun State, Nigeria in fish food security.

Materials and Methods

The study covered nine coastal wetland towns and villages in Ogun Waterside Local Government Area of Ogun State, Nigeria. The study area was divided into two major strata: lagoon and marine fishing communities. The lagoon fishing communities comprised of Iwopin, Ode-Omi, Makun-Omi and Awodikora-Osa while marine fishing communities included Awodikora-Okun, Igbeki, Olosumeta, Igbosere, and Bolorunduro (Figure 1). Interviews were conducted with the aid of structured questionnaires according to FAO (1999) in the two strata (n=50 in each strata) of the study area. The questionnaire was used to elicit information relating to the general personal data of the respondents, educational level, and year of experience in the occupation, their roles in fishing, processing, storage and marketing of fish. Questionnaires were administered only to female fisher folks. The respondents were exclusively interviewed at fish landing spots, smoking huts, and market squares. Completed questionnaires were collated and analyzed with simple statistical tools such as frequencies and percentages. Pie and bar charts were used to elucidate variables of interest.

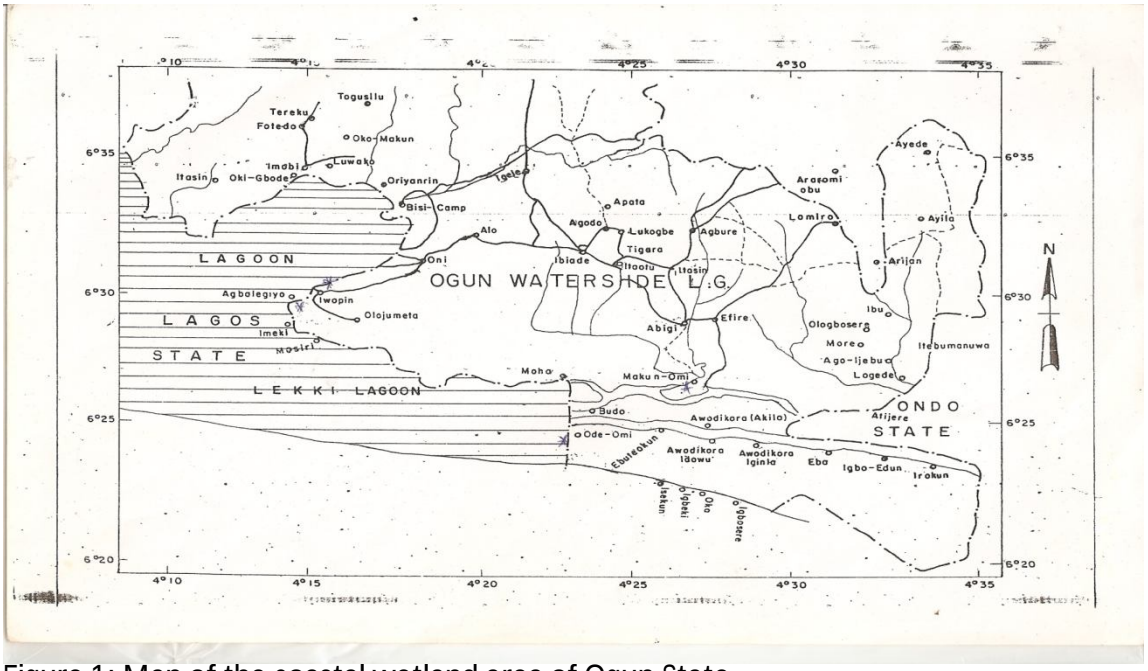

Figure 1: Map of the coastal wetland area of Ogun State

Results and Discussion

The results revealed that the age categories of the women fisher folk differ greatly from one another and that there is decrease in women participation in fisheries activities with increase in age in the study area (Figure 2). Age was an important factor in fisheries activities. However, respondents whose ages were between 21–30 years were the most prominent in coastal fisheries activities, which accounted for 40.9%. The women in this category are still in their active age to contribute meaningfully to fisheries production. Majority of the respondents (93%) were married women still living with their husbands while 2% were widows and 5% were divorced (Figure 3). Eighty-nine percent of the women interviewed in the fishing communities were noted to be from polygamous families while 11% were monogamous. Fifty-three percent of the women had an average family size of 5 children per woman. Riedmiller (1994) reported average family size of six children per woman in fisheries sector of Lake Victoria. The size of the family is a direct factor to the level of responsibilities carried by the women. The wives of the fishermen buy fish from their husbands and smoke them before taking them to the markets. Consequently, the fishermen tend to marry more than one wife so that they can have enough hands to take care of their catch.

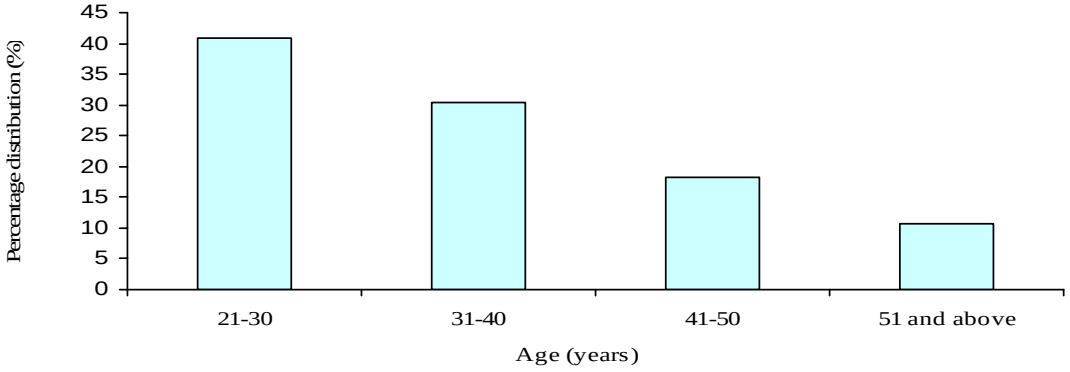

Figure 2. Age distribution of the women fisherfolk respondents in the coastal wetland area of Ogun State, Nigeria.

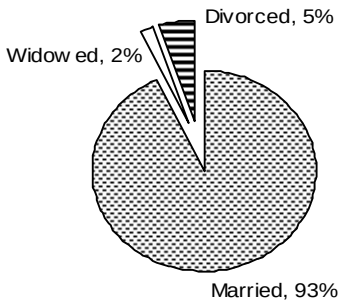

Figure 3. Marital status of women respondents in the coastal wetland area of Ogun State, Nigeria.

It was observed that women were not highly educated; only 20% had secondary school education, which was the highest educational level attained by the respondents (Figure 4). Suwanrangsi (2001) noted that educational status of women in the fisheries sector is inferior to that of men. Nauen (1989), Medard (2001) and Akpaniteaku *et. al*., (2005) reported high degree of illiteracy among women in fishing communities and it was a factor limiting their active involvement in development process. The most common fisheries practice engaged by the women was marketing of smoked fish (63.8%) and active fishing (3.7%) was the least (Figure 5). This result corroborated the report of Akpaniteaku *et al.,* (2005) that in rural fishing communities, women are predominantly engaged in fish handling, processing and marketing. Engagement of women in active fishing is limited to the lagoon area in the study area; it is forbidden for women to be engaged in active sea fishing in the marine wetland area. In some cases, women that are middlemen bought fishing gear and hired them out to men for a share of the catch; which corroborated the report of Medard and Wilson (1996) and Medard (2001). Figure 6 shows that majority of the respondents (31.8%) had been in the business for over twenty years.

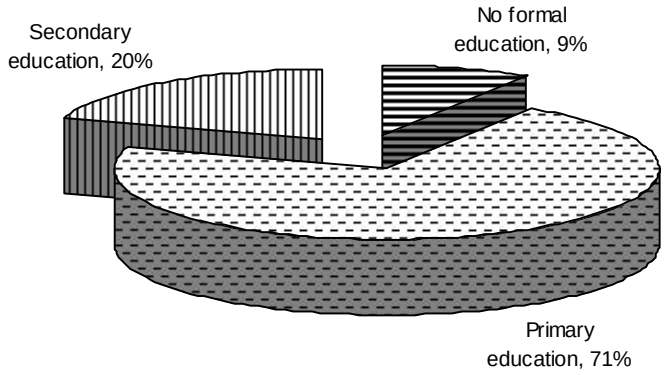

Figure 4. Educational background of respondents

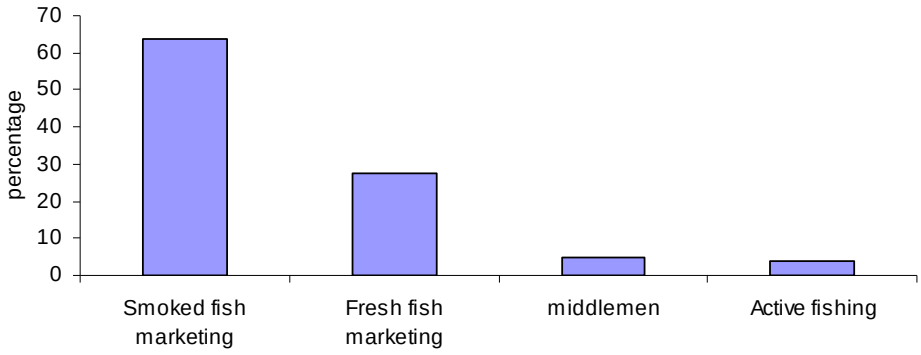

Figure 5. Fisheries activities engaged by the fisherfolk

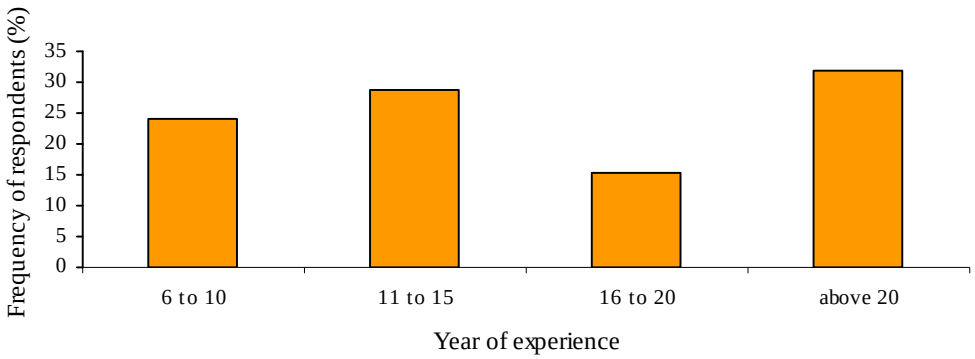

Figure 6. Experience of the respondents in fisheries business

Apart from fisheries activities, the results showed that 95% of the respondents were involved in multiple occupations such as crop farming (rice, cassava, maize and palm oil) and petty trading. This was necessary to augment their income especiallly during the period of low catch and unsteady market prices. Though they have separate budgets from their husbands, women contribute to part of the household expenses. Indeed, the role of women in providing for their families is crucial with the declining returns from artisanal fisheries. Families depend mainly on fresh fish supplied by the women of the household who are engaged in fish marketing (Adeyemo, 1983). Livelihood diversification is a means of risk transfer and reduction in the face of shocks (Cochrane *et. al;* 2009). Apart from active fishing, women engage in other fisheries activities and form trade unions, which moderate their activities. In Lake Victoria, active participation of women in direct fishing is limited to hauling of beach seine (Geheb, 1997). Gears employed by the women in brackish water ecosystem for fishing were traps of various type, set gillnets of small size and hooks coupled with small plank or dugout canoes as fishing crafts. Fisherwomen in the area may have been limited to these gears because of their strength.

Women in the study area are involved in post-harvest fisheries activities. Their participation in fish smoking activities contributes to availability of smoked fish products in the markets. It was observed that smoked fish products command higher price than fresh fish in the study area. This might be due to the fact that there was no other means to preserve their fish rather than smoking since they do not have electricity. Fisher folk lack the facilities to preserve their products and few storage capacities. Lack of means of preservation compel them to sell the fish they cannot handle by smoking fresh and at cheap prices because of the perishable nature of the products. Different types of oven were employed for smoking fish. These include box, mud, full-drum and half-drum ovens (Figure 7). Use of drum ovens was conspicuously absent in marine wetland area, which could be due to the salty nature of the area resulting to short life span of the metallic materials. All the respondents in the area make use of box oven in smoking their fish products. This could be as a result of large quantities of fish being handled at a time. Ikiara (1999) opined that processing as a means of prolonging the shelf life of fish products is complicated by the additional cost it requires.

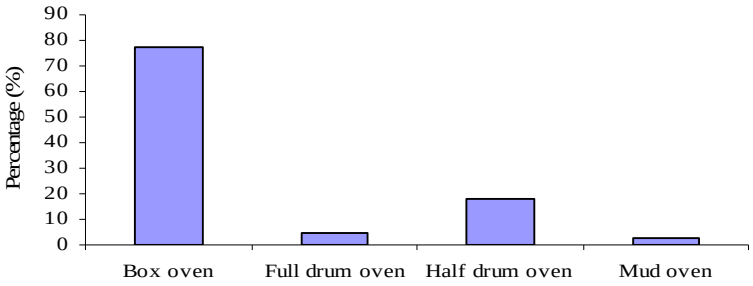

Figure 7. Types of oven used for fish smoking

Makun-Omi, Efire and Epe are popular market outlets, which serve as central markets for all the fishing communities in the study area. Smoked fish products from these markets are the principal source of cheap fish protein for the cities in the neighbouring cities and towns. Transportation of fisheries products from the marine beach to the markets is a herculean task because of the long distance and poor transport infrastructure.

The major constraints facing women in fisheries in the study area as depicted in Figure 7, included lack of fund, poor transportation, lack of fire wood for fuel, invasion of aquatic floating plants especially water hyacinth (*Eichonia crassipes*), which is peculiar to those in lagoon wetland area. Others were lack of gear and smoke from the fuel wood. However, insufficient availability of wood for fuel (83%) and lack of credit facilities (65.7%) were the major constraints militating against the women fisher folks. Sen *et al.,* (1991) reported that access to, and availability of credit facilities are one of the major constraints in fisheries sub-sector and that women in fishing communities have greater difficulties in obtaining formal credit than men.

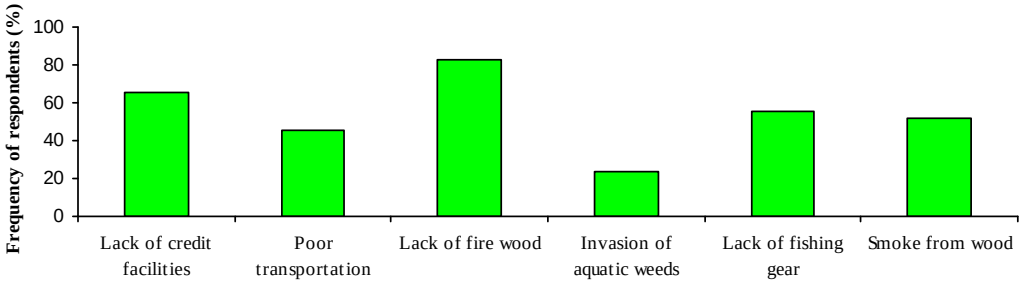

Figure 8. Nature of constraints confronting women fisherfolk in the study area

Conclusion

Women play predominant and significant role in the post-harvest sector of the coastal wetland fish production in Ogun State. Women's role in post-harvest processing, marketing and distribution of fish has not been given the right place. Women in the fisheries should be developed through extension training programs and skill acquisition, provision of credit facilities to improve their businesses, improve transport facilities, health and education services to improve their participation in development programs. Furthermore, women fisher folk should be provided with improved and affordable processing technologies for easy and rapid adoption. Women association should also be encouraged and promoted. Consequently, women fisher folk would be better empowered to contribute their quota to the actualization of one of the millennium goals – food security.

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Contribution of Non-Wood Forest Products (NWFP) to Livelihood Generation Products in Eriti Community Forest Wetlands, Ogun State, Nigeria

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Abstract

An ethno-botanical study of non-wood forest products (NWFP) extraction in Eriti Community Forest Wetlands was carried out with the aim of providing an additional baseline data for policy makers on need for the conservation and proper management of wetlands in forest areas. Respondents (400) drawn from 8 fringe villages of the Eriti Forest Wetlands provided the data for the study. The methods adopted include group discussions, participant observations and interpersonal interviews using pretested and structured questionnaire. The result analyses were descriptive using percentages, mean, mode and frequency distribution tools. The results showed that the respondents were highly dependent on the extraction of NWFP for livelihood generation especially at the subsistence level. The NWFP include medicinal products, edible leaves and fruits, wrapping leaves, mushrooms, wild-animal products, snails, palm wine and chewing sticks. The extraction of the identified products were gender bias as majority of the respondents were males (75%) and married (97%) indicating that the extraction of the products can be integrated into the family lines. The negative impacts of NWFP extraction on the wetland ecosystem was observed because of the destructive means of harvesting. The paper suggests appropriate management policies for the protection of the wetland ecosystems for environmental sustainability.

Key words: Non-wood forest products, Wetlands, Ecosystem, Conservation

Introduction

Wetlands are considered to be the most biologically diverse of all ecosystems whose formation has been dominated by water, and whose processes and characteristics are largely controlled by water. Wetland is a place that is wet enough for a long time to develop specially adapted vegetation and organisms. Wetlands are amongst the Earth's most productive ecosystems. They have been described both as "the kidneys of the landscape", because of the functions they perform in the hydrological and chemical cycles, and as "biological supermarkets" because of the extensive food webs and rich biodiversity they support.

There are more than 50 definitions of wetland. The Ramsar definition is the broadest and the most widely used. As stated in the Ramsar Convention (Article 1.1), wetlands are

> *"areas of marsh, fen, peat land or water, whether natural or artificial, permanent or temporary, with water that is static or flowing fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six meters" (Ramsar, 1971).*

That is, a wetland is seasonally or permanently covered by shallow water. The water table is close to or at the surface. Wetlands are therefore unique areas, representing a combination of terrestrial and aquatic characteristics, and are further categorized by type as marsh, swamp, fen and bog. In the wetlands, water is the primary factor controlling the environment and the associated plants and animals' lives. Delineation of water is mainly dependent on plants, which are typically adapted to saturated soils (Dugan, 1992).

In line with the above definition, Nigeria is endowed with diversity of wetland ecosystems (lakes, swamps, flood plain, natural or artificial ponds, high mountain lakes and micro dams) as a result of formation of diverse landscape. The landscapes are subjected to tectonic movements, a continuous process of erosion and human activities. Some of the recommended types or examples of wetlands are Swamp, Freshwater swamp forest, Slough, Marsh, Flooded grass and savannas, Salt marsh, constructed wetland, Bog, riparian and Peat swamp forest. The economic benefits of wetland have been cited in literature. This could be as a result of its richness in biodiversity of plant and animals. In spite of the benefits associated with forest wetlands, especially Timber and Non-Wood Forest Products for livelihood, timber products are given more attention to the detriments of NWFP, hence, the relevance of this study.

Forestry is a productive sector with significant effects on meeting national socio-economic and environmental functions as well as the improvement of rural livelihoods. The important roles play by NWFP in the livelihood of rural and urban households cannot be overemphasized as majority of rural households in developing countries, and a large proportion of urban households depend on the products to meet some part of their nutritional, health, house construction, or other needs. A large number of households also generate some of their income from trades in forest products e.g. sales of Irvingia seeds in Ibadan (Uke, 2010). Non-wood forest products (NWFP) in particular have been widely advocated by conservation and development organizations as potential alternative livelihood strategies, particularly in the wetland area communities because of their multi-benefits.

The importance of NWFP at the national level lies in the huge number of people involved in gathering, hunting, processing, trading and other aspects of their production and use. As noted earlier, most of the rural people use some forest products, and many obtain part of their income from forest-product activities. Inadequate information and data about the rural and urban people dependent on NWFP from wetlands is bane to any meaningful development of these resources. This study therefore provides an additional baseline data on the significant support provided by wetlands in adding value to the NWFP for rural dwellers in the forest wetland areas. Baseline information is necessary for policy makers to understand the need for the conservation and proper management of wetlands in forest areas.

Study Area

The Eriti forest wetlands is in Obafemi - Owode Local Government Area of Ogun State and is located in the humid tropical rainforest zone on latitude 6°50'N and 7°50'N and longitudes 3.18°'E and 3.32°'E some 20 kilometers on the southern corner of Abeokuta, Ogun State capital. The wetland shares western boundary with Ewekoro and Ifo Local Government Areas, and covers an estimated area of 156Km^2. The population of Eriti Forest Wetlands Community is over 6,000 in numbers. The two major ecosystems are Eriti Forest and banks of Ogun River. The wetland possesses rich alluvial soil useful in farming as a result of seasonal inundation and overflow of the river during raining season.

The fringe communities are well dispersed in settlements and villages. Eriti village appears to be the largest among the villages in the intervention area with a population of about 2,000 people and it is within a walking distance on foot paths to the forest. The least populated village (Saare) is about 100 people. The other fringe villages in and around the intervention area include: Isiba, Ogunpa, Ajegunle, Oluwo Oke, Itori and Arowa. Being an agrarian community, the villagers have utilized the forest wetlands to their best advantage, over the years. Particularly in farming and other means of livelihoods such as fishing, fuel wood production, grazing of animals, hunting, logging and soil excavation for building and other constructions among others.

Methodology

Sampling techniques and sample size

A multistage random sampling approach was adopted to select a total of 400 respondents from the 8 randomly selected fringe villages in Eriti community forest wetlands areas. Combinations of random and purposive sampling methods were used to identify the respondents for data collection. In each of the selected villages, 50 respondents were randomly selected for the purpose of uniformity. The snow ball non-probabilistic techniques' following Mcall and Simmons (1969) and Adekunle (2005) was adopted. The villages selected include; Eriti, Isiba, Ogunpa, Arowa, Ajegunle, Itori, Oluwo Oke, and Saare.

Data Collection

The major data collection method was a structured pretested questionnaire. Four hundred questionnaires were administrated, complimented with participant observations and group discussions. The questionnaires were administered in the homes of respondents and sometimes in open places especially in the evening and on Sundays when the respondents were less busy.

Data Analysis

Data obtained from interviews were encoded in the Microsoft Excel Program and processed using SPSS. The variables analyzed included age, gender, occupation, education and religion. The data on species prioritization were analyzed following Adeola (1995) and Frenzel et al (1996). Descriptive statistical tools such as percentages, and frequencies were used. Results of analysis are presented in Tables.

Results and Discussion

Table 1: Summary of socio-economic characteristics of the respondents

	Frequency	Percentage (%)	Mode
Age Class			
20 – 30	92	23	
31 – 40	114	28.5	31-40
41 –50	106	27.5	
51 – 60	50	12.5	
61^{+}	48	23	
Total	**400**	**100**	
Gender			
Male	298	75	Male
Female	102	25	
Total	400	100	
Marital Status			
Married	386	97	Married
Single	14	3	
Total	**400**	**100**	
Occupation			
Farming	392	98	Farming
Hunting	5	1.25	
Civil service	-	-	
Trading	2	0.5	
Artisan	-	-	
others (Food Vendor)	1	0.25	
Total	**400**	**100**	
Educational Status			
Primary School	64	41	
Secondary school	44	11	
Tertiary school	8	2	
No Formal Education	184	46	No formal Education
Total	**400**	**100**	
Religion			
Christianity	262	65.5	Christianity
Islam	132	33	
Traditional	6	1.5	
Total	**400**	**100**	

Age distribution of the dwellers

The dwellers age group ranged from 20 to 60 years and above. Those in the age group of 31 –40 years are in the majority accounting for about 29%. The majority age group is followed by those in the age group of 31 – 50 representing about 27%. The absence of the youths under the age

of 20 years could be because they are either in the cities attending school or learning one trade or the other.

Gender and marital status

The male respondents are in the majority representing about 75% of the total sample while the female respondents were 25%. Majority of the dwellers (97%) are married while the remaining are single (3%) (Table1). Those classified as singles include the divorcees, widows and widowers. Monogamy was prominent among the dwellers with an average of six people in each household. As majority of the dwellers are married, there is the likelihood of the integration of economic activities especially forest resources exploitation into the family line.

Occupational distribution and land use pattern

Farming is the major occupation and the major land use type with 99% of the respondents involved. Vegetable farming *Cochorus olitorus* (Ewedu) is the most prominent. Farmland sizes range from 0.04ha to 1.0ha. Other arable farm crops include cassava, rice, maize, yams and garden eggs, most of which are for domestic consumption. The arable crops are usually planted as inter crops. Ewedu farming was observed as the major cash earning enterprise. The main perennial cash crops include cocoa, kolanut and palm trees. Hired labour and seasonal fishing business also featured to generate income. In larger settlements such as Eriti, there are non-farming occupations such as petty trading in the home stead's, sales of wares like cigarettes, toiletries, bread, biscuits, alcohols and mineral water, food canteen and illicit gin joints.

Hunting is mainly done on part time bases by most hunters at least twice in a week. The strategy employed is usually an individualistic approach. Many of the respondents have specific areas for hunting while others search for animals all around especially those hunting for snails. The strategies and technologies adopted include setting of wire and gin traps especially where the animals are crop pests and the use of dane guns. Local breeds of poultry birds are commonly kept in small quantity under the extensive management strategy (free range system).

Educational status

According to Table 1, about 54% of respondents had formal education from primary, secondary or tertiary institution while 46% of the respondents had no formal education but are socially enlightened. Although only primary schools were common in the villages, other formal education could have been acquired from neighbouring towns and cities like Oba, Owode, Abeokuta and Lagos.

Religious practices

Religious practices are common, especially the Christian and Muslim religions. About 66% were Christian and the Muslim was 33% of the total (Table 1). This trend could be because Christianity and Islam are the two prominent religions in Ogun State. More so, Abeokuta happens to be the cradle of Christianity in Nigeria.

Land use practices

The major type of land use is farming involving arable crops like leaf vegetables, pepper, garden egg and tomato. Other arable crops include maize, cassava and rice. Fishing and hunting also feature to generate income. Nomadic cattle rearing are also observed because of the presence of grasslands in the area.

Dependence of forest for livelihood

The rural economy is highly dependent on forest resources to general income and to provide food and medicines. The assertion is reflected in this study among the dwellers. Table 2 below shows a sample of some of the forest products and the level of dependency on the products.

Table 2: Non-wood Forest Products: Dependency and Impacts

Forest Products	Level of dependency	Impact on the forest
Medicinal products	High	Negative
Geological materials, stones, gravels	High	Negative
Edible leaves (cultivated and wild)	High	Negative
Wild animals products	Low	Negative
Edible fruits (wild and cultivated)	Low	Negative
Wrapping leaves	High	Negative
Mushrooms	Low	Negative
Snail	Low	Negative
Aquatic fish	High	Negative
Religious activities	Low	Negative

It can be observed from the table that the dwellers depend highly on products such as medicinal products, stones/gravel, edible leaves, wrapping leaves and aquatic fish. The high dependence on stones/gravel, edible leaves, wrapping leaves and aquatic fish could be because the products are major source of income for the rural dwellers in the community forest wetlands. The proximity to Lagos and Abeokuta provides easy market for the products. Also the dwellers are highly dependent on traditional systems of medicine using forest plants because of lack of proximity to orthodox systems of medicine and personnel (Adekunle, 2005).

The extraction of all the products had negative effects on the forest wetland ecosystem. For instance removal of sands/gravels, fish from the wetlands and the unsustainable systems of harvesting of medicinal products, edible leaves and wrapping leaves always predispose the forest wetlands to different levels of threat. In most cases the system of harvesting is destructive and unsustainable.

Prioritization of NWFP by the communities

Based on the answers of the respondents, the different NWFP exploited in the area are listed for prioritization. The basis for selecting the NWFP for prioritization was the frequency of mention. Percent mention has been described as the strongest criteria for selection and ranking of multipurpose species (Adeola 1995). The author asserted that percent mention gives an insight into the acceptability of multipurpose species from which NWFP are sourced by farmers.

To meet an objective basis for ranking, the NWFP were subjected to systematized criteria rating test based on identified criteria. The criteria include species availability, ease of processing, growth characteristics, harvesting and market potentials. Subsequently, a summary of the NWFP exploited in the study area in order of priority is derived (Table 3). The source tree species from which the NWFP are extracted are also shown in Table 4.

Table 3: List of NWFP in order of priority

Items	Frequency of Mention	Ranks
Edible leaves	400	1
Wrapping leaves	400	2
Edible fruits	400	3
Medicinal products	398	4
Geological materials	300	5
Palm wine	240	6
Mushroom	200	7
Honey	140	8

Table 4: List of edible leaves

Local Name	Scientist Name	Status of Domestication	Level of Dependency
Edible leaves			
Ebolo	*Chrysocephun*	Wild	Low
Eforoko	*Telfararia accidentals*	Domesticated	Low
Ewuro	*Vernonia amygdalina*	Wild and domesticated	High
Gbure	*Talinum triangulae*	Wild	High
Ewedu	*Cochorus olitorus*	Domesticated	High
Tete	*Amaranthus spp*	Domesticated	High
Soko	*Celosia argentinea*	Domesticated	High
Wrapping leaves			
Eweran	*Thanmatococus darielli*	Wild	High
Teak	*Tectona grandis*	Wild	High
Edible fruits			
Agbalumo	*Chrysophyum albidum*	Wild	Low
Iyeye	*Spondias mombin*	Wild	Low
Oro/Apon	*Anitiaris toxitaria*	Wild	Low
Mango	*Mangifere indica*	Domesticated	Low
Ghara	*Psidium guajava*	Domesticated	Low

Attitudes of the Community Dwellers toward Participating for Management

It should be noted that all respondents showed interest in more than one mode of participation of wetlands. A high level of willingness to participate in management of the forest wetlands was expressed by the dwellers (Table 5). Even some were ready to take part and be involved in all the suggested options of participation. This observation should be harnessed for the sustainable management of the forest wetlands.

Table 5: Participation in management of forest wetland areas by the dwellers

Mode of participation	Frequency	Percentage
Forest management communities	364	20
Community Development Association	384	21
Monetary contributions	378	20
Planting of trees	382	21
Protection activities	344	18
Total	**1862**	**100**

Conclusion

It can be concluded that beyond timber, Eriti forest wetlands offer other products which are of economic benefits. Hence, wetlands could no longer be referred to as wastelands. The contribution of NWFP extraction in Eriti forest wetlands to the respondent has been recognized. The respondent depended highly on the wild sources for the NWFP, the negative impact of the community on the ecosystem and the integrity of the forest wetlands cannot be over stressed. As farming is the predominant occupation, a large portion of lands will have to be cleared for cultivation every year. A large farming population could mean a high level of forest resources exploitation. Small holder farmers are described as shifting cultivators and also hunter gatherers. Shifting cultivation without adequate years of fallow could result in the loss of forest biodiversity. In the same vein the collection and harvesting of medicinal products are not sustainable and always result in waste as more than needed are always collected with the erroneous believe that nature would replenish itself. As observed in this study, water pollution constitutes a menace to the integrity of the wetlands to support fish. The use of fires for hunting was common especially during the dry season. Also religious activities without control have a negative impact.

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GIS-Supported Survey of Low-Land Rain Forests in South-Western Nigeria

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Abstract

A survey investigating the capabilities of the remaining natural forest as conservation areas for already threatened wildlife population in South-western Nigeria was conducted using Aster and Landsat imageries. Spatial data acquired during the survey were incorporated into a mobile Geographic Information System (GIS) and analyzed in near real-time. Results of ground-survey revealed that a high natural forest patterns are similar to what was observed on the satellite imageries. The estimated total area of remaining natural forest in the reserves was 1,125 km^2 which is about 40 percent of the reserve area and the largest undisturbed natural forest is the 4.6 km^2 Strict Nature Reserve (SNR) found in western Omo. The forests probably still retain some level of their ecological integrity. Therefore there is an urgent need to produce new and accurate maps of the forest reserves to inform government, local people, and planners and to allow more effective management.

Keywords: GIS, Survey, Low-land Rain Forest, SW Nigeria

Introduction

The lowland rain forests of south-west are of considerable biological and socioeconomic importance in Nigeria. Right from the colonial era the rain forests have provided sustainable supplies of timber through controlled logging and had safeguarded water supplies through protection of the watersheds. Several animal and plant species many of which are now endangered flourished abundantly in the rain forests. At that time the forests were far from human enclaves and as such witnessed less human incursions. The strategic geographic location and services provided by the rich ecological composition these rainforests also made them of high importance in the old western region and the nation at large. But today, the originally ecologically rich and biologically abundant forests have come under intense pressure with population growth and economic expansion since Nigerian independence in 1960. At the moment it faces a severe threat of extinction.

Anadu and Oates (1982) in a broad-area survey of southwestern Nigerian forests in 1982 found huge pressures on the natural vegetation, which was being destroyed and converted at a rapid rate from excessive logging, conversion to plantations, farming and oil extraction, decimation of their wildlife populations through indiscriminate poaching. Ola-Adams, (1999) recalled that people were permitted to remain living within 65 km^2 of "enclaves" of Omo Forest Reserve at its establishment in 1925. Today, settler farmers have moved in to occupy many other parts of the reserve, especially since 1966 when the Gmelina Pulpwood Plantation Project began (WRM, 2007). Tree planting also involved the clearance of natural forest by the taungya farming system. By 1997, Greengrass (2006) estimated that 20,000 people were living in the forest reserves. During the 1970s and 1980s large areas of the Omo and Oluwa reserves were converted to monoculture plantations of the fast-growing exotic tree *Gmelina arborea* in a programme assisted by loans from the World Bank and the African Development Bank (Isichei, 1995). The Gmelina plantations was envisaged to provide material for a paper (pulp) mill in Iwopin Ogun State Nigeria but could not meet up with the goal owing to the premature extraction of the plantations. In addition to the many troubles of the rain forest of the southwest is the expansion of the human enclaves within the forests due to large influx of migrant taungya farmers. The remaining areas of the Nigerian southwestern forests have been identified on a continental scale as of high priority with respect to consideration for conservation (Toham *et al*., 2006).

As these forests continue to degrade in the face of excessive exploratory activities by humans, through large scale industrial, commercial and domestic extraction of timber and non-timber forest products, a deep concern is being expressed in many circles on developing effective conservation options for the remaining but threatened clusters of forests and its biological diversities. Developing a good framework for serious conservation option is the crux of the matter in any meaningful study. The recent anxiety about the precarious status of the forest ecosystem in Nigeria is perhaps one of the most critical aspect of environmental degradation debate. In this paper therefore, an assessment aimed at investigating the extent and condition of the natural forest and the status of their wildlife populations were conducted with the aim of developing the best conservation options and make preliminary recommendations for conservation. The study combined an analysis of remotely-sensed imagery with in-situ data from ground surveys with the aid of mobile Geographic Information System (GIS).

Methodology

Study Area

The rain forests of southwestern Nigeria occupy an intermediate position between the Upper and Lower Guinea forests which is a part of an extensive vegetal cover stretching from Sierra Leone to the Ghana-Togo border and reaching into eastern Nigeria and the Central Africa. This southwestern Nigeria rain forest area comprises clusters of contiguous forest reserves spanning parts of Ogun, Ondo and Osun States. These reserves include the Omo, Oluwa, Shasha, Ife and Ago-Owu Forest Reserves which in this paper is regarded as the Omo-Oluwa-Shasha forest complex. Prior to the creation of the state administration in Nigeria, these five forest reserves were all part of the then Shasha Forest Reserve, established in 1925 (Isichei, 1995).

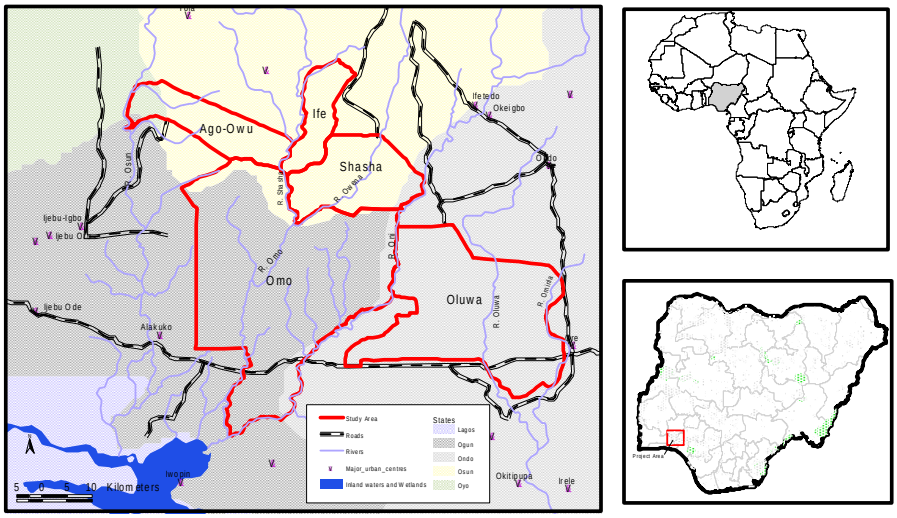


Fig. 1: Map of the forest reserves, showing major rivers and roads (Inset is Map of Nigeria and Africa showing location of the rain forests)

Data Ypes and Equipment for Survey

Geographic data used were obtained from different sources. The data included ASTER satellite imagery of the forest area acquired for January 2007, Landsat image of the same scene acquired for 2003, topographic map sheets and forest reserve boundary maps were assembled for the study.

A couple of hardware considered essential for the study were also acquired these include: ruggedized computer notebooks (Panasonic Toughbook) and a GPS-enabled pocket computer (Trimble GeoXM) for use in the field for mobile data capture. A customized data collection system for the project was developed with the aid of ArcPad GIS software on GPS-Pocket PC. In addition to these other field equipments necessary for the project were procured these include sleeping bags, backpacks, standard GPS units (Garmin Map60-CSx), binoculars, digital camera traps, waterproof cases, and other items.

Preliminary Survey and Establishment of Geographic Information System

Prior to the commencement of the field work a reconnaissance survey was conducted for the purpose of 'ground truthing' and developing the strategy for the actual survey. Next, a Geographic Information System (GIS) was established to support the survey. In order to guide field operations and data collection the ASTER imagery was geo-referenced, and subjected to a supervised classification based on the information obtained from 'ground truthing' during the reconnaissance survey. Maps of the project area were produced from 'on-screen digitizing' of scanned analogue maps of forest reserve boundaries and topographic map sheets. All Geographic features such as rivers and roads were captured from the scanned and geo-referenced map at a scale of 1:20,000. Information gathered from the field ground truthing exercise during the preliminary field works were utilized for database development of the maps produced.

Field Transects and Data Collection Methods

A grid of 5 km x 5 km designed to extend over the entire project area was superimposed on the geo-referenced satellite image. Within any grid cell where the satellite imagery suggests the presence of large areas of natural forest, a 5 km-length transect walks was conducted. Each walk began at the cell boundary which is easily located by means of ArcPad installed on the GPS aided pocket PC for 5 km towards the cell centre. Across the Omo-Oluwa-Shasha complex, a total of twenty-seven 5 km x 5 km cells were selected for the surveys. Of the twenty-seven 5 km x 5 km cells selected for transect surveys on the ground, 9 were located in Omo, 7 in Oluwa, 5 in Shasha, 2 in Ago-Owu, 2 in Ife, and 2 were shared between Omo and Shasha (Fig. 2).

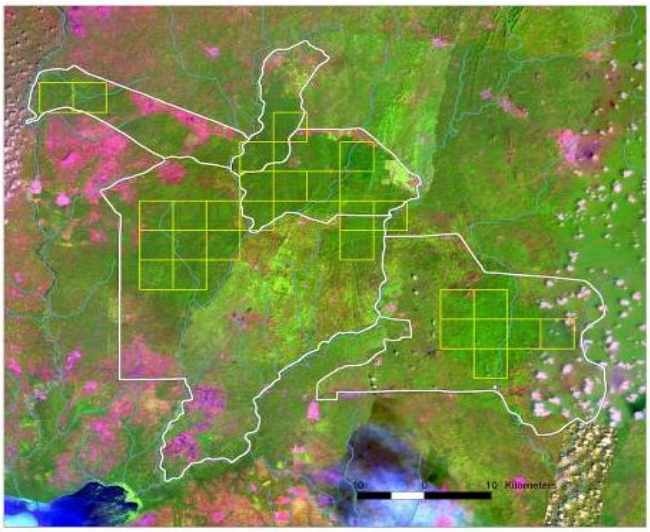


Fig. 2: 5 x 5 km cells selected for reconnaissance surveys

The number of transects created were based on the proportion of natural forest remaining in the reserves, the level of fragmentation observed and evidence of wildlife presence during the reconnaissance survey. Accordingly therefore, data collection along transects were done across three sampling zones: (1) western Oluwa Forest Reserve (west of the Omo River) (9 transects); (2) Ife, Shasha and northeastern Omo Forest Reserves (between the Omo-Shasha River and the Oni River) (6 transects); and (3) Oluwa Forest Reserve (7 transects). Since the remaining natural forest in Ago-Owu is highly fragmented, only one transect census was there, in the far west of the reserve, providing inadequate data for meaningful analysis.

