Determining the Effect of Vegetation on Soil Properties Using GIS in Eleme Area of Rivers State

Wokocha C.C, Wuche G. E. & Kamalu O. J.
Department of Crop and Soil Science
Faculty of Agriculture
University of Port Harcourt
chima.wokocha@uniport.edu.ng

Abstract
The study examined the effect of land cover changes on the soil properties using GIS and remote sensing in the northern part of Eleme Local Government Area of Rivers State, Nigeria. Landsat Tm of 1986, 1999 and land sat ETM of 2015 of 30m x 30m resolution were used for the land cover change analysis. Soil samples were collected from the topsoil (0-15cm depth) into well-labelled polythene bags. The soil samples were air-dried and carefully sieved with 2mm diameter mesh and taken to laboratory for some physical and chemical properties. Descriptive statistics were used to analyse the data. Sand and clay contents were slightly higher in LNV than HV. Soil pH was slightly acidic in the entire study area. Mean total Organic C, total N, K and Na were higher in HV than LNV. However, Mg, Ca and available P were higher in LNV than HV. The study recommended that further depletion of HV should be discouraged and built up area expansion should be done carefully to prevent inadequate conservation of soil, wildlife and biodiversity.

Keywords: *Less/Never Vegetated, Highly Vegetated, land cover*

Introduction

Soil is a major component of the earth ecosystem and it is essential to human survival. Soil acts an engineering medium, a habitat for soil organism, a recycling system for nutrients and organic wastes, a regulator of water quality, a modifier of atmospheric composition, and a medium for plant growth (Powlson, 2005). Soil is relied on for the production of food, fibre, timber and energy crops. Together with climate the soil determines which crop can be grown, where and how much they will yield. With such tremendously important role of the soil, it is pertinent that the soil should be managed for their long term productivity and sustainability. Therefore first step for sustainability of the soil is to ensure that the soil would support the land use activities done on the land and the only way to ensure that the soil supports the land use activity is to understand the soil resource that is available and the key to understanding the soil resource available is through soil survey.

Soil survey is one of a group of activities collectively known as natural resource survey (Zwicker, 1992) and natural resource survey is the study of the natural environment with special reference to its resource potential (Kramer, 2002)**.**Soil survey which can otherwise be called soil mapping is the process of classifying soil types and other soil properties in a given area. Soil survey provides insight into the kind and intensity of land management that will be needed (Lindbo *et al,* 2012). The information assembled in soil survey can be used to predict or estimate the potential and limitation of the soil's behaviour under different land uses.The primary data for soil survey are acquired by field sampling and remote sensing (Lindbo *et al,* 2012).

Remote sensing techniques is one of the most important new and emerging technologies which are rapidly expanding and will greatly enhance the productive capabilities and wealth of those nation and entities that are making appropriate investment on them (Schowengerdt,2007). Remote sensing in soil survey aids in production of maps of land, in such a good detail that involves so many significant factors. Remote sensing techniques provide data at intervals and also present physiographic features which cannot be shown on the base map in details. Remote sensing techniques aid to increase both speed and accuracy of the work of soil surveying (Hoffbeck and Landgrebe, 1996).

Today studies have shown that the use of remote sensing techniques and GIS in soil survey and mapping has given a useful and detailed way to improve selection of areas designed for agricultural, urban and/ or industrial areas of any region (Selcuk *et al*., 2003). Application of remote sensing data has made it possible to study the change in land use in less time at low cost and with better accuracy (Kachhwala, 1985) in association with GIS that provide suitable platform for data analysis, update and retrieval (Chilar, 2000). Digital change detection analysis have demonstrated a great potential as a means of understanding landscape dynamics, detect, indentify, map and monitor differences in land use patterns overtime irrespective of the causal facts.

Study Area

The study is the northern part of Eleme Local Government Area of Rivers State, Nigeria. The area is within the latitudes between 4^o 47’ 00’’N and 4^o 51’ 30’’N and longitudes between 7^o 5’ 30’’E and 7^o 8’ 30’’E (Figure 1 and Figure 2). The study area is bounded by Obio/Akpor LGA in the North, in the East by Oyigbo LGA, in the West by Port Harcourt City LGA and in the South by Okrika LGA and Gokana LGA.

