Available online www.jsaer.com

***Journal of Scientific and Engineering Research*, 2016, 3(6):207-221**

Research Article

ISSN: 2394-2630
CODEN(USA): JSERBR

Modelling Changes in Soil Chemical Parameters of Obio-Akpor, Rivers State, Nigeria using Geographic Information System

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Abstract This research is to show the changes in soil quality, land use, land cover, soil physicochemical parameters and morphology. Satellite data and Geographic Information System (GIS) were used to investigate the soil changes in physicochemical parameters, land surveying and satellite data (Landsat TM and Arcview GIS 3.3) were used in GIS to explain the landforms and correlation between landforms, soil physicochemical properties and the morphological characteristics. The area was dominated by flood plain and marine plain of 58.24% while the water bodies and urban exhibit 41.76%, and the physicochemical properties were mapped. The morphological characteristic showed the textural class to comprise of silty loam, clay loam, sandy clay loam, sandy loam, and loamy sand while the soil structure are weak, strong and medium angular blocky and sub angular blocky with its consistency being non sticky due to the presence of abundant roots and some plastic in a non-root area. There is a prolonged distribution of the constraints of productivity all over the region due to the changes in the soil and land use settlement which could be due to the oil exploration in the region.

Keywords GIS; land use; mapping; physicochemical; remote sensing; soil morphology

Introduction

Rivers State has been the largest producer of oil in Nigeria, before 1971 River State was known for their cultivation in agriculture and their basic source of skill and labour was relied on man which rubber, cassava, yam, cocoyam and pepper were the major crops grown [1]. Soil is a complex and heterogeneous material made out of inorganic and characteristic matter. The ability to depict their portions at an extending level of detail makes soil a fundamental trace proof for research examinations. According to [2] soil maps give a pre-knowledge or basis for clarity about the composition of the soil and its terrain with correlations of soil-landforms and soil variability or differences across landscapes. These models are summed up from direct field perceptions, remotely-sensed information, and unsaid knowledge of soil, landform, geology, vegetation, and land use. Depth characterization likewise gives a key parameter in deciding volumes of polluted soil. Although quantitative estimation and modelling move forward the precision of soil maps, a more noteworthy comprehension of the hidden properties and procedures that result in various temporal and spatial soil patterns and their suggestions to precision farming is required [3]. The soil map is a stock of soil resources of a region, which empowers the user to make most extreme utilization of the data for planning and decision making [4]. The land suitability evaluation procedure in the quantitative approaches involves many simulation modelling systems [5, 6] to quantify the potential of land for specific uses. FAO guidelines on land evaluation system [7, 8] and physical land evaluation methods [9] were widely used for land suitability assessment by considering numerous parameters. GIS hold great promises for improving the convenience and accuracy of spatial data, more productive analysis and improved data access. These technologies have been used to assess the criteria required to define the suitability of land [10-14] and were also adopted for the present study. The main goal of this research was to use geographic information system (GIS) and Landsat TM with ARCVIEW GIS 3.3 for a detailed soil mapping on the changes in their physicochemical properties of the studied area [15]. There exist a distinct lack of successful remote sensing and GIS demonstration, leading to an occurrence of resource management. Many government departments and educational institutions have very little staff with little knowledge of these technologies [16].

Materials and Methods

Study area

Obio-Akpor community of Rivers State in Nigeria, is located between longitude 4^o 00 North to 5^o and 45 North and latitude 5^o and 30 to 7^o 30 East and is located in Rivers state. The research area covers an area of approximately 280km (**Fig. 1**). It is bounded by Etche, Port Harcourt and Ikwerre Local Government Areas.

Soil sampling and collection

Soil samples were collected from 8 profile pits, giving a total of 40 samples for the entire study area. The horizons of each profile were quantitatively sampled. Each profile and mini-pit was examined and described immediately after digging. Profiles measured approximately 200 cm by 100 cm on the surface and at least 100 cm deep. For all profiles the depths depended on the presence or absence of the underlying rock or huge boulder or the nearness of the water table to the soil surface. Profile description followed the standard, soil description in the [17, 18]. Information of the site, profile and horizons of each profile were recorded in detail. Some of the information on each site gathered were profile number, grid reference, date of sampling, elevation, rock outcrops colour, texture, structure, consistence, concretions and other physical parameters that could bring out morphological differences between the soils.

Sample preparation

Soil samples brought from the field were air dried and sieved through a 2mm sieve and materials larger than 2mm was discarded while that below 2mm was retained. The samples were then bagged and labeled [18]. They were later subjected to laboratory analysis, (physical and chemical) following recommended standard operation procedures.