The survey walks followed a path of least resistance on a compass bearing towards the approximate cell centre (along old logging roads, trails, and through the forest undergrowth with light vegetation clearing). Distances travelled were measured with a hip chain. Evidence of larger mammals, large birds and human activity encountered were recorded as a series of way-points on the GPS receiver, and information on land-use/land cover types were recorded at 200 m intervals. In addition to recording major categories of vegetation (e.g., natural forest, farmland, *Gmelina* plantation), the density of undergrowth and density of large trees (as low,

medium or high) were also recorded within 25 m of the waypoint. "Large trees" were defined as those with a stem diameter of at least 30 cm at breast height.

Experimental wildlife samplings were done with four Stealth Cam V450 digital camera traps strapped to trees. The passive Infared Sensor (PIR) of the cameras senses movement and triggers the camera to photograph the moving object object. With this technique a total 24 trapping days in each of Omo, Oluwa and Shasha Forest Reserve were done and the images bushbuck, a side-striped squirrel, small mongooses were recorded.

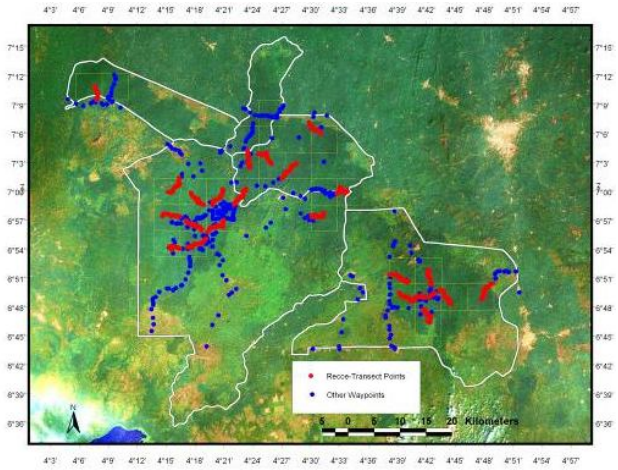


Fig.3: Waypoints: Survey transect walks (red) and other ground-truthing positions (blue)

Results and Discussion

General Observations on Status of Habitat and Wildlife

Gross successions had taken place in large portions of the natural forests ecosystem; natural vegetation have been replaced by other land cover types, and within areas that were predominantly natural forest, there were abundant signs of human activity: footpaths, roads, logging, farming, hunting, and the gathering of non-timber forest products (NTFPs). The observations were in agreement with the reports from previous studies (Ikemeh, 2007) on the conditions of the forest reserves around this area.

Land-use/land-cover types on the ground corresponded quite closely to patterns observed on the satellite imagery. Although several farms were discovered right inside the reserves, areas such as southern Shasha are still predominantly forested. Comparison between the Landsat imagery acquired for 2003and ASTER imagery acquired for 2007 did not reveal any outstanding changes in land cover.

In this study, areas that have not been converted into tree plantations, farms or settlements are regarded as natural forest being the original vegetation of the reserves when they were established, although they might have been modified by many years of logging but not yet totally transformed. In table 1 the area and percent cover of natural forest in each of the reserves are presented.

Table 1: Areas of surveyed reserves, and areas of natural forest in the reserves

Forest Reserve	*Total protection area (km^2)*	*Area of forest reserve still natural (km^2)*	*Percent of forest reserve still natural*
Omo	1,325	381.2	28.8
Oluwa	827	347.9	42.1
Shasha	309	240.8	77.8
Ago-Owu	240	79.4	33.1
Ife	142	75.8	53.2

Omo forest reserve with over 1,300km^2 is largest in terms of area demarcated for protection and forest area (381km^2) still remaining natural. It is followed by Oluwa forest with over 800km^2 reserve area and 347km^2 of it still natural. However in terms of effective conservation, Shaha forest retains the largest percentage of the protected areas as natural forest. This trend might be related with the size of the reserve which makes smaller reserves easy to monitor. For instance, Ife forest is the smallest but it is next to Shaha in terms of effective protected area; about 53% of its original coverage, unlike Omo which retained less than 30% of its original land area. The inclination in these survey finding is further clearly depicted by the chart in figure 4.

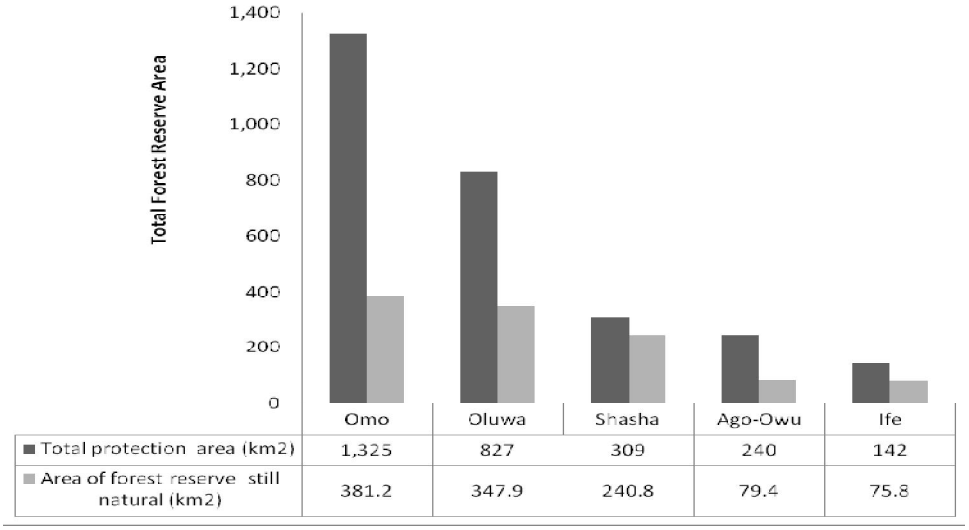


Fig. 4: Chart showing the proportion of natural forest vegetation to total protected area

Most of the forest reserves have been fragmented through human anthropogenic activities. The areas of mostly contiguous natural vegetation (although highly disturbed) are in western Omo, Oluwa, Shasha and parts of southern Ife. Spatial analysis of land cover types suggested that more than 50% of Ago-Owu reserve is still forested. Figure 5 reveals its level of fragmentation.

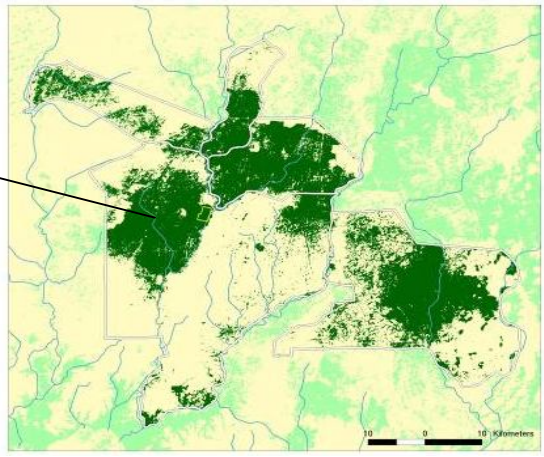


Fig.5: Distribution of remaining natural forest (dark green) in the target reserves, based on ASTER imagery and ground truthing.

In several places, logging has been so intensive that only few stands of timbers remain. The density of large trees varies considerably from place-to-place. Figure 3 indicates that there is a gap of more than 10 km between the remaining area of continuous forest in Oluwa, and the nearest remaining such forest area in northeastern Omo. Ground surveys revealed much of the area has been converted to teak plantation and cocoa farms, with only a few patches of forest left. Forest still fringes the Oni River that marks the boundary between Oluwa F.R. and Omo F.R., but this forest is under pressure from logging and farming.

Estimates of tree density and thickness of undergrowth made at 200 m intervals along transects is another measure of human impact on the forest reserve. This is presented in Table 2.

Table 2: Percent undergrowth and tree density in each class by survey zone

	Western Omo	Shasha Reserve – Oni Reserve	Oluwa Forest Reserve
Density of undergrowths			
High	47.0	66.7	46.6
Medium	40.5	23.0	38.8
Low	12.5	10.3	14.6
Tree Density			
High	32.7	27.6	19.4
Medium	42.9	36.8	52.4
Low	24.4	35.6	28.2

Intensive logging that occurred over the years in all the forest reserves has given rise to vegetal transformation producing dense undergrowth and low density of larger trees. Western portion of Omo forest reserve had the most dense timber population while Oluwa forest had the lowest

density of timber. Western part of Omo forest appears to have been less damaged by logging than the other areas.

Wildlife Distribution Status

The wildlife population distribution in the lowland rain forest in south western Nigeria is influenced by the pattern of its vegetal cover. Table 3 displays records of mammals obtained during the survey. Again western part of Omo had evidence of presence of more mammal than the other forest areas. For instance, signs of elephant's presence were more in western Omo they were not encountered elsewhere. This is because it is only in western, but primates were also much more often encountered in western Omo than in the other areas, and primate evidence was very sparse in the Shasha-Oni zone.

Table 3: Mammal records from transect walks

	Western Omo			**Shasha River - Oni River**			**Oluwa F.R.**		
	No.	*No. per walk*	*No. per km*	*No.*	*No. per walk*	*No. per km*	*No.*	*No. per walk*	*No. per km*
All mammals	105	11.7	2.33	10	1.67	0.33	33	4.71	0.94
Elephants	35	3.9	0.78	-	-	-	-	-	-
Ungulates	20	2.22	0.44	8	1.33	0.27	13	1.86	0.37
Primates	31	3.44	0.69	2	0.33	0.07	13	1.86	0.37

Although signs of elephants are still relatively frequent in western Omo, generally mammals are scarce throughout the survey area, as judged by the relatively sparse evidence of their presence acquired during the survey. Large birds, including large hornbill species, remain relatively abundant, however.

Olmos and Turshak (2007) noted that Omo forest harbours a significant number of birds some of which are endemic to the area and or endangered. For example the globally near-threatened, grey parrot species (*Psittacus erythacus*) and yellow-casqued hornbill (*Ceratogymna elata*).

Figure 6 shows the presence of mammals in the five forest reserves as recorded both on and off transects during the survey. The map shows that western Omo is the richest in animal biodiversity.

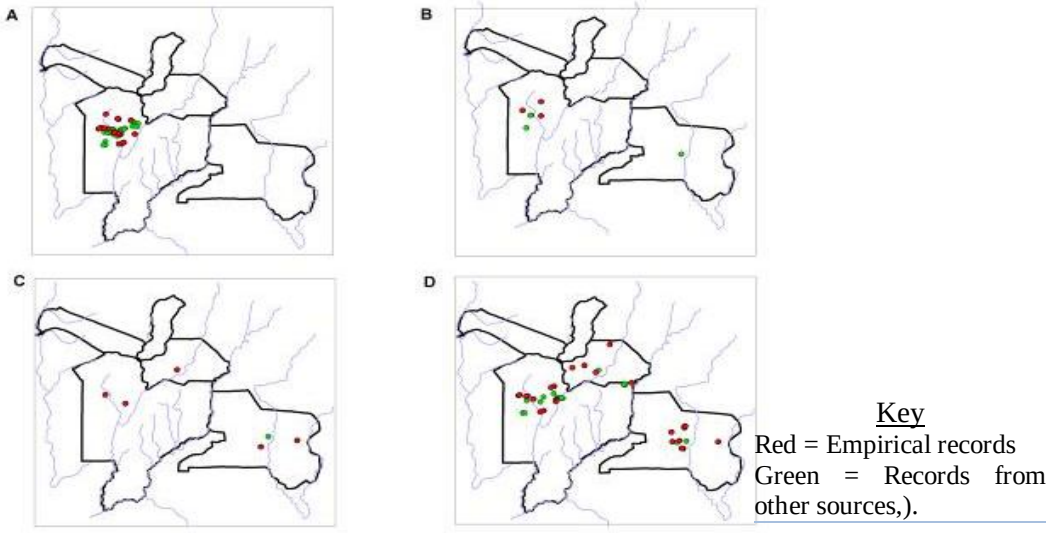


Fig. 6: Map of distribution of large mammal records
(A: Elephant; B: Buffalo; C: Red river hog; D: antelopes)

This trend remains otherwise hidden without the aid of spatial technology. Elephants are present only in western Omo this is obviously due to the density of the vegetation here. Antelopes are common to Omo, Oluwa and Shaha.

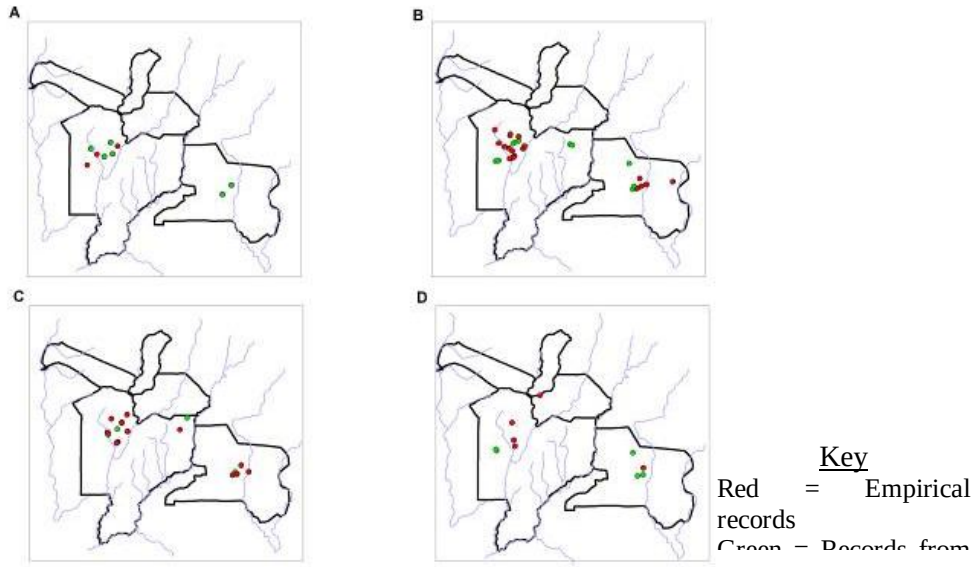


Fig. 7: Distribution of primate records

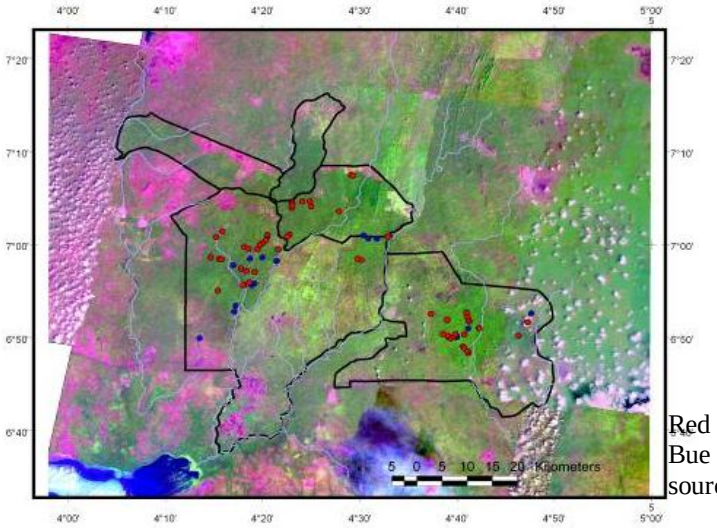
(A, red-capped mangabey; B, mona monkey; C, putty-nosed monkey; D, white-throatedmonkey)

The distribution of these large bird records across survey zones is shown in Table 4. The most readily recognized large birds were large hornbills, of which four species have been recorded in these forests: the black-and-white casqued hornbill (*Bycanistes subcylindricus*), the white-thighed hornbill (*Bycanistes albotibialis*), and the black-casqued hornbill (*Ceratogymna atrata*), in addition to the yellow-casqued hornbill (Olmos & Turshak, 2007).

Table 4: Large bird records from recce transects

	Western Omo			**Shasha River - Oni River**			**Oluwa F.R.**		
	No.	*No. per recce*	*No. per km*	*No.*	*No. per recce*	*No. per km*	*No.*	*No. per recce*	*No. per km*
All large birds	23	2.6	0.51	14	2.33	0.47	21	3.0	0.60
Large hornbills	18	2.0	0.40	13	2.17	0.43	19	2.7	0.54

In some parts of West Africa it is now unusual to encounter any large hornbills. The relative frequency with which these birds were encountered on our survey (0.4-0.5 encounters per km on transects), is an indication that these forests still retain a significant amount of their biodiversity and ecological integrity, despite the abuses they have suffered. The distribution of the birds is presented on the satellite image in Figure 8.



Key
Red = Empirical records
Bue = Records from other sources).

Fig.6: Distribution of large bird

Their niches can be seen to coincide with the less disturbed patches of the forest area. The pink patches are human dominated ecological systems.

Evidence of human impact

Human activities in these forest reserves were widespread and recurrent. No ecosystem can be regarded as pristine. Table 5 presents the records of human activities in the forest reserves.

Contrary to expectations, the largest number of human activity per km was found on the western Omo where species richness of biota was highest.

Table 5. Human Activities Records from Recce Transects

	Western Omo			Shasha R. - Oni R.			Oluwa F.R.		
	No.	*No. per recce*	*No. per km*	*No.*	*No. per recce*	*No. per km*	*No.*	*No. per recce*	*No. per km*
Farming	10	1.11	0.22	2	0.33	0.07	9	1.29	0.26
Hunting	15	1.67	0.33	3	0.50	0.10	17	2.43	0.49
Logging	33	3.67	0.73	13	2.17	0.43	19	2.71	0.54
NTFP	6	0.67	0.13	1	0.17	0.03	3	0.43	0.09
Gathering Camps	7	0.78	0.16	2	0.33	0.07	2	0.29	0.06
TOTAL SIGNS	**71**	**7.89**	**1.58**	**21**	**3.50**	**0.70**	**50**	**7.14**	**1.43**

This perhaps can be explained by the size of the forest relative to the fragmentation. Beyond this is the presence of the Strict Nature reserve (SNR) located on eastern edge of the natural forest area in northwestern Omo; which serves as sanctuary for most wildlife in the area. This pattern again is depicted in Figure 9.

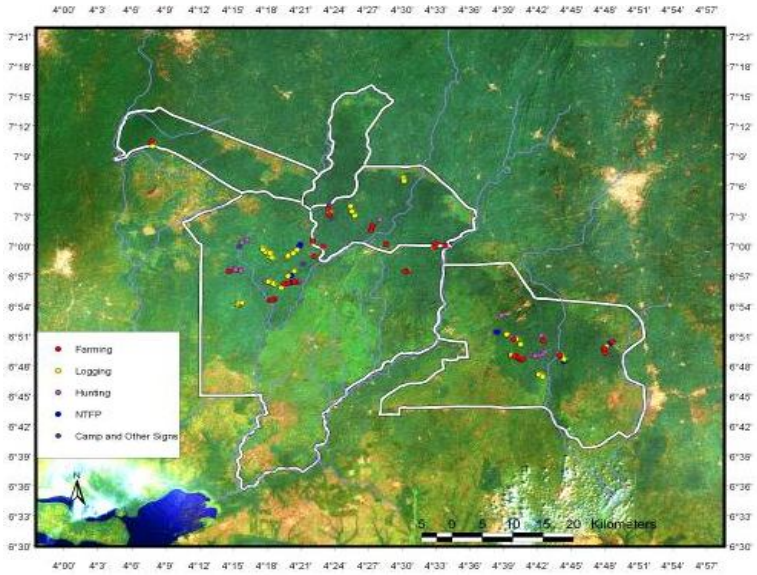


Fig. 9: Records of human activity in the target forest reserves

Around the boundaries of the SNR as shown on the image and ground measurements (Fig. 10) there were no signs of recent human interference with the vegetation during this study.

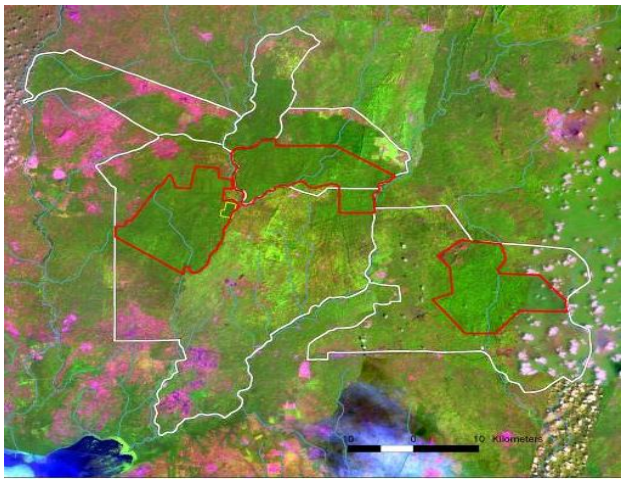


Fig. 10: Suggested areas for protection (within red lines) in Omo, Oluwa and Shasha Forest Reserves.

Conclusion

The Omo-Oluwa-Shasha complex of forest reserves is grossly degraded due to human anthropogenic activities. They are probably the last major rain-forest areas remaining in southwestern Nigeria contain several wildlife species regarded as Endangered or Vulnerable by the World Conservation Union. However, there are still natural forest areas worthy of conservation in Omo, Oluwa, Shasa and Ife Forest Reserves. Pending further biodiversity studies, these areas appear to be of particular national significance, notably because of animal species such as the African elephant (VU), chimpanzee (EN), red-capped mangabey (VU), and white-throated guenon they preserve. Omo Forest Reserve alone houses close to 242 bird species. Although several areas of the rain forest have been heavily degraded, the natural forest ecosystem including its wildlife population could recover, if it is adequately protected even if it should take several decades. The use of GIS will enhance proper management of the forest reserve. Omo, Shasha and Ife reserves are still fairly contiguous though very tenuously, across the Shasha River, forming a block of about 600 km^2 which, if well-managed, could constitute a more viable ecosystem. Although at the moment no area of contiguous natural forest in any single reserve in the complex exceeds 250 km^2.

Recommendations

More Strict Nature Reserves should be established in the areas indicated by the map in figure 10. One protection option would be to gazette Wildlife Sanctuaries similar to the ones created in 1985 within Okomu Forest Reserve of Edo State which subsequently became a national park. In terms of creating protected areas, it is probably helpful that Omo is already formally listed as one of 26 Important Bird Areas in Nigeria by Birdlife International.

Particular attention must be given to reducing human impact in areas of tenuous connection between remaining natural forest areas. This may require relocating people form area demarcated for SNR or wildlife sanctuaries. A particular situation is the Etemi Village, located north of the Strict Natural Reserve.

There is an urgent need to produce new and accurate maps to inform government, local people, and planners. At the moment there are no up-to-date maps to educate people at all levels on the need for protection of natural forests and where to protect. Several people are unaware of the details of reserve names and boundaries. Maps on forest ecology should be widely circulated and made easy to interpret and readily available to local communities.

Funding for the forest maintenance could come from ecotourism. Weeks (1998) noted the tourism possibilities in Omo forest reserve. Another funding possibility that could be explored is the carbon-credit market. The states may be eligible directly (or indirectly through an NGO or the federal government) for carbon credits simply by setting aside areas of natural rain forest for protection.

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Perceived Benefits of Selected Wetlands in South-West Nigeria

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Abstract

Poor appreciation of wetlands has been linked to a massive destruction of wetlands in Nigeria thereby constituting a missed opportunity that would have led to improved income generation, food security and environment sustainability. This study assessed people's perception of selected wetlands benefits in South West, Nigeria. The study was based on primary data obtained in a cross-section survey of 197 individuals that were either resident and/or pursuing livelihood activities in communities around Eleyele, Eriti and Lagos lagoon wetlands of Oyo, Ogun and Lagos States, respectively. The study found that majority of respondents recognised the direct benefits of the Wetlands especially in terms of its role in provision of food, herbs and building materials while only a few recognised its environmental services as it relates to provision of windbreaks, nutrient recycling and microclimate stabilization. The level of appreciation of all Wetland benefits among the respondent was a low Perceived Benefit Index (PBI) value of 0.45 on a scale of one. Tobit regression analysis revealed that age, Wetland share of income, activity type as well as the location of Wetland are factors that significantly influence people's perception of Wetlands benefits. It can therefore be concluded that people around Wetlands have a poor appreciation of Wetland benefits especially the environmental services they provide. The study recommends that governments and NGOs should put in place appropriate community based education/awareness campaign to promote better appreciation of Wetlands benefits.

Keywords: Perception, Wetland benefits, Likert scale, Perceived Benefit Index and Policy.

Introduction

Environmental income (income derived from the ecosystems) is a major constituent of the livelihoods of the rural poor (World Resources, 2005). According to this report, reliance on the environment is now been explored as a veritable tool in economically empowering the rural poor especially in Africa, Asia, and Latin America. The importance of these resources as a sheet anchor can therefore not be overemphasized as any harm done to them will affect the livelihood of the people that depend on them.

Wetlands – generally referring to marshes, swamps, floodplains, mudflats, estuarine and the littoral areas of large bodies of water – are used together with uplands in an integrated manner

by the rural people to sustain livelihood. They are among the Earth's most productive ecosystems (Barbier et al, 1997). They have been described both as "*the kidneys of the landscape*", because of the functions they perform in the hydrological and chemical cycles, and as "*biological supermarkets"* because of the extensive food webs and rich biodiversity they support (Mitsch & Gosselink, 1993). Wetlands perform a wide variety of functions that include flood control, ground water recharge, shore line stabilization and storm protection, climate moderation and also serve as habitat for living things, recreation, tourism and cultural values (FME, 2009; Bikangaga, 2007).

In Nigeria just like everywhere else in the World, floodplains and wetlands are rich sources of livelihood for millions of people yet; their destruction is taking place at an alarming rate, with as much as about 50% of the World Wetlands already lost (O'Connell, 2003, RAMSAR, 2009). Nigeria's most important wetlands, the Hadejia-Nguru Wetlands in Jigawa and Yobe states respectively, have shrunk by as much as two-thirds in the past 30-40 years because of diversions from dams, irrigation developments and drought. Fisheries, farming and wildlife are all impacted by these hydrological changes (Idris, 2008) and by extension the livelihood sustenance of the local communities that depend on them. Also, uncontrolled oil exploration activities with the attendant oil spillage and pollution has caused a vast track of the agricultural land in the Niger-Delta Wetland (the largest in Nigeria, and the third largest RAMSAR designated site in the world) to be laid waste, thus becoming unproductive (NEST, 1991). As a result, surface water in the area is invariably contaminated and polluted, rendering the water undrinkable, and aquatic life destroyed, while the vast majority of the natives whose livelihoods depends largely on the Wetlands are equally impoverished. Most of these loses are unfortunately due to human activities, including large scale diversion of water for irrigation, burning and exploitation of peat land, extensive drainage of marshes, pollution of lakes and rivers (RAMSAR, 2009) as well as balancing the different use options so as to ensure sustainability of the resource. Nevertheless, wetlands can be sustainably exploited if the dynamics of the local institutions that influence accumulation and consumption of livelihood assets are well understood and harnessed appropriately, (Mwakubo and Obare, 2009; Gren et al, 2001). The life support systems that are inherent within the wetland ecosystems can provide a wide range of valuable functions to society if they are used in a sustainable manner, for example, by incorporating the primary users in the management of the wetlands within the context of societal livelihoods and local institutions (Folke, 1991). To achieve this, Springate-Baginski., et al (2009) has opined that decentralization of management to the lowest appropriate level of all stakeholders will help achieve greater efficiency, effectiveness and equity. However, Martin & Sutherland (2003) in reviewing several projects (Soil and Water Research in Malawi, Participatory Management of Kapuwai's Wetlands in Uganda, Forging New Institutional Arrangements for Common Property Resource Management – A Case Study from Southern Zimbabwe) has observed that an understanding of the immediate Wetland community dwellers perception of its benefits is very important. According to them it allows interventions to be targeted to specific groups for whom the problem is most acute. Furthermore, they opined that motivation for participation is strongly influenced by the relevance of the research focus and intervention strategy to stakeholders' priorities, roles and

expectations of benefit. Therefore, an express knowledge of the values they associate with the Wetlands will be the fundamental step upon which correction in their values and the eventually sustainability programme hinges on. Also, more explicit understanding of this relationship has the potential to encourage the greater involvement of specific groups in monitoring and evaluation (Martin & Sutherland 2003). Studies of this nature are thus urgently required to critically assess people's perception of the benefits derivable from Wetlands for policy implications geared towards consideration of how to improve the complementarities of strategies for income generation, food security and environment sustainability.

The broad objective of the study was to assess the economic value and benefits the perception of well as wetland community dwellers perception and Willingness to pay for sustainable management of selected Wetlands in Southwest, Nigeria. The specific objectives were to

1. Describe and compare the socio-economic characteristics of various categories of Wetland service users in the study area;
2. Determine the benefits that the Wetland service users perceived they derive from the existence of the Wetlands in their area; and
3. Examine the influence of various socio-economic, attitudinal, location-specific, and other factors on the perceived value.

Materials and Methodology

Study Area

This study was based on data obtained from a cross-section of 197 respondents drawn across 17 communities around three Wetlands in Lagos, Ogun and Oyo state. The Wetlands included in this survey are the Lagos Lagoon, Eriti in Ogun and Eleyele in Oyo states. The Wetlands of Lagos were included based on the extensiveness of Wetlands found in the state. Eriti Wetland was however included because of its use for Agricultural purposes and its consequent involvement in FADAMA programmes. Eleyele Wetland is also notable in Oyo state particularly as the major source of portable water distributed for household use upon treatment in the area.

Sampling Procedure

Multi stage sampling technique was used in this study. Stage one involves the purposive selection of three Wetlands (Eleyele, Eriti and Lagos Wetlands). The second stage involves the random selection eighteen communities close to the water bodies while the third stage involves systematic random selection of respondents from residential buildings and from farm/ nonfarm enterprises. Communities surveyed around Lagos Lagoon included Ebute Afuye/ Chief in Epe, Foolu, Ise, Odofin and Ibeju in Ibeju-Lekki, Itoga, and Ikoga Zebbe in Badagry. Those surveyed around Eleyele Wetland are Eleyele, Ijokodo, Apete, Awotan and Olopomewa while the communities visited around the Eriti Wetland which is one of the tributaries of the Ogun-Oshun River are Eriti, Oluwo-Isale, Olorunda, Saare, and Mokoloki harbouring another Wetland which is also a part of the Ogun-Oshun River.

Data Collection

Primary data were used for this study. The data were collected through the use of personally administered questionnaire. The data consists of information on socio-economic as well as demographic characteristics of the respondents. Information was also obtained on the benefits that are derivable from these Wetlands as well the degree of importance the respondents attach to such benefits. Based on evidence in literature, the range of benefits presented to the respondents included:

- Access to fresh food produced around the Wetland at a cheaper price.
- Provision of cool breeze
- Provision of sand and other building material.
- Provision of recreation and tourist site.
- Provision of clean air.
- Provision of herbs and pharmaceuticals.
- Helping to recharge ground water.
- Serves as water storage facility thereby making water available all year round.
- Help in controlling flood by accommodating run-off water.
- Provision of wind breaks that serve as storm protection device.
- Helping in nutrient recycle by retaining nutrient from eroded topsoil.
- Micro-climate stabilization such as lowering of day and night temperature

Each of the respondents was required to specify whether the Wetland in his or her area offer these benefits and the extent to which such benefit is important to him/her. Other data obtained included detailed data on direct utilization of Wetland services, the number of years the respondent has been living, or working in the Wetlands among others.

Analytical Technique/ Measurement of Variables

The analytical techniques employed for this study included both descriptive and quantitative techniques. The details of analytical techniques, for each of the specific objectives, are as follows:

Description and Comparison of Socio-economic Characteristics

Simple frequency and cross-tab tables were used to facilitate description of socio-economic characteristics of the sampled respondents, and comparison of socio-economic characteristics of different categories of Wetland service users.

Measurement of Perceived Benefits

A score of one (S = 1) was assigned if a respondent believes the Wetland in his area renders a particular benefit to the immediate society while failure to perceive such benefit attracted a score of zero (S_j=0). The perception score was then weighted on a Likert scale to determine the level of importance a respondent personally attach to such benefit. From this, the perception index for each respondent was computed based on all the benefits presented to them.

The value of PBI falls between zero and one. The higher the PBI the greater the value the respondent attached to the Wetland.

Determinant of Perceived Benefits

The influences of various socio-economic factors on the respondents' perceived benefits (measured by the Perceived Benefit Index – PBI) were examined by specifying and estimating the following Tobit regression model. The choice of Tobit regression model is hinged on the fact that it is well suited in a situation where the dependent variable jumps discreetly at zero (Koutsoyianis, 1982). The model is as stated below

$$PBI_i = \beta_O + \beta_j X_{ij} + e_i$$

where;

PBI_i is the Perceived Benefit Index of the i^{th} respondent
X_1= Age (years)
X_2= Age Square (years)
X_3= Sex (1 if Female 0 if Male)
X_4 = Education (years of schooling)
X_5= No of years living, working or visiting the area (years)
$X_{6=}$ Respondent's income from all sources (naira/year)
X_7= Share of total income derived from Wetland related activities (naira/year)
X_{8j}= A set of dummy variables for various categories of respondent (j=0, 1, ., .,k for residents, farmer, fisher-folks, resource collection, other occupation). It takes a value of 1 if respondent belong to the j^{th} category, and 0 if otherwise.) The dummy variable for residents (j=0) was dropped in the estimation.
X_9= Wetland location (A set of dummy variables for various Wetland location (j=0, 1, 2 for urban, sub urban and rural location). It takes a value of 1 if respondent belong to the j^{th} category, and 0 if otherwise.) The dummy variable for rural location (j=0) was dropped in the process of estimation.

Results and Discussion

Characteristics of Wetland Users

Three main categories of Wetland service users were identified among the survey respondents as shown on Table 1.

An exploration of Table 1 shows that majority (94.7%, 74.2%, and 70.4%) of the respondents in Eleyele, Eriti, and Lagos Lagoon both live and pursue livelihood (indirect and direct users respectively) around all the Wetlands respectively. The same trend is also observed in the pooled data (74.6%) irrespective of the Wetland location. This shows that irrespective of their location, Wetlands are actively explored by their surrounding community in generating income. Also, the Table revealed 14.2% of the respondents come from outside the immediate environment of the Wetland (direct users) to pursue livelihood activities. This by implication further shows that it is not only the Wetland community dwellers that depend on the Wetland for livelihood sustenance. The Table however suggests that about half (48.7%) of the people found around Wetlands are involved in crop farming. Farming is thus the major activity that these Wetlands are being used for although large proportions (63.2%) of the people found

around the Eleyele Wetland are artisans. This may be due to the fact that part of this water body is found in a commercial area (Eleyele Motor Park) while around the Lagos Wetlands other non Wetland livelihood activities such as food vending, trading, transport services, civil service etc constitute about 23.5% of the peoples main occupation.

Socio Economic Characteristics of Wetland Users

Socio economic characteristics of the respondents as shown on Table 2 reveals that majority of the survey respondents and by extension people resident and or pursuing livelihood activities around the selected Wetlands are economically active, aged between 31-50 years (54.5%) and mostly (90.4%) married. They are predominantly educated either to the primary (35.5%) or secondary (39.1%) school level, with as much as 12.7% of them having no formal education. In terms of gender, although both sexes are involved in Wetland related activities, the male folk however constitute the majority (73.6%). By religion, the Christians constitute a slight majority (59.4%) as against the Muslims (40.6%). Also, the Table reveals that majority (64.4%) of the respondents have spent at least 10years either residing and or pursuing livelihood activities around the Wetlands.

Perception of Wetland Benefits

Results on Table 3 shows the benefits clearly recognised by the respondents as; provision of food (67.5%), provision of herbs (57.9%) and provision of sand and other building materials (62.9%). Those poorly recognised include provision of windbreaks (28.1%), nutrient recycling (31.0%) and microclimate stabilization (43.1%). Incidentally, food and sand are some of the Wetland resources that are being actively explored by the people for income generation. Furthermore, the three benefits recognised by the majority of the people are direct benefits of the Wetlands while those poorly recognised are indirect benefits of the Wetlands which are its contribution in balancing the ecosystem. Although recreation and tourism is another income generating potential of the Wetland, this is also not recognised by more than half (66.0%) of the Wetland users. Thus their perception of the Wetland benefits is limited to the present income generating potentials of the Wetlands.

Perceived Benefit Index

The overall strength of the respondent's recognition of all the benefits combined is shown by Perceived Benefit Index (PBI). Table 4 presents this result across the different categories of Wetland service users. The table shows that almost half (48.2%) of the respondents have low / poor perception of the Wetland benefits and this is unaffected even by the category of the Wetland service users. It can thus be inferred that a respondent who live and or pursue livelihood around these Wetlands have low perception or appreciation of the Wetland benefits.

Determinants of Perceived Benefit Index

In Table 5, Age, age square, total income and the share of the income that is derived from the Wetland were discovered to be the socio economic factors that influence people's perception of the Wetland benefits. Positive signs borne by the regression co efficient shows that an increase in the associated variable will lead to an increase in the PBI while the reverse holds for the coefficient that has bear negative signs. Interestingly while age favours an increase in

perception, it can be observed that this is to an extent after which it begins to decline. Also, the higher their total income the lesser they perceive the Wetland as being beneficial while in contrast, the higher the portion of this income that comes from the Wetland the more beneficial they regard them. These therefore go on to show that it's only the direct use value of the Wetlands that are appreciated as those who don't depend on the Wetland for income generation are likely to view them as less beneficial. Among the activity types, it was only the coefficient of fishing that was significant and also positive. A fisherman thus perceives the Wetland benefit better than a resident which is the reference category. This may be because of all the activity types, fishing is the one that depend entirely on the Wetland as they "only harvest without sowing" any substantial input into the Wetland. The suburban dummy coefficient was also significant but negative. This reveals that a respondent in a sub urban area perceives the Wetland in his/her area as less beneficial when compared with the rural Wetland people's perception of their own.

Conclusion and Recommendations

Firstly, Wetlands regardless of their location are being explored for various income generating activities. This if combined with conservational plans for these Wetlands will help enhance their functioning for this purpose and that of ecosystem balancing.

Secondly it was discovered that the use i.e. direct use values of the Wetlands, are better perceived by the people and their perception increases with the share of their income that comes from the Wetland as against a reduction with a higher total income. This implies that they rank and appreciate the use values better than the non use values.

The study therefore concludes that Wetland benefits are lowly perceived by the people especially their roles in ecosystem balancing. Based on these, the study therefore recommends that awareness should be created about all the various benefits and impacts people's activities have on wetlands functioning so as to stimulate them for possible future sustainable management plans.

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Table 1: Distribution of Respondents by Location, type of Wetland Use and Main Occupation.