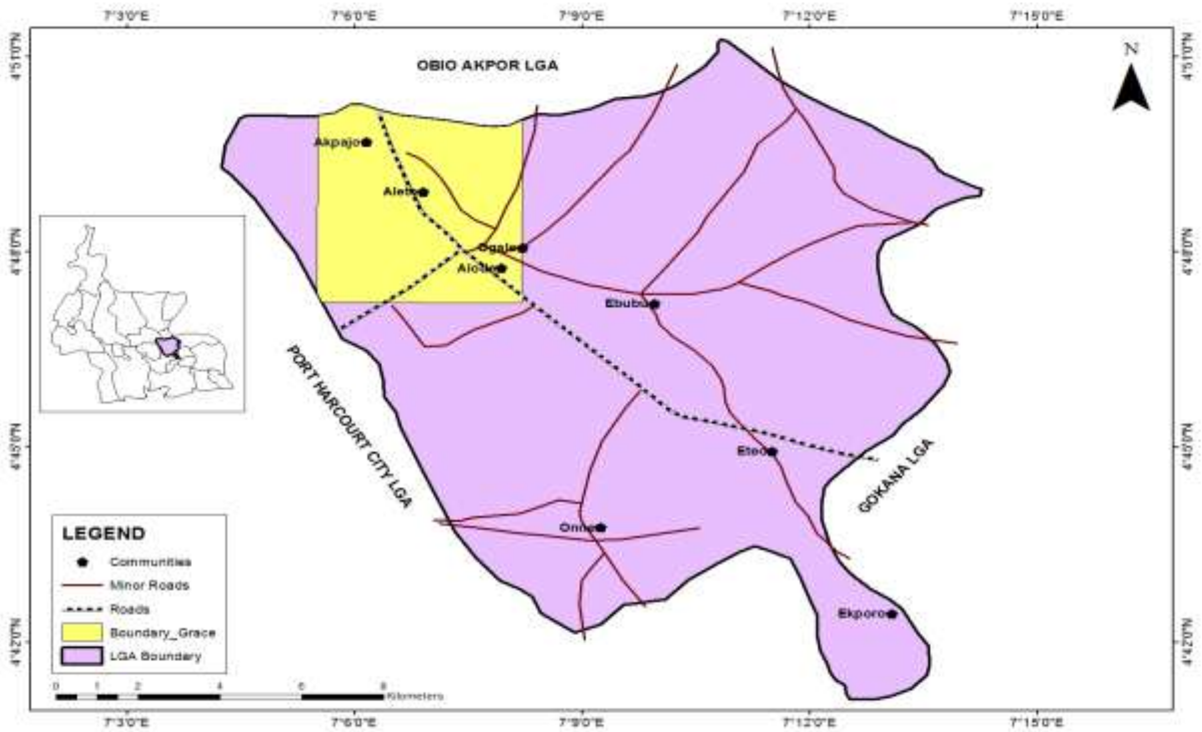

Figure 1: Eleme LGA showing the Study Area
Sources: Rivers State Ministry of Land and Survey, 2016;
GIS Laboratory, University of Port Harcourt, 2016