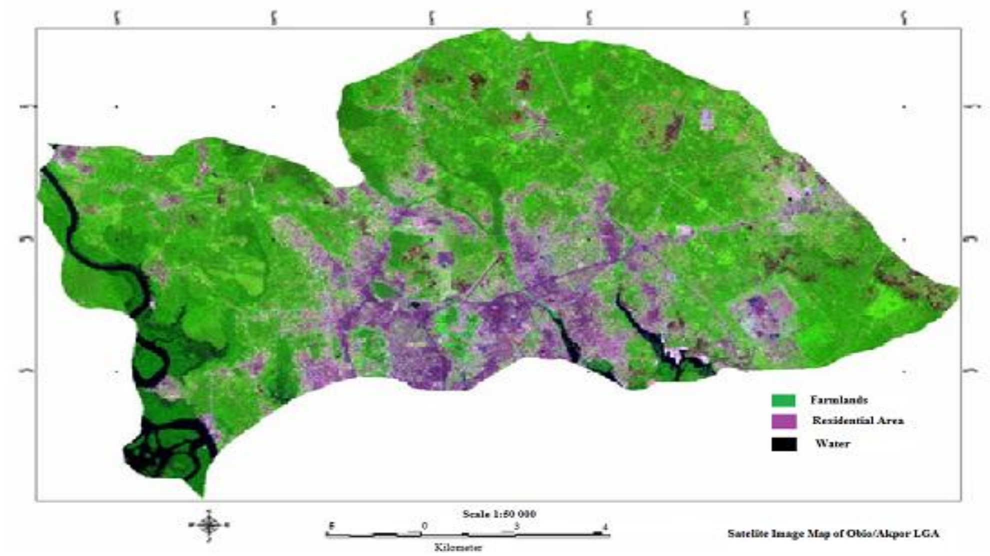

Figure 1: Satellite map of Obio-Akpor community

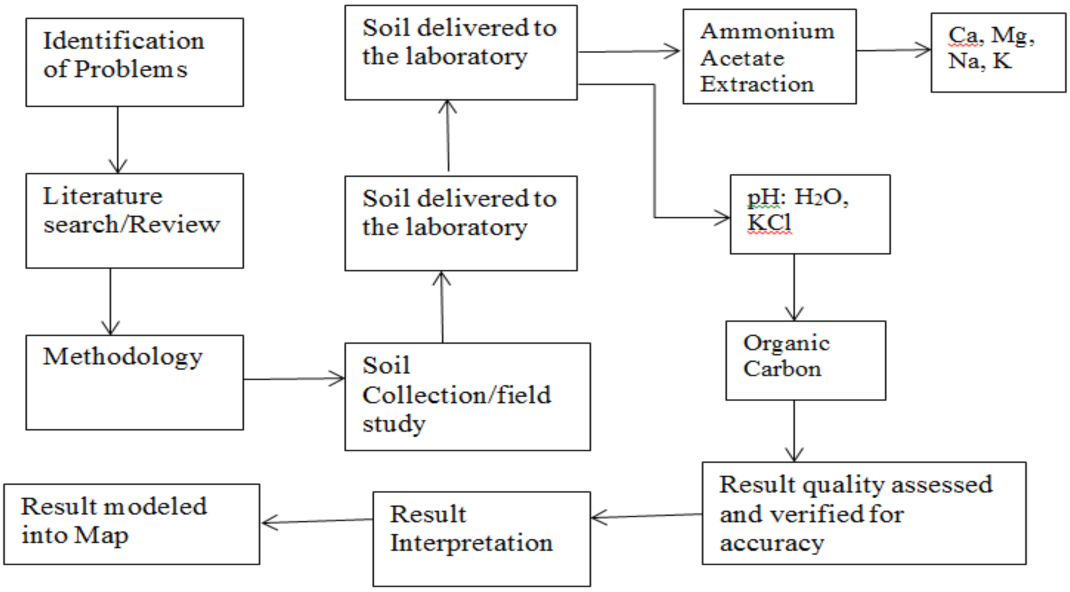

Figure 2: Flow chart of research method used

Laboratory analysis

The hydrometer method was employed as described in ASTM D422-63 [19] as modifications by [20-22]. The pH of soil was carried out in water and in potassium chloride (KCl). In the former, distilled water was used and in the later KCl was the medium. Both analyses were carried out in a 1:1 soil solution ratio [23]. In organic carbon determination, the method [24] was employed. This method also referred to as the wet oxidation method is based on the reduction of dichromate ion by carbon, wherein the unreacted dichromate ion is measured by titration with standard ferrous ion. The percentage of organic matter was gotten by simply multiplication of organic carbon percentage by 1.724 (Van Bemelen factor), on the assumption that organic matter contains approximately 58% carbon. Cation exchange capacity (CEC) was determined by ammonium acetate (1*N*, pH 7.0) extraction procedure, in which case all exchangeable cations in the soil were replaced by ammonium (NH_4) ions. This is the method described by [25] in methods of soil analysis [18]. From the leachate exchangeable (Calcium and Magnesium were determined by EDTA titration methods as outlined by Heald in methods of soil analysis by flame photometry, exchangeable K and Na were determined from the leachate using the EEL Flame photometer as described by Pratt in Methods of Soil Analysis [26] while the Effective cation exchange capacity (ECEC) was calculated by the summation of the values of exchangeable cations and exchangeable acidity [27, 28].

Exchangeable acidity in the soil was determined using the procedure of Mclean (1965) as described by [29]. Determination of total nitrogen was by Kjeldahl digestion and distillation procedure ASTM D6146 – 72 as described by [29] and the same was used by [30] in Methods of Soil Analysis. Total Potassium, Aluminum and Iron were carried out using the standard method of [25]. In this method, 0.5g of soil that had previously been passed through 0.5mm-mesh acid. The mixture was evaporated to dryness and the crucible cooled. Five (5ml) of 6*N* hydrochloric acid (HCl) and 5ml distilled water were added. The mixture was gently boiled to dissolve the contents completely and then filtered into a 100ml volumetric flask and made up to mark with distilled water. The filtrate was saved for the determination of Fe, Al and K. Calorimetric determination of total Fe using orthophenanthroline method was employed. This process was done after the extracted soil had been treated, using the method outlined for dithionate vitrate-bicarbonate Al. Total K was determined calorimetrically using the EEL flame photometer. Total Al was determined calometrically using the modified aluminum method [26, 31].

Remote sensing data analysis software and method

Software used is ArcView 3.3 and was used for displaying then subsequent processing and enhancement of the images. It was also used for carving out Obio-Akpor from the whole of Rivers state satellite imagery. Remote sensing and Geographical Information Systems (GIS) were used to produce the land use maps of the period in consideration (1986-2013) and the approximate square kilometers were calculated. This was done for each land use type per year in order to determine the change and percentage of change in the total area covered. The images used were Landsat TM of 1986 to 2013. Both imageries possessed the same resolution. The Images were imported to Arcview GIS 3.3 and geo-referenced to geographic coordinates using the same control points. Both imageries were perfectly aligned and overlay. In order to determine the boundaries of each land-use type the images were enhanced and smoothened using image analyst via Arcview GIS 3.3. Individual land-use were captured in polygons and rational database created for each land-use. QUERY BUILDER was used to query the database for spatial location of each land-use on the map and the aerial extent was calculated individually for each land-use type. Land-use map of 1986 was then overlaid on the land use map of 2000 using Booliean Logic of UNION OPERATION, to show how a land use type in 1986 has changed to another in 2013. The union operation technique, under Booliean method, was used to graphically show the land use change detection over the years and periods in consideration. Union operation, combines features of an input theme that contains the attributes and full extent of both themes. The themes in this context are the land use and land cover maps of 1986 to 2013.When the two are overlay the output contains the attributes of both. These attributes can then be queried in order to determine the land use change over time in the study area. This was achieved using the equation (1).

$(LU\ 1986)$land use “AND (LU 2013)=$Land\ use\ type$” (1)

This method comes under the supervised classification method which is more precise for mapping classes but highly dependent on the image specialist skills.

Data description

Landsat TM, (Thermatic mapper), imageries of 1986 to 2013, which both had spatial resolutions of 30 meters, that each pixel represent an area on the earth surface 30m x 30m. It also has an orbital altitude of 710 km. The Landsat TM is an active sensor and it has enough energy to penetrate soil for as much as 1 meter. The imageries covered the entire study area. Landsat TM was acquired with Path 188 and row 056 having a resolution of 30m and scale of 1:50,000.

Mapping methods

The mapping method adopted for this survey are preliminary photo interpretation, ground reconnaissance and establishment of mapping units and profile sites using the imageries of the year 2000 and the topographic map of the research area. Field work: (a) profile digging, examination/description (b) soil sampling from profiles. Photos were preliminarily interpreted by tentative identification of land-use and land-cover types of the research area. Land-use and land-cover types identified include the following; (i) water (ii) mangrove, (iii) primary forest, (iv) secondary forest, (v) farmland (vi) sparse vegetation, (v) settlements. Pedon locations used on the result tables are from Choba, Elelenwo, Eneka, Obokuru, Orazi, High Mould, Elingbu and Rumuokoro which are represented as Pedon A1, A2, A3, A4, A5, A6, A7 and A8 respectively.