	Wetland			
	Eleyele	**Eriti**	**Lagos lagoon**	**All respondents**
Benefit type				
Direct & Indirect users	18 (94.7%)	72 (74.2%)	57 (70.4%)	147 (74.6%)
Direct users	1 (5.3%)	16 (16.5%)	11 (13.6%)	28 (14.2%)
Indirect users	0 (.0%)	9 (9.3%)	13 (16.0%)	22 (11.2%)
Occupation				
Farming	3 (15.8%)	53 (54.6%)	40 (49.4%)	96 (48.7%)
Fishing	2 (10.5%)	17 (17.5%)	8 (.9%)	27 (13.7%)
Fish farming	0 (.0%)	2 (2.1%)	4 (4.9%)	6 (3.0%)
Sand mining	0 (.0%)	9 (9.3%)	1 (1.2%)	10 (5.1%)
Artisan	12 (63.2%)	2 (2.1%)	9 (11.1%)	23 (11.7%)
Others	2 (10.5%)	14 (14.4%)	19 (23.5%)	35 (17.8%)
TOTAL	**19**	**97**	**81**	**197**
	100.0%	**100.0%**	**100.0%**	**100.0%**

Source: Data from Field Survey 2010

Table 2: Distribution of Respondents by Personal Characteristics

Description	Wetland Service User Category			
	Direct users	Indirect users	Direct &Indirect users	All respondents
Number of respondents	**28 (14.2%)**	**22 (11.2%)**	**147 (74.6%)**	**197(100.0%)**
Age Group				
Below 30	6 (21.4%)	2 (9.1%)	27 (18.5%)	35 (17.9%)
31-40	8 (28.6%)	7 (31.8%)	48 (32.9%)	63 (32.1%)
41- 50	7 (25.0%)	8 (36.4%)	29 (19.9%)	44(22.4%)
51-60	4 (14.3%)	5 (22.7%)	25 (17.1%)	34 (17.3%)
Above 60	3 (10.7%)	0 (0.0%)	17 (11.6%)	20 (10.2%)
SEX				
Female	4 (14.3%)	10 (45.5%)	38 (25.9%)	52 (26.4%)
Male	24 (85.7%)	12 (54.5%)	109 (74.1%)	145 (73.6%)
Marital Status				
Married	25 (89.3%)	17 (77.3%)	136 (92.5%)	178 (90.4%)
Single	2 (7.1%)	3 (13.6%)	7 (4.8%)	12 (6.1%)
Widow(er)	1 (3.6%)	2 (9.1%)	4 (2.7%)	7 (3.6%)
Educational Level				
No Formal education	2 (7.1%)	4 (18.2%)	19 (12.9%)	25 (12.7%)
Primary	9 (32.1%)	5 (22.7%)	56 (38.1%)	70 (35.5%)
Secondary	13 (46.4%)	10 (45.5%)	54 (36.7%)	77 (39.1%)
Tertiary	4 (14.3%)	3 (13.6%)	18 (12.2%)	25 (12.7%)
Religion				
Christian	19 (67.9%)	14 (63.6%)	84 (57.1%)	117 (59.4%)
Muslim	9 (32.1%)	8 (36.4%)	63 (42.9%)	80 (40.6%)
Years spent around the Wetland				
Less than 5	6 (21.4%)	2 (9.1%)	25 (17.0%)	33 (16.8%)
5-10	5 (17.9%)	8 (36.4%)	24 (16.3%)	37 (18.8%)
11-15	9 (32.1%)	5 (22.7%)	31 (21.1%)	45 (22.9%)
16-20	3 (10.7%)	3 (13.6%)	18 (12.3%)	24 (12.1%)
Greater than 20	5 (17.9%)	4 (18.2%)	49 (33.3%)	58 (29.4%)
TOTAL	28 (100.0%)	22 (100.0%)	147 (100.0%)	197 (100.0%)

Source: Data from Field Survey 2010

Table 3: Respondent Perception of Wetland Benefits

Wetland Benefits	**NR**	**NI**	**IND**	**IMP**	**VI**
Supply of Fresh Food	61 (31.0%)	4 (2.0%)	3 (1.5%)	35 (17.8%)	94 (47.7%)
Provision of Herbs	83 (42.1%)	7 (3.6%)	0 (0.0%)	35 (17.8%)	72 (36.5%)
Supply of Sand	64 (32.5%)	9 (4.6%)	7 (3.6%)	27 (13.7%)	90 (45.7%)
Recreation and Tourism	130 (66.0%)	3 (1.5%)	6 (3.0%)	19 (9.6%)	39 (19.8%)
Air Purification	110 (55.8%)	1 (0.5%)	7 (3.6%)	26 (13.2%)	53 (26.9%)
Provides Cool Breeze	83 (42.1%)	1 (0.5%)	3 (1.5%)	29 (14.7%)	81 (41.1%)
Ground Water Recharge	112 (56.9%)	3 (1.5%)	4 (2.0%)	25 (12.7%)	53 (26.9%)
Water Storage Facility	95 (48.2%)	1 (0.5%)	10 (5.1%)	33 (16.8%)	58 (29.4%)
Flood Control	133 (67.5%)	1 (0.5%)	3 (1.5%)	26 (13.2%)	34 (17.3%)
Provision of Wind Break	139 (70.6%)	1 (0.5%)	3 (1.5%)	21 (10.7%)	33 (16.8%)
Nutrient Recycle	132 (67.1%)	2 (1.0%)	3 (1.5%)	32 (16.2%)	28 (14.2%)
Micro Climate Stabilization	105 (53.3%)	1 (0.5%)	7 (3.6%)	24 (12.2%)	60 (30.4%)

Source: Data from field survey 2010

Table 4: Distribution of Respondents by Overall Perception Score.

Description	Wetland User Category			
	Direct users	Indirect users	Direct & Indirect users	All Respondents
Perceived Benefit Index				
Low perception (less than 0.45)	15 (53.6%)	10 (45.5%)	70 (47.6%)	95 (48.2%)
Moderate perception (0.45-0.64)	6 (21.4%)	8 (36.4%)	28 (19.0%)	42 (21.3%)
High perception (greater than 0.65)	7 (25.0%)	4 (18.2%)	49 (33.3%)	60 (30.5%)
Total	28 (100.0%)	22 (100.0%)	147 (100.0%)	197 (100.0%)

Source: Data from Field Survey 2010

Table 5: Estimated Tobit Model of Perceived Benefit Index

	Regression Parameters		Marginal
Explanatory Variables	**Coefficient**	**t-ratio**	**Effect**
Constant	-0.5223	-1.3462	
Age	0.3336E-01**	1.9910	0.7227E-02
Age Square	- 0.3958E-03**	-2.1867	-0.8574E-04
Female dummy	0.7004E-01	0.8107	0.1517E-01
Education in years	0.1386E-02	0.1694	0.3002E-03
Years spent around Wetland	0.2707E-02	1.0049	0.5864E-03
Total Income	-0.1406E-06***	-2.6005	-0.3000E-07
Wetland share of income	0.1997**	2.4157	0.4326E-01
Farming	-0.3601E-01	-0.4645	-0.7799E-02
Fishing	0.1755**	2.1937	0.3801E-01
Resource Collection	-0.1617	-1.5844	-0.3502E-01
Other livelihood options	-0.1820	-1.6291	-0.3943E-01
Sub urban dummy	-0.6041***	-5.8979	-0.1309
Urban dummy	-0.7870E-01	-0.9395	-0.1705E-01
Log-likelihood function	-260.4342		
Predicted F (I)	0.2166		
Squared correlation	0.1595		

*NOTE: ***, **, * implies that associated parameter is significant at p<0.01, p<0.05 and p< 0.10 levels respectively*

Rapid Epidemiological Mapping of Cholera in Some Parts of Abeokuta Metropolis: A GIS-Supported Post-Epidemic Assessment

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Abstract

An outbreak of cholera epidemic was reported in some parts of Abeokuta city in Nigeria. Reports indicated that loss of lives was involved. This study investigates the immediate and remote sources of contamination of water supply system in the city by a GIS supported investigation. The study relied on the integration of Geographic Information System, Global Positioning System and Remote Sensing. The network of water pipelines was digitized from the master plan. The geo-ecological characteristics of the environment were captured from a high resolution (Ikonos) satellite image of the affected communities. Water samples were collected from various points and their coordinates obtained. The water samples collected from Ogun River (abstraction point), water treatment tank and faucets within the affected communities were analyzed for the presence of *Vibrio cholerae*. Results revealed a high load (>180 MPN/1000ml) of cholera bacteria at the abstraction point, which reduced to < 10 MPN/1000ml in the treatment tank. As the assessment progressed from the water works farther into the communities, there was a concomitant progressive increase in cholerae contamination. The Vibrio count has risen above 180 MPN/1000ml by the time the assessment got to the cholerae endemic area. It was found that the sanitary practices of the indigenes of the area were very poor; there were no proper sewage or waste disposal systems, heaps of refuse dumps were found on pipelines. The study established pre and post epidemic water contamination in the area. Although the study could not attribute the incidence to direct negligence of water management board but rather to poor maintenance of the water facilities; which were already old, rusty and leaking. This, in conjunction with the substantiated finding on the poor sanitation of people of the area, can be said to hold a high significance for future cholerae epidemics in this part of the city.

Keywords: GIS, Utility board, Geo-ecological characteristics, Cholera

Introduction

As Geographical Information Science (GIS) finds more applications in the fields of environmental health, parasitology and epidemiology, more and more assurance of timely control Bubonic plague is given through accurate predictions and decision support with respect to interventions. GIS in its unique capabilities of efficient storage, manipulation, analysis and seamless integration and display of large quantities of environmental data is giving investigators grand support rapid epidemiological surveys. In recent past, GIS has been developed for a wide range of applications in public health safety studies. Since it is a spinoff of Information Communication Technology, GIS through mapping and modeling of spatial information enables better form of communication between people in research and the society at large (Goodchild, 2000; Twigg, 1990).

Available evidence from literature reveals the extreme usefulness of GIS application in specific areas of environmental/public health such as chemical contamination of water and water borne diseases. For instance GIS application in the exposure of man to contaminated drinking water by non volatile organic compounds (VOC) in groundwater reservoir has been demonstrated (Ara and Maslia, 1996). It was possible with this, to determine extent of contamination and location of vulnerable population on the public water supply network. Similarly, the advantage of GIS in drinking water epidemiology through comparison of two supply area with different disinfection practices were presented (Nuckol et al., 1995).

With particular reference to water borne diseases, application of GIS may be relatively new (Dangedorf *et al*., 2002). But several works involving GIS have been done on water quality and quantity assessment. Evidences from available literatures still prove the extreme usefulness of GIS in other areas of health risk assessments. Orebiyi *et al*., (2008) applied Geographical Information System to ground water quality assessment over the city of Abeokuta metropolis while Gbadebo *et al*., (2010) examined the variability distribution of nitrate in ground water of Abeokuta metropolis. Ekpo (2006) applied GIS in the investigation of guinea worm amongst school age children in Ogun state while. Rapid Geographical Assessment of Bancroftian Filariasis (RAGFIL) using GIS was conducted in three countries (Ghana, India and Myamar).

The spatial analyses accompanying this investigation, assisted in discovering the existence of spatial autocorrelation among districts within each country. Gyapong *et al.,* (1996) suggested that the rapid epidemiological studies in Ghana was a good proxy measure of the levels of endemicity of filariasis. Similarly, an informal consultation on Rapid Epidemiological Mapping of Onchocerciasis (REMO) using GIS held in Burkina Faso in1996 had a standard methodology developed (UNDP/World Bank/WHO, 1998b). The implication of these examples of GIS application in environmental health is the possibility of applying it to waterborne epidemics study such as cholera.

Background to the Study

The need to trace the source of ravaging cholera outbreak in a particular part of Abeokuta; a large city within south western Nigeria in a post epidemic survey arose as a result of the outbreak of cholera reported in Adedotun/Ilugun area of the city in 2005. The case was

reported to be pandemic; leading to loss of hundreds of lives. Inhabitants of the affected part of the city blamed the epidemic on human error and carelessness; claiming that they must have been served untreated water by the city water board was at the time of the incidence. The authority of the water board however refuted these allegations and there was the need to investigate into the immediate and remote cause of the disaster. This requires a rapid post-epidemic survey that will locate the source of infection, determine the extent of the contamination, and estimate the population exposed to risk of infection. The task appeared to be onerous yet the immediate or remote causes of the cholera must be identified and adequately addressed before the situation becomes catastrophic. For effective and timely decision making a rapid mapping of the cholera must be carried out and the root of the causes identified. The only efficient way of doing this in good time is to employ the aid of GIS. Existing spatial and in-situ data must be incorporated into spatial technologies in order to provide an insight to the root of the problem. Geographical Information systems, Remote Sensing and Global Positioning system were therefore integrated with in-situ field data for the investigation.

In this paper therefore, the report of the Rapid Epidemiological Mapping of Cholera in Abeokuta city of Nigeria is presented. In Nigeria also, it is a fact that information concerning water-borne diseases and outbreaks are rare and not easily available: it is apparent that works along this line are scanty and so relevant data are very rare, The paper is hence an attempt to contribute to knowledge base with respect to application of space technologies to environmental health and epidemiology in Nigeria, while at the same time show casing the efficacy of GIS in rapid investigations on source of water borne infections. The paper demonstrates the usefulness of GIS in tracing the source of infections of public water network with vibrio cholera. It lucidly presents spatial information on the source, distribution of V. cholera, and exposure of human populations to cholera infested water.

Materials and Methods

Study Area

The study was conducted in some part of Abeokuta: an ancient city which lies in the sub-humid tropical region of Southwestern Nigeria (Latitudes $7^{o}5^{o}$ N to $7^{o}20^{o}$ N and Longitudes 3^{o} E to $3^{o}27^{o}$). The city enjoys a tropical climate with distinct wet and dry seasons and a dry spell of about 130 days (10). Ogun River is the major water body which has sustained the Abeokuta through several generations. Its importance in agriculture is almost unquantifiable especially with flood plain farming during the dry season. At present, Ogun River is the main source of water for municipal water supply. Figure 1 shows the location of Abeokuta city with a ring on the study area, and an inset map of Nigeria location of Abeokuta city within Nigeria while, plates 1 and 2 are clips of a high resolution satellite image of Abeokuta.

Methods

The pipeline distribution networks, map was scanned, imported into a GIS, geo-referenced and digitized at a scale of 1:20000 in layers using Arc views 3.2a software. Other features such as water abstraction point, treatment tank, water faucets and location of affected persons were imported into the GIS map as events themes.

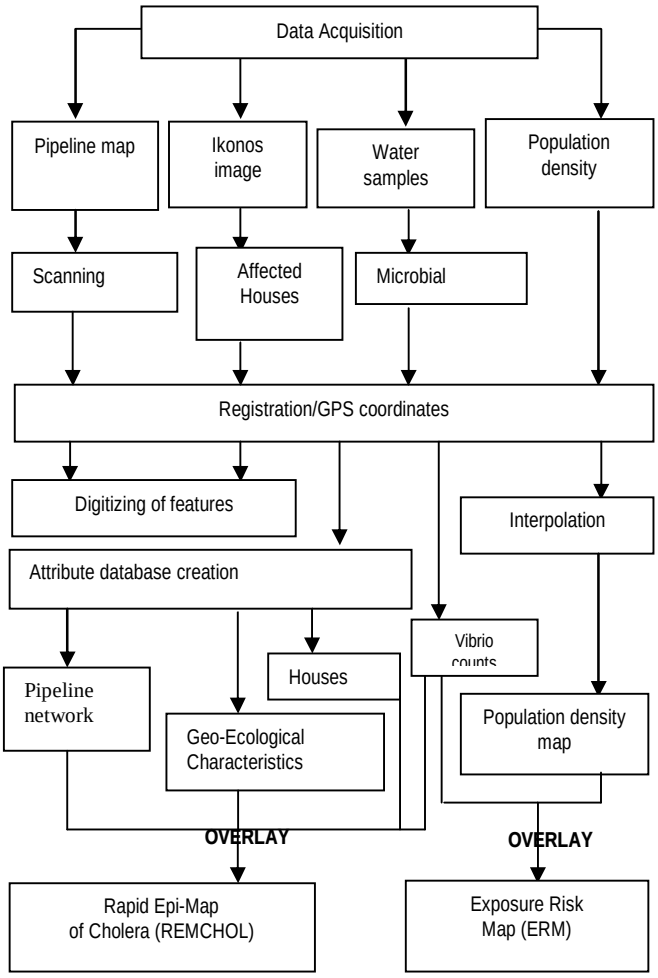

Figure 1**:** Cartographic model for rapid epidemiological mapping

The geo-ecological characterization of the study area was captured from the (Ikonos)s satellite image. Point layers were symbolized differently and overlaid on the base map (Pipeline networks and features extracted from topographic map). The schema above is the cartographic model summarizing the entire methodology for the study.

Water Samples Analysis and Vibrio Cholerae Counts

Water samples were collected from the abstraction point and water treatment tank at the Arakanga water works station. Water samples were also collected from the faucets within the affected communities. About 1litre of water samples were collected aseptically, stored in

already sterilized plastic bottles. The bottles were then kept in a cooler which has been conditioned to ice temperature (0^{o}C) in order to arrest chances of getting spurious result on analysis. The water samples were taken to the microbiology laboratory of the university and analyzed for *Vibrio cholerae* tube techniques were then used for enumeration of *Vibrio cholera*

Data Acquisition

Relevant data that will aid the full realizations of the objectives of the study were acquired. Map of water distribution facilities and the Ikonos image of the city acquired information on the location and number of people per community were obtained from the Local Government office. Where specific houses and water faucets needed to be mapped, the Local Government health officials guided the tour of the communities. Geographical coordinates of affected houses, water taps were collected and other geo-ecological characteristics of the study area were obtained with the aid of hand-held GPS receiver.

Database Development

The result of the *Vibrio cholerae* count per sample was used to build up the attribute for each of the water sample points in the GSI map. The levels of the contamination could then easily be displayed on the map.

Estimation of Population Exposure to Risk of Infection

In order to locate and estimate population exposed to the risk of infection, the water analysis was super imposed on population distribution map which was produced through surface interpolation of unit locations with known population. A unit population location which corresponds to about 500x500m on land was derived from population census enumeration area demarcation of 2006. The level of the populace's exposure to risk of contamination was categorized into 3 namely; high moderate and low risks and was subsequently depicted on the map.

Results and Discussion

In Table 1, a summary of the laboratory analysis water sample are presented. At the water works abstraction point in Ogun river, the water sample analysis showed a *Vibrio cholerae* count of >180 MPN/1000ml, but at the water treatment tank, the count was >10 MPN/1000ml; which is an indication of effective treatment of the polluted water from the river. Meanwhile, as the survey progresses into the communities, there was a steady rise in the number of *Vibrio cholerae* count.

For example at Ilugun the count was 10 MPN/1000ml at Ajitadun and Ikereku communities it has risen to 50 and 60 MPN/1000ml respectively. Within the zone where the impact was mostly felt the count had gone up to 180 MPN/1000ml as can be seen in the chart in figure 2.

Table 1: Presumptive Vibrio count in water samples at various locations

Sample locations	Nothings	Eastings	Vibrio count MPN/1000ml
Abstraction point	7.19357	3.33660	>180
Water works	7.19334	3.33981	~0
Ilugun	7.17685	3.34666	<10
Ajitaadun	7.17748	3.34166	50
Ikereku	7.17920	3.34260	60
Ita – Aka	7.17636	3.34051	>180
Mokola	7.17290	3.34260	150
Ago- Ika	7.16057	3.33660	>180

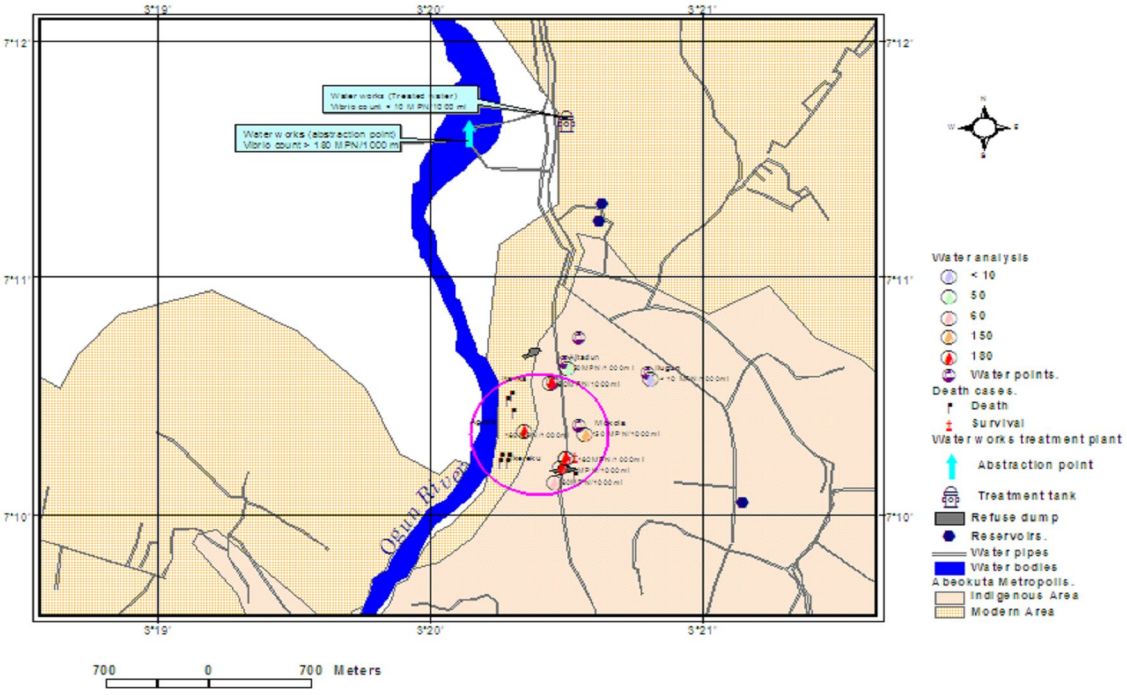

Figure 2: Contamination with distance from water works.

The inference that can be drawn from the foregoing is that the water must have been contaminated between the water works station and the affected communities. But where exactly the source of contamination is located still remains a puzzle yet unraveled.

Geo-ecological characterization of the area revealed the general sanitation while is very poor as refuse dump and unhygienic waste disposal are found littering open places. As can be seen in Figure 3, the map reveals possible sources of contamination of drinking water in pipes. For instance, a huge refuse dump is located directly on a 300mm pipe. This is a probable source of contamination especially where the pipes are leaking; infiltration under low pressure is easy.

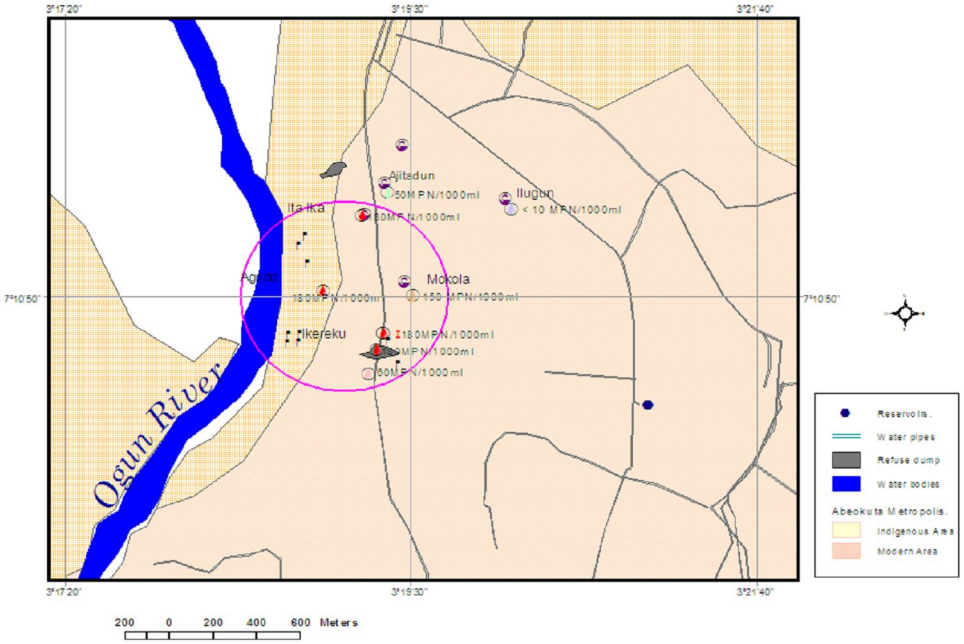

Figure 3: Map showing possible sources of contamination of drinking water in pipes.

Water samples collected from the faucets around this area show a very high *Vibrio cholerae* count of above 180 MPN/1000ml.

In Figure 4, the map showing the distribution of water taps and the value of *Vibrio cholerae* counts in the samples analyzed is presented. The map revealed that the clustered cholera cases were found where the contamination values were highest (above 180 MPN/1000ml). The circle on the map shows the area where death occurred. Black flag symbols imply death while the road cross symbols implies survival.

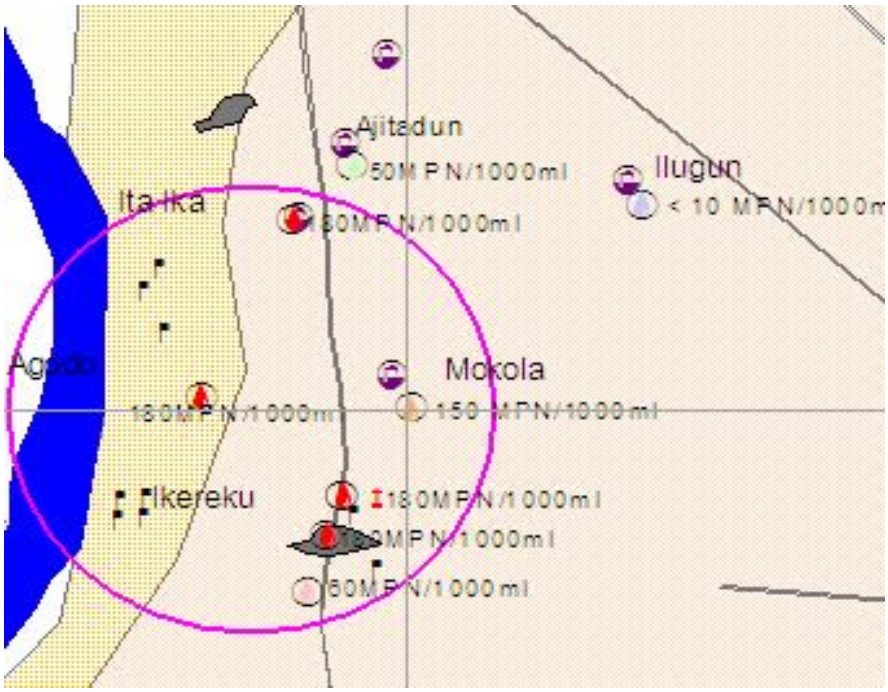

Figure 4: Map showing distribution of water taps and the value of *Vibrio cholerae* counts in the water from the faucets

Table 2 is the population exposed to risk of infection in the area. The level of risk varies spatially. This could explained by the level of sanitation from place to place. Generally, the study area is the very indigenous area of Abeokuta city; as such the level of sanitation in the area is very low relative to the well planned modern area of the city. Poor refuse and sewage disposal characterizes the area. The houses are also not well spaced and ventilated. This possibly could aid the spread of the disease.

The population exposed to risk of infection in is quite significant (3306) compared to the area of study (1.2km^2). Since the pipeline is a network the entire city might not be exempted from the epidemic. Abeokuta city is densely populated: with population density of 3964 persons per square kilometers it is highly essential to give attention to monitoring systems.

Table 2: Estimated population exposed to risk of infection

Community	Population	Level of exposure
Ilugun – Isale	580	Low
Ajitaadun	276	Moderate
Ikereku	274	Moderate
Ita – Aka	377	Very High
Mokola	720	Very High
Ago – Ika	492	Very High
Ilugun – Oke	583	Moderate
Total	3306	

Conclusion

One major area in which GIS and health research have come together is the study of environmental and geographical epidemiology (Kistemann et al 2000). The rapid investigation of cholera outbreak in this part of Abeokuta city was supported and accelerated substantially by the use of GIS. It was possible to trace likely source of contamination to the sanitary practices of the area and not necessarily due to the negligence of the water board.

Firstly, a possible and ready source of contamination is exposed by GIS, and secondly the affected communities are contagious with the cholera epidemic zone in the city.
Links between disease outbreak, environment, and disease clustering etc with the aid of GIS have been established in past studies (Clarke et al 1996; Dunn,1992).

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FLOOD AND EROSION PROBLEMS AND MITIGATION

Effect of Moisture Variation on the Strength Characteristics of Laterite: A Case Study of Abeokuta, Ogun State, Nigeria

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Abstract

Nigeria, a country in the tropical region is characterized with heavy rainfall and high temperature. It is therefore appropriate to say that climatic factors affect its roads. Many of the roads are flooded with water after heavy rains due to inadequate drainage system. The roads in Ogun State are plagued with various distresses and failures. This study examined the effect of moisture variation on the strength characteristics of laterite in Abeokuta, Ogun State, Nigeria. Samples of laterite soils were obtained from Oke-Mosan burrow-pit, Abeokuta and engineering properties such as the natural moisture, sieve analysis, Atterberg limits, compaction and the strength characteristics were evaluated. The un-soaked California Bearing Ratio (CBR) value of the soil compacted at optimum moisture content was 32%. The effect of moisture variation on the strength of laterite was determined from results of CBR of the compacted laterite soils soaked in water for 5 days to simulate the worst moisture condition in the field for the laterite. The result showed that an increase in the soaking period of the compacted soil sample from 1 to 5 days result in decrease in the CBR of the soil from 6.57% to 6.16% also, there was also increase in the bulk density from 2060.74 kg/m^3 to 2169.20 kg/m^3. The study revealed that affinity for water and the corresponding low shear strength of the laterite soils are responsible for the failure of roads in Abeokuta metropolis.

Keywords: Laterite, Moisture variation, Strength characteristics, Abeokuta

Introduction

Laterite is the product of intense weathering, in hot and wet tropical areas, of the underlying parent rock which is enriched in iron and aluminium. The soil name "laterite" was coined by Buchanan (1807) in India, from a Latin word "later" meaning brick. Nearly all kinds of rocks can be deeply decomposed by the action of high rainfall and elevated temperatures. The percolating rainwater causes dissolution of primary rock minerals and decrease of easily soluble elements as sodium, potassium, calcium, magnesium and silicon. The process gives rise to a residual concentration of more insoluble elements predominantly iron and aluminium. The iron oxides goethite and hematite cause the red-brown colour of laterites (Aleva, 1994).

In this tropical part of the world, laterites are used as a material in road construction and they form the sub-grade of most tropical roads. They are also used as sub-base and base courses for

low cost roads, which carry low to medium traffic. In some rural areas of Nigeria, laterites are used as material in building construction for moulding of blocks and plastering (Muhammed, 2000). The problems encountered on major highways in Nigeria are mainly as a result of deficiency in the properties of the sub-grade, sub-base, and base courses of the road pavement. The engineering properties of soil are considered in the design and construction of road and the soil property of main interest to an engineer is the strength characteristics. That is the ability for the pavement to withstand the dynamic axle load being transferred to the soil beneath. Fine grained soils or granular materials that contain excessive amount of fines are generally more sensitive to water changes than coarse-grained soils. An unpaved road may possess the required strength when constructed initially but exposure to water can result in loss of strength, coupled with detrimental effect of traffic operation (Rosa and Jeb, 2000). Also, Oguara (2006) noted that not all laterite soils encountered on a site can be used directly for construction purposes due to poor strength characteristics of the soil. To prevent mud pumping, sub-bases must be either free- draining or be resistant to the erosive action of water. This study therefore examined the effect of the factors on the load bearing capacity of laterite soil and determines ways of improving such properties.

Study Area

The study area is Abeokuta – the capital of Ogun State, South-West Nigeria. There are two main seasons: the wet and dry season. The wet season extends from April to October, the wettest month being June. The Dry Season, which is very hot, is between November and March. The seasonal climatic conditions over Nigeria gives rise to more predominant annual rainfall occurrence in the south than the north. Abeokuta lies in the fertile part of the country, the surface of which is broken by masses of grey granite. Geographical coordinates are 7^0 9' 39" North and 3^0 21'54" East. The city is characterised with good and bad roads. The study site is an active burrow- pit from which laterite, which is used for the construction of many roads within Abeokuta is obtained. The burrow pit used is located at Oke-Mosan in Abeokuta-South Local Government Area of the State. One noticeable feature of the bad roads is lack of drainage facilities. Absence of drainage means that there is usually stagnancy of rainwater on roads for days.

Material and Method

Disturbed soil samples were collected at sufficient depth from the burrow-pit, in air-tight polythene bags. Collected samples were thoroughly mixed and air-dried before use after determining the natural moisture content in the laboratory. Soil Classification tests were performed and the soil classified in relation to American Association of State Highway and Transportation Officials (AASHTO) and Unified Soil Classification System (USCS). The moisture content, particle size distribution and Atterberg limits tests were conducted on the laterite samples. Compaction and California Bearing Ratio (CBR) tests were also conducted. All tests were performed in accordance with BS 1377 (BSI 1990).

Results and Discussion

The soil properties determined by laboratory experiments are summarized in Table 1. The sample was soaked for a period of 5 days and the average moisture content of the compacted laterite sample in the mould was calculated for each soaked day. Figure 1 shows an increase in the average moisture content absorbed after each day of soaking. The CBR, which represent soil strength decreases with increasing number of soaking days (Figure 2). The relationship between the CBR and average moisture content (Figure 3) reflected a downward curve. The downward direction of the curve implies that the CBR of the laterite decreases with increase in the amount of moisture content absorbed.

Table 1: Summary of Soil Properties

Physical Properties	**Quantity/Unit**	**Specifications**	**References**
AASHTO Classification	Silty sand A-2-4		
USCS Classification	Poorly graded sand and silt SP-SM		
Coefficient of Uniformity, C_u	3.125		
Coefficient of Curvature, C_c	1.125		
Liquid Limit, LL	32.64%	< 50%	FMWH (1970)
Plastic Limit, PL	23.37%		
Plasticity Index, PI	9.27%	< 30%	Ditto
Consistency Index, I_c	2.88		
Maximum Dry Density, MDD	1.945 Mg/m^3		
Optimum Moisture Content, OMC	8.80%		
Natural Moisture Content, NMC	5.97%		
CBR (un-soaked)	32%		
CBR (after day 1 of soaking)	6.57%	6 – 20% (fair to good sub-grade under Casagrande's classification).	FMWH (1970) and RRL (1952)

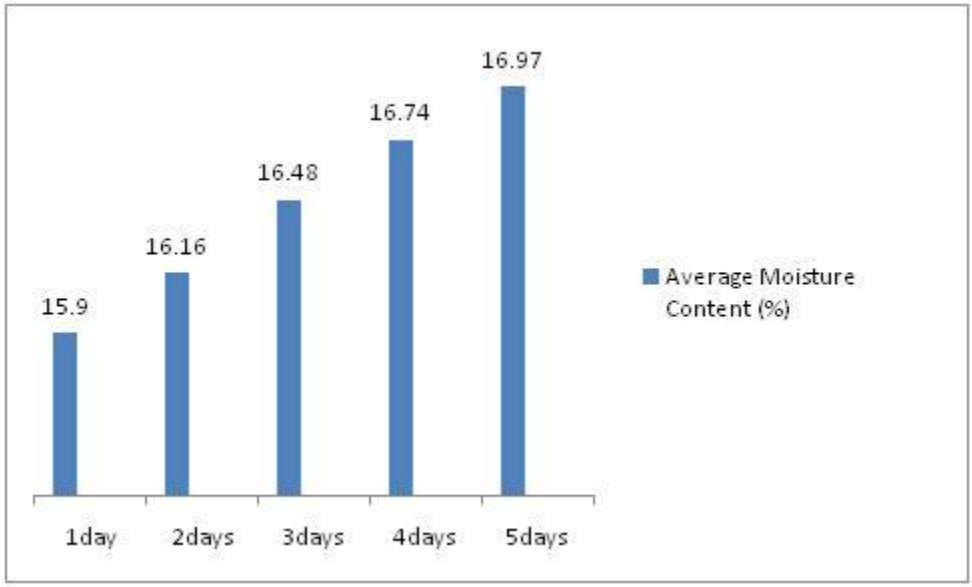

Figure 1: Moisture Content Variation with Soaking Period

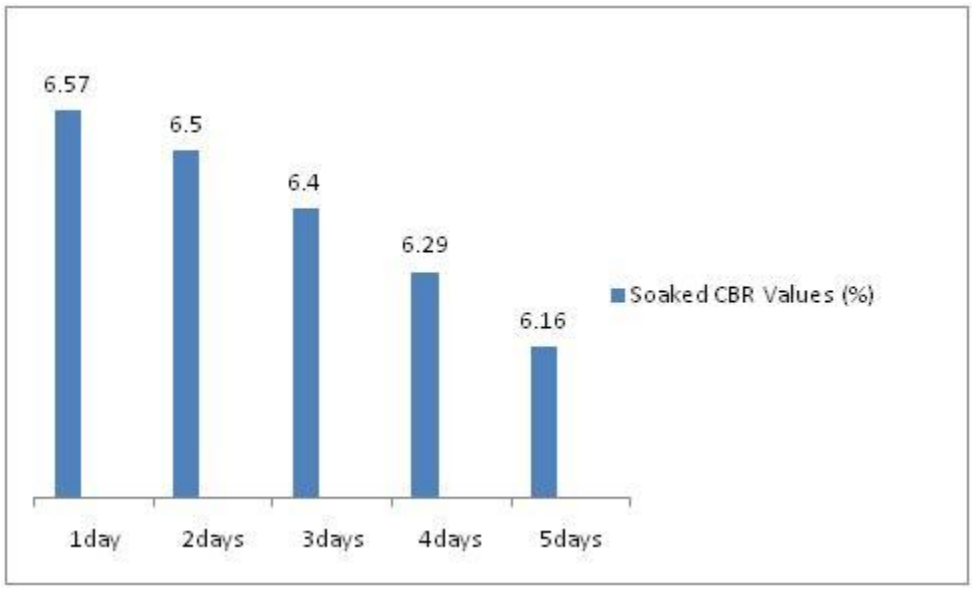

Figure 2: Variation of CBR Values with Soaking Period

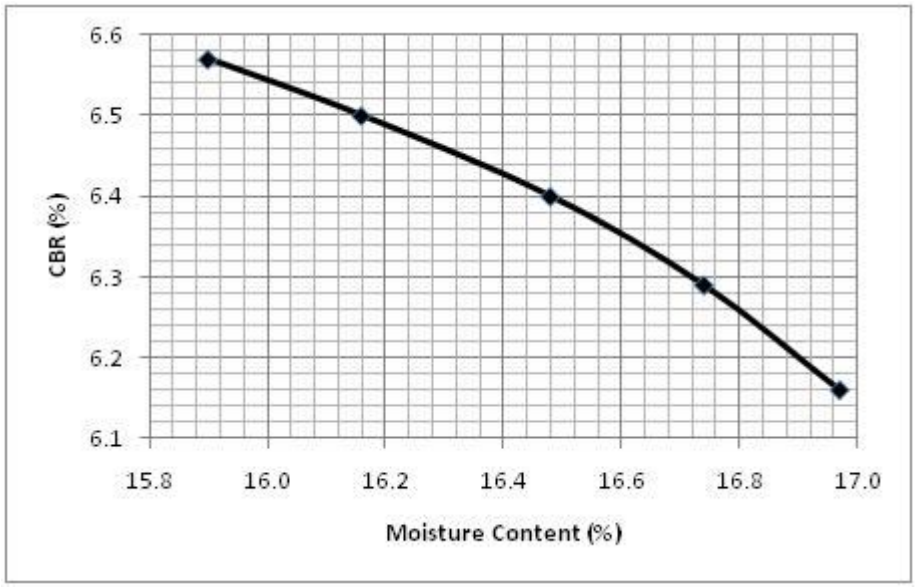

Figure 3: Relationship between CBR and Average Moisture Content

The soaked and remoulded laterite sample was weighed and its bulk density determined for the soaking period under consideration. The bulk density of the soil increases from day 1 to the day 4 of soaking (Figure 4). The same bulk density (2169.20 kg/m^3) is recorded for day 4 and 5. The result indicated that the soil became saturated by day 4. Soaking beyond the 4th day would therefore have no impact. Figure 5 showed the relationship between the CBR and the bulk density of laterite soaked for a period of 1 to 5 days. The CBR decreases with increase in the bulk density of the soil. The top face of the soaked soil has a CBR value greater than the bottom face (Figure 6), indicating that the contact face absorbed more water.