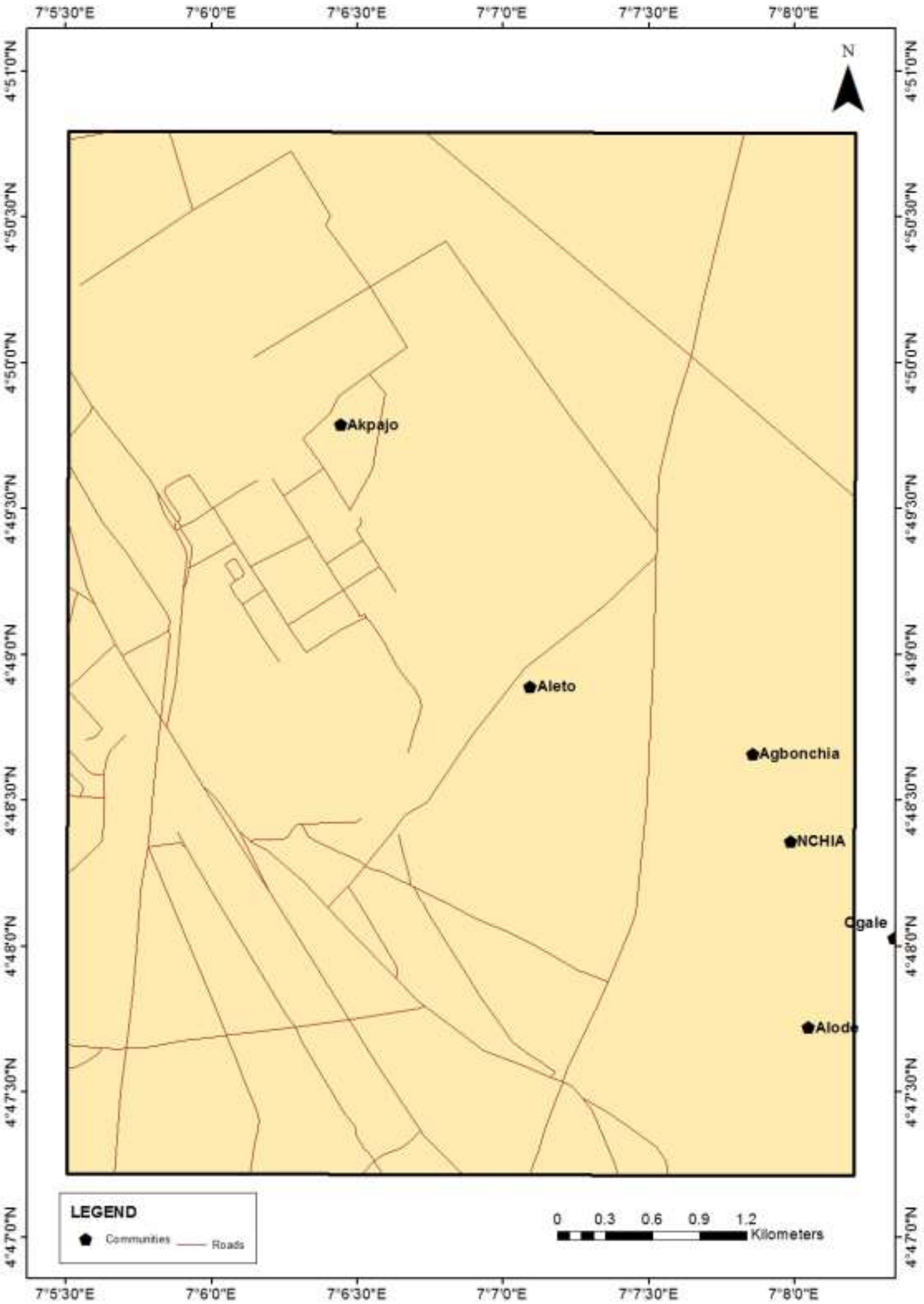

Figure 2: Study Area

Vegetation

Vegetation in Eleme is a characteristic of the rainforest vegetation type and it is equally rich in tropical biodiversity. The vegetation is a mixture of both dense and sparsely sense with lots of grasses and shrubs. The vegetation is nourished with high rainfall and high temperature, which provide favourable condition for the growth of a varieties of tall and big trees like mahogany, Obeche, Afara and abundance of oil palm trees and several other species of economically valuable plants such as ferns and grasses (Eludoyin et al, 2013). The major feature of the vegetation of the area is its distinctive three layer canopy characteristics with the topmost canopy reaching a height of 35-40m, second layer within the range of 25-30m forming interlocking canopy which normally prevents the penetration to the ground surface and the third layer is about 10m.