Results and Discussions

Morphological Characteristics

The morphological characteristic results are shown in (Table 1) signifying the soil colour by moist method, textural class, soil structure, consistency, roots/rootlets mottling and boundary while the physicochemical properties for pH, carbon nitrogen ratio (C:N), organic matter (OM), total nitrogen (TN), organic carbon (OC) sodium (Na^+), potassium (K), Calcium (Ca^{2+}), magnesium (Mg^{2+}), total exchangeable bases (TEB), total exchangeable acids (TEA), effective cation exchangeable bases (ECEC) and base saturation are shown in (**Table 2**). **Table 3** indicates the percentage change of each land use and land cover from 2000 to 2013 (**Fig. 11**), meanwhile the GIS mapping for changes in physicochemical characteristic of the soil of the study area between year 2000 and 2013 are shown in (**Fig. 3 – 8**), the land cover and land use map between the years of 1986 to 2013 are alienated in (**Fig 9 and 10**). As shown in (**Table 1**), it revealed that the textural class comprises of silty loam, clay loam, sandy clay loam, sandy loam, and loamy sand while the soil structure are weak, strong and medium angular blocky and sub angular blocky with its consistency being non sticky due to the presence of abundant roots and some plastic in a non-root area. As indicated in the GIS (**Fig. 3)**, there was a reduction of organic matter in the land use types. This proved a correlation between the soil analysis results with that of the GIS analysis. Soils of the study area cannot easily clump and form aggregates. There was a drastic reduction in the organic carbon content of the soils in the mapping area. This is presented in (**Fig. 4**). Organic carbon aided increase of cation exchange capacity of soils as well as water holding capacity [32, 33]. It also contributed to the structural stability of the soil by helping to bind aggregates together. It also holds trace elements important for plant growth. The reduction of this parameter led to a decline in soil fertility of the study area. Base saturation of the study area in (**Fig. 5**) showed a slight decrease in concentration in the year 2013 when compared with the year 2000. It could be said that the base saturation of the study area was higher in the year 2000 because of the application of fertilizers resulting from high level farming activities and thus gives credence to the fact that there was a decrease in agricultural activities in the year 2013. Soils with a high clay fraction have a higher cation exchange ratio. In (**Fig. 6)** it shows that ECEC of the soils of the study area reduced thus indicating its inability to hold nutrients. Using the analysis of the GIS as indicated in (**Fig. 7)**, it was discovered that there is a decrease in soils of the study area. This is attributed to factors like prolonged and intensive fertilization. It has also led to a reduced crop yield and damages. Under this condition, the soils availability of micronutrients such as manganese, aluminum and iron have increased and as a result of the increase toxicity problem of micronutrients have occurred. This has also led to the absence of availability of essential nutrients such as nitrogen, potassium and calcium. Thus monitoring soil pH changes over time is an important management tool. This will make it possible to provide adequate management to improved crop production. From the GIS map of the soil analysis it can be seen that there was a general decline in the nitrogen content of the soils of the study area (**Fig. 8**). This is because the soils in the mapping area are low with marshy land. The soils found in this area have gone through the process of de-nitrification, where soil nitrogen is lost to the atmosphere. Leaching also occurs in marshy area since the soils are saturated with moisture. Crop removal deforestation has led to runoff and subsequent reduction in the nitrogen content of the soils of the study area.

Land use change detection analysis

The different Land use changes detected during the analysis are presented in (**Table 3**). Farm lands of the study area covered a high percentage area of 23.86% in 2000 but reduced to 20.17 %.This was due to rush for white collar jobs. This led to a reduction in agricultural activities. Occasional flooding caused by torrential rainfalls in the study area also washed away farmlands thus hampering agricultural production.

Primary forest of the study area decreased from the year 2000 to 2013. A value of 20.71% in the year 2000 to 14.18 % in 2013 was noted, this also has been related to the activities of man in the study area. The study area is rich in petroleum resources and is thus a great attraction for industrialization and development processes.

This has led to a lot of deforestation activities in the study area. Mangrove forest reduced from 8.02 % in the year 2000 to 5.33 % in the year 2007, there was also a further reduction from 5.33 % to 3.4 % between 2007 and 2013 (**Fig. 11**).This was simply due to the activities of man in the study area, and they included construction, industrialization and commercialization activities. During these processes, mangrove forests are cleared to make available land for development. Moreover since there is an increase in the cases of oil spills in the study area, which is another factor that has contributed to a reduction of mangrove forest in the study area. In the case of the secondary forested areas, there was a reduction from 2000 to 2013 (23.06 % to 7.38 %), this is human induced and has been attributed to increased oil exploration in the study area.

Between the years 2000 and 2013 changes in water bodies occurred (2.85% & 4.26%).This could be related to development activities which resulted in water staying mostly on the surface of the soils, it could also be an indicator for soil compaction and increased bulk density of soils of the study area. The blocking of water channels, erection of buildings on the drainage paths can cause some of these problems. All these have led to water remaining on soil surface of the study area. This is also an indication of the effects of climate change in the study and should be taking as a warning. Surprisingly, and it could also be an index by which climate change can be monitored and measured. The land use settlement pattern of the study area also showed very significant trend of changes from between the years 1986 to 2013. There is an increase in the settlement pattern of the study area between 1986 and 2013 which from (**Fig. 9**) the settlement pattern indicates dispersed type of settlement which (**Fig. 10**) for 2013 clearly shows a nucleated pattern of settlement which shows increase in the settlement of the study area. This is visibility the highest change in the pattern of land use distribution in the study area. People migrate to the study area for various reasons, principally due to the fact that the study area is a hot spot for oil exploration and production, which has led to the existence of many oil servicing jobs. This has also put a high demand on housing, health and general services in the study area. There exist a high demand and desire for oil jobs and white collar jobs and other means of livelihood and this has led to a decrease in farming activities, (people now want easier ways of livelihood) and subsequently farmland. Looking at the settlement pattern, it shows a high influx of people into the study area. This has also led to increase in crime, health disorders and generally poor living standards.

Classification of the Soils

The soils are mainly ultisols (Choba, Elelenwo, Eneka, Elingbu, Rumuokoro and Obukuru) pedons and inceptisols (Orazi and High mound) pedons. The first six pedons are characterized by dark colored top soils described as having mainly Umbric Epipedon. In the subsurface evidence of illuvial clay accumulation was prominent giving them argillic horizons. Because the coastal plains areas have greater than 2500 mm of rainfall annually, the predominant soil moisture regime is Udic. These six soils can be classified as udults. The remaining two pedons (Orazi, and High Mound) do not have well developed horizons. They are located on relatively less stable physiographic units, have light colored surface soils (Cambic horizons), and either have no distinguishable subsurface diagnostic horizons. Their base saturation is also relatively higher than the first set of pedons. They are classified as inceptisols (ochrepts).

Table 1: Morphological characteristics of study area

Horizon	Depth(cm)	Soil Colour (moist)	Texture	Structure	Consistency	Roots/Rootlets	Mottling	Boundary
PEDON A1								
Ap	0-15	5YR3/4	SL	2,m-ab	Non-sticky	Abundant roots/rootlets	Absent	W
B	16-30	5YR3/6	SL	3,m-ab	Non -sticky	Abundant roots/rootlets	Absent	W
B1	31-55	5YR5/8	SL	3,m-ab	Non- sticky	Few roots/rootlets	Absent	S
B2	56-69	5YR4/4	CL	3m,-ab	Slightly plastic	Absent	Absent	S
B3	70-84	5YR4/4	CL	3m-ab	Slightly plastic	Absent	Absent	S
PEDON A2								
Ap	0-15	5YR4/4	SL	2,m-ab	Non- sticky	Abundant roots/rootlets	Absent	W
B	16-30	5YR4/2	SL	2,m-ab	Non -sticky	few roots/rootlets	Absent	S
B1	31-55	5YR4/4	SL	2,m-ab	Non-sticky	Few roots/rootlets	Absent	S
B2	56-69	2.5YR4/4	SL	2,m-ab	Non-plastic	Absent	Absent	S
B3	70-84	2.5YR4/4	SL	2,m-ab	Non-plastic	Absent	Absent	S
PEDON A3								
Ap	0-15	5YR3/3	SL	3,m-ab	Non-sticky	Abundant roots/rootlets	Absent	W
B	16-30	10yr3/3	SL	3,m-ab	Non-sticky	Abundant roots/rootlets	Absent	S
B1	31-55	5YR4/4	SL	3,m-ab	Non-sticky	Few roots/rootlets	Absent	S
B2	56-69	5YR4/8	CL	3,m-ab	Slightly plastic	Absent	Absent	S
B3	70-84	10yr4/4	CL	3,m-ab	Slightly plastic	Absent	Absent	S
PEDON A4								
Ap	0-15	5YR5/4	LS	2,m-ab	Non-sticky	Abundant roots/rootlets	Absent	W
B	16-30	5YR4/2	SiL	3,m-ab	Non-sticky	Few	few	S