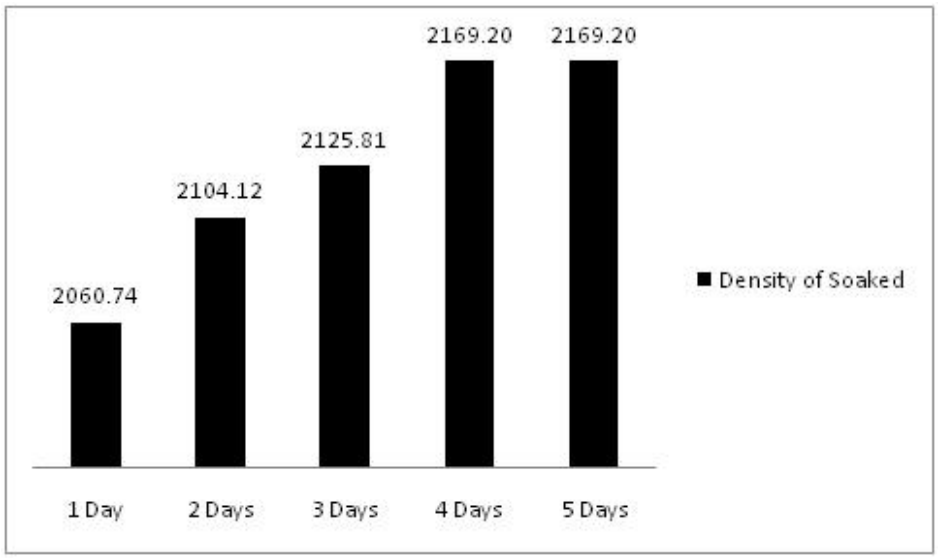

Figure 4: Variation of Bulk Density with Soaking Period

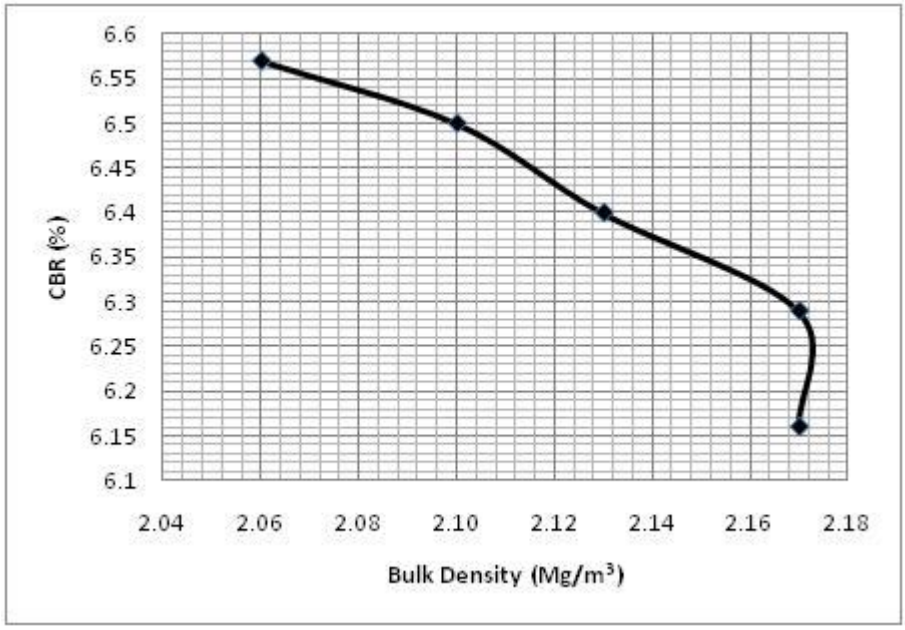

Figure 5: Relationship between CBR and Bulk Density of Laterite

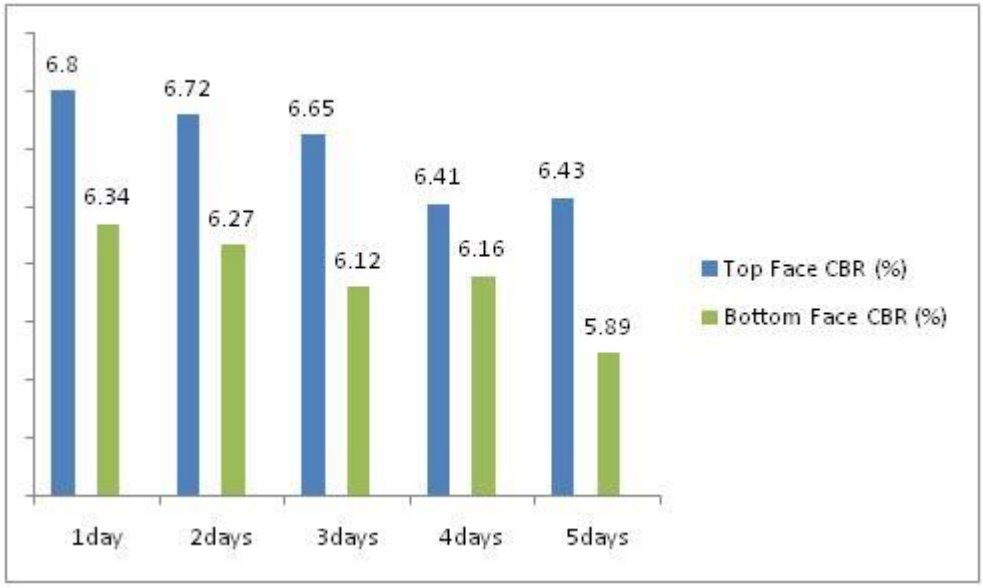

Figure 6: Variation of CBR along the Mould

Conclusion

The study revealed that the CBR of laterite soil decrease with increase in number of soaking days in water. The reduction in CBR may be attributed to the water holding capacity of the soil which made it yield when subjected to load. The situation of soil breakdown may be worsened by water, due to the softening effect on the soil and to the strength reduction it causes. The above consequently leads to pavement distress and partially to failure. An understanding of the dependence of the CBR strength of local soils on water content will contribute towards better

design and maintenance practices. Provision of adequate drainage and stabilization of the soils are also recommended.

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Mitigating the Effects of Floods and Erosion In the Niger South Catchment Area through Integrated Flood Management (IFM)

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Abstract

Natural disasters, such as the occurrence of floods, cause much misery, especially in developing countries where low-income earners undergo great stress. Losses due to floods reduce the asset base of households, communities and societies through the destruction of standing crops, dwellings, infrastructure, machinery and buildings, in addition to tragic loss of life.
The goal of IFM is to identify and maximize the net benefits from floodplains, reduce flood risks, and minimize loss of human life due to flooding in a sustainable manner, thereby shifting the emphasis from flood control to flood management. The method integrates land and water resources management in the river basin, through the adoption of a three-fold approach: i) avoiding; ii) reducing; and iii) mitigating adverse environmental impacts, without compromising flood management objectives. These approaches are put into perspective in the Niger South Catchment Area, which constitutes parts of the lower Niger River and where erosion and the associated flooding constitute serious environmental hazards. The dominant types of erosion, as well as the human activities and natural occurrences that constitute erosion menace in the catchment are identified and used as a guide to recommend erosion and flood management strategies. Use of flood control dams and reservoirs, as a means of attenuating flood peaks downstream, are recommended. Based on hydrological forecasts, the reservoirs can be regulated to minimize the chances of coincident peaks from floods in different tributaries and synchronize with the main stem of the river downstream. Public education and flood warnings, with clear and accurate messages, as well as timely emergency preparedness are recommended as complements to all forms of intervention.

Keywords: Floods, Erosion, Niger South Catchment, Integrated Flood Management, Environmental Impact

Introduction

The goal of IFM is to maximize the net benefits from floodplains, to reduce flood risks, and to minimize loss of human life due to flooding in a sustainable manner. The need for a paradigm shift in thinking from flood control to flood management is the catalyst behind the concepts of IFM. It integrates land and water resources management in the river basin. Integrated Flood

Management adopts a threefold approach of i) avoiding; ii) reducing; and iii) mitigating adverse environmental impacts without compromising flood management objectives. It is desirable to minimize the negative impacts of flood management interventions that limit natural productivity, health and services provided by the ecosystem, including flood alleviation processes, to a reasonably practical level.

Natural disasters cause much misery, especially in developing countries where they cause great stress among low-income earners. Approximately 70 per cent of all global disasters are linked to hydro-meteorological events Flooding poses one of the greatest natural risks to sustainable development. Flood losses reduce the asset base of households, communities and societies through the destruction of standing crops, dwellings, infrastructure, machinery and buildings, quite apart from the tragic loss of life. In some cases, the effect of extreme flooding is dramatic, not only at the individual household level, but in the country as a whole. There is a need, therefore, to find ways of making life sustainable in the floodplains – even if there is considerable risk to life and property. The best approach is integrated management of floods.

An understanding of the interplay between floods, the development process and poverty is vital to ascertain the way in which current and future development processes can and do increase flood risk. A population might be poor because it is exposed to flooding or it might be exposed to flooding because it is poor and occupies the most vulnerable land. The appropriate method of intervention will differ according to which diagnosis is correct. Further, a community with a weak asset base and few multipliers of community well-being is exposed to many different disturbances, some of which may have a greater impact than floods. Decision-makers and development planners at all levels need to be sensitive to this prospect.

Extreme demands on natural resources due to population growth have forced people and their property to move closer to rivers in many parts of the world. Flood control and protection measures have encouraged people to utilize newly protected areas extensively, thereby increasing flood risks and consequent losses. At the same time, various other activities for development and improvement of life, livelihoods and human security are drivers of environmental and ecosystem degradation. Flood management policies and practices have to be viewed within the overall context of such drivers. It is, therefore, extremely important to balance development imperatives, flood risks, social and economic vulnerability, as well as sustainable development vis-à-vis the preservation of ecosystems.

Defining Integrated Flood Management

Integrated Flood Management is a process of promoting an integrated – rather than fragmented – approach to flood management. It integrates land and water resources development in a river basin, within the context of Integrated Water Resources Management (IWRM), and aims at maximizing the net benefits from the use of floodplains and minimizing loss of life from flooding. Globally, both land – particularly arable land – and water resources are scarce. Most productive arable land is located on floodplains. When implementing policies to maximize the efficient use of the resources of the river basin as a whole, efforts should be made to maintain or augment the productivity of floodplains. On the other hand, economic

losses and the loss of human life due to flooding cannot be ignored. Treating floods as problems in isolation almost necessarily results in a piecemeal, localized approach.

Integrated Flood Management calls for a paradigm shift from the traditional fragmented approach of flood management. Integrated Flood Management recognizes the river basin as a dynamic system in which there are many interactions and flux between land and water bodies. In IFM, the starting point is a vision of what the river basin should be. Incorporating a sustainable livelihood perspective means looking for ways of working towards identifying opportunities to enhance the performance of the system as a whole. The flows of water, sediment and pollutants from the upper catchments of the river into the coastal zone (ridge to reef) – often taken to extend dozens of kilometres inland and to cover much of the river basin – can have significant consequences. As estuaries embrace both the river basin and the coastal zone, it is important to integrate coastal zone management into IFM. Figure 1 depicts an IFM model.

It has to be recognized that the objective in IFM is not only to reduce the losses from floods but also to maximize the efficient use of floodplains with the awareness of flood risk – particularly where land resources are limited. That is, while reducing loss of life should remain the top priority, the objective of flood loss reduction should be secondary to the overall goal of optimum use of floodplains. In turn, increases in flood losses can be consistent with an increase in the efficient use of floodplains in particular and the river basin in general.

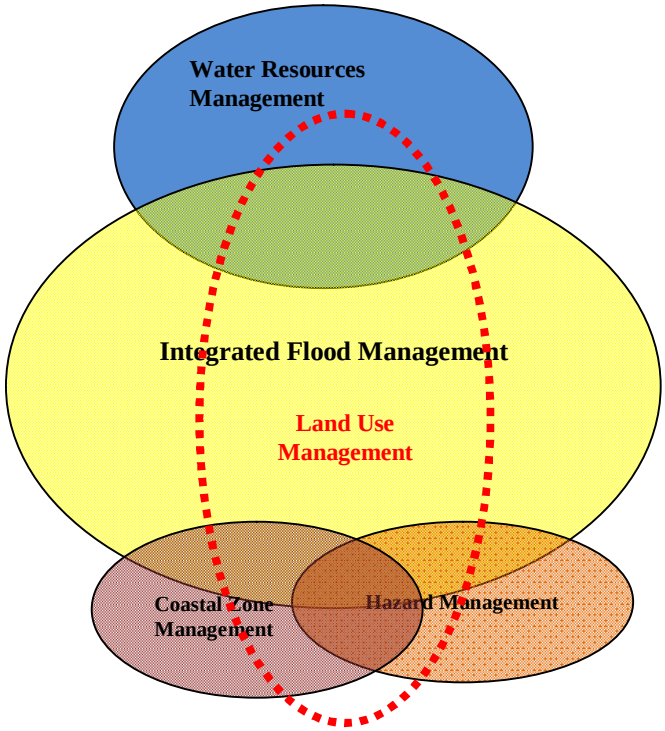

Figure 1: Integrated Flood Management Model

The Niger South Catchment

Nigeria is the final downstream country through which the Niger River flows, and contains 28.3 percent (424,500 km^2) of the basin area. The Niger Basin extends across 20 of the 36 States of Nigeria and comprises two main rivers, the Niger and the Benue, and 20 tributaries. Of Nigeria's major rivers, more than half are in the Niger River Basin. Their combined length accounts for almost 60 percent of the total length of all important rivers in Nigeria (Figure 2). Almost 60 percent of Nigeria's population, or about 67.6 million inhabitants, live in the Basin. These Nigerians comprise 80 percent of the population of the entire Basin. Given Nigeria's size and location, its agricultural production, both rain fed and irrigated, is substantial.

The Lower Niger River and the Niger Delta hydrographic region of the Niger River Basin is approximately the Hydrologic Zone 5 in Nigeria. States in the Niger South Catchment include Delta, Rivers**,** Bayelsa, parts of Edo, Anambra and Kogi States. At Lokoja, the Niger River enters the Lower Niger River segment, which includes the Niger Delta (Figure 2). Also at Lokoja before reaching the Niger Delta, the Niger River is joined by its major tributary, the Benue River, which originates in the highlands of Cameroon's Adamawa Plateau. From Lokoja, the Niger River takes a north to south direction for 200 km; it receives only a few small tributaries, including the Anambra, on the left bank, which drains a basin with significant rainfall. Onitsha is the last monitoring station on the river. The Lower Niger flows for another 100 km and the lower valley progressively transforms into the vast Niger Delta covering approximately 30,000 km^2, with no fewer than 30 outlets to the ocean. The main course of the Niger takes the name of Nun as it crosses the Niger Delta and discharges to the Gulf of Guinea, 4,200 km from its source in Guinea.

Soil Erosion and Flooding

For many communities in the Niger South Catchment, erosion and the associated flooding constitute serious environmental hazards. Different types of erosions, such as sheet, rill, and gully, are pervasive in Anambra and Edo States, and to a lesser extent in Kogi State. However, gully erosion constitutes the most significant threat to the survival of individuals and communities (Figure 3). Human activities, such as bush burning, deforestation, improper farm practices, and, more importantly, construction activities (building of roads, houses, industries), that undermine natural landscape or drainage systems account for much of the erosion menace plaguing the States. However, given the unconsolidated underlying geologic formations in these areas, rainfall intensity and duration is the most important natural cause of soil erosion (Okpara, 1993). Increase in the frequency of heavy rains and flooding had lead to widespread erosion and siltation with more dramatic impact on the areas. Its impacts include destruction of valuable property, loss of farmland and livelihood, loss of soil nutrients and biodiversity, productivity collapses, and loss of flora and fauna (e.g. fishes in rivers and streams) due to the transportation of sand deposits or pollutants to other natural ecosystems (Figure 4). Loss of productivity and valuable property undermine food security, personal security, and social order in a community with consequences for internal displacement. Although climate change may not be the cause of soil erosion in the catchment, it is already amplifying its impact due to severe

precipitation. Consequently, unchecked or severe erosion has lead to increased demand by local people on governments (Federal, State and Local) and has precipitated conflicts.

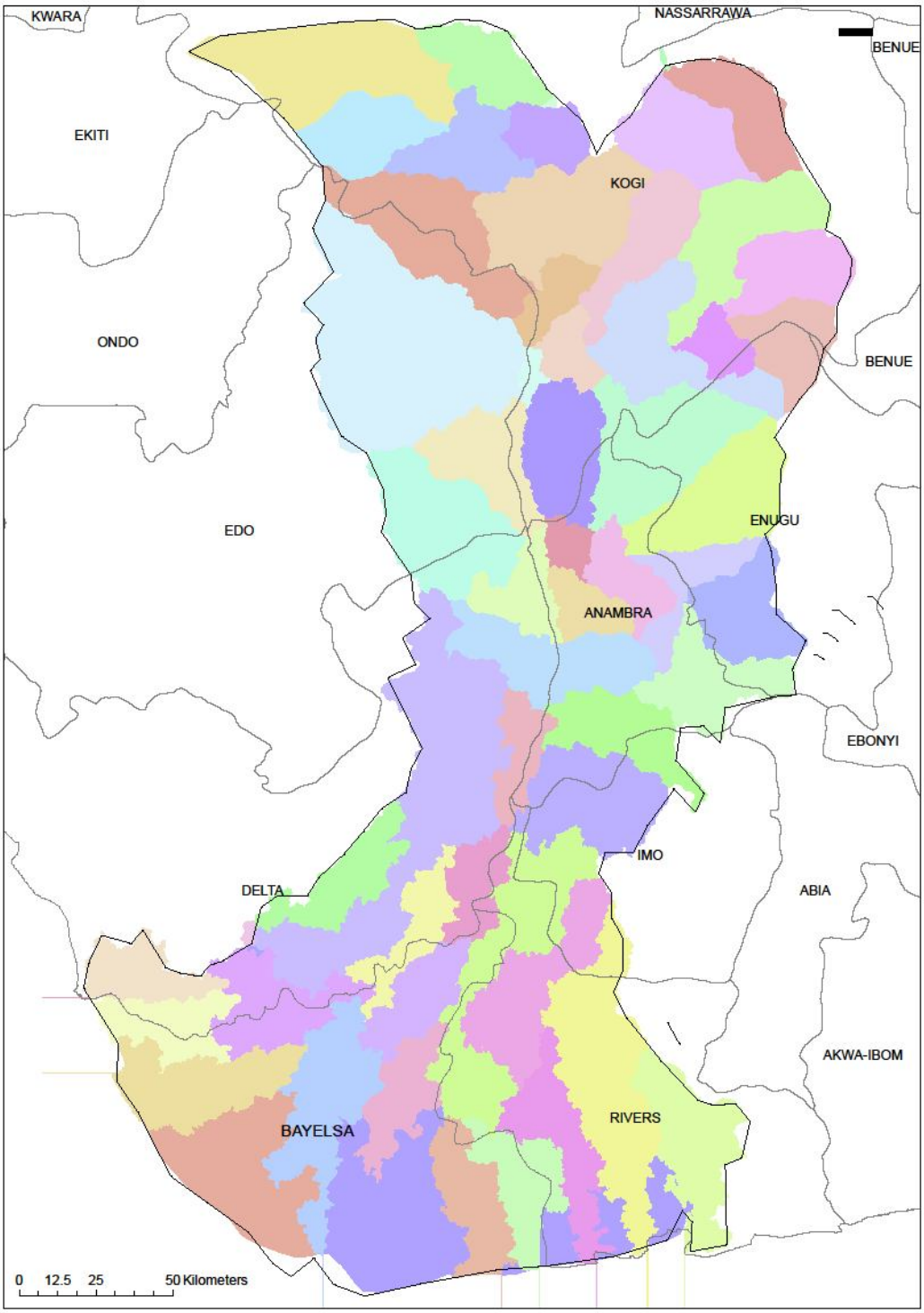

Figure 2: The Niger South catchment

Figure 3: Farm erosion in Anambra State, Nigeria

Coastal Erosion and Flooding

Coastal erosion and flooding is the most important environmental problem pervasive in the Niger Delta segment of the Niger South Catchment (Figure 4). Nigeria has a coastline of approximately 853 km, and the Niger Delta accounts for about 450 km of the coastal zone. Over 75% of the 30 million inhabitants of the Niger Delta region live along the coastal area and survive mainly on fishing and agriculture. The problem of coastal erosion and flooding due to sea-level rise and storm surges constitute a significant source of threat to life, property, livelihoods, and infrastructure in the Niger Delta region (Ezirim, 2008b). This is made worse by the destruction of mangrove forests due to oil exploitation activities. Flooding is widespread in the Niger Delta because of low relief, the reduced hydraulic capacities of water channels, and high rainfall. In the mangrove swamp forest areas, diurnal tidal movements result in floods, exacerbated by rising sea levels, coastal erosion and land subsidence (UNEP, 2006).

Figure 4: Urban flooding in Yenagoa, Balyesa State, Nigeria

Interestingly, it has been noted that severe flooding in the Niger Delta has become more frequent with floods wiping out crops and disrupting traditional farming practices (Best and Lawson, 2008). Worst still, a UN report has estimated that about 30% of Africa's coastal infrastructure, including coastal settlements in the Gulf of Guinea, Senegal, the Gambia, and Egypt, could be inundated by 2085 due to climate change (UNEP, 2006). Although scientists generally dispute the warning that sea levels will rise by 2 m by the year 2010, it is strongly estimated that a 0.2 meter rise in sea level would lead to displacement of about 200 villages in the Niger Delta region. A projected sea level rise of more than 1 m could flood much of the Niger Delta and force up to 80 percent of the delta's population to higher ground, with a consequent property damage that the IPCC estimated at $9 billion (World Bank, 1996).

General Methods of Controlling Floods

Flood Control Dams and their Reservoirs

Flood control dams store all or a portion of the flood waters in the reservoir, particularly during peak floods and then releases the water slowly. Typically, the principal use of such dams is to store a portion of the flood volume in order to delay and attenuate flood peaks downstream. Space within a reservoir is generally reserved to store impending floods. Based on hydrological forecasts, the reservoir is regulated in a way to minimize the chances of coincident peaks from floods in different tributaries synchronizing in the main stem of the river downstream. Small to medium floods generated from the catchment are fully captured by the reservoirs. However, extreme flood events are only partially attenuated and their transformation downstream is delayed. The extent of attenuation depends on the available storage capacity vis-à-vis the magnitude of the flood event. The main performance parameter in assessing the flood control

benefits of a reservoir is, therefore, the extent of the flood peak reduction during extreme events.

Many dams have multiple purposes and flood management may be required only for a few days or weeks in any particular year. Potential conflicts between flood management objectives (where storage space in the reservoir is required) and hydropower and irrigation (where it is desirable to keep the storage capacity as filled as possible) make it difficult to operate a multiple purpose reservoir. While allocating water for various uses, the need to maintain environmental flows should also be addressed. This should not only be guided by the percentage of the total flows released, but also by the need for variability of outflows in the downstream of a storage reservoir to be mimicked to maintain near-pristine conditions.

Sediment and Organic Material

Dams also disrupt the natural flow of sediments and organic materials. As stream flow slackens in the reservoir, the sediment transport decreases and suspended sediment along with the organic material, which provides vital nutrients for downstream food webs, also drops out and is lost to the downstream ecosystem. The organic silt is mostly retained in the reservoir, instead of fertilizing the downstream flood plains, estuarine and coastal ecosystems. The elimination or reduction of high flood events changes the structure and functioning of the downstream floodplain ecosystems. As the river remains within its channel for long periods of time, the lateral connectivity between the river channel and their fringing wetlands is lost.

The availability of resources to the food chain downstream is affected in various ways. The reservoir exports plankton and algae in the flow releases. On the other hand, there is a lack of organic matter such as wood and leaves, which are retained in the reservoir. In most cases, the turbidity of downstream water is decreased below a reservoir, which may lead to increased primary productivity in the reach. Algal growth may occur in the channel immediately downstream from dams because of the nutrient loading of the reservoir releases. With a decrease in flood magnitudes downstream of a dam, there is an invasion of new varieties of plants into the river sand bars and islands, resulting in reduced conveyance capacity of the river during flooding.

Sediment-depleted water released from dams can erode finer sediments from the receiving channel, thereby scouring the downstream streambed and banks until the equilibrium bed load is re-established. It may also result in coarsening of the streambed which, in turn, reduces habitat availability for many aquatic species living in or using interstitial spaces. Without new sources of sediment, sand and gravel bars alongside and within streams are eventually lost, along with the habitats and species they support. In addition, as the stream channel becomes incised, the water table underlying the riparian zone also lowers, thereby affecting the composition of vegetative communities within the stream corridor.

Other methods of controlling floods are detention and retention basins, bye-pass and diversion channels, and channelization.

The traditional management response to a severe flood was typically an ad hoc reaction – the quick implementation of a project that considered both the problem and its solution to be self-evident, and that gave no thought to the consequences for upstream and downstream flood risks. Thus, flood management practices have largely focused on reducing flooding and reducing the susceptibility to flood damage. Traditional flood management has employed structural and non-structural interventions, as well as physical and institutional interventions. These interventions have occurred before, during and after flooding, and have often overlapped.

Source controls intervene in the process of the formation of runoff from rainfall or snowmelt, and take the form of storage in the soil or via the soil. The use of this strategy normally considers the consequential effects on the erosion process, the time of concentration in the soil and the dynamics of evapo-transpiration. The assessment of the likely effectiveness of source control also considers pre-flood conditions such as the state of saturation of the soil, and whether or not the ground is frozen. Thus, a potential drawback with some forms of source control, and other forms of land-use modification such as afforestation, is that the capacity to absorb or store rainfall depends on the antecedent conditions of the catchment.

Surface water storage, through such devices as dams, embankments and retention basins, is a traditional approach to attenuating flood peaks. Water storage modifies floods by slowing the rate of rising waters, by increasing the time it takes for the waters to peak and by lowering the peak level. More often than not, such storage serves multiple purposes, and flood storage can be the first casualty in any conflict among purposes. Moreover, by completely eliminating the low floods, such measures can give a false sense of security. Storage has to be used in an appropriate combination with other structural and non-structural measures.

Seemingly self-evident, but regularly overlooked in practice, is the need to make flood management a part not only of the planning and design, but also of the operation of reservoirs. Releases from reservoirs can create risks, and the careful operation of reservoirs can minimize the loss of human life and property due to such releases. In this context trans-boundary cooperation is indispensable. Increasing the carrying capacity of a river changes its natural morphological regimes and ecosystem, affects other river uses and has a tendency to shift the problem spatially and temporally. Deepening of channels may also affect the groundwater regime in the region. Dikes or flood embankments are most likely to be appropriate for floodplains that are already intensely used, in the process of urbanization, or where the residual risks of intense floodplain use may be easier to handle than the risks in other areas (from landslides or other disturbances, for example).

Flood warnings and timely emergency action are complementary to all forms of intervention. A combination of clear and accurate warning messages with a high level of community awareness gives the best level of preparedness for self-reliant action during floods. Public education programmes are crucial to the success of warnings intended to preclude a hazard from turning into a disaster. Evacuation is an essential constituent of emergency planning, and evacuation routes may be upward into a flood refuge at a higher elevation or outward, depending upon the

local circumstances. Outward evacuations are generally necessary where the depths of water are significant, where flood velocities are high and where the buildings are vulnerable.

Integrated approach to flood management therefore calls for a best mix of structural and non-structural measures. An isolated flood management option may achieve a certain objective, e.g. protection of a certain area, but cannot address the various objectives that should be addressed at the river basin level. The residual risks associated with structural solutions, for example due to uncertainty in the input information for analysis of these options or due to a series of chain failures of structural control and protection works, have to be taken into account.

Challenges of Flood Management

Key challenges of flood management that need to be addressed in an integrated approach include:

- Population growth and economic growth exert considerable pressure on the natural resources system;
- Increased population and enhanced economic activities in floodplains further increase the risk of flooding;
- Designing for large floods must account for the likelihood of failure in cases of floods of magnitude below the notional design standard;
- Riverine aquatic ecosystems provide such benefits as clean drinking water, food, materials, water purification, flood mitigation and recreational opportunities;
- The magnitude and variability of the flow regime needed within a basin to maximize the benefits to society and to maintain a healthy riverine ecosystem must strike a balance between competing interests in the river basin;
- Intensity and duration of precipitation events are likely to increase due to climate change, resulting in an increase of the frequency of major floods in many regions.

Elements of Integrated Flood Management

Integrated Flood Management takes a participatory, cross-sectoral and transparent approach to decision-making. The defining characteristic of IFM is integration, expressed simultaneously in different forms: an appropriate mix of strategies, carefully selected points of interventions, and appropriate types of interventions (structural or non-structural, short- or long-term). An IFM plan should address the following six key elements that follow logically for managing floods in the context of an IWRM approach (Figure 1).

- Flood management plans should include drought management, and should take measures to maximize the positive aspects of floods such as by retaining part of flood flows for use in crop production.
- IFM recognizes the need to manage all floods and not just those floods up to some design standard of protection. Flood plans must consider what will happen when a flood more extreme than the design standard flood occurs, and must foresee how such a flood will be managed.

- Urban flood plans must manage both storm water quantity and the effects of storm water on water quality.

Integration of Land and Water Management

Hydrological responses to rainfall strongly depend on the local characteristics of soil, such as water storage capacity, infiltration rates and preceding rainfall conditions. The type and density of vegetation cover and the land-use characteristics are also important in understanding a catchment's response to rainfall. Human alterations to catchments can play a significant role in increasing flood hazards if the runoff generation process is changed, especially when the infiltration capacity of the soil decreases or a change in soil cover occurs. Environmental degradation and uncontrolled urban development in high-risk zones, such as historical inundation plains and the bases of mountain ranges, lead to an increased vulnerability to catastrophic events for those communities on the floodplains. Changing pervious natural surfaces to less pervious or impervious artificial surfaces, leads to an increase on storm water runoff rates, and the total volume of runoff may also affect water quality. Changes in natural water storage as a consequence of urbanisation also cause significant changes to the temporal characteristics of runoff from an urbanized area, such as shortening the runoff travel time, and can result in an increased incidence of flash flooding.

Land-use planning and water management should be combined in one synthesized plan with a certain common field, such as the mapping of flood hazards and risks, to enable the sharing of information between land-use planning and water management authorities.

Flood management needs to recognize, understand and account for linkages between upstream and downstream to realize synergies in improving river basin performance.

Management of Risk and Uncertainty

Risk and uncertainty in flood management should take the following into consideration:

- Flood risks are related to hydrological uncertainties which are subordinate to social, economic and political uncertainties: the biggest and most unpredictable changes are expected to result from population growth and economic activity.
- Flood risk management consists of systematic actions in a cycle of preparedness, response and recovery, and should form a part of IWRM.
- Risk management calls for identification, assessment, and minimization of risk, or elimination of unacceptable risks through appropriate policies and practices.

Adoption of a Best-Mix of Strategies

Table 1 displays the strategies and options generally used in flood management. The adoption of a strategy depends critically on the hydrological and hydraulic characteristics of the subject river system and region. Three linked factors determine which strategy or combination of strategies is likely to be appropriate in a particular river basin: the climate, the basin characteristics and the socioeconomic conditions in the region. The nature of the

region's floods and the consequences of those floods are functions of these linked factors. Optimal solutions depend upon knowledge that is complete, precise and accurate. In light of the uncertainty about the future, flood management plans should adopt strategies that are flexible, resilient and adaptable to changing conditions. Such strategies would be multi-faceted with a mix of options. Successful IFM looks at the situation as a whole, compares the available options and selects a strategy or a combination of strategies that is most appropriate to a particular situation. In addition, flood management plans need to include both long-term and short-term interventions.

Table 1. Strategies and Options for Flood Management

Strategy	Options
Reducing Flooding	Dams, levees and flood embankments. High flow diversions. Catchment and managements.
Reducing Susceptibility to Damage	Floodplain regulation Development and redevelopment policies. Design and location of facilities Flood proofing Flood forecasting and warning
Mitigating the Impacts of Flood	Information and education Disaster preparedness Post-flood recovery Flood Insurance
Preserving the Natural Resources of Flood Plains	Floodplain zoning and regulation

Participatory Approach

Identification and involvement of all stakeholders is an important component of IFM. The following are important in ensuring participatory approach:

- IFM should encourage the participation of users, planners and policy-makers at all levels and should be open, transparent, inclusive and communicative; this requires the decentralization of decision-making, and includes public consultation and the involvement of stakeholders in planning and implementation.
- IFM has to keep gender, religious and culture differences in perspective.
- It is important to make use of strengths of both "bottom-up" approach and "top-down" approach in determining the appropriate mix.
- River basin committees or organizations, at basin or sub-basin levels, can provide appropriate coordination and cooperation across functional and administrative boundaries.

Adoption of Integrated Hazard Management Approaches

- A holistic approach to emergency planning and management is preferable to a hazard-specific approach, and IFM should be part of a wider risk management system.

- Integrated Hazard Management Approach consequently ensures consistency in approaches to natural hazard management in all relevant national or local plans.
- Early warnings and forecasts are key links to the series of steps required to reduce the social and economic impact of all natural hazards, including floods.

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PHYSICAL DEVELOPMENT AND BIODIVERSITY

Impact of Human Urine Contamination on Soil Biota

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Abstract

The role of human urine as an organic pollutant to soil biota was examined in this study. Using standard methods, the impact of human urine on the physicochemical parameters, fauna and microbial load in the soil microcosm was considered. Ten replicates of Urine contaminated soil (UrCS) and Uncontaminated Agricultural soil (UnCS) samples respectively were collected from points pedestrian urine deposition within Olabisi Onabanjo University, Ago-Iwoye and University of Agriculture, Alabata both in Ogun State. pH was determined using the pH meter. Moisture content (MC) was determined by drying and difference in weight method. Organic Carbon (OC) was determined using the Walkey-Black method and Organic Matter (OM) was estimated by the formula %OC = %OC x 1.729. Phosphate and nitrate concentrations were determined by spectrophotometric method while sulphate concentration was determined by the turbidimetry method. Ammonium concentration was determined by distillation method using 40% boric acid with methyl red indicator. The fauna record was conducted by heat extraction into alcohol or normal saline while microbial load was estimated by the pour plate and serial dilution techniques. UrCS recorded a significantly higher MC, OC, OM, phosphate, nitrate, sulphate, ammonium concentrations and lower pH ($p<0.05$) than UnCS. A complete absence of microfauna (protozoa), mesofauna (mites, lion ants, insects, insect eggs) and macrofauna (beetle, beetle caterpillars, millipedes, pill millipedes, earthworms, earthworm castings) was recorded in UrCS while UnCS samples recorded their presence. UrCS recorded a significantly lower ($p<0.05$) microbial loads than UnCS. The most adverse impact of human urine on soil biota is the lowered pH and increased acidity which unleash a vicious cycle on soil biota persisting as long as urine deposition continues unhindered on the same spot.

Keywords: human urine, soil fauna, microbial load, impact, vicious cycle

Introduction

Despite soil being the habitat for the majority of earth's terrestrial species, far less attention has been paid to understanding maintenance of soil biodiversity until recently as pointed out by Wardle (2002). Now, there is a growing interest in the belowground biodiversity, largely as a result of advances in techniques that enable more ready characterization of these belowground diversity (Blaxter and Floyd, 2003; Young and Crawford, 2004) and also because of the

increasing recognition among ecophysiologists that soil biota play key roles in ecosystem functioning, especially organic matter turnover, nutrient mineralization (Hooper *et al*., 2000; Wardle, 2002; Heimsbergen *et al.,* 2004; Wardle *et al.,* 2004; Bardgette *et al.*, 2005) and material flow through the ecosystem (Bardgette *et al.,*2005).
Healthy soil played a major role as habitat for various forms of living things ranging from microflora, microfauna, mesofauna, macrofauna to megafauna. And these group in turn by their activity help to maintain a healthy, fertile and productive soil by breaking down organic wastes into bioavailable nutrients which aid plant germination and growth.

Soil fauna activity are essential for the functioning of all terrestrial ecosystem, they are important in the physical and chemical transformation of litter, maintenance of soil fertility and sustained productivity. Hagiar (1994) and VanStraalen (1998) had earlier pointed out that soil fauna respond to different environmental stress through changes in species or community structure hence can be used as an important indicator of contaminated, polluted or healthy soil.

The use of by-products of vegetable, animal and human origins to restore or to increase soil fertility has been well known for over 2000 years and as pointed out by Clapp *et al*. (2005) there has been an exponential increase in deposition of organic materials from municipal solid wastes, sewage sludge and agro-industrial wastes. Millions of tonnes of organic matter are land-filled or incinerated and transformed into methane, carbon dioxide, nitrogen oxides and sulphur oxides.

Though much study on organic pollutions and their resultant effect on the soil environment have been conducted, not much information are available on the impact of urine on soil environment especially of human origin. Human urine in itself is not toxic except when mixed with faeces in septic tanks (Ecosan Publication, 2008) and have been used as fertilizer for over 6,000 years (Halbach, 2008). Kaiser stated that a lot of nitrogen in manure come from urea which is contained in urine as such human urine is a rich source of organic fertilizer.

Urine is a filtered product of kidney which contains only low molecular weight substances and at excretion the pH is normally around 6 but can vary between 4.5 and 8.2 (Lentner *et al.,* 1981). It was further shown by Lentner *et al.* (1981) that of the Nitrogen constituent of urine 75-90% is excreted as Urea and the remainder as ammonium and creatinine. In the presence of urease, urea is quickly degraded to ammonium and carbon dioxide and the hydroxide ions produced will invariably increase soil pH to 9 – 9.3 and this usually occurs within hours of deposition (Vanneras *et al.,* 1999 and Jonssen *et al.,* 2000). But the continual deposition of urine at a spot lead to net acidification of the soil because the conversion of ammonium (NH_4) to nitrate (NO_3) involves release of protons, thereby promoting acidity.
Whitehead and Bristow (1994) reported that the presence of urine of cattle origin in soil inhibited pasture response and there is a marked decline in soil pH in the urine patch following nitrification. This had earlier been demonstrated by Ball *et al.* (1979) that application to pasture of urine from beef cattle resulted in soil acidification.

In Nigeria, urine deposition in public places go on unchecked and has become a menace, a close examination of such soil macrocosm reveals patchiness of soil, obvious discolouration, pungent ammoniacal smell (pers comm.). There is therefore the need to establish the impact of human urine deposition on soil biota. The aim of this study is to determine the impact of human urine on soil microenvironment viz impact on soil fauna, physicochemical parameters and soil microflora.

Materials and Methods

Study Location

The study was first conducted in April – May, 2008 at Olabisi Onabanjo University Campus, Ago-Iwoye, latitude $7^0$30'N and longitude $4^0$32'E, altitude of 76m above sea level with a mean annual rainfall of 1779mm and temperature of 27 ^{0}C. The same study was repeated May – June, 2011 at University of Agriculture, Abeokuta located between latitude $7^0$12'N - $7^0$20'N and longitude $3^0$12'E - $3^0$28'E, altitude of 76 m above sea level with a mean annual rainfall of 1,037mm and 34.7 ^{0}C.

Sample Collection

Ten replicates of soil samples were collected from ten points of pedestrian urine deposition within the Olabisi Onabanjo mini campus and University of Agriculture (hereby called Urine Contaminated Soil, UrCS) and 10 samples from Uncontaminated agricultural soil (hereby called Uncontaminated Soil, UnCS). The soil samples were air dried for two days, sealed in separate polythene sachet and transferred to the soil laboratory.

Physicochemical Analysis of Soil

At the laboratory, 2mm and 0.5mm mesh-size sieves were used to sieve the soil samples. The sieved soil samples were analysed for pH, Moisture content (MC), organic carbon (OC), organic matter (OM), phosphate, ammonium, nitrate, sulphate. pH was determined using the pH meter. MC was determined by drying and difference in weight method. OC was determined using the Walkey-Black method and % OM was estimated by the formula %OC = %OC x 1.729. Phosphate and nitrate were determined by spectrophotometric method while sulphate was determined by the turbidimetry method. Ammonium is determined by distillation method using 40% boric acid with methyl red indicator.

Fauna Records and Microbial Loads

Soil fauna such as insects, worms and arthropods generally were analysed using heat extraction into alcohol while nematodes, cysts and other protozoan were extracted using normal saline. The extracts were then viewed under the microscope to determine their presence or absence. The bacterial load was determined using the pour plate technique and serial dilution using nutrient agar while potato dextrose agar was used for the fungal count.

Statistical Analysis

Using the statistical package SPSS version 17.0, the means and standard deviations were calculated for all results obtained. The means were compared using t-test and significance was established at a probability level of $p < 0.05$.

Results

The Organic matter (OM), organic carbon (OC), Moisture Content (MC), PO_4, NH_4, NO_3 and SO_4 were significantly higher ($p<0.05$) in urine contaminated soil (UrCS) than uncontaminated soil (UnCS) samples while pH was significantly lower ($p<0.05$) (Table 1).

There was complete absence of microfauna (protozoa), mesofauna (mites, lion ants, insects, insect eggs) and macrofauna (beetle, beetle caterpillars, millipedes, pill millipedes, earthworms, earthworm castings) in urine contaminated soil (UrCS) while uncontaminated soil (UnCS) samples recorded their presence (Table 2).