Methodology

Landsat TM of 1986; 1999 and land sat ETM of 2015 were utilized for the land use change analysis. The satellite images used in this study were obtained from the Global Land Cover Facility (GLCF). The descriptions of the images are presented in Table 1. Each of the images has 7 bands (1,2,3,4,5,6,7). The bands were combined and composite image was obtained for each year. The adequate composite image bands used were 3, 4 and 7. The shape-file of the boundary of the study area was used to clip the composite image in order to cut out the study area only from the entire imagery. Supervised classification using maximum likelihood algorithm was used to classify the imagery into major land use (thick vegetation, built up area, swamp forest, farmland/sparse vegetation, water-bodies).

The composite image of each year was subjected to further geo-processing analysis of Normal Difference Vegetation Index (NDVI). The NDVI was calculated using band 4 (infrared band) and band 3 (red band). The status of vegetation health can be more appropriately measured in near infrared and red bands (Uchegbulam and Ayolabi, 2013). The results of the analysis classified the study area to less/not vegetated and highly vegetated landuse types. The spatial coverage was computed using simple arithmetic. The computation helped to understand the difference in the vegetal cover in the different periods (1986, 1999 and 2015) considered in this study. The analyses were done in Erdas Imagine and ArcGIS 10.1.

Table 1: Details of Landsat Satellite Images

Year	Date Acquired	Sensor	Cloud Cover (%)	Path	Row	Resolution
1986	19/12/1986	Landsat 4 Thematic Mapper (TM)	0	188	057	30m x 30m
1999	17/12/1999	Landsat 5 TM	0	188	057	30m x 30m
2015	09/01/2015	Landsat 8 Enhanced Thematic Mapper (ETM)	0	188	057	30m x 30m

Source: US Geological Survey, 2016

Soil Sampling Technique and Collection

The entire study area was gridded into 10m x 10m quadrat. 7 quadrats were randomly picked from the highly vegetated areas and 6 quadrats were also randomly picked from less/not vegetated areas for soil samples. A total of thirteen (13) soil samples were collected using a hand trowel from the topsoil (0-15cm depth). The soil samples were collected into a well-labelled polythene bags and the coordinates of soil sampling points were recorded using a global positioning system (GPS) (Figure 3 and Figure 4). The soil samples were air-dried and carefully sieved with 2mm diameter mesh after which standard laboratory techniques were used to determine the physical and chemical properties of soil.