						roots/rootlets		
B1	31-55	3YR4/4	SL	3,m-ab	Non-sticky	Absent	few	S
B2	56-69	3YR4/4	SL	3,m-ab	Slightly plastic	Absent	few	S
B3	70-84	10yr4/4	SL	3,m-ab	Slightly plastic	Absent	few	S
PEDON A5								
Ap	0-15	5YR4/2	SL	2,m-ab	Non-sticky	Few roots/rootlets	Absent	W
B	16-30	5YR4/3	SL	3,m-ab	Non-sticky	Few roots	Absent	S
B1	31-55	7.5YR4/4	SL	3,m-ab	Non-sticky	Absent	Absent	S
B2	56-69	7.5YR4/4	SL	3,m-ab	Non-plastic	Absent	Absent	S
B3	70-84	10YR4/4	SL	3,m-ab	Non-plastic	Absent	Absent	S
PEDONA6								
Ap	0-15	5YR6/6	SL	2,m-ab	Non-sticky	Abundant roots/rootlets	Absent	W
B	16-30	7.5YR4/4	SCL	1,m-ab	Non-sticky	Few roots/rootlets	Few	S
B1	31-55	7.5YR4/4	SCL	1,m-sab	Non-sticky	Few roots/rootlets	Few	S
B2	56-69	7.5YR4/4	SCL	1,m-sab	Slightly plastic	Absent	Few	S
B3	70-84	7.5YR3/4	SCL	1,m-sab	Slightly plastic	Absent	Few	S
PEDONA7								
Ap	0-15	5YR4/4	SL	2,m-ab	Non-sticky	Abundant roots/rootlets	Absent	W
B	16-30	5YR4/4	SiL	2,m-ab	Non-sticky	Abundant roots/rootlets	Absent	S
B1	31-55	2.5YR4/4	SiL	1,m-ab	Non-sticky	Few roots	Absent	S
B2	56-69	10YR4/4	SiL	1,m-ab	Slightly plastic	Absent	Absent	S
B3	70-84	10YR4/4	SiL	1,m-ab	Slightly plastic	Absent	Absent	S
PEDON A8								
Ap	0-15	5YR4/4	SL	2,m-ab	Non-sticky	Abundant roots/rootlets	Absent	W
B	16-30	5YR5/2	SL	1,m-ab	Non-sticky	Few rootlets	Absent	S
B1	31-55	10YR5/2	CL	1,m-ab	Slightly plastic	Few rootlets	Absent	S
B2	56-69	10YR5/2	CL	1,m-ab	Slightly plastic	Absent	Absent	S
B3	70-84	10YR5/2	CL	1,m-ab	Slightly plastic	absent	Absent	S

Where CL = Clay Loam, SiL= Silty Loam, SCL= Sandy Clay Loam, SL = Sandy Loam, LS= Loamy Sand, l=weak, 2= moderate, 3=strong, m= medium, ab=angular blocky, sab = sub angular blocky.

Table 2: Chemical properties of mapping units

PEDON	**Horizon**	**Depth (cm)**	**Soil pH**	**(%)**				**(meq/100g. soil)**							**%**
			KCl1:1	**OC**	**OM**	**TN**	**C:N**	**K^+**	**Na^+**	**Ca^{2+}**	**Mg^{2+}**	**TEB**	**TEA**	**ECEC**	**BS**
A1	Ap	0-15	5.16	0.63	1.08	0.05	12.6	0.07	0.59	3.09	0.81	4.56	1.09	5.09	100
	B	16-30	6.20	0.10	0.20	0.03	3.33	0.04	0.40	3.00	1.35	4.79	0.35	5.35	93
	B1	31-55	5.19	0.07	0.02	0.04	1.75	0.03	0.47	3.00	1.45	4.95	0.30	5.30	93
	B2	56-69	5.19	0.07	0.07	0.06	1.16	0.03	0.49	3.00	0.80	4.32	0.25	4.25	94
	B3	70-84	5.10	0.07	0.07	0.05	1.16	0.03	0.43	2.90	1.00	4.36	0.30	4.30	93
A2	Ap	0-15	6.00	0.10	0.52	0.03	3.33	0.06	0.31	3.20	0.70	4.27	0.40	4.40	91
	B	16-30	6.05	0.31	0.57	0.22	1.40	0.03	0.28	3.50	0.80	4.81	0.36	5.36	93
	B1	31-55	6.04	0.29	0.30	0.20	1.45	0.02	0.26	2.66	0.80	3.74	0.25	4.25	94
	B2	56-69	6.04	0.08	0.12	0.01	8.00	0.02	0.31	2.50	1.20	4.03	0.35	4.35	92

	B3	70-84	6.04	0.09	0.00	0.01	9.00	0.02	0.26	2.66	1.20	4.14	0.34	4.34	92
A3	Ap	0-15	6.14	0.42	0.80	0.04	10.50	0.07	0.47	3.49	0.90	4.93	0.52	5.52	91
	B1	16-30	6.14	0.17	0.16	0.02	10.50	0.06	0.48	2.50	0.75	3.79	0.40	4.40	91
	B2	31-55	6.14	0.05	0.00	0.01	15.00	0.05	0.36	2.45	0.40	3.26	0.30	3.30	91
	B3	56-69	6.14	0.06	0.00	0.01	16.00	0.02	0.42	2.10	0.60	3.14	0.33	3.33	90
	B4	70-84	6.14	0.14	0.00	0.01	14.00	0.03	0.49	2.00	0.10	2.62	0.44	3.44	87
A4	Ap	0-15	6.09	0.17	1.09	0.03	5.60	0.45	0.51	4.75	0.60	6.31	0.57	6.57	91
	B1	16-30	6.10	0.29	0.30	0.03	9.60	0.25	0.30	4.70	0.40	5.65	0.45	6.45	93
	B2	31-55	6.10	0.22	0.27	0.02	11.00	0.18	0.05	2.66	0.10	2.99	0.36	3.36	89
	B3	56-69	6.13	0.09	0.12	0.01	9.00	0.02	0.44	2.00	0.20	2.66	0.33	3.33	90
	B4	70-84	6.13	0.80	0.12	0.01	8.00	0.01	0.42	2.11	0.20	2.74	0.45	3.45	87
A5	Ap	0-15	6.09	0.50	0.87	0.03	16.00	0.03	0.16	4.00	3.10	7.29	0.55	7.55	93
	B1	16-30	6.10	0.17	0.00	0.02	8.50	0.01	0.03	4.10	2.35	6.49	0.47	6.47	93
	B2	31-55	6.10	0.16	0.00	0.01	6.00	0.01	0.03	2.35	2.25	2.64	0.45	5.45	92
	B3	56-69	6.13	0.06	0.00	0.00	7.00	0.01	0.03	2.20	1.50	2.74	0.44	4.44	90
	B4	70-84	6.12	0.06	0.00	0.10	7.00	0.01	0.03	1.70	1.10	2.84	0.46	3.46	87
A6	Ap	0-15	6.00	0.05	0.85	0.02	2.50	0.04	0.58	1.20	3.24	4.06	0.37	5.37	93
	B1	16-30	6.19	0.11	0.00	0.01	11.00	0.02	0.50	1.20	3.19	4.91	0.33	5.33	94
	B2	31-55	6.17	0.11	0.00	0.02	5.50	0.04	0.42	1.15	2.00	3.61	0.32	4.32	93
	B3	56-69	6.10	0.02	0.00	0.03	4.00	0.04	0.42	1.15	2.00	3.61	0.31	4.31	93
	B4	70-84	6.10	0.03	0.04	0.00	0.75	0.04	0.40	1.15	2.00	3.59	0.37	4.37	92
A7	Ap	0-15	6.00	0.34	0.27	0.04	8.50	2.39	0.37	1.07	1.65	5.48	0.35	5.35	93
	B	16-30	6.10	0.18	0.00	0.03	6.00	1.45	0.32	1.07	2.00	4.84	0.36	5.36	93
	B1	31-55	6.10	0.18	0.00	0.02	4.00	1.64	0.33	1.40	1.40	3.77	0.32	5.32	94
	B2	56-69	6.10	0.08	0.00	0.02	9.00	1.54	0.38	2.10	1.30	5.32	0.37	5.37	93
	B3	70-84	6.10	0.09	0.00	0.02	9.50	1.20	0.40	1.20	1.10	3.90	0.38	4.38	91
A8	Ap	0-15	6.04	0.55	0.85	0.05	11.00	0.07	0.39	1.13	2.10	3.69	0.36	4.36	92
	B	16-30	6.06	0.18	0.00	0.03	6.00	0.06	0.20	1.00	1.35	2.61	0.38	3.38	89
	B1	31-55	6.06	0.19	0.00	0.03	6.30	0.05	0.17	1.00	1.25	2.47	0.35	2.35	85
	B2	56-69	6.06	0.07	0.00	0.04	4.25	0.03	0.17	1.00	1.10	2.30	0.36	5.36	93
	B3	70-84	6.06	0.06	0.00	0.02	1.50	0.03	0.18	1.00	1.15	2.36	0.29	2.29	87
MIN			**5.1**	**0.02**	**0**	**0**	**0.75**	**0.01**	**0.03**	**1**	**0.1**	**2.3**	**0.25**	**2.29**	**85**
MAX			**6.2**	**0.8**	**1.09**	**0.22**	**16**	**2.39**	**0.59**	**4.75**	**3.24**	**7.29**	**1.09**	**7.55**	**100**
MEAN			**6.001**	**0.185**	**0.217**	**0.036**	**7.167**	**0.255**	**0.331**	**2.261**	**1.287**	**4.015**	**0.393**	**4.618**	**91.625**
SD			**0.288**	**0.176**	**0.333**	**0.045**	**4.288**	**0.556**	**0.156**	**1.070**	**0.806**	**1.211**	**0.135**	**1.133**	**2.648**