The microbial load viz total viable count, total coliform count, total fungi count and total yeast count recorded from urine contaminated soil (UrCS) were significantly lower ($p<0.05$) than that recorded from uncontaminated soil (UnCS) samples (Tables 3).

Table1: Descriptive Statistics and Independent t-test of Physicochemical parameters between Urine Contaminated and Uncontaminated Soil Samples

Physicochemical Parameters	UrCS Mean±SD (N=10)	UnCS Mean±SD (N=10)	t-statistics	Sig.
Organic Carbon (OC)	0.995±0.059	0.569±0.059	16.16	<0.05
Organic Matter (OM)	1.706±0.103	0.979±0.102	11.24	<0.05
Moisture Content (MC)	14.90±1.79	7.86±0.84	15.826	<0.05
PO4	0.045±0.005	0.022±0.006	9.22	<0.05
NH3	0.017±0.001	0.010±0.001	12.36	<0.05
NO3	0.009±0.004	0.004±0.001	25.15	<0.05
SO4	0.005±0.002	0.002±0.001	50.13	<0.05
pH	5.00±0.20	7.86±0.84	-15.52	<0.05

Key: UrCS: Urine Contaminated Soil; UnCS: Uncontaminated Soil

Table 2: Faunistic Record of Urine contaminated and Uncontaminated Agricultural soil

Fauna	UrCS	UnCS
Microfauna		
i. Protozoa	Absent	Present
Mesofauna		
i. Mites	Absent	Present
ii. Lion ant	Absent	Present
iii. Insects	Absent	Present
iv. Insect eggs	Absent	Present
Macrofauna		
i. Beetle	Absent	Present
ii. Beetle larvae	Absent	Present
iii. Millipede	Absent	Present
iv. Pill millipede	Absent	Present
v. Earthworm	Absent	Present
vi. Earthworm Casts	Absent	Present

Key: UrCS: Urine Contaminated Soil; UnCS: Uncontaminated Soil

Table 3: Descriptive Statistics and Independent t-test of Microbial Load in Urine Contaminated and Uncontaminated Soil

Microbial Load	UrCS Mean±SD (N=10)	UnCS Mean±SD (N=10)	t-statistics	Sig.
Total Viable Count ($x10^4$)	28.50±15.78	153.00±54.27	-6.966	<0.05
Total Coliform Count ($x10^4$)	3.71±1.25	61.50±51.51	-3.546	<0.05
Total Fungi Count ($x10^4$)	3.60±1.89	11.40±1.84	-9.338	<0.05
Total Yeast Count ($x10^4$)	3.00±0.89	15.60±5.66	-5.897	<0.05

Key: UrCS: Urine Contaminated Soil; UnCS: Uncontaminated Soil

Discussion

Generally, the result of the study revealed that human urine has great impact on soil microcosm. Physical examination of the soil showed that the colour of urine contaminated soil is much darker than the uncontaminated soil and this may be an indication of the high level of organic carbon and organic matter contained in the urine contaminated soil.Further physical examination of the urine contaminated soil revealed patchiness of such soil and no plant growth was observed despite the significantly higher levels of nutrients in urine contaminated soil. The significantly higher moisture content of urine contaminated soil is as a result of low volatility & high viscosity of urine and also because the high organic carbon and matter contained therein tend to have high affinity for water.

Urine Contamination, Increased Soil Acidity and Impact on soil fauna and Microorganisms

The major physical impact of urine deposition on soil is the significantly lower pH, indicating high soil acidity. This is as the result of microbial oxidative process of urea which takes place in urine contaminated soil.

$CO(NH_3)_2 + 2H_2O \rightarrow (NH_4)2CO_3$
$(NH_4)2CO_3 + 8O \rightarrow 2HNO_3 + H_2CO_3 + 2H_2O$

The high acidity will greatly interfere with nutrient cycling between soil, air and water to the extent that higher deposition and dissolution of nutrients will occur in urine contaminated soil, hence the significantly higher content of PO4, NO3 and SO4 recorded from urine contaminated soil. It was earlier revealed that when soils become acidic their capacity to adsorb cations is reduced, hence the loss of such cations from the soils by leaching while N, P and S remain immobilised for longer in the soil organic matter. Furthermore, the form of nitrogen taken up by plant roots may be NH_4^+ instead of NO_3^- because nitrification is inhibited. All these and the increased deposition of cations such as Al and Mn results in the creation of adverse growth environment for both flora (micro) and fauna (micro, meso and macro) in urine contaminated soils therefore, leading to their death and possibly migration.
The above assertions probably resulted in the observed patchiness of soil with the absence of plant growth or death of germinating or growing plants. Not only this, the microbial load viz total viable count, total coliform count, total fungi count and total yeast count were significantly lower ($p<0.05$) in urine contaminated soil. In addition, the absence of microfauna (protozoa), mesofauna (mites, lion ants, insect eggs) and macrofauna (beetle, beetle larvae, millipedes, earthworms, earthworm castings) was also an indication of the adverse effect of the soil acidity which impinge negatively on the physiology of these soil dwelling fauna leading to their death or dispersal from such soils.

The Vicious Cycle

As long as urine deposition continues unabated into our soil microcosm, a vicious cycle is set in motion whereby the increased urine deposition leads to increased soil acidity which in turn leads to the impairment of the living environment of soil organisms and in turn leads to drastic reduction in the population of soil organisms. The reduction in soil microbial load and complete absence of fauna leads to the drastic increase in soil organic carbon, organic matter, phosphate, nitrate, sulphate and ammonium to levels far exceeding the threshold thereby leading to the interference with the biogeochemical cycles of these nutrients. This means there is more nutrient loads in the soil than needed making them to become toxic to the living organism and this eventually culminate in the total impairment of the soil health (Fig 1).

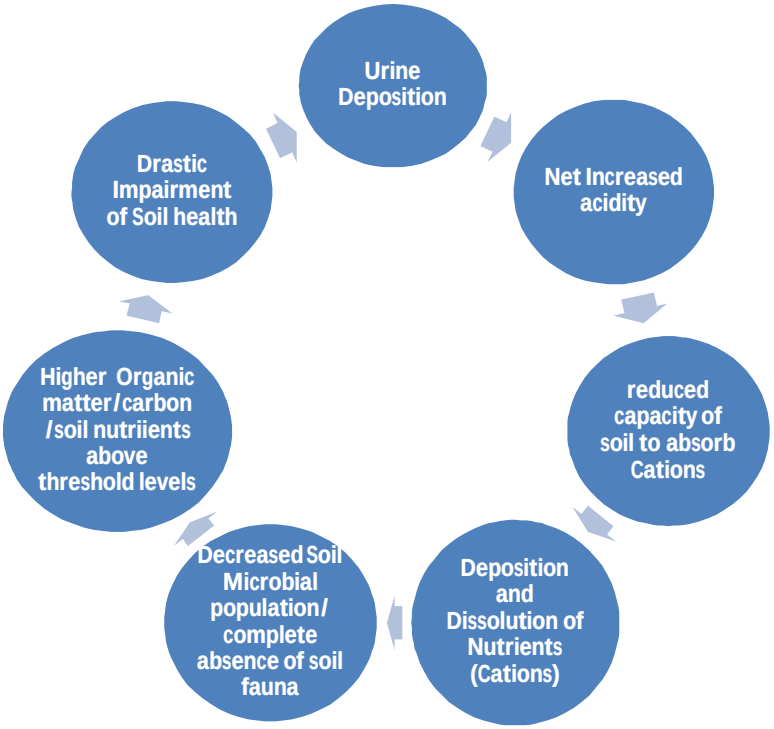

Fig 1: The Vicious Cycle of continuous Urine deposition on soil microcosm

In conclusion, it is evident that continuous deposition of human urine at a spot in the environment has negative value on the health of soil biota and is aesthetically unsightly. It is therefore necessary to prevent the indiscriminate deposition of human urine on soil biota and at public places by providing functional urinary at different points of easy accessibility for pedestrians. Furthermore, soils from such public urinary could be collected periodically, sun dried and used as organic fertilizer, since this study has revealed that such soils are rich in organic nutrients. Further study should be conducted on this beneficial aspect of human urine deposition on the soil.

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Spatio-temporal Analysis of Wetland Ecology of Ijebu-ode, Southwest Nigeria

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Abstract

Wetlands are critical habitats providing fish and other wildlife resources in support of the country's economy. In the context of climate change, it is feared that these ecosystems are faced with enormous threat from possible impacts of anthropogenic activities that may result in widespread loss of these habitats. Land use changes around wetlands increase the impacts of climate change on these ecosystems and may be disastrous for the welfare of wetland communities due to its potential impacts on property, water and food security. Remotely sensed imageries obtained from National Space Research and Development Agency (NASRDA), Abuja was used for this study. The first is a SPOT-MS of 1984, while the second is also a SPOT-MS of 2007, thereby covering 23 years. The method of supervised classification was adopted for the classification of land-use within the area. Thereafter, ground-truthing exercise was carried out to verify and ensure that the land use was appropriately classified. The projection used for the image registration and final map production was Universal Transverse Marcator (UTM), zone 31.

The paper observed that the wetland in Ijebu ode had witnessed tremendous change due to infilling of wetland, loss of biodiversity, alien invasion and pollution of wetland areas. Thus, it was posited that in order to enjoy the ecological services performed by wetlands, impact of anthropogenic activities should be managed sustainably.

Keywords: wetlands, land use changes, wetland sustainability, Remote sensed imageries, land use classification

Introduction

Wetland, a collective term used to describe land where excess of water dominates, is essentially designed by nature to catch, clean and preserve any unused surface water. Wetland are characterized as having a water table that stand at or near the land surface for a long enough season each year to support aquatic points (Ramsar Convention, 2010). It also is an area of land whose soil is saturated with moisture, either permanently or seasonally, with

heavy growth of aquatic or semi – aquatic plant and relatively thick organic deposits. Such areas may also be covered partially or completely by shallow pools of water.

Locally, they may form anywhere drainage is impeded – in quarries, grave puts and along highway and railroads. Wetland soils are among the most maligned soil in the world because they are too wet for agriculture, too unstable for buildings and are often associated with pest and diseases. The traditional response is to drain and fill them. Inland, most wetlands are fresh. However, wetlands with brackish or of intermediate salinity from the mixing of fresh water and salt water can be found close to coast. Wetlands are among the richest biological habitats on earth (Costanza et al., 1997) and are the most biologically diverse of all ecosystems. Ecosystem is a fragile, highly organized and structured environment in which all part exists in a delicate balance.

Wetlands contain numerous goods and services that have economic value, not only for the local people, but also to people living outside the periphery of the wetland. They are important sources of water and mittens' necessary for biological productivity and often sheer survival of people. Wetland also reduces storm damage by adsorbing waves, it slows down floodwater and permit nutrient rich particle to settle out. In addition, wetlands can act as reservoir and release water slowly into lake, streams or aquifers, thereby preventing floods (Enger and Smith, 2002). Human and physical factors have shaped the ecosystem and have contributed to increased pressure on the environment in recent years as a result of expansion of urban areas which has lead to residential construction, sand filling and wetland farming (flood plain Agriculture). In return, this has led to loss of habitats by organisms, modification of the local hydrology, invasive species encroachment, salt water intrusion and water quantity and quality reduction.

There exists significant evidence that ecosystems around the world are declining in terms of the species that live in them and the services that they provide for humans (Daily, 1997; World Resources Institute, 2002) and experts have therefore concluded that within a few decades, virtually all of the world's ecosystems will have suffered significant negative impacts from human activities. There are immediate causes of this trend, but underlying these causes is the fact that humans give a relatively low value to ecosystems compared with the value given to activities that potentially degrade them. Many economists and ecologists argue that this lack of clarity about human dependence on the environment is a major force underpinning environmental decline (Pearce and Moran, 1994). It also limits public support for better environmental management. For example, experts can agree that ecosystem of all sorts around the world are in poor and declining condition with respect to the purification and delivery of water (World Resources Institute, 2002), but the majority of people do not understand what this means for them in their day-to-day decisions and thus, ecosystems continue to be given low value in economic decision and there is limited political will to address the issues.

People seek multiple and different services from ecosystem and thus perceive the condition of an ecosystem in relation to its ability to provide the services desired. The ability of ecosystems to deliver particular services can be assessed separately with various method and measures. An adequate assessment of the condition of ecosystems, the provision of services, and their

implications for human being well-being require an integrated approach. With such an assessment in hand, a decision process can then determine which set of services are valued most highly and can manage the system in a sustainable way.

In a narrow sense, the sustainability of the production of a particular ecosystem services can refer simply to whether the biological potential of the ecosystem to sustain the yield of that services (such as food production) is being maintained. Thus, a fish provision services is not degraded by human activities. More generally, however, sustainability is used in the context of "sustainable development" to refer to a pattern of development that meets current needs without diminishing prospects for future generations. Sustainability and sustainable management refer to this goal of ensuring that a wide range of services from particular ecosystem is sustained. Therefore, information about the condition and sustainability of each category of ecosystem services is of great importance. This study is designed to provide information about the state of wetlands in metropolitan Ijebu Ode. Lambin *et al*, (2003) has reported the need to understand land-use/cover changes and its effect on the overall ecosystems. Understanding local patterns and processes is important since land-use and ecosystem change is closely linked to the sustainability of socio-economic development (Lambin *et al*. 2003). There is increasing evidence that variables interacts across spatial and temporal scales to cause changes and result in varied clusters, which vary across regions and time and that areas affected by degradation can be identified and mapped in order to cope with the variability. There is then the need to understand the past and present pattern of land-use/cover so as to device appropriate adaptive mechanisms for enhanced sustainability. Therefore, this study seeks to assess the extent and trend of wetland ecosystem in Ijebu Ode.

Study Area

The study was conducted in Ijebu-Ode Local Government Area (LGA) of Ogun State. In actual sense, the study area falls within two LGAs in the State; Ijebu Ode and Odogbolu Local Government Areas. The wetland area is really the boundary that separated the two LGAs, but because of the nature of urban development in the area, the entire place is still classified as Ijebu Ode. The area can be located between latitudes 6^0 47'N and 6^0 52'N and between longitudes 3^0 53'E and 3^0 59'E (Figures 1 and2). Ijebu-Ode is an ancient city, which is centrally located in relation to other human settlements around it.

Geologically, southwestern Nigeria rests wholly on basement complex structure of old crystalline rock which in turn is overlaid by deeply weathered sedimentary rock units that include Abeokuta, Ewekoro and Ilaro Formations, in addition to the Coastal Plain Sands. Occurring in different parts of the study area are the Basement Complex rocks, Abeokuta and Ilaro Formations, as well as the Coastal Plan Sands.

Generally, Ijebu-Ode's climatic condition is of alternate wet (April to October) and dry seasons from (November to March). The mean annual rainfall is between 1523 mm and 2340 mm, while the temperature ranges between 25^0C and 32^0C with the average annual temperature of about 27^0C.

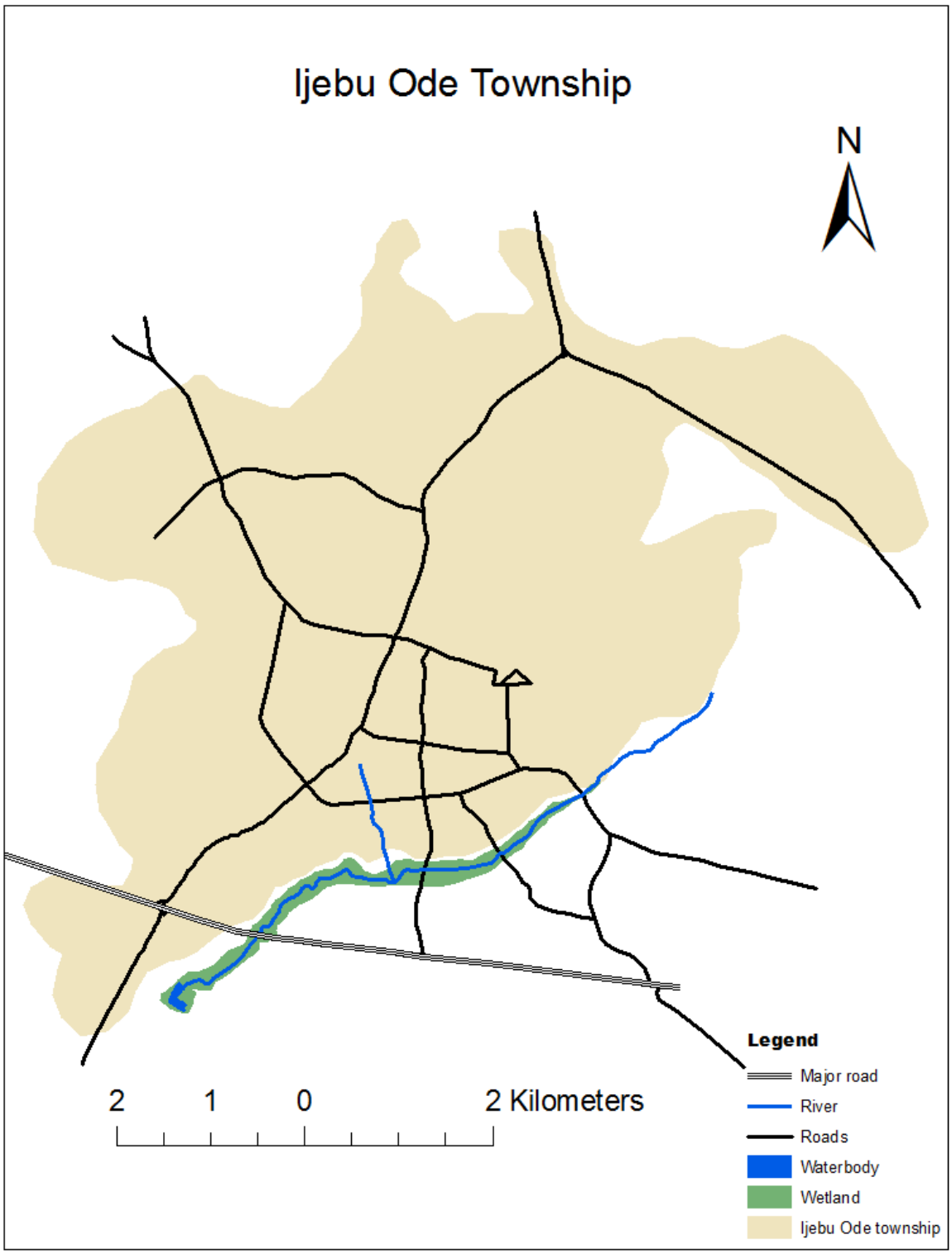

Fig. 1: Map of Ijebu-ode township

The alternate season of wet and dry is responsible for fluctuation in the volume of surface water bodies, such as rivers and streams in Ijebu-Ode (Ogunnowo, 2004). Ijebu-Ode region is well drained by some rivulets/streams that are historically connected to the founders of Ijebu Kingdom. The rivers include Osun, Yemoji, Okanmiayan, Aye, Atikiriji, Ona while the streams include Yemule, Owa and Eriwe.

Research Method

Data Source

Two remotely sensed imageries were obtained for this study. The first is a SPOT-MS of 1984 while the second is also a SPOT- MS of 2007. Accordingly, the study period covered about 23 years. The two imageries were obtained from the National Space Research and Development Agency (NASRDA), Abuja. The imageries were trained accordingly while the method of supervised classification was adopted for the classification of land-use within the area. Thereafter, groundtruthing exercise was carried out to verify and ensure that the land-use was appropriately classified. The projection used for the image registration and final map production was Universal Transverse Marcator (UTM), zone 31.

Table 1: Land use classification scheme

Code	Land use classification
1	Wetland
2	Built-up area
3	riparian forest
4	Water body

Method of Data Analysis

Two methods of data analysis were adopted in this study.

(i) Calculation of the land-use area in kilometers for each study year and subsequently comparing the results.

(ii) Overlay Operations

The two methods mentioned above were used for identifying change in the land-use types with time. The comparison of the land-use land cover statistics assisted in identifying the percentage change, trend and rate of change between 1984 and 2007. In achieving this, the first task was to develop a table showing the area in kilometres and the percentage change for each year (1984 and 2007) measured against each land-use land cover type. Percentage change to determine the trend of change can then be calculated by dividing observed change by sum of changes multiplied by 100. Furthermore, a Markovian chain analysis was used to describe land-use change from one period to another, and this was used as the basis to project future changes. Finally, an overlay operation was carried out which was presented in map format. Overlay operation shows the area where changes have occurred over time. In other words, the vector extracted from 1984 imagery was superimposed on that of 2007, and by so doing the

areas of change were clearly identifiable pictorially while the statics obtained were subsequently used for the computation. The rate of change obtained was thereafter used to project the change in wetland area that is likely to occur by year 2020. Also during the groundtruthing and field observations, certain biological species that are peculiar to wetland environments were identified. The areas/communities under the influence of this wetland include Oke-Owa, Imoru, Ondo and Ijagun road axis. These areas constitute a major landscape or basin that drains major rivers that dissect Ijebu-Ode Township.

Results and Discussion

Using Geographical Information System (GIS), remote sensing and habitat assessment techniques, Figure 2 depicts the state of wetland in Ijebu Ode between year 1985 and 2007 and based on this, the following inferences are discussed.

Ecological Dimension of Wetland Uses in Urban Ijebu-Ode

Due to socio – economic and environment purposes, Ijebu-Ode urban wetland is being put to different use. The habitat assessment and ground truthing techniques revealed the havoc that has been done on urban wetland of Ijebu Ode. Figure 2 reveal changes that have occurred on the wetland between year 1985 ad 2007. While there was an observed expansion of the cities of Ijebu ode, the wetland which was tailed toward the eastern part of the city in 1985 was experiencing sand filling as at 2007, showing great anthropogenic impact. While the area covered by wetland in the year 2007 was 1.04 km^2 with a perimeter of 11.56 km, in 1985 the perimeter was 17.4 km and the wetland covered area was 1.38 km^2. About 0.34 km of the wetland area has been lost to different uses such as construction between the year 1985 and 2007. Within the 22yrs, it means that the wetland is reducing at the rate of 1.5% (0.02 km) per year. What that implies is that by now (2011), it would have been depleted to about 0.39 km. This shows that the wetland is being used by people thereby preventing the continuous natural enjoyment of the natural services played by it. Thus, the uses of wetland for cultivation, settlement and infrastructural development, solid waste disposal as well as fishing have had ecological consequences on the sustainable functioning of wetland.

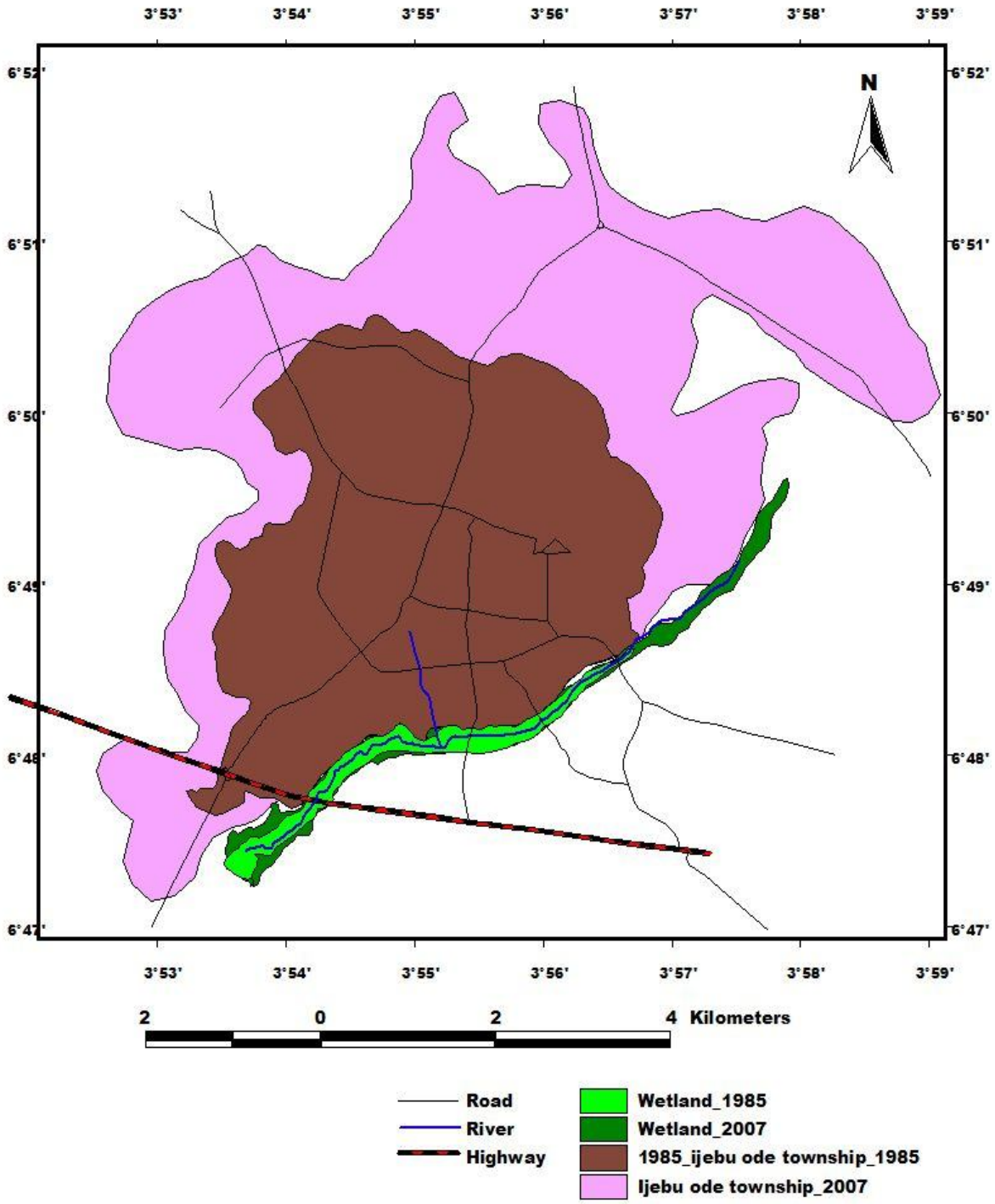

Fig. 2: Changes in wetland areas of Ijebu-ode between 1984 and 2007

The use of wetland for cultivation has lead to the problem of infilling of the wetlands which have also led to the reduction of wetlands. Intensive ploughing and harrowing close to the wetland area have accelerated soil erosion leading to infilling of the wetlands by deposition of soil and organic materials carried through surface runoff or overland flow.

Alien Invasion in Wetland

The use of wetland for cultivation has also disturbed the species composition in the area. The disturbance of the area has attracted rooted plants. The sea hen plant species common in this area have now entered the wetlands and are now out-competing the wetland species. As a result the ecology of the area has changed. The presence of the hen species is also leading to the reduction of water in the wetlands. The presence of rooted plant (a hen species) in the wetlands has strong negative effect on the habitat value of wetland. Increased shading caused by the presence of trees cover has decreased the vigour of indigenous plant, such as sedges, bulrushes and reeds, which were not adapted to this condition, with the possible extinction challenges.

Loss of Biodiversity

The use of wetlands for settlement and infrastructural development has led to the destruction of most of wetlands plant species such as reeds, sedge and grasses. In the absence of these plant species, the wetland is failing to play their important functions such as trapping of sediments, removal of waste material and purification. This loss is leading to total destruction of the wetland and this has impacted the ecology of the areas. This is mostly observed at Ondo road axis.

Pollution in Wetland

People see wetland as a waste land for the disposal of solid and sewage waste, which is rampant in urban wetlands. As a result of this, the water's natural purification process in the wetland has ceased to operate as more and more solid wastes and sewage are been disposed into the wetlands. The waste has discolored the water, thus reducing the penetration of sunlight that is essential to biological activities. This in turn greatly lowered the quality of water. As a result, this foul-smelling water is no longer home of fish and other aquatic organism; it becomes unsafe for human consumption. It also makes the area to become an eye sore and unattractive for human being. Greater impact on the fish and aquatic animals are noticeable. Reduction in the magnitude of wetland due to water diversion was also observed.

Conclusion

The wetland in Ijebu ode had witnessed interference of human activities in the form of infilling of wetland, loss of biodiversity, alien invasion and pollution of wetland areas. It is posited that in order to retain the ecological value and enjoy the ecological services rendered by wetland, urban wetland should be sustainably used. Advocacy is therefore necessary for more environmental education, public orientation while favourable policies and planning programmes toward wetland sustainability in Ijebu Ode and its environs should be put in place.

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Strategic Planning Methodology and Guidance for Establishing Effective Floodplain Management Programmes: Case Study Oyan Dam floodplain

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Abstract

Policies and regulations in Nigeria have put in place adequate regulatory framework for water resources utilisation, protection and management. In the same manner there are adequate laws and regulation to mitigate the negative effects of floodplains development, but unfortunately, these provisions have not adequately taken care of the benefitting stakeholders. This presentation looks at the roles of the various statutory development agencies and believes that the State and Local Governments have huge roles to play in the development programmes of the water resources sector; floodplains and wetlands in particular. A simple strategic planning procedure is presented.

Keywords: Floodplain, reservoir, risk, stakeholder, strategic

Introduction

Oyan dam floodplain spans across the Rain Forest into the Lowland Rain Forest. The Oyan Dam is very important for water provision to both Ogun and Lagos States and has a good potential for 9MW of power production; it is a high risk dam considering the downstream settlements.

Oyan River Dam

Dams are very significant human interventions in the hydrological cycle and have been significant part of social development for many centuries (Acreman, 2000). They are built to impound water in reservoirs during times of high flow, so that it can be used to meet water requirements during times that natural flows are inadequate. The Oyan River Dam (Figure 2) is one of such structures and it is in Abeokuta North Local Government Area of Ogun State in the South-West Nigeria. It is about 20 km North-West of Abeokuta, the State capital. The dam was constructed across Oyan River, a major tributary of Ogun River. It is primarily conceived to supply raw water to Lagos and Abeokuta, but with auxiliary uses in irrigation and power generation.

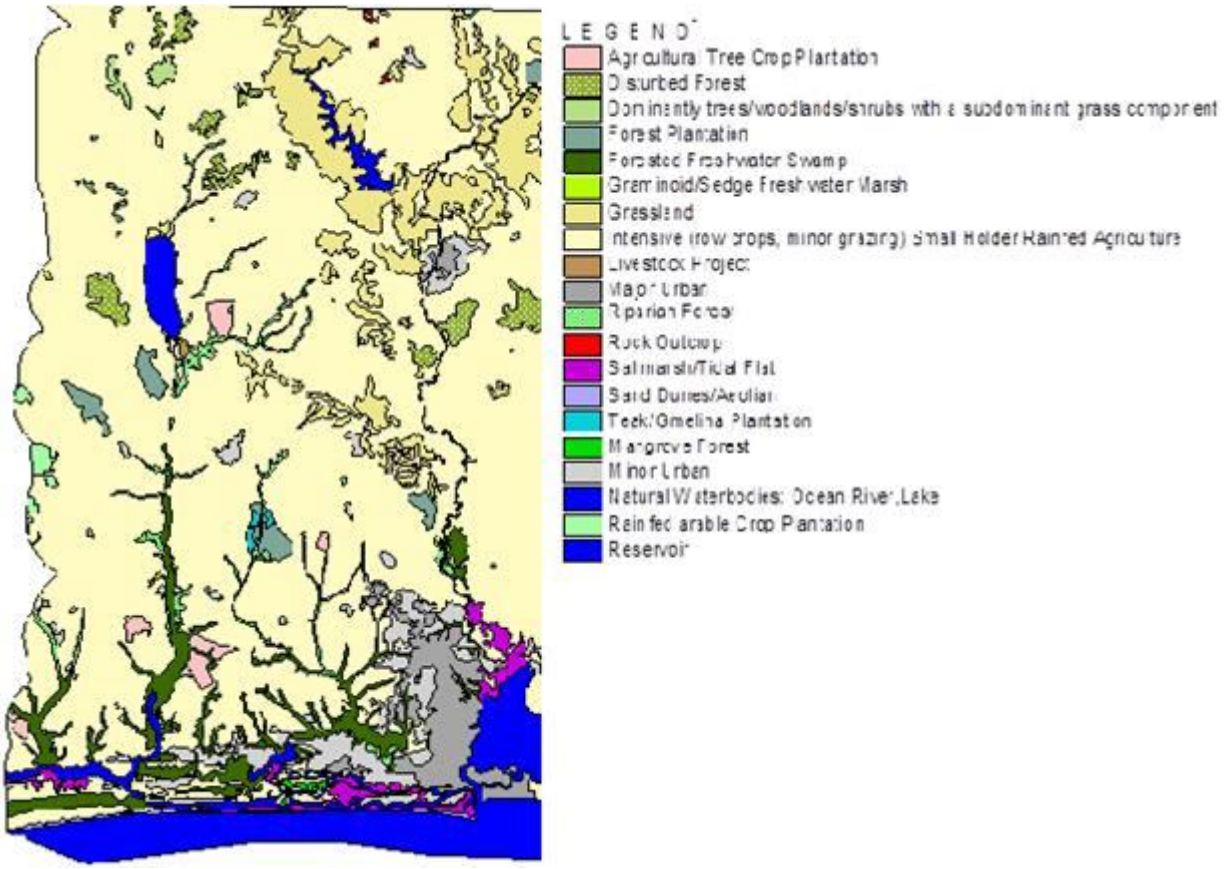

Fig. 1: Oyan Floodplain Landuse Pattern

Fig 2: Oyan Dam Downstream Face showing Hydropower Building

The dam was commissioned on 29 March, 1983 and is operated by the Ogun-Oshun River Basin Development Authority (OORBDA). The reservoir is situated within the coordinates 07^{o} 15 – 07^{o}

25' N and 03^{o} 06' – 03^{o} 18' E. It is in the northern fringe of the rain forests belt. It covers 4,000 hectares and has a catchment area of 9,000 km^{2}. The dam has an embankment crest length of 1044 m, a height of 30.4 m, four spillway gates (each 15 m wide and 7 m high), and three outlet valves (each 1.8 m in diameter). The reservoir has a surface area of 40 km^{2}, a gross storage capacity of 270 million m^{3}, and a dead storage capacity of 16 million m^{3}. Three turbines of 3 megawatts each were installed in 1983, but as of June 2010, they had not been used. During construction, 22 villages were submerged, with the displaced people moved to three settlement camps. Some of the settlers fish on the lake and grow vegetables along the fertile shoreline as the lake recedes in the dry season.

The dam was designed to support 3,000 hectares in the first phase, but development has not fostered the plan. The lake is relatively rich in fish and other wildlife, and has potential for ecotourism. The reservoir is used for breeding fish, sprinkler irrigation, and water supply to downstream end-user and livestock watering.

Water discharge is by a regulated opening of the gates and valves. For water releases to the intended users, the percentage opening for each day is set and the water level is read off an automated gauge. Water discharge during each opening period was read off an operating chart provided by the construction engineers.

Stakeholders

Wetlands provide both direct and indirect economic benefits to communities located within them**.** The people living within Oyan Dam Floodplain gather wetland resources such as timber, snails, wild meat bamboo shoots and mushrooms in the rainy season, as well as other minor forest products e.g. honey and edible plants. The water storage in Oyan reservoir was conceived for domestic consumption, agriculture, fishing, livestock watering and for power generation. Moreover, it was found that Oyan reservoir is an attractive resource for research, students' industrial attachment, outdoor recreation, adventure and nature study. The indirect values of Oyan floodplain as bird habitat, food sources of aquatic animals, underground water sources, prevention of flood and drought and for building conservation awareness is difficult to evaluate.