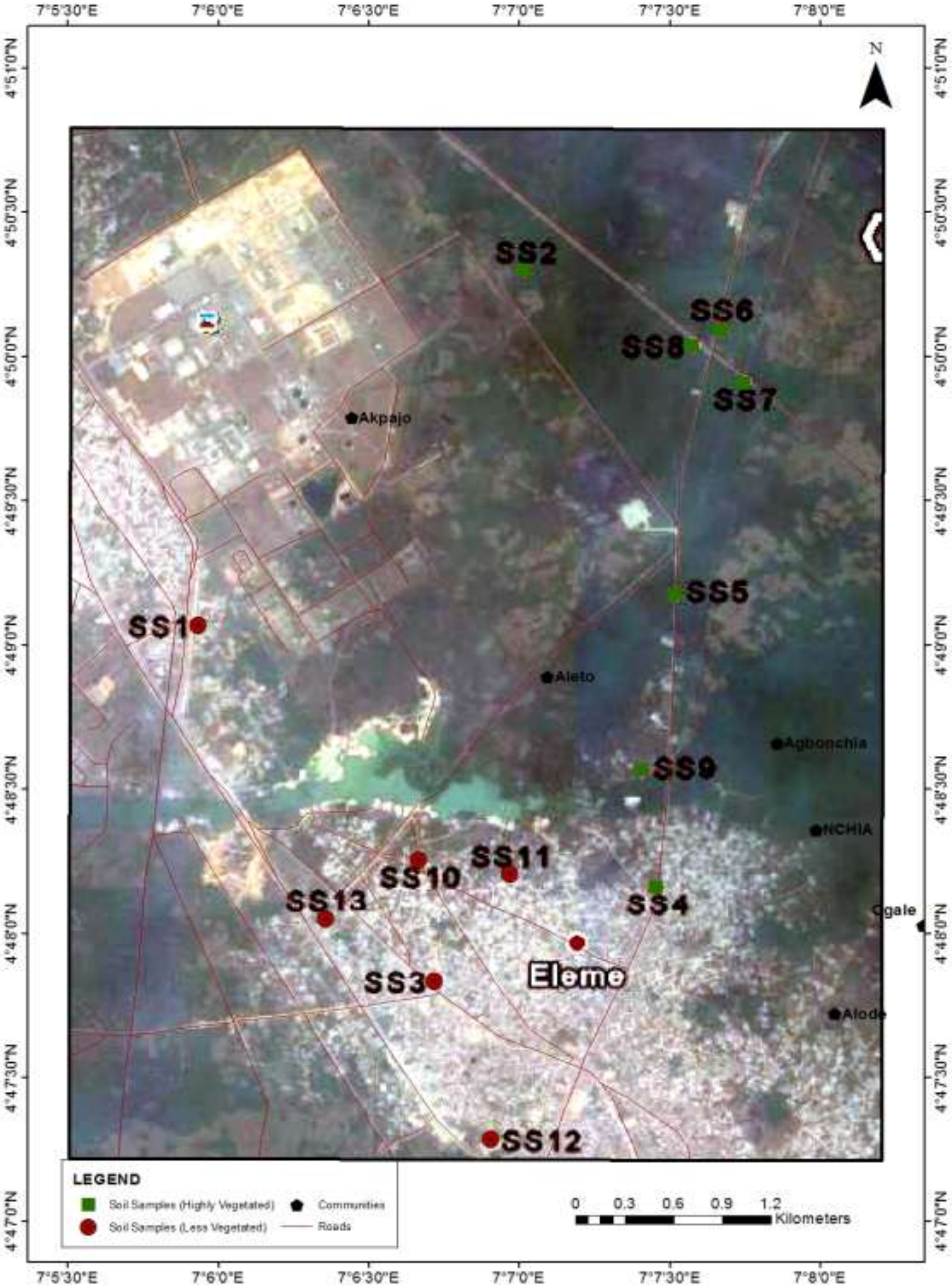

Figure 3: Imagery and Soil sampling Points
Sources: Google Earth, 2016; GIS Laboratory, University of Port Harcourt, 2016