Where OM= Organic Matter, OC = Organic Carbon, TN= Total Nitrogen, C:N Carbon Nitrogen ratio, K^+= Potassium, Ca^{2+} = Calcium, Mg^{2+} = Magnesium, Na^+ = Sodium, TEB = Total Exchangeable Base, TEA = Total Exchangeable Acid, ECEC= Effective Cation Exchangeable Capacity, BS = Base Saturation, cm = Centimeter, Meq= Milli-equivalent, % = percentage, g = Grams, SD = Standard Deviation, Max = Maximum, Min = Minimum

Table 3: Percentage change of each land use and land cover from 2000 to 2013

	2000		**2007**		**2013**	
Land use	% change	Area (m^2)	% change	Area (m^2)	% change	Area (m^2)
Farmland	23.86	66555925	20.17	56240457	29.31	81744300
Mangrove	8.02	22382281	5.33	27712793	3.4	14870700
Primary forest	20.71	57749450	18.31	51038237	14.18	39554100
Secondary forest	23.96	66815864	10.58	29499932	7.38	20585700
Settlement	20.6	57453183	37.32	104026407	39.54	110286900
Water body	2.85	7958037	3.68	10247941	4.26	11873700

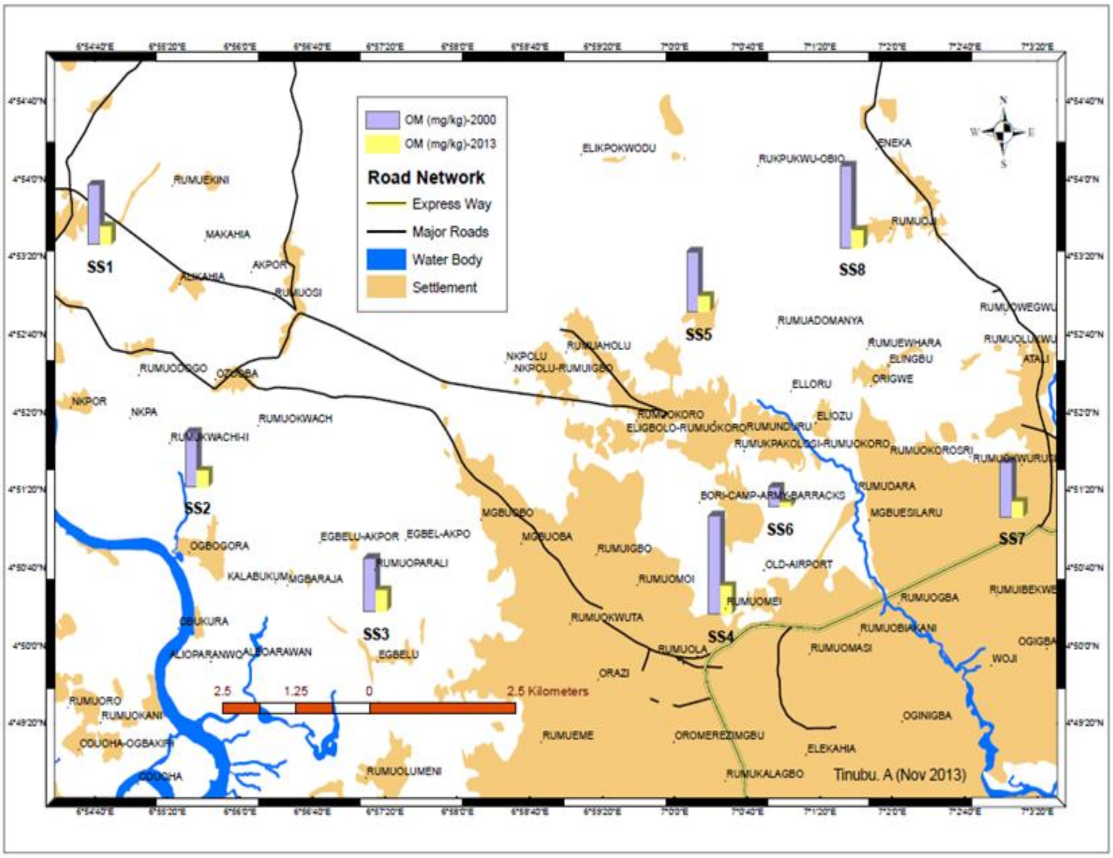

Figure 3: Organic matter map