The Oyan floodplain traverses the lowland rainforest/montane forest southwards, through the freshwater swamp forest/mangrove forest and finally discharges into the lagoon of the Atlantic Ocean through the coastal vegetation ecologies. The physical and climatic diversity permits the growth of a wide variety of crops. The 960 km coastal area in the south is indented by lagoons and by the immense Niger River Delta. There exist four broad systems of land use in the floodplain: crop production (rotational fallow, semi-permanent or permanent cultivation) and mixed farming; livestock production (predominantly pastoral); fisheries (inland freshwater and brackish water); and forestry (agro–forestry). Bearing these uses in mind, the following roles and stakeholders are recognised:

i. Infrastructure development, management and coordination: The OORBDA as representative of the Federal Government

ii. Downstream infrastructure development and management: States and Local Governments, Agricultural Development Projects and other Federal and State Ministries and parastatals, lawmakers;
iii. Water users: Ogun State Water Corporation, Lagos State Water Board and Power Holding Company of Nigeria (Oladoja and Adeokun, 2009);
iv. Resource users: crop farmers, Fulani pastoralists, livestock farmers, fish farmers (Ikenweiwe et al, 2007);
v. Resource harvesters: fishermen, hunters, firewood exploiters, cottage industrialists;
vi. Researchers: Federal University of Agriculture, University of Lagos, Ogun State University, Nigerian Institute of Freshwater Fisheries Research, etc (Oyebande et al, 1980; Akinbile, 2007; Ikenweiwe et al, 2007; Omotayo, 2010)
vii. Pollution Monitoring: National Environmental Standards Regulation Enforcement Agency NESREA and States' Environmental Protection Agencies (Ofoezie et al, 1997; Ofoezie and Asaolu, 1997; NIFFR, 2002; Uyigue, 2005; Steinmann et al, 2006; Sam-Wobo et al, 2009)
viii. Disaster control and relief management: Federal and States' Emergency Management Agencies and Local Governments (thenationonline, 2009)
ix. Extension works: States' Ministries responsible for Agriculture, States' Agricultural Development Projects and Local Government;
x. Land monitoring and peace making: Local Governments and the traditional rulers;
xi. Rural land allocation & monitoring: Local Government, Traditional rulers

Table 1: Floodplain Situations

S/No	Stakeholder	Constitutional Mandate	Accomplishments	Remarks
1	FGN/ OORBDA	Develop Infrastructure	i. Developed Dam ii. Flood monitoring and regulation iii. Hydropower infrastructure (Fig. 2) iv. Fishery regulation and control v. Established 3No settlement camps: Ibaro and Abule Titun in Ogun State and Igbo-Ora in Oyo State vi. Irrigation facility emplacement is on-going	Oyan Dam is a high risk structure thus there is need for proper funding for effective maintenance of the structure (Fig 3). Needs strengthening to be able to complete planned irrigation scheme. (Fig. 4) For effectiveness irrigation, fisheries, etc. development should be ceded to the States and Local Governments.
2	States	Downstream infrastructure Development	Water Supply through the water Supply Agencies.	There is need for the states to be involved in downstream infrastructure development for fishery, Agriculture, Irrigation, Tourism, etc. in accordance with the provisions of Chapter II of the the Constitution (FGN, 1999). .
3	Local Govts		Noticeable involvement of these groups are not observed	The Local Government are to function in the Government of the State in matters relating to primary, adult and vocational education, health and the development of agricultural and natural resources and other functions a that may be conferred by the State Assembly (FGN, 1999a)
4	Legislators			
5	PHCN	Power generation	Nil	PHCN needs to immediately set up the machinery to work with the OORBDA towards commissioning of the 9 MW potential on this dam
6	Resource users	i. Farming, fishing, livestock, etc	Level of participation limited by finance, technology, education, land ownership,	Coordination by the extension agents of the States and Local Governments is essential
7	Researchers	Academic requirements for promotion	Fisheries, flood mitigation, agriculture, tourism, livestock, health, socio-economics: UL. FUAB, UI, OgSU	Very little research funding are noticed in the reports accessed.
7a	NIFFR	i. Fishery ii. Water weed control and utilisation	i. Clupeid enrichment of small water bodies ii. Annual Pre-season Training of Rural Fish Farmers	This agency needs funding to be very effective
S/No	**Stakeholder**	8**Constitutional Mandate**	**Accomplishments**	**Remarks**
8	Students	Industrial Attachment	293 University of Agriculture, Abeokuta students on IT between 1994 and June 2006	This floodplain offers excellent environment for IT in agriculture, water resources, tourism, etc
9	NEMA/SEMA	Disaster relief and mitigation measures	May 2009- Oyan dam flood Sept 2009, 2010 Across the country (Fig	These agencies should mature beyond relief to mitigation measures
10	NESREA/ SEPA	i. Water quality standards ii. Limitations on effluents for source points iii. EIA assessment for new projects 1992	i. Investigations into distribution of snail host and human schistosomiasis.	NESREA/SEPA need to be properly strengthened to maintain and improve the quality of the unique environment resource endowment and physical characteristics of the wetlands and prepare ecological masterplans to guide the use of wetlands for diverse and often conflicting individual and social activities for the continuous viability of all aspects of the ecosystem
11	Ministries of Agriculture	i. Agric. Landuse mapping ii. Extension Services	Both Ministries have extension agents but are lacking in facilities to carry out the extension work.	Adequate capacities are not made available at state level for project implementation.
12	Ministries of Commerce and Industry	Tourism	The Ministries will have to address the issues of high, uncompetitive costs to the export oriented businesses, low capacity utilisation for medium scale industries and frustration, late deliveries and poverty to small-scale businesses (OgSG,	Promote establishment of infrastructures for tourism, water sports, cottage industries, etc (kenweiwe et al, 2007)
13	Community Leaders	Land allotment advisory services to Local Govts, States	Land allotment, conflict resolution	Most conflicts can be resolved at LGA level with the assistance of traditional rulers of the communities concerned (Fig. 5). There is need to develop a strategy for On-Farm Animal Feed Security (Fig. 6 & 7))
14	Inhabitants and Developers	Ensuring compliance with development regulations	Very often obtain fake permits or out of ignorance for development purposes and thus are subject to flooding (Fig. 8).	Developers will benefit from Enlightenment campaign and community education programmes. States and Local Govts should rise up to provision of facilities (education, health, etc) and for the citizenry (Fig. 9)

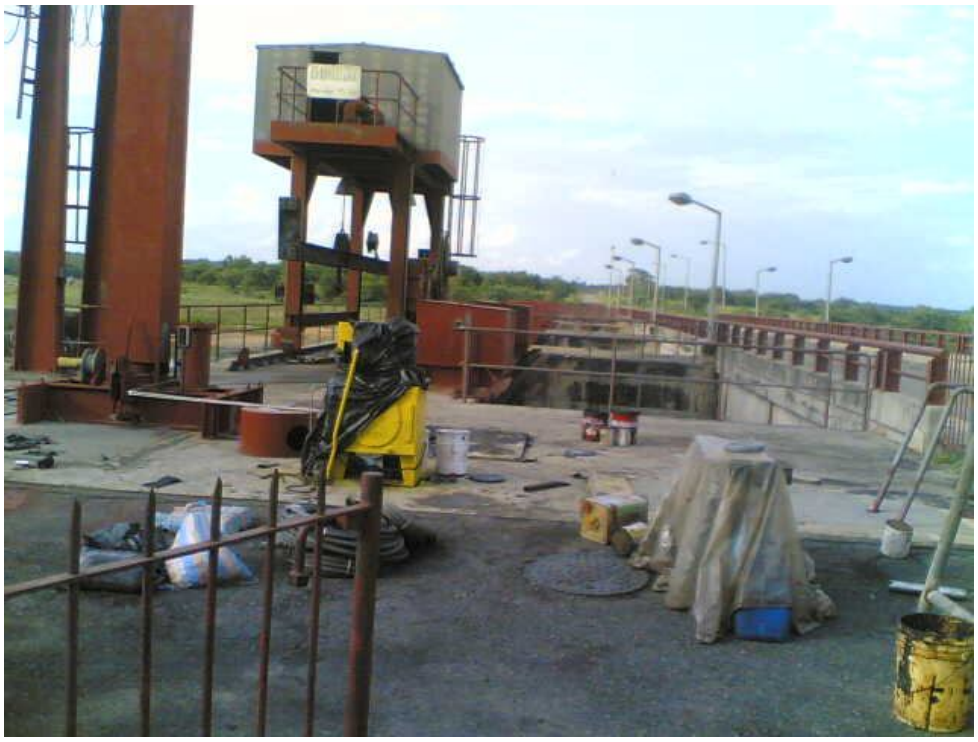

Fig. 3: On-going maintenance activity (May, 2010)

Fig. 4: Construction activity for expansion of irrigation scheme

Fig. 5: The Baale of Ibaro with some members of the community

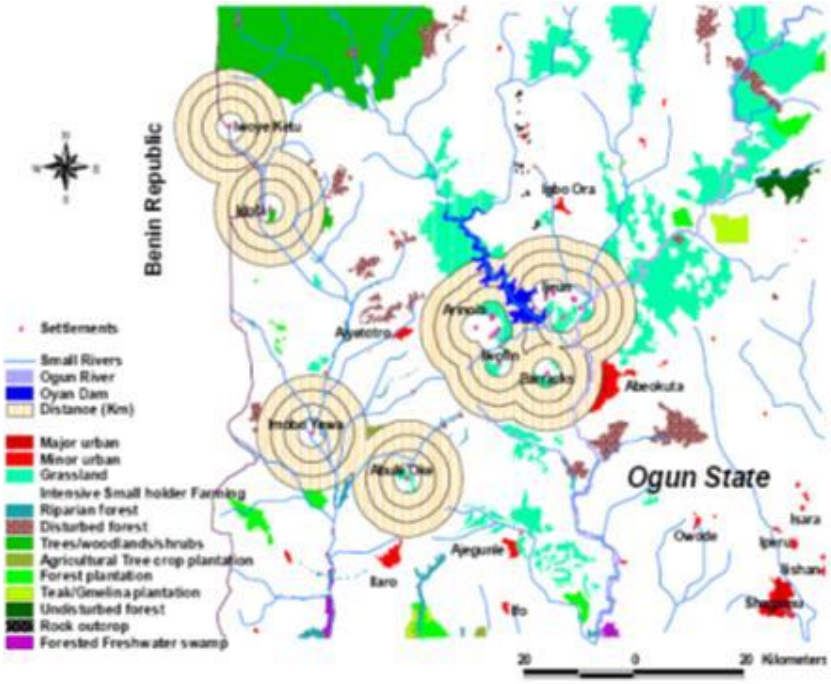

Fig 6: Map of a section of Ogun State showing the spheres of influence of Fulani Pastoralists' activities (Omotayo, 2010)

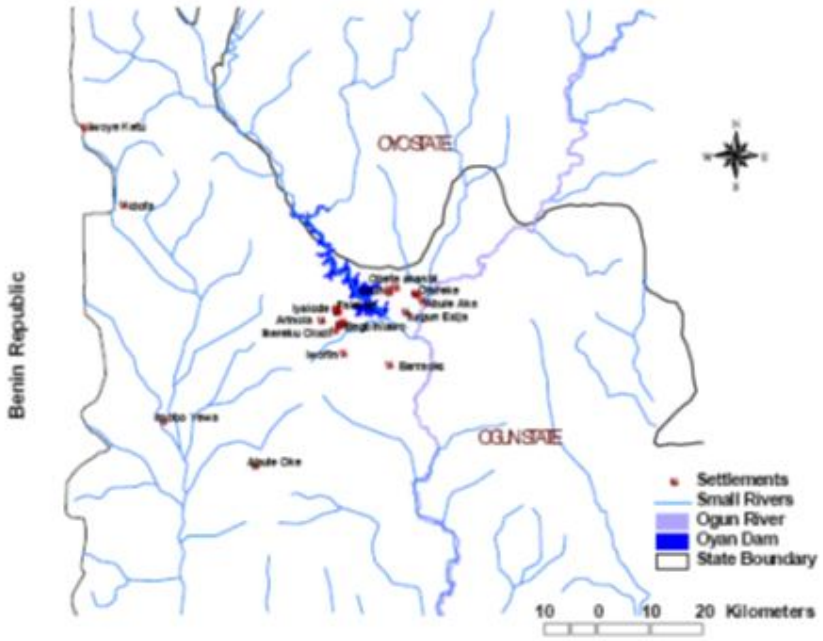

Fig.7: Map of a section of Ogun State showing Fulani Pastoralist settlements

Fig 8: Flooded Ikorodu Area of Lagos (Metro Oct 19, 2010 Vanguard on line edition)

Table 2: Summary of Infrastructure Situations

S/N	Infrastructure	Availability	Remarks
1	Electrification	Poor	No electrification is observed in Ibaro community
2	Water Supply	Poor	Water supply is from wells
3	Transportation	Poor	Commercial vehicles are scarce: probably only on hire
4	Communication	Fair	GSM networks exist
5	Healthcare	Poor	The walking distance to a hospital is 14 km
6	Education	Poor	No secondary school. The roof of the existing primary school is blown off (Fig. 9)

Fig.9: The Primary School in Ibaro (January, 2011)

Dam, Reservoir and Floodplain Management Scenario

Dams, reservoirs and floodplains are components of water resources. The constitution of the Federal Republic of Nigeria charges the three tiers of government in Nigeria to be involved in the administration and management of water resources in the country since the management and development of water resources is in the exclusive and concurrent legislative list in the Nigerian Constitution (FGN, 1999b).

At the Federal level, there is The Federal Ministry of Water Resources (FMWR) with the River Basin Development Authorities. At the State level, we have the administration of water resources being undertaken by various State Ministries such as Agriculture, Natural Resources, Works and Public Utilities. At the Local Government level, attention is paid to rural water supplies and sanitation.

The overall management of water resources is the exclusive responsibility of the FMWR headed by the Minister for Water Resources with the responsibility to enforce all national policies, federal laws and regulations relating to water resources management and development. The FMWR thus has the overall responsibility for policy advice and formulation, data collection, monitoring and planning, management and coordination of water resources.
The Federal Ministry of Water Resources, like the River Basin Development Authorities, was not spared the consequences of policy inconsistencies as it was severally merged and separated from the Federal Ministry of Agriculture and Rural Development in the past. The series of changes affecting the institutional arrangements, in term of policies and acts, are as detailed below:

1915 The Waterworks Act of 1915 wherein Colonial Nigeria (shortly after Amalgamation in 1914) passed the law specifically to keep water from being polluted. It prohibits the pollution of water in Nigeria by noxious or harmful matters;

1917 The Minerals Act of 1917 (as amended), now Cap. 226 that This law vests the Head of State of Nigeria with power to make regulations for the prevention of pollution of any watercourse;

1917 The Public Health Act of 1917 prohibits the fouling of water and vitiation of the atmosphere;

1968 The Oil in Navigable Waters Act, 1968 prohibits water pollution by oil spillage;

1969 The Petroleum Act, 1969 covers prevention of pollution by inland waters, rivers, lakes and watercourses;

1971 Public Health Act, 1971 which prohibits the fouling of water and the Pollution of the atmosphere;

1972 The National Electricity Power Authority Act, 1972 in part 11, empowers the Authority to construct buildings and works necessary for the abstraction of water from any lake, river, stream or other natural;

1973 Decree No. 33 of 1973 establishment of the Sokoto Rima Basin Development Authority and the Chad Basin Development Authority;

1976 Decree No. 35 of 1976 that increased the number of River Basin Development Authorities from two to eleven;

1979 Decree No. 37 of 1979, that expanded the scope of activities of the RBDAs to include the development of water resources, agriculture, transportation, fisheries, livestock, forestry, industrialisation, rural development, energy, etc;

1980 Establishment of the National Council on Water Resources;

1985 Decree No.3, 1985 that established the National Water Resources Institute located at Kaduna as a training and research institution;

1987 Decree No. 35 of 1987 was enacted to repeal the 1979 Decree, thus modifying the functions of the RBDAs to exclude agriculture, transportation, fisheries, livestock, forestry, industrialisation, rural development, energy, etc.;

1988 Harmful Waste (Special Criminal Provisions, etc.) Act 1988 prescribes Criminal Prosecution for dumping of harmful wastes in Nigerian Territorial Waters or its Inland Waterways;

1989 National Policy on Environment 1989;

1990 RBDA Act, 1990 defines the mandate and functioning of the River Basin Development Authorities;

1990 Oil Pipelines Act 1990: Empowers the NNPN to refrain from issuing any license as would permit the construction of such works in, under or over, or deposit such material in or make such alteration in the flow of water required for domestic, industrial or irrigational use as would diminish or restrict the quantity of water available for such purpose, or construct such works or make such deposit in any waterway as would cause flooding or erosion;

1990 The Minerals Act, 1990 which while vesting control of all rivers, streams and water courses throughout Nigeria in the State authorities empowers the Minister for Solid Minerals Development to issue licenses to the holder of a mining lease for construction of a dam, reservoir, pumping station or any construction for the collection, storage, conveyance of water for mining activities;

1991 National Effluent Limitation Regulation 1991: Control of discharge of industrial waste and sewage into watercourses;

1991 National Guidelines and Standards for Environmental Pollution Control in Nigeria 1991: Pollution control in watercourses as part of the environment;

1991 Nigeria Ports Authority Decree, 1991 empowers the Nigerian Ports Authority to supply water to shipping vessels and control pollution arising from oil or any other substance from ships using the port limits or their approaches. The authority also has power in section 8 to construct work and develop embankments and jetties;

1991 Pollution Abatement in Industries and Facilities Generating Wastes Regulation 1991: Control of industrial pollution;

1991 The National Electricity Power Authority Act, 1972 in part 11, empowers the Authority to construct buildings and works necessary for the abstraction of water from any lake, river, stream or other natural;

1991 Waste Management Regulation 1991: Waste management;

1992 The Environmental Impact Assessment (EIA) Decree, No. 86 of 1992 seeks to protect the physical and aquatic environment;

1993 The Water Resources Act 1993 vests control of all surface and groundwater and any water course affecting more than one State in the Government of the Federation for purpose of planning, co-ordination and management;

1997 The Inland Waterway Authority Act, No 13 of 1997 empowers the authority to grant licenses for water intake in respect of all Federal navigable waterways as contained in the second schedule of the Act in respect of navigation of those waterways;

1999 The 1999 Constitution of the Federal Republic of Nigeria puts in the Exclusive Legislative List (ELL) shipping and navigation on the River Niger, and on any such other inland waterway, as may be designated by the National Assembly to be an international waterway or to be an interstate waterway. The ELL also includes water from such sources as may be declared by the National Assembly to be sources affecting more than one and in the concurrent legislative list such acts as the regulation of the right of any person or authority to dam up or otherwise interfere with the flow of water from sources in any part of the Federation; protect and improve the environment and safeguard the water, air and land, forest and wild life of Nigeria.

2000 Niger Delta Development Commission (Establishment) Act, 2000 empowers the Niger Delta (Joint) Development Commission to conceive, plan and implement development projects for waterways and water supply in the Niger Delta and addressing environmental problems arising from oil exploration, and also to advise States on prevention and control of oil spillage;

2007 NESREA Act 2007: With the approval of the Minister, NESREA can "establish programmes for setting standards and regulations for the prevention, reduction and elimination of pollution and other forms of environmental degradation in the nation's air, land, oceans, seas and other water bodies and for restoration and enhancement of the nation's environment and natural resources;

The 36 States all have additional and separate laws designed for the management of water in their jurisdictions. In RBDA Act 1990, the RBDAs are charged in their respective catchment areas with the development of surface and groundwater resources with emphasis on provision of irrigation infrastructure, control of floods and erosion and watershed management. They are empowered to construct, operate and maintain dams, dykes, wells, boreholes, and irrigation and drainage systems. They are also charged with the supply of water from storage schemes and the development of comprehensive water resources master plans (Okoye, 2007). However, as part of its service provision and delivery goals, OORBDA intends to facilitate policies of the government in putting all irrigable land under irrigation

projects into use by the year 2025. It is hoped that the States and Local Governments within the catchment areas of these RBDAs will immediately rise up to these opportunities of harnessing the potentials of these development for the benefits of the citizenry and relief the RBDAs the ordeal of awaiting funds for project completion. Some limitations facing OORBDA are:

i. The inadequate fund allocation and releases for projects affect ability to attain Missions and Vision.
ii. Lack of fund to ensure staff training and development.
iii. Insufficient relevant equipment to prosecute projects by direct labour**.**

Strategic Planning

Planning becomes feasible and usable when specific problems are identified and there is concerted plan to address the issues involved. Very often, such comments by the intelligentsia like "these flood-induced emergencies occasioned by water deliberately released from dams (Usoroh, 2010)" are orchestrated in the news media. An extreme case is the court action by the Niger State Government against PHCN (Sule et al, 2011). The Niger State action is an attempt to divert the attention of the populace from its inability to rise up to the challenges of its responsibilities (FGN, 1999) to the citizenry. If the other States have not taken PHCN to court, they are not faring better in the discharge of their responsibilities with regards to flood situations.

The Strategy

In addition to the flood management challenges, OORBDA needs a consistent cooperative approach to support States and Local Government partnerships and the ability to leverage State capability. Strategic planning is a collaborative business practice that can be used by OORBDA, the States and the LGAs to establish a vision for an effective and comprehensive State floodplain management programme/partnership. It can increase development activity and financial accountability and link funding to State and Local Government needs, capabilities and capacities.

Strategic Plan Goals

The following goals may be considered appropriate for the strategic plan for a floodplain:

i. Lead an integrated approach that strengthens the Nation's ability to address disasters, emergencies and plans;
ii. Deliver easily accessible and coordinated assistance for all programmes;
iii. Provide reliable information at the right time for all users;
iv. Allow for mutual investment by the service provider and the beneficiary to ensure mission success;
v. Build public trust and confidence through performance and stewardship.

To accomplish the goals the programme shall be:

i. Clear, well-communicated and based on well-understood national policy;
ii. Beneficiary-focused, field-based, and results-oriented;
iii. Compassionate and oriented towards service delivery to all stakeholders;
iv. Provided executing agents with strong leadership spirit subject to teamwork and accountable at all levels;

v. Have professional workforce of motivated employees who are empowered and equipped to act;
vi. Involved all stakeholders at all levels of planning, design, emplacement and management;
vii. Strong partnerships that leverage capabilities and capitalise on public-private efficiencies;
viii. Business approach focused towards achieving desired results with a strong foundation in technology,
ix. Emplaced a monitoring and evaluation schedule to ensure continuity and sustainability

Characteristics of Effective Floodplain Management Strategy

1. Establishment of an effective network of hydrometeorological information gathering, processing, storage and utilisation programme

It is suggested that in the first instance the ideal network size is determined. In determining the network, all potential users of the data should be consulted. Each station in the ideal network should be prioritised. In order to do this, a simple prioritisation system, such as the one in Table 3, will be useful.

Table 3: A simple prioritisation sytem

S/No	Category	Priority	Relative Importance
1	A	High	Major multi-purpose water resources development site, state boundary river, operation of major scheme, major ungauged basin, heavily polluted major supply source
2	B	Medium	Medium scale water resources development project site, secondary basin, industrial development area i.e. potential water quality problems)
3	C	Low	Minor irrigation project site, secondary gauging station on tertiary tributary, major water course but already extensively gauged

The above categories and priorities are merely highlighted by way of example. Each State /Local Government/ Development Stakeholder needs to set its own priorities based on its own policies and objectives. In prioritising sites, the following questions should be asked:

i. What are the socio-economic consequences of not collecting streamflow data at the site?
ii. What are the alternatives to establishing a streamflow gauging station at the site under consideration?

An estimate of the number of stations within each State, Division and Sub-division which can realistically be well maintained should be made. When deriving this estimate, the following factors should be considered:

i. The recurrent budget implications;
ii. Short and longer term manpower requirements and availability of suitably skilled personnel;
iii. Capacity of instrument repair, spare part provision and calibration facilities;
iv. Long term availability of logistic support facilities such as vehicles.

The ideal and realistic network size estimates should be compared. If necessary, the size of the ideal network should then be reduced by removing the lower priority stations.

For OORBDA, the coordination of the hydrometeorological network shall be the responsibility of the OORBDA, but will be subject to harmonisation with the national network. An ideal network would comprise:

i. Thermometer (Max/Min/Ord);
ii. Automatic Raingauge;
iii. Barograph;
iv. Hair Hygrograph;
v. Thermograph;
vi. Pyranograph;
vii. Sunshine Recorder;
viii. Soil Thermometers (5,10,20,30,50,100cm);
ix. Barometer;
x. Dew Recorder;
xi. Grass Minimum thermometer;

However, Local Governments may not be able to maintain this ideal station, but may, in some cases be limited to meteorological stations which can be placed in schools for data collection and as visual aid for learning in natural sciences.

2. Floodplain management programmes need strong, clear authority.

i. A floodplain development programme must be registered with the administering RBDA; and
ii. Effective wetlands development programmes should be stable and long lasting – they are founded with clear legal authority, work cooperatively with Local Governments and other State and Federal agencies, and are supported by adequate resources. Good State-level floodplain management programmes allow evolution and improvement in response to changes such as major floods, new research and management techniques, and new Federal programmes and initiatives.

3. Floodplain management programmes should be comprehensive and integrated with other State and Local functions. Through proper coordination, well-informed efforts, the public and private sectors can:

i. Reduce loss of human life and property damage resulting from flooding;
ii. Preserve the natural, beneficial and cultural functions of floodplains; and
iii. Avoid actions that exacerbate flooding on others, now and in the future.

4. Flood hazards within the floodplain must be identified and flood risks assessed.

One of the basic foundations of floodplain management is the identification and delineation of flood prone areas and floodplain resources within the floodplain; however there is need to recognise that flood hazard areas change over time, through deliberate modification, development activities or as a result of natural changes in the watershed or the body of water itself. An effective floodplain management programme ensures that the

flood risks are known and that changing conditions are accounted for. Flood hazard areas need to be identified and delineated in order to:

i. Avoid future flood damage and disaster costs;
ii. Apply regulatory criteria;
iii. Inform property owners and the public; and
iv. Craft mitigation measures for existing at-risk development

5. Natural floodplain functions and resources throughout the basin need to be respected.

Effective State floodplain management programmes recognise the additional effort needed to manage the floodplain resources and functions, and allow for the fact that not all flood loss reduction techniques automatically account for natural functions and resources. Effective programmes take a holistic approach to floodplain management—one that moves beyond simply protecting people and property to recognising the value of allowing floodplains to function as floodplains, and enjoying the benefits that accrue when they do. Effective project planning coordinates and integrates their goals and activities with the many other projects (and federal, local, and private) programmes, agencies, and departments whose activities affect floodplain functions, such as:

i. Control of sediment and erosion;
ii. Protection of water quality, wetlands, aquifer recharge, and open space;
iii. Management of coastal areas, shorelines, overall growth, and stormwater;
iv. Preservation of wild and scenic rivers, rare and endangered species, cultural resources, and agricultural lands; and
v. Public recreation.

Effective State floodplain management programmes set a performance standard by ensuring not only that flood hazards are identified, avoided, minimised, and mitigated but also that floodplain functions and resources are protected whenever State construction projects or State-funded projects are undertaken. In addition, State floodplain management programmes should be comprehensive and be integrated with elements from many State agencies and programmes (ASFPM 2010, 2011a)-

6. Development within the floodplain must be guided away from flood-prone areas; adverse impacts of development both inside and outside the floodplain must be minimised.

Adverse floodplain impacts can be avoided or minimised if communities within the floodplain have the authority, tools, and political will to guide development to less hazard-prone areas, or to examine the full extent of impacts—both on-site and off-site—when floodplain development *is* proposed. By guiding development away from flood-prone areas, the development agency protects its citizens in the following ways:

i. It protects landowners by requiring that their development activities meet certain standards to avoid flood damage to their property.
ii. It protects the entire community by requiring that those activities do not adversely affect others. (ASFPM, 2004)

Participating communities regulate the location and design of floodplain construction in order to minimise flood loss and guide development away from flood-prone areas (King, 2005).

7. Flood mitigation and recovery strategies should be in place throughout the floodplain.

There is usually a "damage, recover, damage again" cycle in flood situations, particularly since many developments and public infrastructure installations were constructed before the frequency and impacts of flooding were fully recognised. The flood cycle would thus continue unless it is broken by changing what is at risk.

Effective floodplain management programmes use post-flood mitigation and recovery strategies to break this cycle. Immediately after a flood, citizens and governments are most aware of the risks and far-reaching consequences of flood losses. In addition to prompting a higher degree of cooperation, this scenario may make it possible to leverage additional funds to implement specific flood-reduction projects because governments feel compelled to help right after a disaster.

8. The stakeholders need to be informed about flood hazards and mitigation options.

An effective State flood management programme provides the appropriate authority and encourages use of informational tools for flood hazards. Better informed citizens, property owners, private sector entities, public officials, and government agencies are more likely to make sound decisions about whether and how to develop and redevelop property, and how to make sound land and home purchases (ASFPM, 2004; ASFPM, 2011).

9. Training and technical assistance in floodplain management need to be available to the stakeholders.

Effective State programmes assess community needs and provide ongoing training opportunities and access to technical assistance. In most communities, floodplain management is just one of the many responsibilities that must be handled by small staffs, but the administration of the floodplain provisions can be quite complex, and the consequences of inadequate attention to the flood hazards can be disastrous and expensive. Effective planning and management programmes should be able to:

i. Produce a reference manual to inform local officials about floodplain management;
ii. Monitor how communities are administering their regulations, including enforcement actions for any violations;
iii. Support community efforts to participate in the Community Rating System;
iv. Hold workshops and training on a variety of issues;
v. Encourage local staff to become Certified Floodplain Managers;
vi. Support State-level professional associations;
vii. Produce newsletters and web pages; and
viii. Are accessible to local staffs. (ASFPM, 2004; ASFPM , 2011a)

10. The levels of funding and staffing for floodplain management should meet the demand within each project.

Effective floodplain management projects know that it is not enough to rely on Federal funding to meet State or Local Government needs or to effectively reduce State, regional and local flood costs and damage. Behind an effective floodplain management programme

are State executive and legislative branches that have committed adequate staff resources and funding to the necessary programme elements and agencies.

Effective projects have assessed the needed level of funding and staffing, based on factors appropriate to their States, such as frequency and severity of flooding, extent and capability of local administration and the anticipated functions of staff members. With this information, a budget is developed that includes salaries, operations, mapping, mitigation grants and other activities. Creative ways of obtaining funds and generating revenue should not overlooked.

The second most important element of an effective floodplain management programme is adequate financial and staffing support.

11. Monitoring and evaluation of the effectiveness of floodplain management programmes is essential and successes should be documented.

Achieving and maintaining an effective floodplain management programme is an ongoing effort. When programme effectiveness is measured through regular evaluations, it is easier to identify opportunities to make adjustments or to add new programme elements. An effective programme finds ways to tally and keep records on different aspects of the status of floodplain management within its jurisdiction, such as inventorying flood-prone property, taking advantage of the post-disaster period to document damage avoided and the success of mitigation projects, taking an accounting of areal extent of floodplain lands preserved in a natural state or otherwise protected, monitoring community programme administration, and tracking the progress of mitigation projects. Such data are essential in evaluating how effective programmes are, and how to adjust the programme to be even more effective.

Characteristics of a useful Strategic Plan

A useful strategic plan exhibits many characteristics (Cox, 1997). Specifically, it should be:

i. A set of priorities. Setting priorities allows for the plan to be adjusted according to changing needs or resources.
ii. Achievable, measurable, and time sensitive. Remember, it's better to do a few things well than many things poorly. The plan should contain goals that are measurable and have deadlines.
iii. Flexible and responsive to changing conditions. The plan is a road map that may contain unforeseen detours such as unexpected crises, new opportunities, or changes in resources.
iv. Short and simple. Plans that are more like a book will sit on a shelf. Keep it focused on the most important things to accomplish.
v. A unit, not a menu. A useful plan is not a wish book. Everything in the plan needs to be accomplished.
vi. The means to an end, not an end in itself. The plan is the process by which it reaches its destination; it is not the destination.
vii. Based on a three- to five-year period. The strategic plan should be a living document that has a one-year drop off and a new year added so that it always covers the same time period.

Conclusion

Floodplain development and management in Nigeria has been ascribed by other tiers of government to the Federal Government, whereas the Constitution of the Federal Republic stipulates that all the three tiers of government have responsibilities in this regard to the citizenry.

There is adequate regulatory framework for water resources utilisation, protection and management. In the same manner, there are adequate laws and regulation to mitigate the negative effects of floodplains development, but unfortunately, these provisions have not adequately taken care of the benefitting stakeholders.

This presentation is of the view that the resources available in the floodplains of Nigeria can best be harnessed for economic development if the three tiers of government play their respective roles. A simple method for the development of a strategic plan is presented.

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Need for Geo-scientific Maps for a Reasonable Planning and Physical Development of Coastal and Wetland Areas of Nigeria

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Abstract

The provision of various categories of Land Use Maps is fundamental to the planning and physical development of any area worldwide. The recent spate of wetland area development in different parts of Nigeria due to pressure on land without maps for planning is very dangerous and objectionable. This paper highlights the need for an urgent Governmental Policy to embark on the scientific production of maps for planning. Geo-scientific maps, such as Engineering Geological, Geotechnical, Remote Sensing and Seismic monitoring Maps of Coastal and wetland areas in particular, are urgently required for reasonable and economical planning. Some of the dangers inherent in the non availability of these maps are highlighted, with examples from the mega city of Lagos.

Keywords: Geo-scientific maps, physical development, coastal and wetland areas

Introduction

The progressive growth of population in the mega city of Lagos has resulted in very serious pressure on land for development. Land that was previously regarded as waste or difficult has suddenly become targets of all sorts of 'improvement' for development and converted to housing or industrial estates without adequate or essential professional and technical planning. Natural canals and muddy flood plains are being reclaimed by local and unauthorized persons with substandard soil materials under the supervision or contractor-ship of unqualified artisans for the construction of unplanned homes and commercial centers. The current spate of the incidence of collapsed buildings and dilapidated engineering infrastructures is not unconnected with this unfortunate situation. The mega city of Lagos is located in a wetland environment that requires very effective professional planning and development. Figure 1 show the topography of the southern part of the mega city, consisting mostly of the coastal sedimentary deposits, lagoons and swampy lowlands.

Figure1: Map of Lagos showing its location in Wetland environment

Like in many old towns and cities all over the world, Lagos has been developed over a few centuries without modern planning. Planned and unplanned developed areas are closely juxtaposed, creating a jumble of incongruent cultural outlook. It therefore seems that a beginning of modern planning has to be made by the commencement of the Technical Mapping of the various land components that constitute the mega city of Lagos. In addition to the production of various categories of Land Use Maps, Engineering Geological and Geotechnical Maps to guide the professional planning of the city, together with a number of Seismic Monitoring Stations should be established in the Coastal and hinterland wetland areas to monitor their daily magnitudes of seismicity.

Importance of Maps

Maps should be regarded as one of the most fundamental documents needed for land planning and subsequent development. Without maps, development is haphazard, dangerous, wasteful and unreasonable. Useful maps are in essence, professionally produced. They are documents that result from field and laboratory research, and each category of maps has a specific theme to propagate. Land use maps for instance are needed for the planning of all development schemes such as agriculture, housing, recreation centers, and forest reserves among others. The development of each scheme is subject to the establishment of State and bye-laws to prevent chaotic degeneration. In addition, special Technical Maps are essential to guide actual civil engineering planning, design and development. In the latter category of

maps are Engineering Geological and Geotechnical Maps. Their functions relate to the accurate location, field categorization and utilization to guide the design and construction of safe and economical foundations for all civil engineering structures. All civil engineering structures are founded on the earth's surface, and it is only reasonable that the long term stability of the structures is assured by an effective understanding of the possible immediate and long term behavior of soil materials under engineering usage. It is well known all over the world that any structure that is constructed but not in harmony with its foundation material and general geological environment sooner or later goes to waste.

Engineering Geological Maps

The formal establishment of the concept of Engineering Geological maps is a modern phenomenon. A special Commission on Engineering Geological Mapping was appointed by the International Association of Engineering Geology (IAEG) in 1968. It published its report that has since become the classical guide to the production of Engineering Geological Maps in 1972. A symposium was subsequently held in the University of Newcastle upon Tyne in 1979 to provide an opportunity for engineering geologists and civil engineers to meet together to discuss the methods, application and usefulness of mapping in engineering geological terms to planning, design and construction in civil engineering (Dearman et al, 1979).

The symposium focused on many aspects of the mentioned category of maps, with the presentation of many technical papers. The following aspects were examined in detail:

1. Regional engineering geological maps for planning
2. Hazard Mapping in risk evaluation for engineering structures
3. Civil Engineering site mapping practice
4. Land and Sea-floor geophysical mapping for civil engineering structures
5. Terrain Evaluation and Remote Sensing
6. Engineering Geo-morphological mapping

Each map category is essentially a large scale map, such as 1: 5000, 1: 10,000 1: 25,000. to facilitate a reasonable inclusion of essential geological features and structures (Dearman et al, 1979).

In recent years, very remarkable progress has been achieved in the composition and production of Engineering Geological maps in the industrially developed countries of Europe, North America, Asia Australia and New Zealand since 1979. By contrast in Nigeria, only a few attempts have been made to coordinate site investigation test results for the production of Engineering Geological maps. Akpokoje (1979) produced some preliminary maps of the Niger Delta area from a summary of geo-morphological, hydro-geological and some soil mechanics test data. Malomo et al (1980) produced a preliminary Engineering Geological Map of the Federal Capital City, Abuja for the proposed development of the City through a Geological Mapping assignment offered to the Geological Consultancy Unit of the Department of Geology, University of Ife. Madedor et al (1987) and Okogbue (1995) have similarly attempted to construct preliminary Engineering Geological maps of parts of the Niger Delta for civil engineering development projects. However, there is need to develop an understanding between the geological and civil engineering professions in Nigeria before Engineering Geological Maps can be acceptably produced and published to become regular documents in

the planning and execution of development projects in the country. It is a most unfortunate scenario that despite the remarkable development of multi-disciplinary cooperation between the earth sciences and engineering professions in all other countries, Nigeria still operates an indefensible stance of segregation in the professional practice of the two respective disciplines. This is a serious setback that should be effectively addressed and jointly corrected by the respective professions nationally.

Engineering Geo-morphological Maps

In addition to topographical maps, Engineering Geo-morphological maps are also desirable for effective planning. These are also little known in Nigeria. Large scale geo-morphological maps are very fundamental to the successful planning, design and construction of roads and highways (Brunsden et al, 1975). It seems that the provision of topographical maps should be revisited in the country before emphasis can be reasonably put on geo-morphological maps. There has been little improvement on the series of Topographical maps produced in the country since the British Colonial era. It is even virtually impossible to obtain several of those maps in the country today. Some of those still available were produced in 1948 and revised in 1952 by the ''Department of Federal Surveys''. The present post Independence Nigerian Federal Ministry of Surveys is yet to revise the maps and endeavour to produce modern digitized topographic maps that would be the basis for the production of publishable engineering geo-morphological maps of Nigeria.

Geotechnical Maps

Geotechnical maps are constructed from coordinated results of field and laboratory test results of civil engineering site investigations. They show the spatial distribution and relationships of foundation soil bearing capacities, consolidation settlements, engineering soil or rock classifications, varying values of the California Bearing Ratios (CBR), and all other foundation engineering soil parameters characteristic of particular soil horizons that are of interest to structural engineers. In the United Kingdom for example, many counties have been geo-technically mapped to assist in the execution of engineering development programs (Dearman et al 1979).

Wetland areas being developed at present in Lagos mega city by private developers represent very alarming engineering mismanagement of land. Many of the developers employ the services of unqualified personnel to execute shell and auger drilling and offer foundation proposals. Very spurious recommendations are made, and proposed structures are constructed, with little or no input from trained geotechnical engineers. Within months of their completion, the buildings signify structural failures by tilting, ugly cracking or massive subsidence. Several such examples are found at Ifako-Gbagada, Ogudu flood plain, Oyadiran Estate at Ebute Meta, Oto-Ido area, to mention a few. So far, many of the affected houses had to be demolished by the appropriate governmental Agencies. Almost in all cases, the structures were constructed haphazardly located to obstruct the drainage in canal zones.

In a very critical case of the structural failure of a nearly completed massive hotel building located in a natural canal terrain, the authors were invited (April, 2010) to conduct authentic engineering site investigation backed with the 2D electrical resistivity tomography to confirm the engineering subsoil conditions in the vicinity of the building. The results of the investigation showed that the sub soils were very heterogeneous. A section of the building

was constructed over acceptably competent sandy stratum while about one third of the foundation stood over piles terminated in a soft clay stratum. The badly tilted building had to be demolished. Plate 1 shows the affected building and the commencement of the 2D geophysical tomography investigation, while Plate 2 shows the affected building at the initial stage of demolition.

Similarly, a structural development of a major residential housing estate also located in a canal area of Ebute Meta was commenced with little understanding of the Engineering Geological nature of the environment and its sub soils. The erected structures consisted of 4nos. six storey and 4nos. four storey blocks of flats. The initial soil investigation report was very inaccurate as it indicated that it was feasible to install bored and cast-in-situ reinforced concrete piles terminated at varying depths to sustain the proposed block of flats. Over 900 such piles were constructed and terminated within a very thick sequence of soft peat to sustain the buildings. Within a few weeks of their completion, all the structures failed by pronounced tilting and remarkable differential settlement. The executed post failure shell and auger borings and geo-electrical 2D tomography revealed the thick sequence of peat within which the bored piles were terminated. The only solution to the entire problem was a complete demolition of the entire blocks and a fresh commencement of the housing project with the adoption of appropriately designed precast reinforced concrete piles, driven to hard resistance at varying depths. It was a costly mistake that conclusively illustrates possible wastage that may accompany an inadequate understanding of the geotechnical environment.

Plates 1and 2 below show some completed buildings in a Housing Estate in a prime area in Lekki, a south-western part of the Mega city. The estate was completed for occupation in the dry season some years ago. At the onset of the rainy season, it was found that it was impossible to control the degree of flooding ravaging the estate, and most of the houses had to be abandoned. Planning during construction was so poor that the estate roads were constructed higher than the ground floor. Unfortunately also, this is illustrative of several such examples of ongoing engineering site mismanagement reported in some parts of the mega city.

Plate 1

Plate 2

Plates 1 and 2: Abandoned buildings due to poor planning against flooding

Seismicity Maps

The monitoring of seismic wave propagation has not been a regular aspect of engineering planning in Nigeria. It appears that the relative seismic quiescence so far enjoyed in the country has prevented the necessary awareness to prepare for any onset of earthquakes. Recent developments in the knowledge of 'Plate Tectonics' have shown that no part of the earth's crust is absolutely free from seismic vibrations. It is the intensity that varies from place to place. This means that seismic vibrations occur daily in different parts of Nigeria, but there are no seismic stations to monitor the vibrations. This lapse needs to be corrected as urgently as possible. In the Lagos mega city, Victoria Island and Ikoyi areas which are prime areas close to the sea should geologically be viewed as possible targets of seismic sensitivity.

A critical examination of the geological structure of South Eastern coastal area of Nigeria and the Cameroons shows that the group of rocks designated as 'effusives' (Aseez, 1975) are essentially relicts of ancient dormant volcanic city (Figure 3). The volcanic islands of Sao Tome, Principe and Fernando Po are aligned structurally with the volcanic, active Cameroon Mountains. Whiteman and Burke (1969) have speculated that the area might represent a zone of impending seismicity where continental fracturing might be initiated. Should this be possible, a tsunami (volcanic eruption in the sea) would be expected in the area as part of the possible tectonic process. Monitoring stations established in Port Harcourt would certainly be of tremendous advantage to monitor and predict the expected seismic vibrations.

Conclusion

The need for the planning of coastal and wetland areas of Nigeria with various categories of Maps for development purposes has been presented. Lack of maps for planning renders development proposals ineffective, wasteful and nonsensical. Land Use maps of various categories, Topographical, Engineering Geological, Geotechnical and Seismic Monitoring Maps are essential technical documents that universally assist in the engineering planning and physical development of sensitive regions and local sites such as the Coastal and wetland areas.

It is therefore strongly recommended to the Federal Government of Nigeria that adequate administrative, financial and relevant logistics provisions be made for the appropriate mapping of these sensitive terrains in Nigeria.