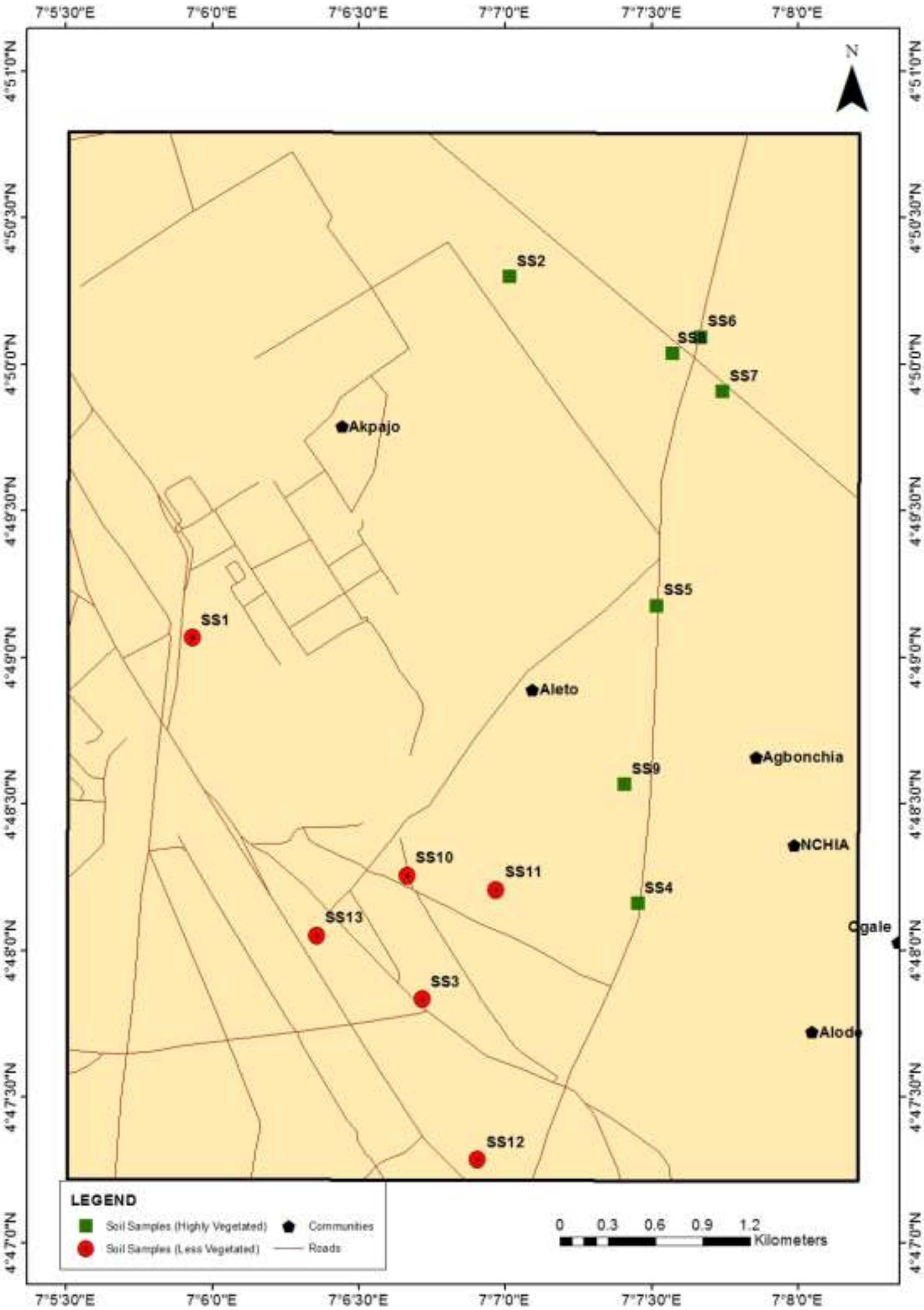

Figure 4: Soil Sampling Points in the Study Area
Sources: Google Earth, 2016; GIS Laboratory, University of Port Harcourt, 2016

Analysis for Soil Properties

Both physical and chemical soil samples were tested in a lab. The result of the analysis was then subjected to descriptive statistics (mean and standard deviation) to explain the soil properties (physical and chemical properties). Percentages were also used to explain the changes in landcover. All the analyses were carried out using Statistical Package for Social Sciences (SPSS) 20.0 version and Microsoft Excel 2007 version. Results were presented using tables and graphs.

Spatial Change of Highly Vegetated and Less/Not Vegetated Landuse

NDVI was used to analyse the status of the vegetation in the area. The status of vegetation health in 1986, 1999 and 2015 are presented in Figure 4.5, Figure 4.7 and Figure 4.9 respectively. In 1986, the pixel extent explaining healthy vegetation is between 160-260. In 1999, the pixel extent having healthy vegetation was between 100 and 200. In 2015, the healthy vegetation covered between 50 and 120. It can be deduced that the pixel covering the healthy vegetation decreased between 1986 and 2015.