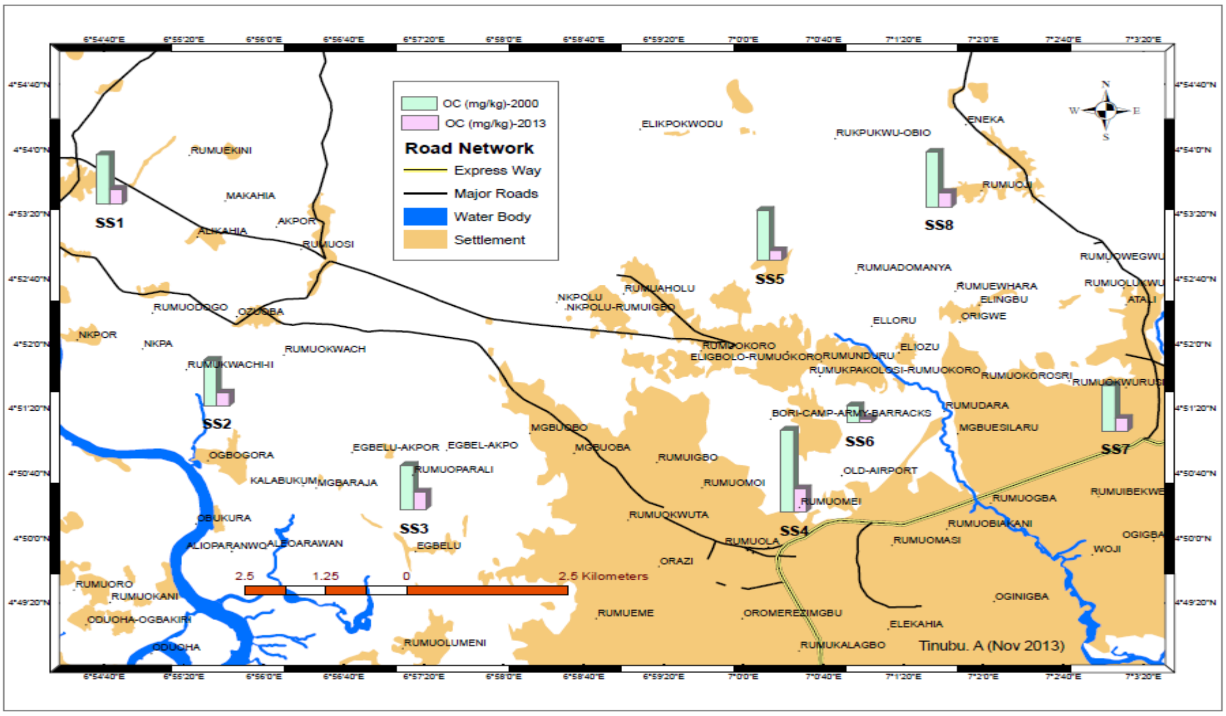

Figure 4: Soil organic carbon map

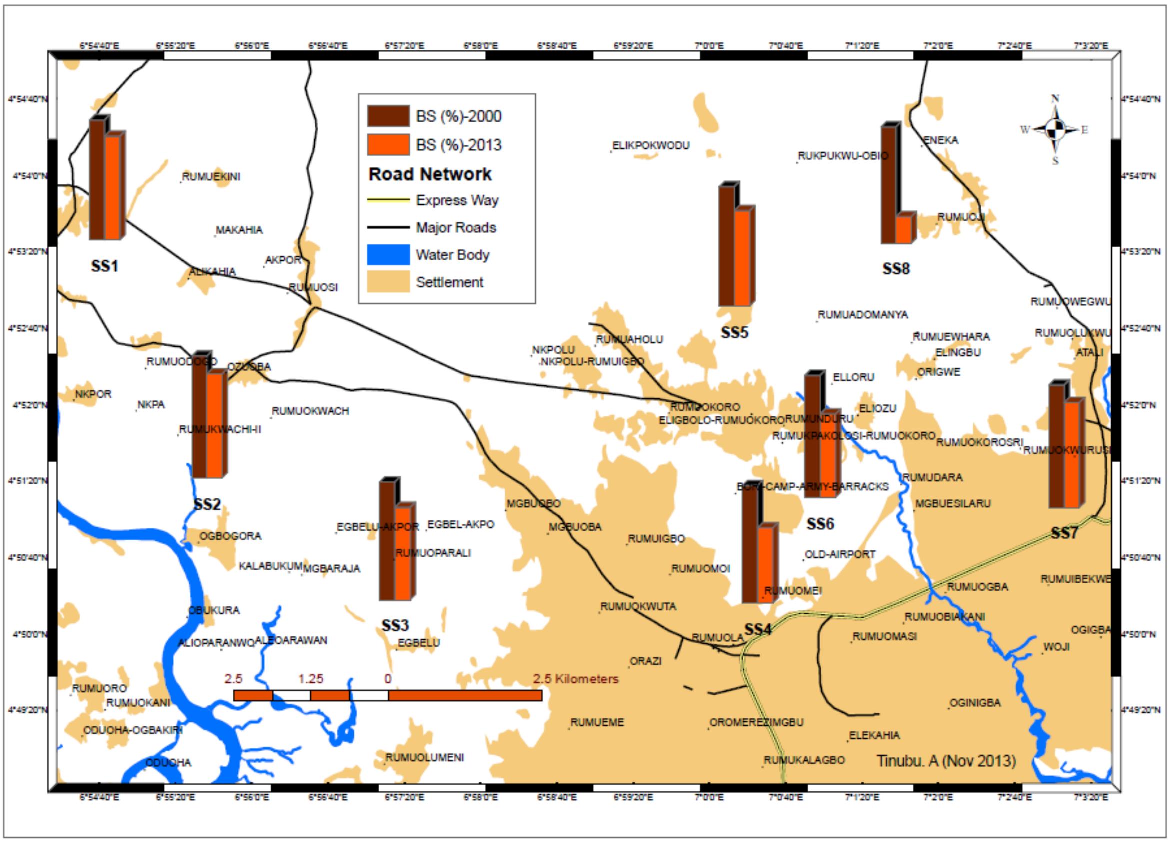

Figure 5: Base saturation map

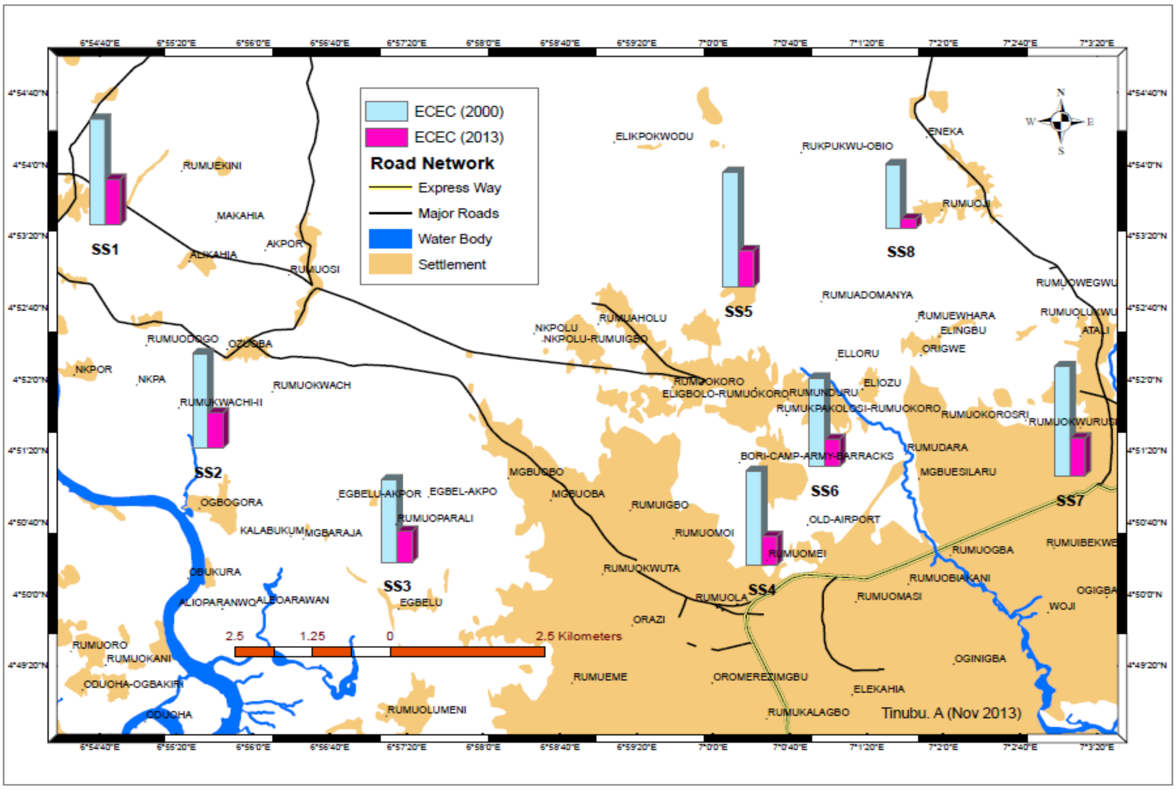

Figure 6: Effective cation exchangeable capacity (ECEC) map

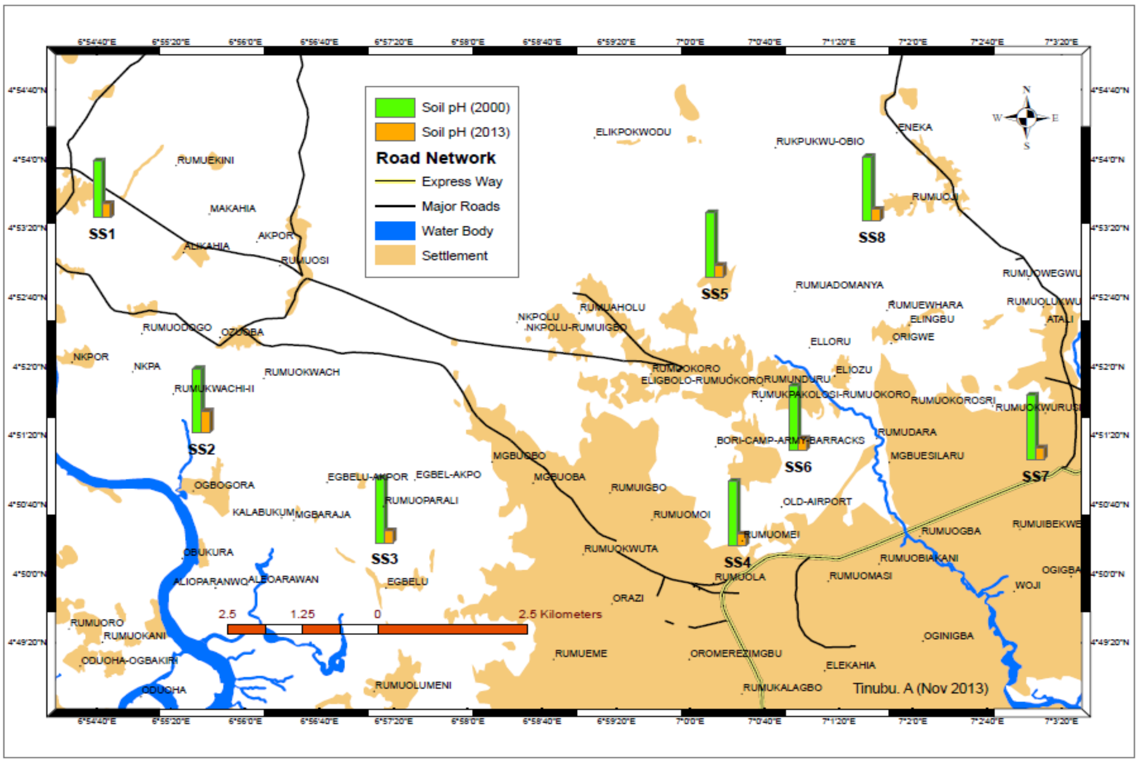

Figure 7: Soil pH map

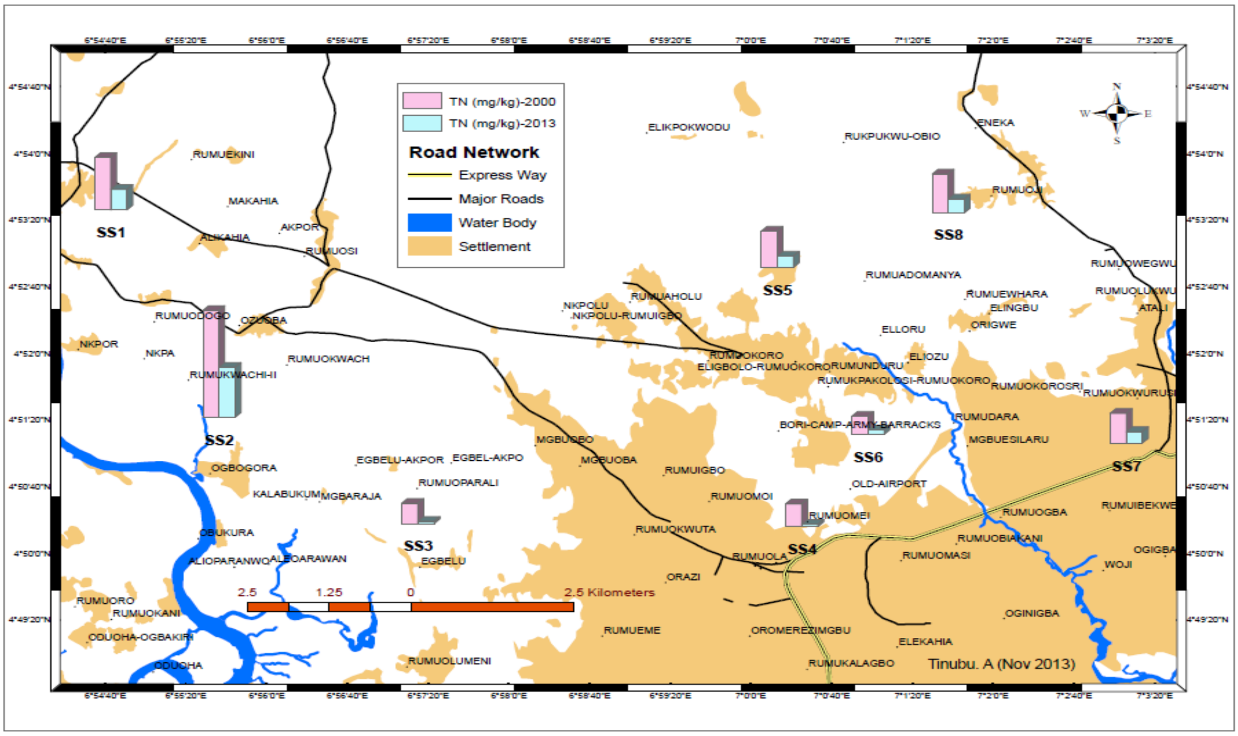

Figure 8: Total nitrogen map

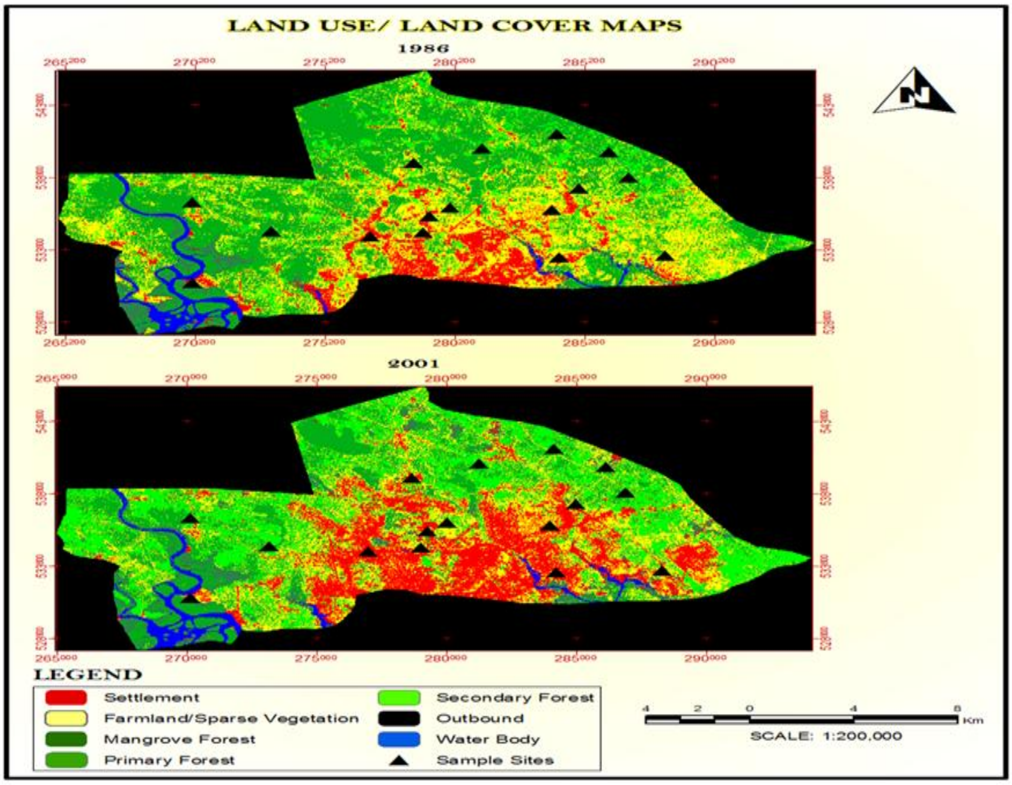

Figure 9: Land use and land cover of the study area from 1986 – 2001

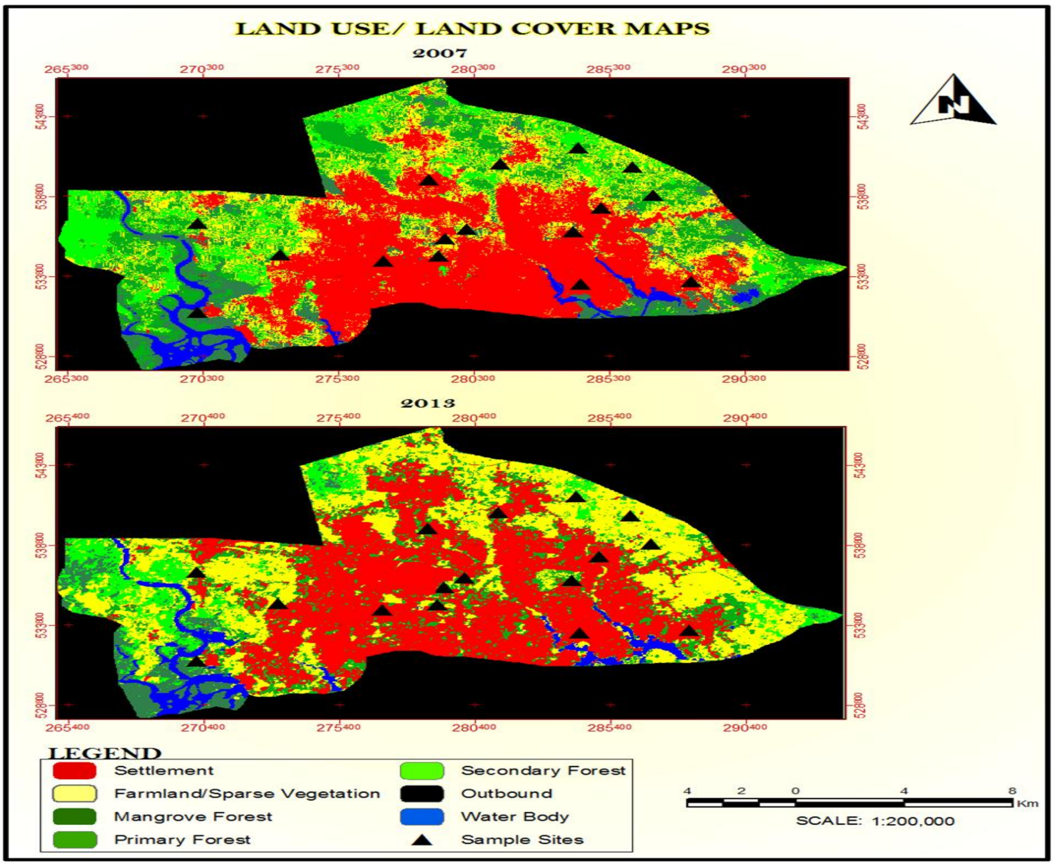

Figure 10: Changes in land use and land cover between 2007 and 2013

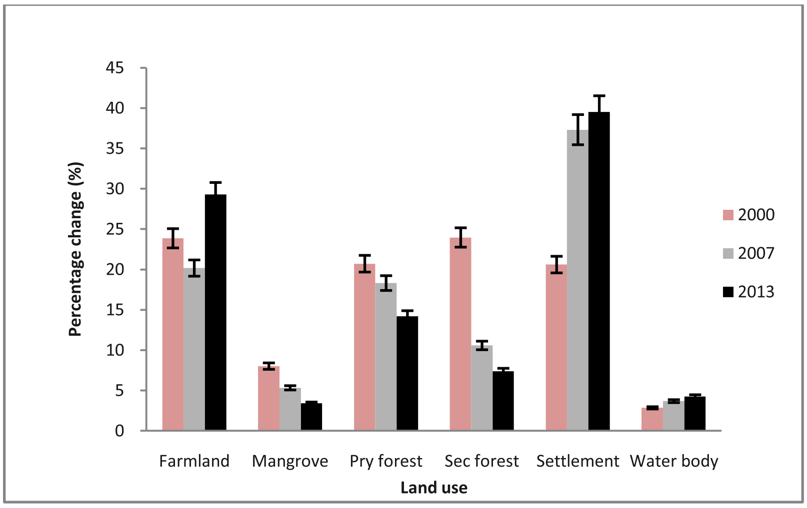

Figure 11: Percentage change of each land use and land cover from 2000 to 2013

4. Conclusion

The study reaffirms the importance of the Geographic Information System (GIS) and satellite images in solving and defining the main land forms and the soil changes in physicochemical and morphological properties within the study area. Though the problems of