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Nutrient Inputs via Stem Flow in a Rubber - *Hevea brasiliensis Wild Muell-Arg. Euphorbiaecae* - Agro-ecosystem Plantation at Ikenne, Southwest, Nigeria

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Abstract

Nutrients via stem flow are important in tropical agro ecosystems that receive little or no external sources of essential nutrients. This study compares stem flow of three age stands (40, 15, and 5 year-old) of rubber (Hevea brasiliensis) in Ikenne, South west, Nigeria. Stem flow solutions were collected with stem flow collars spiralled round eight selected trees in a 0.1ha (50m x 20m) experimental plot established in each of the three rubber stands. Collected data were analysed statistically using one-way analysis of variance (ANOVA); and the student t- test to assess the significant differences ($P < 0.05$). Total nutrient returns via stem flow for the 15-year-old stand were 28.39, 4.49, 38.9, and 3.54 kg ha^{-1} $year^{-1}$ for Ca^{2+}, Mg^{2+}, K^{+} and Na^{+} respectively compared to 22.7, 3.64, 36.3, and 3.17 kg ha^{-1} $year^{-1}$ for Ca^{2+}, Mg^{2+}, K^{+} and Na^{+} respectively, in the 40-year-old stand. Except for Cl^{-}, anions were greatly reduced suggesting nutrient uptake and less pollution. High amount of Ca^{2+} also suggest the contribution of dry deposition of local origin to the leached metabolites. The 15-year-old stand appears to have more efficient nutrient return compared to the younger 5-year-old stand on one hand and the older 40-year-old stand on the other. There is the need for augmented nutrients in the plantation by adding fertilizers in quantities that will not alter nutrient cycles and at the same time ensure sustainable and productive agro-ecosystem.

Keywords: Nutrient inputs, agro-ecosystem plantation, stem flow, *Hevea brasiliensis*

Introduction

Sustainable growth of forests and tree crop agro ecosystems depends on the cycling of nutrient elements. As management practices and environmental factors can result in changes in soil structure and nutrition, it is necessary to understand the cycling of nutrient for proper forest management (Nilsson *et al.,* 1995). Studies of nutrient uptake and cycling are important components for understanding the long-term dynamics of structure and function of forest ecosystems (Vitousek and Sanford, 1986; Tamm, 1995; Nilsson et al, 1995; Ranger et al., 2001). Input fluxes into any production system include soil mineral weathering and atmospheric deposition (McDowell, 1998; Weathers et al., 2000; Balestrini and Tagliaferri, 2001; Balestrini et al., 2002).

In the aboveground, incident precipitation is redistributed spatially by trees into stem flow and through fall. The difference between the sum of these two fluxes and the incident rainfall

gives the canopy interception (Chuyong et al., 2004). Fluxes of nutrients as through fall and stem flow are more rapid, when compared to the rate at which nutrient are released (mineralization) from decomposition of litters.

Nutrient inputs and outputs are directly related to the magnitude of the fluxes of water moving into and out of ecosystems, resulting in an additional transfer of nutrients with different components (Hedin, 1995; Parker G.G. 1983). The potential importance of the atmosphere as a nutrient source to forest ecosystems has received increased attention (Soulsby and Reynolds, 1994; Mitchell et al., 2001) most especially in temperate forest and agro ecosystems. It has been established that in major forest ecosystems, inputs of nutrients through atmospheric deposition appeared to be of low magnitude (Jordan 1982; Brouwer 1996), and thus develop a tight internal nutrient cycle and related nutrient conserving-mechanisms (Jordan and Herrera 1981; Bruijnzeel 1991).

Anthropogenic activities such as that of industries can have dramatic effects on atmospheric chemistry, just like other non-industrial human activities, such as deforestation, agriculture and biomass burning can also have a large impact on atmospheric chemistry (Linsey et al. 1987; Mosello and Marchetto, 1999; Nelson, 2002). Estimation of the fluxes of elements in precipitation, through fall, and stem flow can be used as a routine part of nutrient budget studies in forests (Crockford and Richardson, 1996; Schlesinger, 1997; Levia and Frost, 2006). As the tree canopy partition rainfall into stem flow, the intercepted water washes off nutrients that were deposited in the canopy by dry atmospheric deposition or animal droppings (Crockford & Richardson, 2000).

Stem flow water can further be partitioned into water intercepted by the litter layer or water which actually reaches the soil surface (Owens and Schreiber, 1992). It is regarded as a spatially localized input point of precipitation and nutrients to the forest floor at the tree base (Levia and Herwitz, 2002). In most forests, through fall is by far the dominant pathway taken through the canopy (Wilby, 1997), however, stem flow has higher nutrient concentrations than through fall (by up to an order of magnitude (Parker, 1983) due to a longer canopy residence time for stem flow water than for through fall, which is in turn more greatly enriched than the incident precipitation (Johnson and Lehmann, 2006). Greater leachability of bark tissue also contributes to a chemical concentration gradient of water fluxes in the order: stem flow > through fall > precipitation (Levia & Herwitz, 2000; Johnson and Lehamnn, 2006). Nagata et al. (2001) reported temporal variations in the amount of stem flow produced by an individual tree vary as seasonally variable rainfall intensities alter the amount of rainfall partitioned to stem flow.

The chemical composition of stem flow for an individual tree is also influenced by climatic factors such as rainfall intensity and wind speed as well as the duration of the dry period preceding the storm (Mina, 1967, Liu et al., 2003). Stem flow was also found to be related to physical tree characteristics such as diameter, basal area or crown projection area (Ford and Deans, 1978; Hanchi and Rapp, 1997), suggesting that these relationships could be exploited to estimate stem flow at the stand level. In addition, canopy architecture and leaf morphology affect the chemical concentrations of stem flow water. Stem density and crown structure may be important for stem flow generation (Hölscher et al., 2005; Dietz et al., 2006). Levia & Herwitz, (2000) pointed out that intercepted water may become more enriched due to canopy

features that increase residence time of water in the canopy, such as leaf concavity and shallow branch angle. Furthermore, older trees of the same species tend to have greater trunk surface roughness, resulting in less stem flow due to increased storage capacity (Houle *et* al., 1999; Levia, 2003; Levia & Frost, 2003), while rough-barked species show higher nutrient concentrations than smooth-barked species (Parker, 1983). In general, stem flow deposits within a small area around the tree trunk and the effects of stem flow on soil characteristics are more prominent near the trees (Gersper and Holowaychuck, 1971; Andersson, 1991; Chang and Matzner, 2000).

In forested and agricultural ecosystems, stem flow may be of hydro-ecological and biogeochemical importance ((Levia and Frost, 2003). Although, some studies (e.g. Parker, 1983; Crockford and Richardson, 1990; Hölscher *et al*., 1998; Owen *et al*., 2003), have reported that the quantitative contributions of stem flow to the nutrient cycle are small, however, some other studies (e.g. Andersson, 1991; Chang and Matzner, 2000) revealed that stem flow can be significant under some circumstances. For instance, Gersper and Holowaychuk (1971) reported that quantitative variations in the physico-chemical properties of soils near the trees were caused by stem flow, suggesting that the quality and quantity of stem flow and through fall from individual tree influences soil properties. It also affects soil moisture distribution (Durocher, 1990), soil chemistry (Matschonat and Falkengren-Grerup, 2000; Chang and Matzner, 2000), soil erosion (Herwitz, 1988), runoff generation, ground water recharge, and the distribution of under-story vegetation and epiphytes (Andersson, 1991; Levia and Frost, 2003).). Chang and Matzner (2000) reported that the stem flow of beech represented a significant input of elements to the soils. According to Murakami (2009) stem flow typically accounts for several percent of rainfall, and is often a minor component of the water budget in forest hydrology in comparison with through fall, that amounts to 60 to 90% of rainfall.

Overall, the understanding of biogeochemical cycling in tropical and subtropical forests is still relatively poor compared with temperate forests (Bruijnzeel and Proctor, 1995; Vitousek and Sanford, 1986). There is the paucity of reliable experimental data on the contribution of atmospheric deposition most especially stem flow to the nutrient dynamics of forests and tree crop agro ecosystems in tropical forests such as south western Nigeria, except few (e.g. Muoghalu and Johnson, 2000; Muoghalu and Oakhumen, 2000). It is also known that stem flow studies have received far less attention (Chuyong et al., 2004). There is the need to critically evaluate the current understanding of stem flow in agro ecosystem such as rubber; identify gaps in our present knowledge of stem flow; and stimulate further research in areas where present knowledge is weak.

A better understanding of the partitioning of incident gross precipitation into stem flow will result in improved knowledge of the hydrology and biogeochemical cycles of nutrients. This paper therefore examines nutrient inputs via stem flow in a *Hevea brasiliensis Wild Muell-Arg. Euphorbiaecae* agro ecosystem plantation at Ikenne, South west, Nigeria. The paper looks at mineral cycling in plantation agro ecosystems, assess ways, which improves prediction and forecast of changes, which in turn can inform decisions on sustainable agro ecosystem.

Study Area

The study was conducted at the Remo Rubber Plantation located in Ikenne, southwest, Nigeria

(Latitude 6^{o} 50' N and Longitude 3^{o} 40' E (Figure 1). Precipitation varies from 1500 mm to 1750 mm annually, with nearly all falling as rain in the wet season (April-October). The mean diurnal and temperature ranges vary between 8^{o}C to 10^{o}C during the dry season and between 3.5^{o}C and 5^{o}C during the wet season. The rainy climate has the temperature of the coolest month to be >18^{o}C (68^{o}F). The mean annual temperature is about 27^{o}C with high relative humidity (80%) (Ayoade, 1988). The site lies on the sedimentary rock (Abeokuta formation) of the southern part of Nigeria, which is underlain by the crystalline basement complex rocks of the Precambrian period (Kehinde-Phillips, 1992).

The relief is generally an undulating one, and hardly does any area exceed 150m above sea level. Periaswamy and Ashaye (1982) classified the soil of the area as Ultisols due to the annual rainfall with base saturation often less than 50 %. The soils belong to the suborder *Ustults* with appreciable exchangeable Al characteristic of Ultisols (Soil Survey Staff, 1975; Lal, 1989; Juo and Franzluebbers, 2003). Ultisols are considered marginal for agricultural production since the soils are highly weathered, low in CEC, base saturation and pH. Trees species commonly found include *Isotonia boonei, Anthocleista Vogeli, Cola gigantea Antiaris africana, Pentaclethra macrophylla,* and *Elaeis guineensis* (Gbadegesin, 1992; Aweto and Obe, 1993). Deterioration of the soil structure is noted in the study area, which has led to several soil degradation processes like crusting, surface and sub-surface compaction, surface runoff, and accelerated soil erosion. Anthropogenic influences (e.g. population increase, urban development, transportation) can have considerable effect on the atmospheric chemistry of the area, which was once pristine.

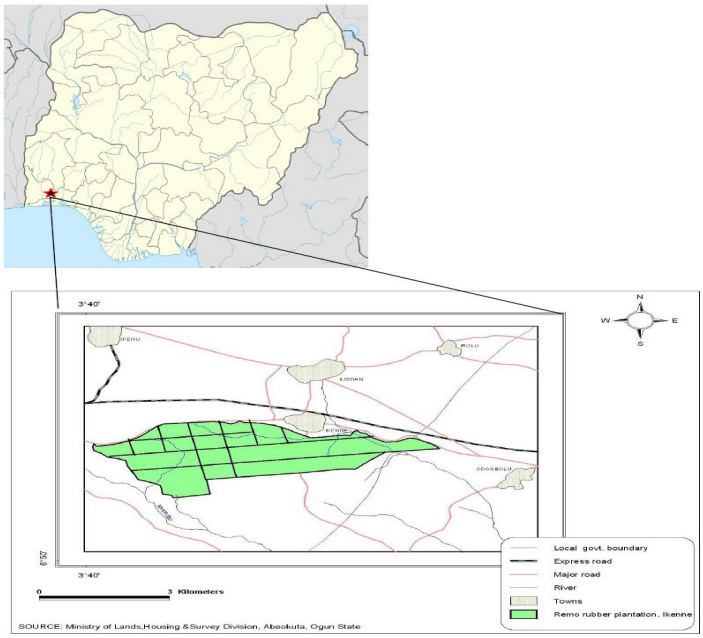

Figure 1: Map of Remo Rubber Plantation, Ikenne, South western, Nigeria

Materials and Methods

The study was conducted for 2 years from mid-June 2005 to mid-June 2007. Stem flow samples were collected bi-weekly based on representative trees in each stand taking into account tree age, class, diameter, and height. Ten replicate trees were sampled in each age stand for stem flow collection. The choice of fewer stem flow collectors was based on the recommendation of the ICP Forest manual (Programme Coordinating Centre, 1994) that gives a guideline number of 5 to 10 stem flow gauges especially for homogenous, even-aged stands. Stem flow was collected with collars consisting of vinyl tubing, cut longitudinally and attached to each tree trunk in an upward spiral using galvanized nails.

Silicone sealant was applied to seal the collar to the trunk and to plug nail heads. The uncut section of each stem flow collar was connected to an 80-litre capacity collection bin lined with a chemically inert sampling bag. The collars were mounted at the breast height (1.3 m above the forest floor), and were checked regularly for leakages. The spirals were steep enough to allow a rapid emptying of the rain water from the collars. Total stem flow amount was extra polated for each plot by formulae of the Programme Coordinating Centre (1994), which is expressed as:

$$\text{Total volume in the plot (mm)} = \frac{\text{Total Stemflow of n trees}}{\text{Plot area (ha)}} x \frac{\text{Total basal area of all trees in the plot}}{\text{Total basal area of the n trees}} x10^4 \quad (1)$$

Where n is the number of trees used in the stem flow measurements (Thimonier, 1998). In addition, the percentage of rainfall partitioned to stem flow (SF %) integrates the canopy architectural and climatological factors influencing rainfall partitioning. SF% was determined as the percentage of incident rainfall delivered as stem flow on a volumetric basis as follows:

$$SF\% = \frac{SF}{PPT} x100 \quad (2)$$

Where SF is the volume of stem flow on per hectare of forest basis and PPT is the volume of rainfall per hectare of open area.

The bi-weekly stem flow samples were taken to the laboratory in pre-labelled 120cm^3 capacity snap lid collection bottles and immediately frozen at 4 ^{0}C. The analyses were performed on filtered samples (0.4cm) except for measurement of pH and conductivity for which unfiltered samples were used. All samples were filtered in the laboratory. Water pH was measure electrochemically, while conductivity (Konduktometer CG 855, Schott) was measured within one week of sampling. Cation concentrations (Na^+, Ca^{2+}, Mg^{2+}, and K^+) were determined by flame atomic absorption spectrometry (AAS Atomic Absorption Spectrum- 932, GBC Scientific Equipment Pty. Ltd, Australia). Sulphate (SO_4-S) sulphur was determined by Inductively Coupled Plasma Atomic Emission Spectrum (ICP-AES, IRIS ER, Thermo Jarrel Ash Corporation, USA). Phosphorus was determined using molybdenum blue colorimetric procedure (Institute of Soil Academia, Sinica, 1978).

Total N was obtained by Kjeldahl digestion followed by analyses of NH_4^+-ions (micro-Kjeldahl distillation and titration with 0.001 NHCl). NO_3^--N was determined after reduction to NO_2^- - N

by colorimetric method (Sulphhanilmide /N-I-napthyethylene-diamnie dihydrochloride, Institute of Soil Academic, Sinica, 1978). To ensure sample integrity, glass wares were soaked in two phases: (i) IM HNO_3 solution; and (ii) a 10 % HCI solution (Sevruk, 1989; Levia, 2003). De-ionized water was also used to rinse glassware during preparation of standard for atomic spectrometry.

Mean stem flow volumes were calculated for each of rubber tree sampled, and then multiplied by the number of trees for each stand age. These values were then summed to provide estimates of the total stem flow for the stand. Stem flow from the sampled trees were summed over the entire period and the total volume used to compute the funneling ratio from the equation of Herwitz (1986):

$$FR = V \diagup BG \qquad 3$$

Where FR = funneling ratio, V = stem flow volume (l), B = basal area (m^2) and G = the depth equivalent of rainfall (mm). Funneling ratio relates stem flow volume to the expected volume from a rain-gauge with a collecting area equivalent to the stem's basal area (Herwitz; 1986; Chuyong, 1994; Chuyong et al., 2004). Trees with ratios exceeding unity indicate that funneling of rain water had occurred. These ratios were used to compare the magnitude of stem flow for the different rubber trees. Volumetric weighted means were found by multiplying individual nutrient concentrations by their sample volumes, summing and then dividing by the total volume collected (Liu, et al., 2002; Chuyong et al., 2004). Stem flow inputs of the each sample tree were also summed over the entire period and expressed per unit sample plot. These were then used to compare the nutrient inputs of the different stands. Elemental concentrations in stem flow in the three different rubber stands were compared statistically using one-way analysis of variance. Differences were considered statistically significant at *P* (0.05) unless otherwise stated using the student *t*- test. The statistical analyses were performed using the SPSS for windows Version 11.0 (SPSS, 2003).

Results and Discussion

Hydrological Fluxes

Although the amount of bulk open field deposition (OF), through fall (TF), were also measured during this study, only the nutrient inputs and concentration in stem flow was considered in this paper. The mean annual rainfall in the area was 1540.3 mm (Table 1). Annual precipitation measured in the study area by automatic rain gauge for the study period ranges from a minimum of 2.3mm in December 2005 to a maximum of 440.9mm in June 2007. Canopy interception in the different rubber stand was characterized by a distinct seasonal pattern, a low capacity for water storage, and was greatly influenced by the total rainfall and rainfall intensity. The amount of incident rainfall intercepted by the canopies in the rubber plantation varied among the different stand ages. It ranged from 13% of precipitation in the 15-year-old rubber stand to 18.9% in the 40-year-old rubber stand (Table 1).

Table 1: Precipitation (P) partitioning into through fall, stem flow, and interception loss in the 40, 15, and 5 year-old rubber stands at the Remo Rubber Plantation, Ikenne (July 2005-June 2007).

	40 year-old		15 year-old		5 year-old	
	mm y^{-1}	% of P	mm y^{-1}	% of P	mm y^{-1}	% of P
Through fall	990.1	64.3	1036.6	67.3	1075.0	70
Stem flow	258.9	16.8	303.4	19.7	210.2	14
Interception	291.3	18.9	200.3	13	255.1	16
Precipitation	1540.3	100.0	1540.3	100.0	1540.3	100.0

Canopy interception in the 5-year-old rubber stand is 16% of incident rainfall. Monthly interception ranged from 6.2 to 19.4% in the rainy season and 18.5 to 70.3% in the dry season. Interceptions exceeded 25 mm for most of the rainy season, with the greatest interception of 89 mm in June 2006. During the dry season, most of the incident rainfall was low and of low intensity, therefore intercepted by the canopy. Overall, the amount of interception loss by the rubber canopy increased with rainfall. However, the rate of interception, expressed as the ratio of interception by canopy to rainfall, decreased with rainfall.

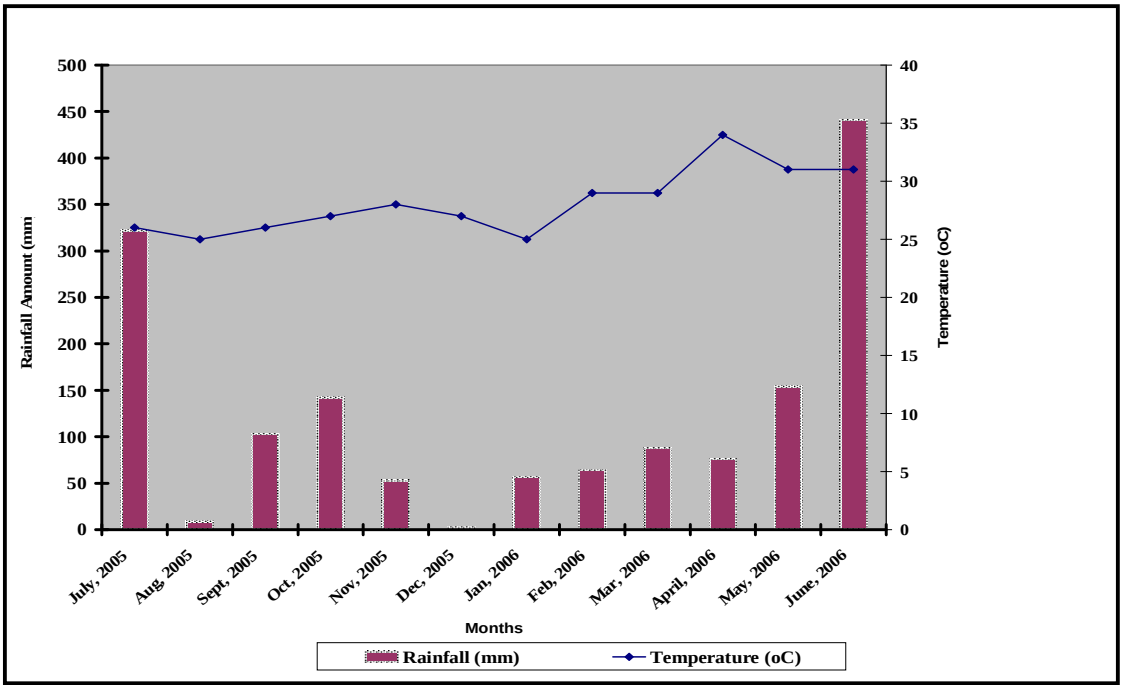

Figure 2: Incident rainfall and temperature at Remo Rubber Plantation (July 2005-June 2007)

Dynamics of Stem Flow (SF)

Comparison of stem flow from stems of different stand ages

Within the rubber plantation, the amount of stem flow comprised only 17% of the annual rainfall on the average. Estimated total stem flow (expressed in mm of incident rainfall) for the study period (June 2005 to June 2007) were 258.9 mm, 303.4 mm and 210.2 mm (Table 1), constituting 16.8, 19.7 and 14% of the annual incident rainfall in 40 years, 15 years and 5 year-old rubber stands respectively. Monthly stem flow was significantly and positively correlated with incident rainfall ($r = 0.96$, 0.94 and 0.95 for the 40 years, 15 years and 5 year-old rubber stands forests respectively, $n = 35$, $P < 0.05$). Stem flow estimates for the three rubber stands were very variable and high values. This variability among different stand age (also within the same stand) was reflected in their funneling ratios (FR) which ranged from 0.8 to 35.6, with majority of the rubber trees sampled in the study having FR >10.0.

In this study stem flow was higher in the 15 year-old stand, which is smaller in size to the 40-year-old stand. The stem flow is significantly increased in the 15-year-old rubber stand (19.7% of total incident rainfall). This is quite high compared with 9.02 % for Lenga trees *Nothofagus pumilio* in Chile (Godoy, Oyarzun & Bahamondes, 1999), or 0.70% for Red pine *P~nzrs resinosa* in Canada (Mahendrappa, 197), or 1.96% for Stone oak, zhui shu *Lithocarptrs-Castanopsis* association with bryophytes in China (Liu, Fox & Xu, 2003). It is however similar to the 20.00 % reported for Vismia (fallow species) *Ksmia* spp. in Brazil (Schroth *et al.,* 2001) and 22.00 % for Monterey Pine *Pinus radiate in* Chile (Uyttendaele & Iroume, 2002). Some studies have found a positive correlation between stem flow on the one hand, and tree basal area (Crockford and Richardson, 2000) and stem angle (Martinez-Meza and Whitford, 1996) on the other. Stem flow amounts were found to increase with tree size or canopy size, i.e. tree age, because larger and taller trees tend to have a greater catchment area for rainwater. Johnson (1990) found that stem flow yield decreased with tree age from 39% (age 14) to 2% (age 63) of total rainfall in five stands in the UK

Maximum monthly stem flow occurred in June 2006, the same period with the maximum monthly rainfall, with 84 mm (19% of that month's rainfall). Stem flow was greatly reduced during the dry seasons (November to March) because the rubber canopies intercept much of the incident rainfall. However stem flow is greater in the 15-year-old rubber stand indicating the potential for more nutrient release than the two other stands. Many forest and agricultural hydrologist have observed that stem flow production increases with the magnitude of a precipitation events (Xiao et al., 2000; Kuraji et al., 2001). For smooth-barked trees, once the interception storage capacity is reached, stem flow generation closely match the rainfall pattern of the precipitation event.

Since stem flow water and nutrient inputs are controlled in part by branching angle (Levia and Herwitz, 2002; Levia, 2003), tree species with larger proportion of erectophile branches may have higher stem flow leachate inputs than those with gently sloping branches. Rubber trees have steep sloping leaves and therefore produce considerable high amount and nutrient inputs. Individual stem flow increased in a linear function with increasing rainfall depth Stem flow data from wet and dry seasons were statistically compared to determine the influence of leaves on stem flow generation in the study area. Stem flow amounts collected during wet season differ significantly ($P < 0.05$) from those of dry season demonstrating that in the rubber plantation, the absence of leaves during winter months affect generation of stem flow.

Rubber trees especially the younger ones have smooth barks tend to increase the amount of stem flow more than the older trees. SF amount was 258.9 mm (16.8 %) of gross precipitation in the 40 year-old rubber stand, while it was 303.4 mm (19.7%) and 210.2 (14%) of gross precipitation for the 15 and 5 year-old stands respectively (Table 1).

Nutrient concentration in stem flow

The weighted monthly pH values (5.8 to 7) for precipitation is close to neutrality. The solution flowing along the trunk surface already contained elements caught in the canopy but also collected large amounts of elements from contact with stem bark. This is an indication that the canopy partitioning of incident rainfall exerts a strong influence on nutrient fluxes delivered via stem flow. The enhancements in concentration with respect to rainfall was just about 1-1.5 times for NO_3^--N, SO_4^{2-}-S and total N, but was much higher and more variable for Ca^{2+}, Mg^{2+}, K^+, and Na^+ (Table 2, Figure 3), which were significantly higher in stem flow from stems of the 15 year-old rubber stand than the two other stands. The median of the volume weighted mean concentrations of cations such as Ca^{2+} (18.96µeq l^{-1}) is greater than that of anions such as Cl^- (10.87µeq l^{-1}) in the 15 year-old stand as well as the two other stands. The most abundant cation (in terms of equivalent concentration, which is molarity times the ion valence) was Ca^{2+}, followed by Na^+, K^+ and Mg^{2+}. The order of abundance of anions was Cl^-, SO_4^{2-}, NO_3^-, and H^+,

Table 2: Descriptive chemistry of seventeen stem flow collections at Remo Rubber Plantation, Ikenne, south-western Nigeria (July 2005-June 2006)

N		Ca^{2+}	Mg^{2+}	K^+	Na^+	NH_4^+	H^+	SO_4^+	NO_3^-	Cl^-
					µ eql^{-1} yr^{-1}					
					40 year-old					
Min.		11.97	0.04	1.34	2.52	<0.01	<0.01	0.04	<0.01	7.33
Max.		20.95	0.13	2.56	4.04	<0.01	<0.01	0.07	<0.01	11.83
Median	17.46	0.12	2.04	2.43	<0.01	<0.01	0.05	<0.01	9.28	
St. Dev.		2.90	0.01	0.27	0.22	<0.01	<0.01	0.01	<0.01	1.66
St. Error	0.70	<0.01	0.07	0.10	<001	<0.01	<0.01	<0.01	0.40	
C.V. (%)	11.49	11.61	12.39	11.86	85	87.09	15.56	101.74	12.81	
					15 year-old					
Min.		14.99	0.08	1.53	2.39	<0.01	<0.01	0.05	<0.01	7.39
Max.		25.45	0.16	2.87	4.73	<0.01	<0.01	0.09	<0.01	13.69
Median	18.96	0.11	2.42	2.63	<0.01	<0.01	0.07	<0.01	10.87	
St.Dev.		3.36	0.02	0.36	0.39	<0.01	<0.01	<0.01	<0.01	1.76
St. Error	0.81	<0.01	0.09	0.09	<001	<0.01	<0.01	<0.01	0.43	
C.V. (%)	17.54	15.75	12.84	12.63	37.68	45	14.18	17.10	9.83	
					5 year-old					
Min.		10.97	0.09	1.23	2.48	<0.01	<0.01	0.05	<0.01	7.19
Max.		27.45	0.13	2.41	4.15	<0.01	<0.01	0.06	<0.01	10.97
Median	15.96	0.12	1.92	2.54	<0.01	<0.01	0.06	<0.01	9.82	
St.Dev.		2.54	0.02	0.22	0.31	<0.01	<0.01	<0.01	<0.01	1.65
St. Error	0.85	<0.01	0.08	0.10	<001	<0.01	<0.01	<0.01	0.36	
C.V. (%)	8.52	10.13	16.77	12.72	74.15	65.8	14.139	50.58	5.69	

Note: Values of through fall chemistry were expressed in µeql^{-1} yr$^-$ to show the degree of concentration of each ion.

Total annual nutrient inputs reaching the rubber floors in each stand indicated that canopy leaching increased each nutrient amount. Canopy partitioning of incident rainfall exerts a strong influence on nutrient fluxes delivered via stem flow in the rubber stands. Comparing fluxes the three different stands and rainfall regimes shows larger stem flow fluxes of $Ca2^{+}$, Na^{+}, K^{+} and Mg^{2+} regardless of season. In contrast, SO_4^{2-}, NO_3^{-}, and $H^{+,}$ showed an indeterminate relationship with stem flow partitioning. High amount of precipitation does not simply imply larger stem flow fluxes for these plant-mobile nutrients. However, to a certain extent, increased precipitation generally results in larger volumes of more dilute stem flow.

The total annual stem flow input to the rubber stands on per hectare basis constitute a minor component, accounting for 4 % of that through fall for most nutrients due to the high amount of water flowing through them. Johnson and Lehamnn (2006) argued that dilute nutrient concentrations in precipitation imply that foliar leaching is much more common than foliar uptake.

Foliar leaching of cations from plant tissue is driven by exchange reactions with rainfall-supplied hydrogen ions (Fan & Hong, 2001). These H^{+} ions more easily displace those nutrients that are mobile within the plant. Although K^{+} is a more mobile nutrient in plants and therefore is more easily leached to stem flow than Ca^{2+} (which is incorporated into cell walls) as reported by authors (Bruijnzeel, 1991; Marques and Rangers, 1997; Johnson and Lehamnn, 2006), there is far more Ca^{2+} in the stem flow for this study suggesting external sources of Ca^{2+} deposition (most probably due to anthropogenic influences e.g. bush burring, dust and soil erosion). Foliar uptake occurs when lower elemental concentrations are found in plant tissue than in rainfall. In addition, epiphytic plants and lichens contribute to uptake of nutrients from intercepted rainfall (Houle *et* al., 1999). The nutrient inputs through stem flow are however quite substantial considering the fact that the plantation is not receiving additional inputs of nutrient in form of fertilizers. Stem flow leaching of Ca^{2+}, K^{+}, Na^{+}, and Mg^{2+} are of particular significance due to their key roles in plant metabolism (Marschner, 1995).

Elevated K^{+} concentrations may also be the result of burning (Delmas, 1982) which is a common phenomenon in many parts of West Africa during land preparation for farming. Biomass burning has been cited as the reason for acidic precipitation in some parts of the tropics (Lacaux et al. 1987). There is also the presence relatively low H^{+} concentration (relatively high pH) of atmospheric depositions (stem flow and through fall) collected during the study suggest the presence of alkaline buffer, probably HCO_3^{-}, associated with various base cations, Ca^{2+}, K^{+} , $Mg^{2+}$and Na^{+}.

The result of the one-way analysis of variance of stem flow solutions among the rubber stands showed that the amount returned to the soil varied significantly ($P < 0.05$). The flux of nutrients in the plantation revealed significant variations between and within rubber stands ($P < 0.05$).

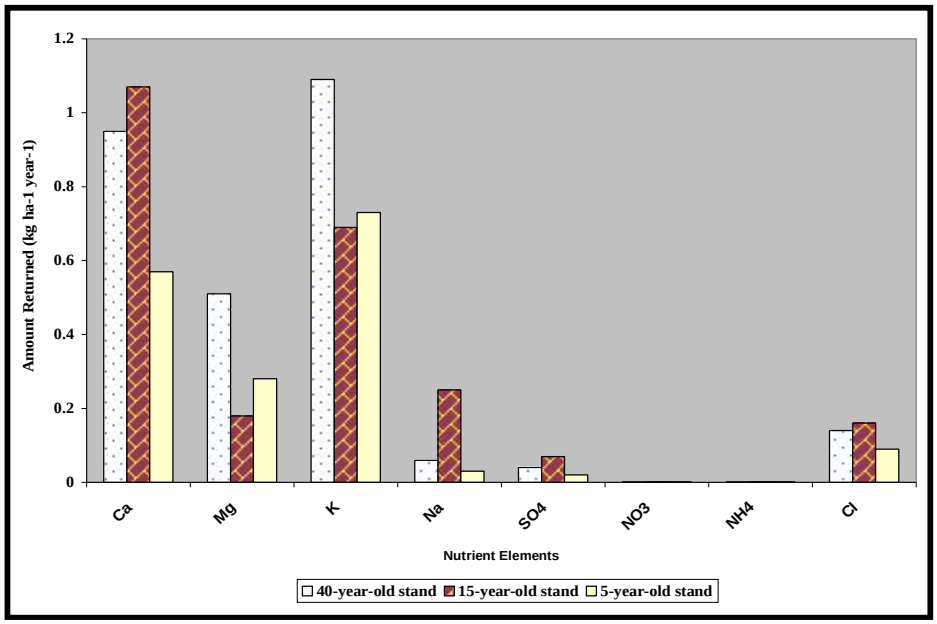

Figure 3: Nutrient return via stem flow (all Stands) in rubber (*Hevea brasiliensis*) plantation agro ecosystem at Remo Rubber Plantation, Ikenne, South west, Nigeria

Nutrient dynamics in stem flow solution are enriched in some elements (Ca^{2+}, Na^{+}, Cl^{-}, and K^{+}) but others are impoverished (total N, NH_4^{+} , -N, and NO_3^{-} - N) as a result of stem bark interactions. The stem bark significantly affect the amount and chemistry of stem flow especially in the 15 year-old rubber stand because their smooth barks allowed more stem flow volume than the 40 year-old stand whose stem bark is coarse due to old age and the 5-yer-old stand whose stem bark is still slender and with smaller basal area which do not support as much stem flow volume as the 15 year-old rubber stand.

Table 3: Seasonal and annual input of nutrients via stem flow (all Stands) in rubber (*Hevea brasiliensis*) plantation agro ecosystem at Remo, Ikenne, SW Nigeria, in dry season (n= 6) and wet season (n=11)

Items	Season	Ca^{2+}	Mg^{2+}	K^{+}	Na^{+}	SO_4^{+}	NO_3^{-}	NH_4^{+}	Cl^{-}
		Kg / ha year $^{-1}$							
40 year-old Stem flow	**Dry**	0.12	0.02	0.15	0.01	0.01	< 0.001	< 0.001	0.02
	Wet	0.83	0.49	0.94	0.050.03	< 0.001	< 0.001	0.12	
	Total	0.95	0.51	1.09	0.060.04	< 0.001	< 0.001	0.14	
15 year-old Stem flow	**Dry**	0.24	0.08	0.27	0.03	0.01	< 0.001	< 0.001	0.06
	Wet	0.83	0.10	0.42	0.220.06	< 0.001	< 0.001	0.10	
	Total	1.07	0.18	0.69	0.250.07	< 0.001	< 0.001	0.16	
5 year-old Stem flow	**Dry**	0.06	0.01	0.10	0.01	0.01	< 0.001	< 0.001	0.01
	Wet	0.51	0.27	0.63	0.020.01	< 0.001	< 0.001	0.08	
	Total	0.57	0.28	0.73	0.030.02	< 0.001	< 0.001	0.09	

The 15 year-old stand stem bark also intercept more mineral elements than the two other stands going by the higher nutrient concentrations. Enrichment of stem flow water has been attributed to inputs from mosses, lichen and other organisms living on the surface of boles and branches of trees (Nye, 1961; Yawney *et al.,* 1978; Veneklaas, 1990; Weathers, 2000; Levia, 2003). Other has also attributed the enrichment to the presence of epiphytes (Coxson and Nadkarni, 1995; Lowman and Nadkarni, 1995; Liu et al., 2002). Epiphytes reportedly increase total atmospheric input in tropical montane forests o values 2.5 times higher than for lower elevation forests (Bates and Farmer, 1992).

Conclusion

Going by the amount of nutrients in different rubber age stands, it is concluded that there are significant differences in the composition of nutrients in stem flow in the three age stands. The atmospheric deposition data for the study area show a generally low cycling rate of mineral elements. Atmospheric dust is enriched in Ca^{2+}, Na^{+}, and K^{+}, which is a source of cations to the typically cation-depleted West African soils. The abundance of Ca^{2+}, Na^{+}, Mg^{2+}; and K^{+} can be attributed to pollution from growing urban population and aeolian soil erosion. Generally, NH_4^{+}, NO_3^{-}, and H^{+} are greatly reduced due to absorption by the canopies, whereas base cations and organic acids are leached from foliage.

Inputs of major elements such as Ca^{2+}, Na^{+}, Mg^{2+}, and K^{+} in the different rubber stands are higher in the 15 year-old stand than the 40 year and 5 year-old stands. This in effect show that the rubber stands reached the highest capacity to cycle nutrients effectively and efficiently around the 15 year age bracket after which the ability to function well in nutrient cycling start to decline. Old rubber stands like the 40 year-old have gone past their productive capacity and needs to be felled and new ones planted. Atmospheric deposition of nutrients can vary significantly between years, therefore a long term monitoring programme is desirable where atmospheric deposition monitoring programme can be maintained with relative ease Monitoring of atmospheric deposition is not only relevant to the study of biogeochemical cycle and health of forest ecosystem but it can also be used as an index of changes in land use in these forests. The resultant data from monitoring atmospheric nutrient deposition can also be combined with measurements of nutrient fluxes from other sources to construct a whole agro ecosystem nutrient budget to achieve sustainable management.

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Application of Remote Sensing and Geographic Information System for selecting Dumpsites and Transport Routes in Abeokuta, Nigeria

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Abstract

Waste management problems result from indiscriminate waste disposal which stems from inadequate planning and implementation. This fact led to the present study which applied the techniques of GIS and RS to disposal sites and transport route selection in the emerging megacity of Abeokuta. Spatial data such as land-cover types; road and drainage networks of the city were extracted from a geo-referenced high resolution satellite image through on-screen digitizing using GIS softwares such as ILWIS and ArcView 3.2a. The existing dumpsites were geo-located and added as a layer to the map of the city. The land-cover, drainages, and roads were buffered at 30, 160 and 200 meters respectively using preset criteria such as distance of site from a street at 30 m, surface water at 160 m, major roads at 200 m and absence of important economic or ecological features; to determine candidate sites from the land-cover types. Four legal dumpsites in *Saje*, *Olomore, Totoro* and *Ita-Oshin* and patches of illegal dumpsites were identified. GIS analysis gave a total of nine sites out of which only four met the preset criteria. *Saje, Ita-Oshin, Sam-Ewang,* and *Ita-Ika* areas were the most appropriate sites having an area of 19.64 km^2 out of the total study area of 79.95 km^2. The shortest route connecting the proposed dumpsites gave a total Travel Cost (in distance) of 27.30 km while the cost of making a round-trip (Tour Route Cost) was 36.00 km. It was therefore concluded that *Olomore* and *Totoro* dumpsites should be relocated, while *Sam-Ewang* and *Ita-Ika* dumpsites should be upgraded and made to function as legal waste disposal sites.

Keywords: Geographic Information System, Remote Sensing, Dumpsite, Transport Route.

Introduction

The current global trend of waste management problems stems from unsustainable methods of waste disposal, which is ultimately as a result of inadequate planning and implementation. The practice of direct dumping of wastes into water bodies, open, abandoned lands and any other "appealing" sites without proper treatment have led to serious environmental pollution and health-related problems.

Solid Waste according to The United State Environmental Protection Agency (USEPA, 2005) is defined as any garbage, refuse, sludge from a waste water treatment plant, water supply treatment plant or air dried material, including solid, liquid, semi-solid or contained gaseous material resulting from industrial, commercial mining and agricultural operations and from community activities.

Municipal solid waste disposal is an enormous concern in developing countries across the world, as poverty, population growth, and high urbanization rates combine with ineffectual and under-funded governments to prevent efficient management of wastes (UNDP, 2004).
Waste management issues should be confronted in a more generalized manner, which means that new strategies need to be designed for considering diverse and variable urban models. This fact demonstrates the necessity of developing integrated, computerized systems for obtaining more generalized, optimal solutions for the management of urban solid waste (Karadimas et al, 2004). Geographic Information System (GIS) and Remote Sensing are such computerized systems which can be integrated to get optimal solutions for sustainable management and planning of solid waste.

Geographical Information System (GIS) is any system that captures, stores, analyzes, manages, and presents data that are linked to location(s). It is the merging of cartography, statistical analysis, and database technology for informing decision making. It is a tool that allows users to analyze spatial information, edit data, maps, and present the results of any operations (Wikipedia, 2011).