coverage land use and soil data acquisition have improved, the high cost of satellite data caused by commercialization has seriously impended utilization, especially in developing countries like Nigeria.

In the course of this study, it was noted that the study area is already over populated causing large migration of people into the area seeking for a means of livelihood. Effects of climate change are being felt in the study area. Torrential rainfalls and winds with no breakers sweep through the study area bringing in flood, thus causing large scale damage on the study area. Afforestation projects should be established especially along the coast line areas. Indeed, between the periods of 1986 and 2013, spatial expansion of the study area tended only towards the North East, in the direction of the old city. There is a possibility of a continuation of that trend (direction of development), over the next 10 to 15 years. After the initial reduction in farm land between 1986 and 2007, the study area has witnessed a steady increase in this class and consequently agricultural production will definitely continue to grow upwards. A deliberate attempt should be made by the authorities of the area to increase the development and improvement of farm activities, since this will lead to food security.

The outcome of this research brings benefit to the society through the creation of quality soil land cover information for better decision making. It is expected that the results of this research shall contribute to the on-going development in Rivers state, Nigeria as a whole, and will benefit society in general.

Acknowledgements

The authors would like to thank the Institute of Agriculture and Research Development, University of Port Harcourt for gracefully granting us the used of the research laboratory for this study.

Disclosure statement

The authors declare that they have no conflict of interest.

Compliance with ethical standards

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