Remote sensing is the small or large-scale acquisition of information of an object or phenomenon, by the use of either recording or real-time sensing device(s) that are wireless, or not in physical or intimate contact with the object (such as by way of aircraft, spacecraft, satellite, buoy, or ship). In practice, remote sensing is the stand-off collection through the use of a variety of devices for gathering information on a given object or area (Wikipedia, 2011).
This study emanated from the obvious problems of population and city expansion as a result of rural migration to urban centres; increase in solid waste generation as a consequence of over-population; distance of location of dumpsites from residential areas which encourages indiscriminate waste disposal at illegal locations; insufficient dumpsites leading to a creation of patches of dumpsites all over the places; and an inadequate organized system of waste handling for a major part of the city.

The study focused on identifying the present locations of refuse dumps and assessing their suitability; determining other locations best suited as landfill sites across the study area; and determining the most appropriate, efficient, and least-cost routes for transporting waste to landfills or recycling centres.

Solid Wastes

Characterization of municipal solid wastes (MSW) are impacted by a number of factors, including climate, population, season, income level, social behaviour, the size of market for waste materials, the extent of urbanisation, effectiveness of recycling, work reduction and the

presence of industrial activity. Wastes from tropical areas generally contain a relatively high concentration of organic matter (Diaz et al, 2005).

Solid waste generation is a part of every human activity or process stream. Nigeria, having a population of 120 million (Adewumi et al., 2005), generated 0.58kg solid waste per person per day. Several factors influencing solid waste generation in Nigeria and the city of Abeokuta include the following: inadequate technology, facility for separation at source, strength of solid waste management policy and enforcement (Sridhar and Adeoye, 2003). Also are education, income and social status (Abel, 2009).

Solid Waste Disposal and Disposal Options

Disposal of solid waste generated in a community is the ultimate step in a solid waste management system. In the advanced technologies, disposal is preceded by engineering activities such as sorting, volume reduction and / or receding. The open dump method of solid waste disposal is considered as both naïve and dangerous. This is because of the leachate effect (i.e the chemical and biological contaminant in wastes) which could constitute a direct risk to human health (Lasisi, 2007). In some parts of Nigeria, refuse is generally buried, though some heedless burning is sometimes observed (Igoni, et al., 2007).

An extensive research was carried out by Diaz et al. (2005) in which he succinctly classified the various types of waste disposal into the following: Uncontrolled open dump; Controlled open dump and Controlled and sanitary landfills.

Disposal Site Selection

Daneshvar *et al*. (2005) ascertained that GIS is an ultimate method for preliminary site selection as it efficiently stores, retrieves, analyses and displays information according to user-defined specification.

To arrive at the selection criteria for choosing a site for landfill, relevant literature and decision makers' opinion should mostly be sought. Adeofun et al (2006) and Sani et al (2010) gave some of the following specifications:

- Site must be close to at least a street with a buffer of 30 m
- Site must be 3 km from residential areas, with the exception of areas with barriers (trees, hills, etc.)
- The site should be located on a terrain with a slope less than 20
- Site should be located more than 160 km away from surface water, within 200 m of a major road, 2 km from the Local Government
- Site should be constructed in areas which do not have an important economic or ecological value

Furthermore, a decision hierarchical structure using the Analytical Hierarchical Process (AHP) can be developed and implemented to rank between suitable sites according to their suitability for disposal site location. This is to assist in identifying and weighting selection of criteria and expediting the process of decision making, coming out with the best alternative (Sener, 2010).

In addition, the use of GIS is found ideal for preliminary waste disposal site selection studies. Shrivastava and Nathawat (2006) explained the possibility to relate the groundwater of a site with the health parameters of its inhabitants. The ability of overlay was also stated to have a unique power in helping to make decisions about the identification of waste disposal sites. Once a GIS database is developed, it can provide an efficient and cost-effective means of analyzing the best site for disposal of solid waste.

Designing Transport Routes for Waste Collection and Transport

Designing short routes for waste collection is possible within a GIS system. The application of GIS in route planning and designation of collection points in some experiments has brought up a number of lessons. First, GIS is capable and can help improve waste collection in residential neighbourhoods in urban areas.

Secondly, in order to have an efficient solid waste management system, GIS may be adopted because it is capable of handling both spatial and non-spatial data necessary for effective solid waste collection system.

Thirdly, solid waste collection contractors prefer routes which are short and cheap, with high rate of return within a short period. However, traditional methods of handling data are incapable of identifying the least cost routes for solid waste collection.
Fourthly, GIS has been proved to be a tool that provides the alternative method of minimizing operational costs for contractors (Kyessi and Mwakalinga, 2009).

Methodology

The study was conducted in Abeokuta, Ogun State. Abeokuta is both the capital and administrative headquarters of Ogun State situated in the South-Western part of Nigeria with coordinates between latitude 7° 09′ N and 7° 19′N and longitude 3^0 29′E and $3^0$41′E .

Materials

A Satellite Image (IKONOS, December 2006) of Abeokuta metropolis was obtained from the GIS unit of Institute of Food Security, Environmental Resources and Agricultural Research (IFSERAR), University of Agriculture, Abeokuta (UNAAB).

Land-use / land-cover map, road map, topographic map, drainage map, and other relevant maps were obtained from relevant agencies including the Water, Environmental and Sanitation (WES) department of the Local Governments, Cartography Laboratory at the Department of Water Resources Management and Agrometorology and the GIS Unit of IFSERAR, UNAAB. Global Position System (GPS) device was used to determine the coordinates of existing dumpsites.

Hardware and Software

The hardware used in this study include Compaq Presario CQ 60, HP DeskJet 1220C color printer, HP Scan Jet 2400, Logic Trace Digitizer, Garmin 12x Global Positioning System (GPS)

device and Sony digital camera (8mp). The software used in preparing and analysis of the data include ILWIS 3.2, ArcGIS 9.3 and ArcViewGIS 3.2 with Network Analyst extension.

Data Analysis

Five major GIS spatial operations were performed to achieve the set of objectives for this research. These are digitizing, buffering, overlay, query and network analysis (Sani et al, 2010).

Results

Location of Existing Dumpsites in Abeokuta

The dumpsites in Abeokuta were located on a map in Fig 1. The legal dumpsites are located at Saje (Old Quarry Site) which happens to be the largest dumpsite in Abeokuta; Olomore, Totoro and Ita-Oshin areas while the illegal dumpsites are arbitrarily located at any available space. Some of them as shown in Fig 1 include Lafenwa, Oke-Efon, Ilugun, Ita-Eko, Akinolugbade e.t.c. areas.

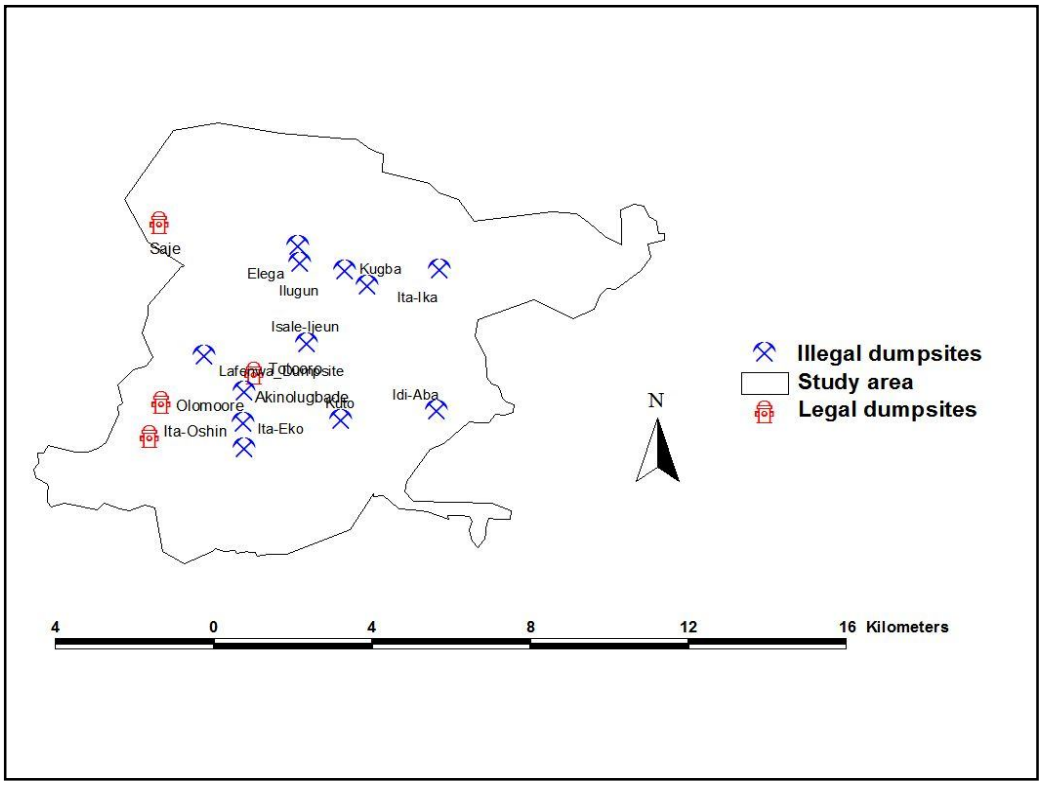


Fig. 1: Map of Study Area Showing the Legal and Illegal Dumpsites in Abeokuta

Road and Drainage Networks in Abeokuta

The road and drainage networks in Abeokuta were located on a map in Figs 2 and 3 respectively. The road network consists of the streets, major roads, railway and express road while the drainage network consists of the major river – Ogun River as it cuts across the study area and the surrounding tributaries.

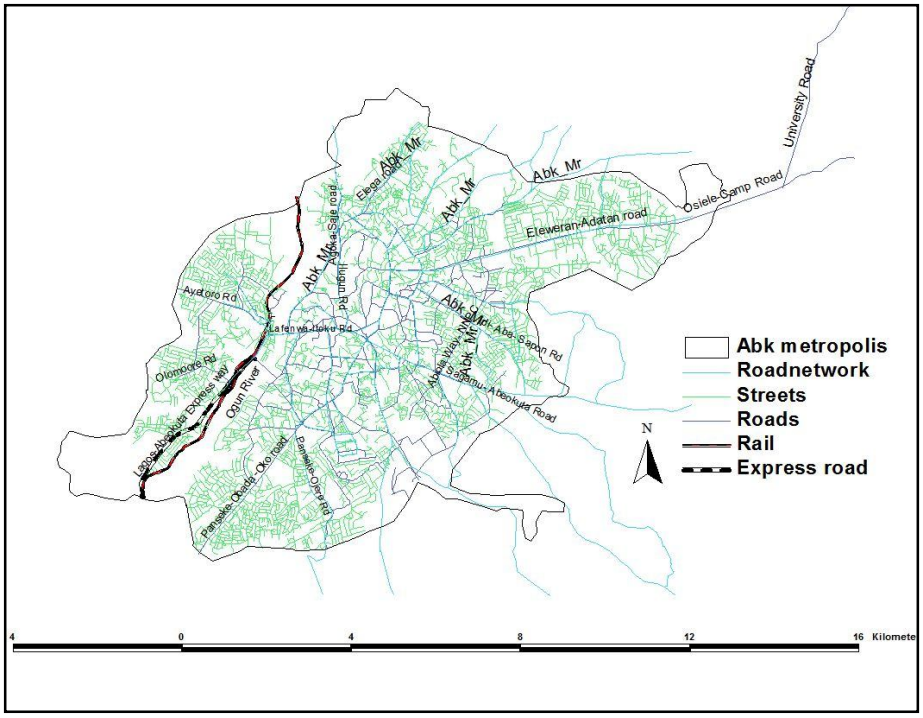


Fig. 2: Map of Study Area Showing the Road Networks in Abeokuta

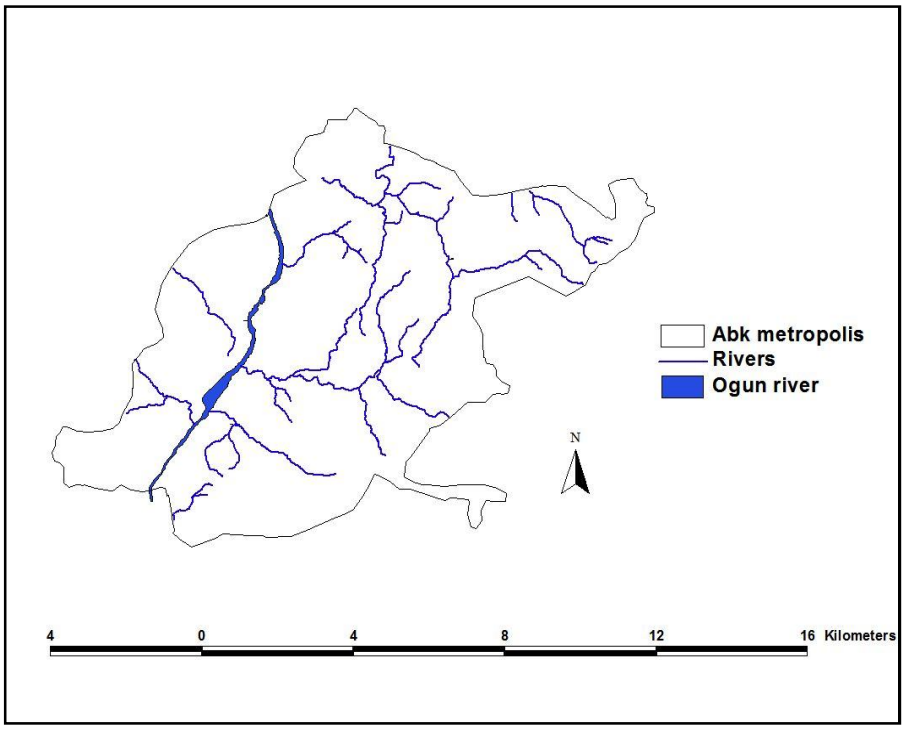


Fig. 3: Map of Study Area Showing the Drainage Networks in Abeokuta

Land-Cover Types in Abeokuta

The land-cover types in the study area are given in Fig 4 below. Land-cover types in Abeokuta include the following: modern and indigenous residential layouts; sports centres; water bodies; religious centres; parks and gardens; commercial centres; barracks and military zones; industrial areas and undeveloped lands among others.

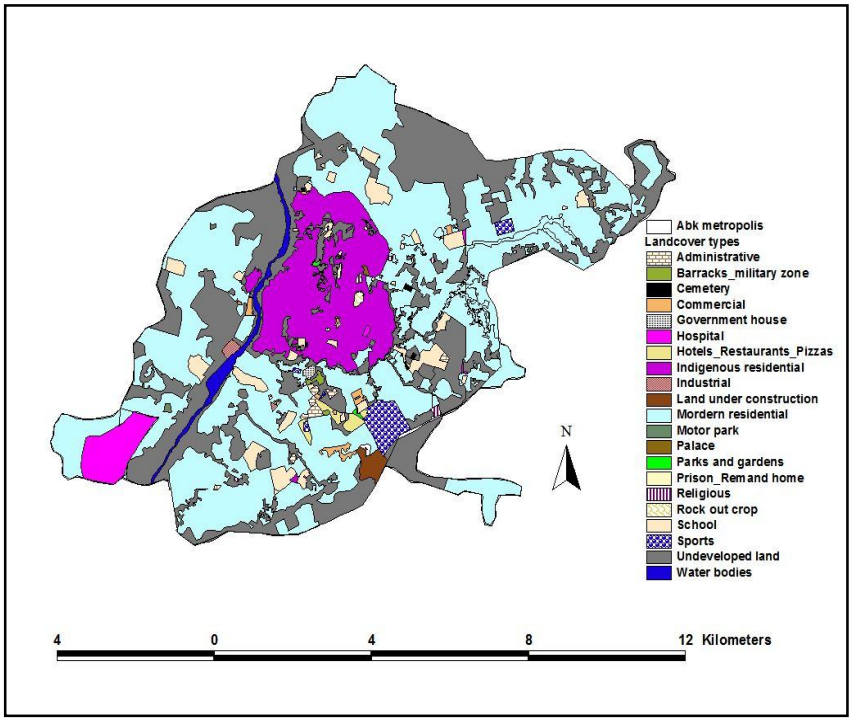


Fig. 4: Map of Study Area Showing the Land-Cover in Abeokuta

Buffering Analysis

In determining the most appropriate locations for siting dumpsites in Abeokuta, a set of buffering analysis were performed on the drainages, land-cover and roads as depicted in Figures 5, 6 and 7 respectively. The distances for creating the buffer zones were adapted from the specifications given by Adeofun et al (2006) and Sani et al (2010). The drainages, land-cover and roads were buffered at 160m, 30m and 200m respectively.

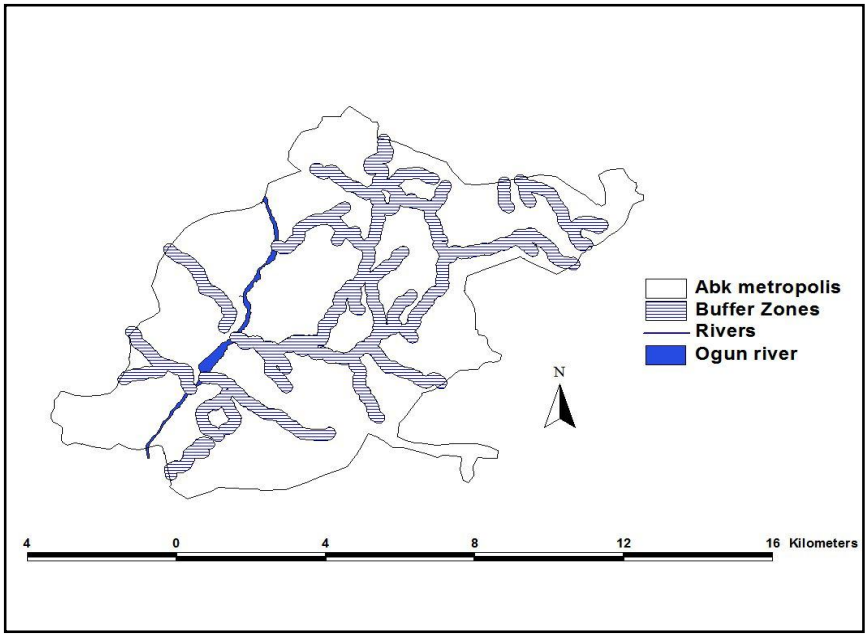


Fig. 5: Map of Study Area Showing the Drainage Buffered at 160m

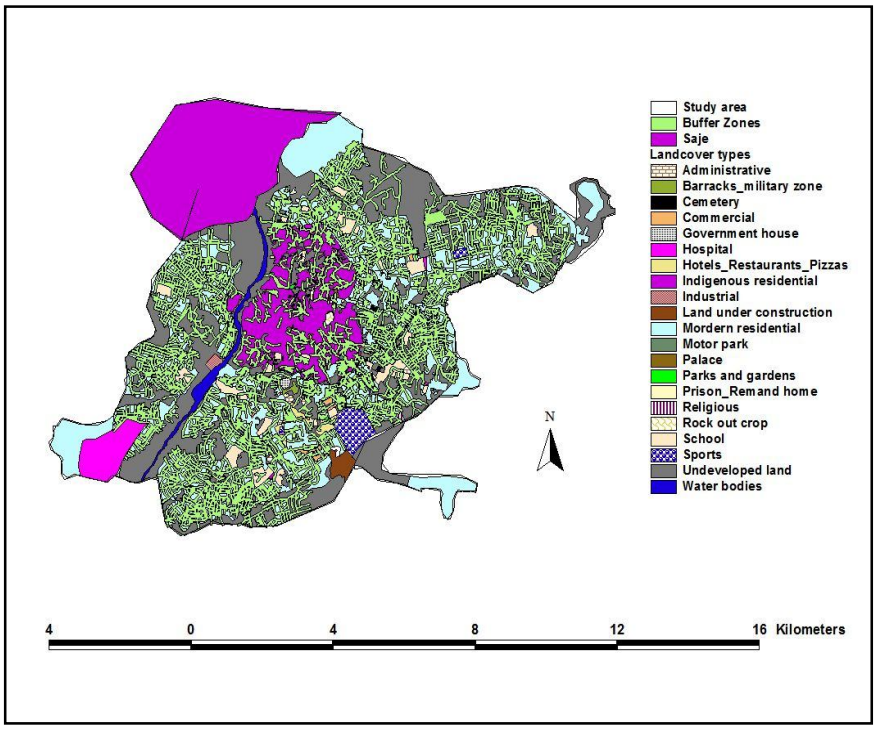


Fig. 6: Map of Study Area Showing the Residential/Land-Cover Buffered at 30m

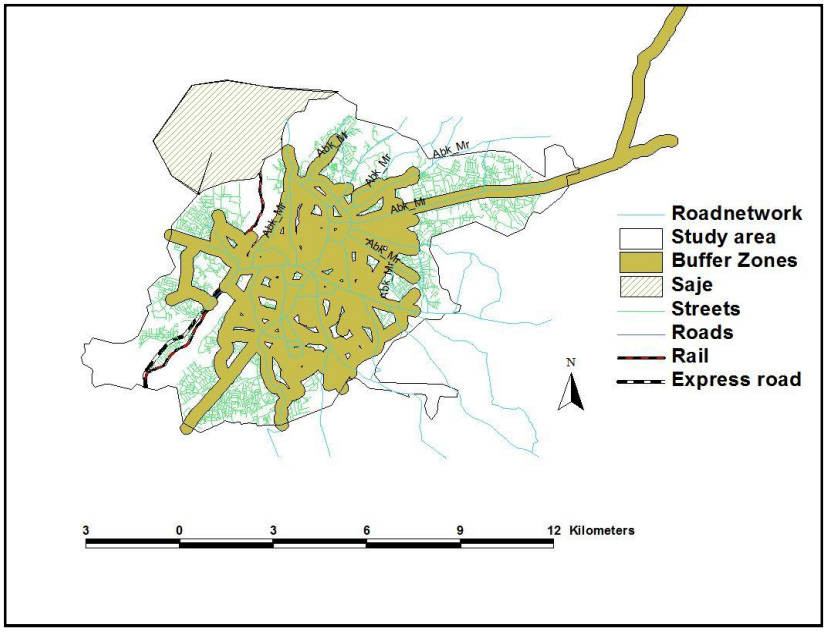


Fig. 7: Map of Study Area Showing the Major Roads Buffered at 200m

Fig 8 shows the initial results of the buffering analysis; the candidate dumpsites (unbuffered areas) overlaid with important resources such as Ogun River, railway, express road and the other tributaries. It can be seen that some of the candidate sites are overlapping these important resources with economical / ecological value. Hence, these sites were digitized to exclude parts of the resources.

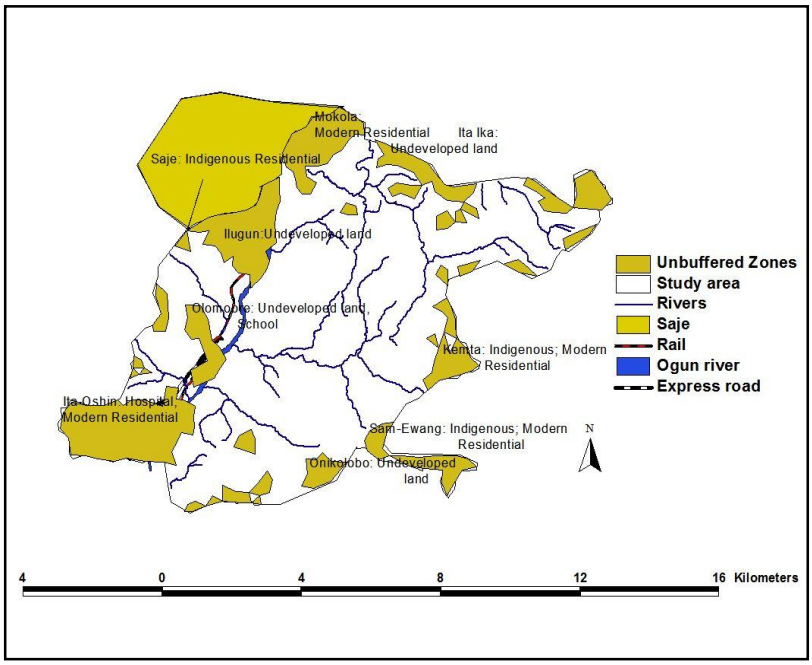


Fig. 8: Map of Study Area Showing the Candidate Dumpsites (Unbuffered Zones) Overlaid with Important Economic / Ecological Resources

Fig 9 shows the combination of all the buffered zones, i.e. the drainages, land-cover and roads, and clearly illustrates the areas left 'unbuffered'. The areas left after buffering can be seen from the legends on the various maps. These areas are the digitized "candidate dumping sites" which were subjected to further analysis to determine the most suitable locations.

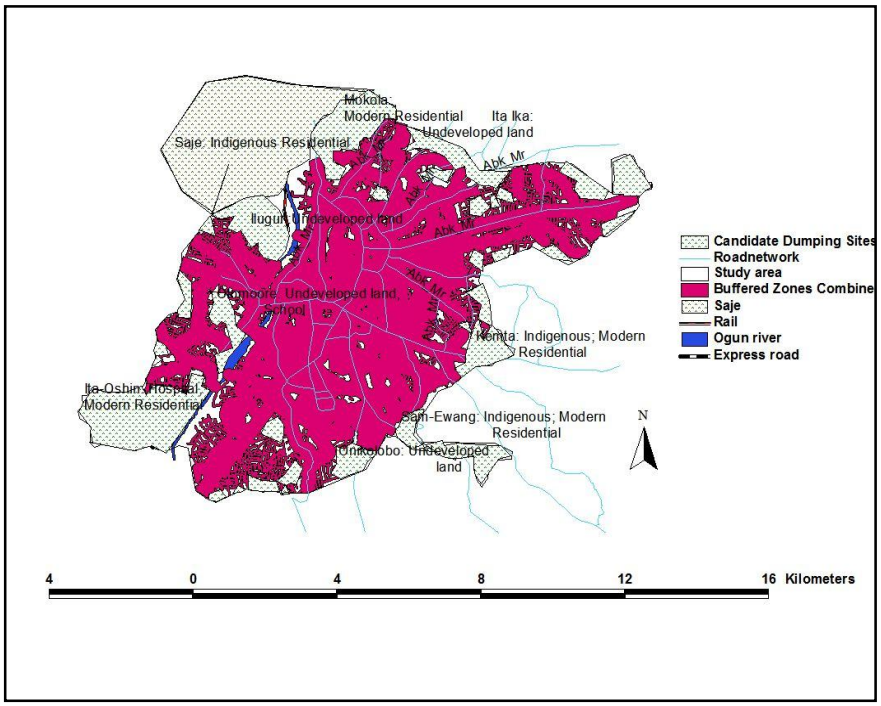


Fig. 9: Map of Study Area Showing the Combination of all the Buffered Zones and Candidate Dumpsites ("Unbuffered Zones")

Determining the Most Appropriate Dumpsite Locations

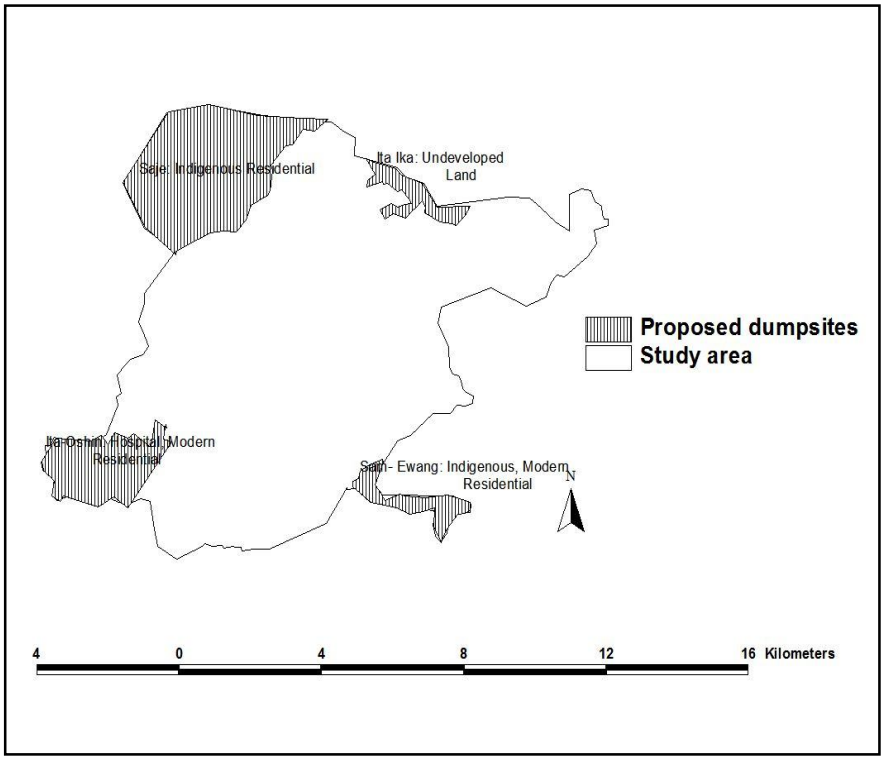
The locations proposed as dumpsites in Abeokuta as shown in Fig 9 include *Saje*, *Ilugun*, *Olomore*, *Ita-Oshin*, *Mokola*, *Ita-Ika*, *Onikolobo*, *Sam-Ewang* and *Kemta*. The areas of the candidate sites are given as 12.06km^2 for Saje being the largest site; 4.64km^2, 2.66km^2, 2.14km^2, 1.47km^2, 1.47km^2, 1.44km^2, 0.87km^2 and 0.71km^2 for Ita-Oshin, Mokola, Ilugun, Ita-Ika, Sam Ewang, Kemta, Olomore and Onikolobo respectively.

Saje, with an area of 12.06km^2 and an indigenous residential area located far away from any resource of economical / ecological value, can be described as one of the most appropriate site.
Ilugun has an area of 2.14km^2 and is described as an undeveloped land. It is however situated some few kilometers near a railway station and is not readily accessible.
Olomore has a small area of 0.87km^2 and overlaps the railway station, express road and the Ogun River and is described as "undeveloped land".

Ita-oshin with a fairly large area of 4.64km^2 is described as a modern residential area and has a notable hospital. It is also overlapping the railway station, express road and the Ogun River which are resources of important economic / ecological value.

Onikolobo and *Ita- Ika* are areas described as 'undeveloped land' with areas of 0.71km^2 and 1.47km^2 respectively and located away from resources of economic importance.
Sam Ewang, Kemta and *Mokola* have areas of 1.47km^2, 1.44km^2 and 2.66km^2 respectively and consist of indigenous and modern residential areas with no attachment to any resource of economic / ecological importance.

From the descriptions above, the most appropriate sites are given in Fig 10 as follows: *Saje, Ita-Oshin, Sam-Ewang,* and *Ita-Ika*. The total area of the four most appropriate sites is 19.64km^2 out of a total area of 79.95km^2 for the study area.



Fi.g 10: Map of Study Area Showing Locations of the Proposed Dumpsites in Abeokuta

Determining the Shortest and Least Cost Routes

The proposed transport routes are depicted in Fig 11. These gave directions which are the shortest distances between the proposed dumpsites and are also cost-effective. It was found out that the first "stop" is Saje and it is cost-effective to travel through Ita-Ika and Sam-Ewang before making a final stop in Ita- Oshin and vice-versa if Ita-Oshin becomes the first stop.
The total cost for the "stop" routes which is the shortest route that connects the stops is 27.30km as shown in Table 1 while the total cost to make a round-trip (Tour Route Cost) is given as 36.00km. The difference which is 8.70km represents the cost for making a straight trip from "stop" 1 (Saje) to "stop" 4 (Ita-Oshin).

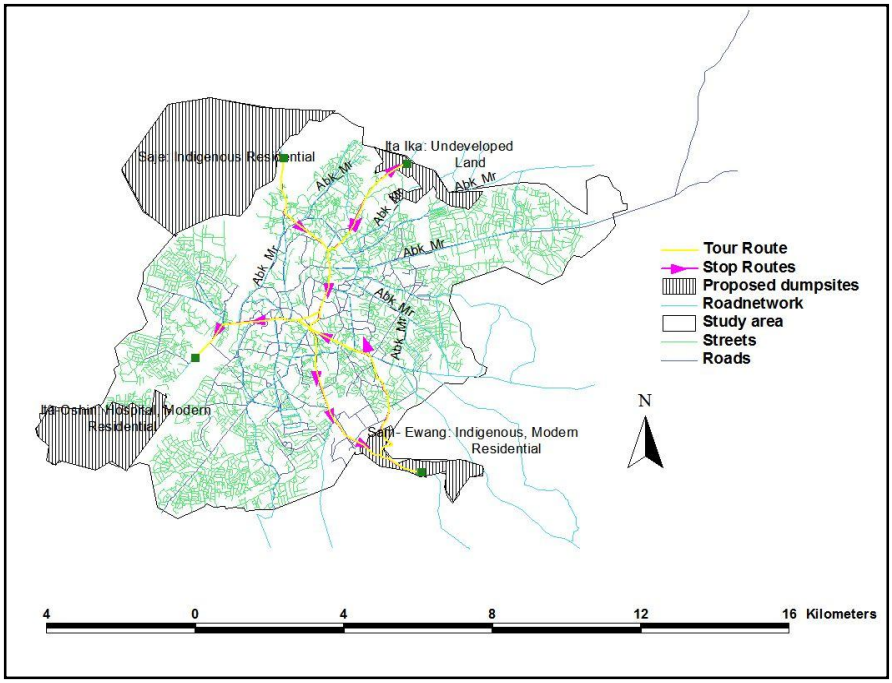


Fig. 11: Map of Study Area Showing the Proposed Transport Routes in Abeokuta

Table 1: Attributes of Tour Routes Theme in Network Analyst

Shape	*Path_Id*	*Proposed Dumpsite*	*F_label*	*T_label*	*F_Cost (km)*	*T_Cost (km)*	*Distance (km)*
PolyLine	1	Saje	*Stop 1*	*Stop 2*	0.000	0.058	0.00
PolyLine	2	Ita-Ika	*Stop 2*	*Stop 3*	0.058	0.158	6.39
PolyLine	3	Sam-Ewang	*Stop 3*	*Stop 4*	0.158	0.247	17.49
PolyLine	4	Ita-Oshin	*Stop 4*	*Stop 1*	0.247	0.326	**27.30**

Path_Id = An Identifier *F_Label* = "From" Label *T_ Label* = "To" Label
F_Cost = Cost of Reaching the F_Label Point
T_Cost = Cost of Reaching the T_Label Point

Discussion

The arbitrary and indiscriminate siting of dumpsites in Abeokuta has led to the creation of so many patches of unsightly mountains of refuse scattered around the city. Four major areas which are Saje, Olomore, Ita-Oshin and Totoro are currently regarded as legal dumpsites while the others are termed as arbitrary. Burning still remains the most applied method of waste disposal especially for the illegal dumpsites, because the frequency at which waste is burned is higher when compared to that of the legal dumpsites (Ogwueleka, 2009).

The final selection of the dumpsites after various analyses in ArcViewGIS is influenced by several factors including the size (area) of candidate sites, nearness to resources having ecological / economical importance, accessibility to roads and type of development activities that have taken place in such a location (Adeofun et al, 2006; Sani et al, 2010 and Sener, 2010). *Saje,* one of the proposed sites, is preferred for its large size and distance from areas with important economical/ecological value; and will serve *Ilugun* and *Mokola* which were initially selected but later eliminated. *Ilugun* and *Mokola* were eliminated during the selection process because they were closely located to *Saje* which is large enough to serve the areas. Furthermore, *Ilugun* is overlapping the railway, Ogun River and express road and would not be large enough if any attempt is made to reduce it farther away from these obstacles; it is also not on the road network i.e. not currently accessible to other locations.

Sam – Ewang is another proposed site lying between *Onikolobo* and *Kemta* which were both eliminated as well due to the clustered nature of their locations. It is therefore intended that *Sam-Ewang* will serve both locations as it lies in-between and is accessible from both locations. *Ita-Oshin* was favoured in the selection process even though it overlaps some obstacles because of its large area. It is therefore advised that about 1.5km – 2km of its 4.64km should be carved out from the obstacles before siting the dumpsite in the area. It will also serve Olomore area which was initially selected but later eliminated because of its nearness to resources of important value and very small size.

Determining transport routes for waste collection and transportation services is very essential in order to reduce travel costs and increase efficiency in transferring wastes to disposal sites (Ogra, 2003). The most appropriate route from the starting point, *Saje,* is through *Ita-Ika, Sam-Ewang* and finally to *Ita-Oshin* and vice-versa.

Conclusion and Recommendation

It has been demonstrated beyond every reasonable doubt that GIS is a very important tool for determining the most appropriate locations for siting dumpsites and finding the least-cost travel routes for waste transportation and disposal. Therefore, the proposed dumpsites should be considered as appropriate waste disposal / landfill sites and as such, approved for location. Locating disposal / landfill sites should not be arbitrary and its management should be deliberately planned and consistent to ensure a continuous and efficient waste management program. Transport routes should be short to allow for multiple trips, efficiency in waste collection and transportation and cost-effectiveness. Also, the following recommendations are made:

- *Saje* dumpsite should be retained and considered a possible location for siting landfill.
- *Olomore* and *Totoro* dumpsites should be relocated while *Sam-Ewang* and *Ita-Ika* dumpsites should be upgraded and made to function as legal waste disposal sites
- The road network should be expanded to enable a wider coverage of inaccessible areas for efficient waste collection and transportation

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Environmental Management Conference
September 12 – 15, 2011

Secretariat: College of Environmental Resources Management (COLERM) Building, University of Agriculture (UNAAB), PMB 2240, Abeokuta, Ogun State;
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Theme: Managing Coastal and Wetland Areas of Nigeria

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Communiqué

An Environmental Management Conference was held from September 12 -15, 2011 at the University of Agriculture, Abeokuta with the theme "Managing Coastal and Wetland Areas of Nigeria".

Assessing the challenges and solutions to environmental management in the coastal and wetland areas of Nigeria, professionals in the water, public health, urban planning and infrastructural development sectors discussed best practices, regulation and innovations for provision of safe and green environment. The following recommendations were made:

1. Experts in environmental and urban development should generate and make use of appropriate maps in developmental projects of fragile environments like the coastal and wetland areas;
2. Reclamation and regeneration of coastal and wetland areas of Nigeria;
3. Promotion of ecotourism to boost the economy of the country;
4. The government should be proactive in providing information on natural disasters like flood, seismic and volcanic activities by providing adequate number of seismic monitoring and hydrometeorological stations for sustainable monitoring and forecasting of natural hazards;
5. Enforcement of environmental policies to curb dumping of solid wastes and discharge of industrial effluents into the natural ecosystems by the advocate of polluter-pays policy;
6. The need to control the increasing encroachment of farming and building activities around the wetland to avoid soil erosion, removal of the vegetation and degradation of the ecosystem ;
7. Development of a mandatory localized sustainability reporting framework for deforestation, and land degradation due to oil and gas exploitation in line with international best practices;
8. Observation of high degree of surface water and shallow groundwater pollution calls for immediate action with respect to governmental operation of regulatory laws in respective local government areas in the country;
9. The inability of surface water development alone to satisfy the future water demand of water users was recognised. To reduce unmet demand, waste water treatment, introduction of water meters to check wastage, building of new dams or increasing the capacities of existing ones, groundwater development, information dissemination and development of manpower in the field of water resources are recommended.

These recommendations are specifically made in good faith for the attention of the following arms of government whom we consider as the direct stakeholders:

1. Federal Ministry of Water Resources
2. State Water Corporations
3. River Basin Development Authorities
4. Nigeria Integrated Water Resources Management Commission
5. Nigeria Society of Engineers
6. National Institute of Land Surveyors
7. Nigerian Mining and Geosciences Society
8. Federal Ministry of Environment

We regard this phenomenon as a critical challenge to all stakeholders, and we sincerely expect that ad hoc programmes would be initiated for a proper implementation of the remedial measures on all the above enumerated problems.

Prof. O. Martins
Chairman Local Organizing Committee

Dr. E. A. Meshida
Chairman Technical Sub-Committee

September 14, 2011

Acknowledgement

The Local Organising Committee of the Environmental Management Conference 2011, wishes to acknowledge the support of the Federal University of Agriculture, Abeokuta and Africa Geoscience Review, Paris, France.

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