Table 2: NDVI in 1986, 1999 and 2015

NDVI	1986 (km^2)	Percentage (%)	1999 (km^2)	Percentage (%)	2015 (km^2)	Percentage (%)
Less/Not Vegetated	10.46	31.79	12.02	36.53	17.89	54.38
Highly Vegetated	22.44	68.21	20.88	63.47	15.01	45.62
Total	32.90	100.00	32.90	100.00	32.90	100.00

Source: Researcher's analysis, 2016

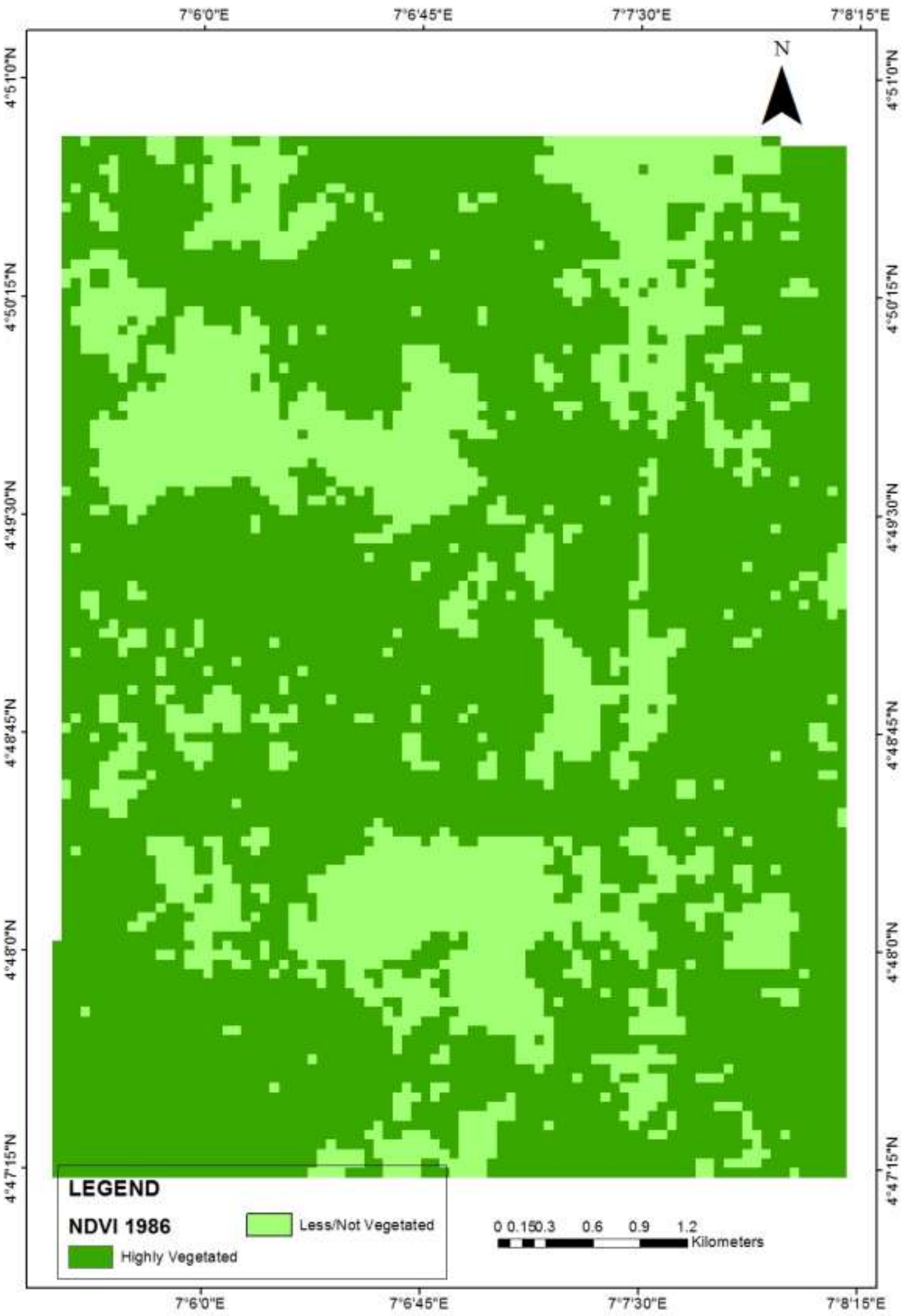

Figure 5: NDVI in 1986

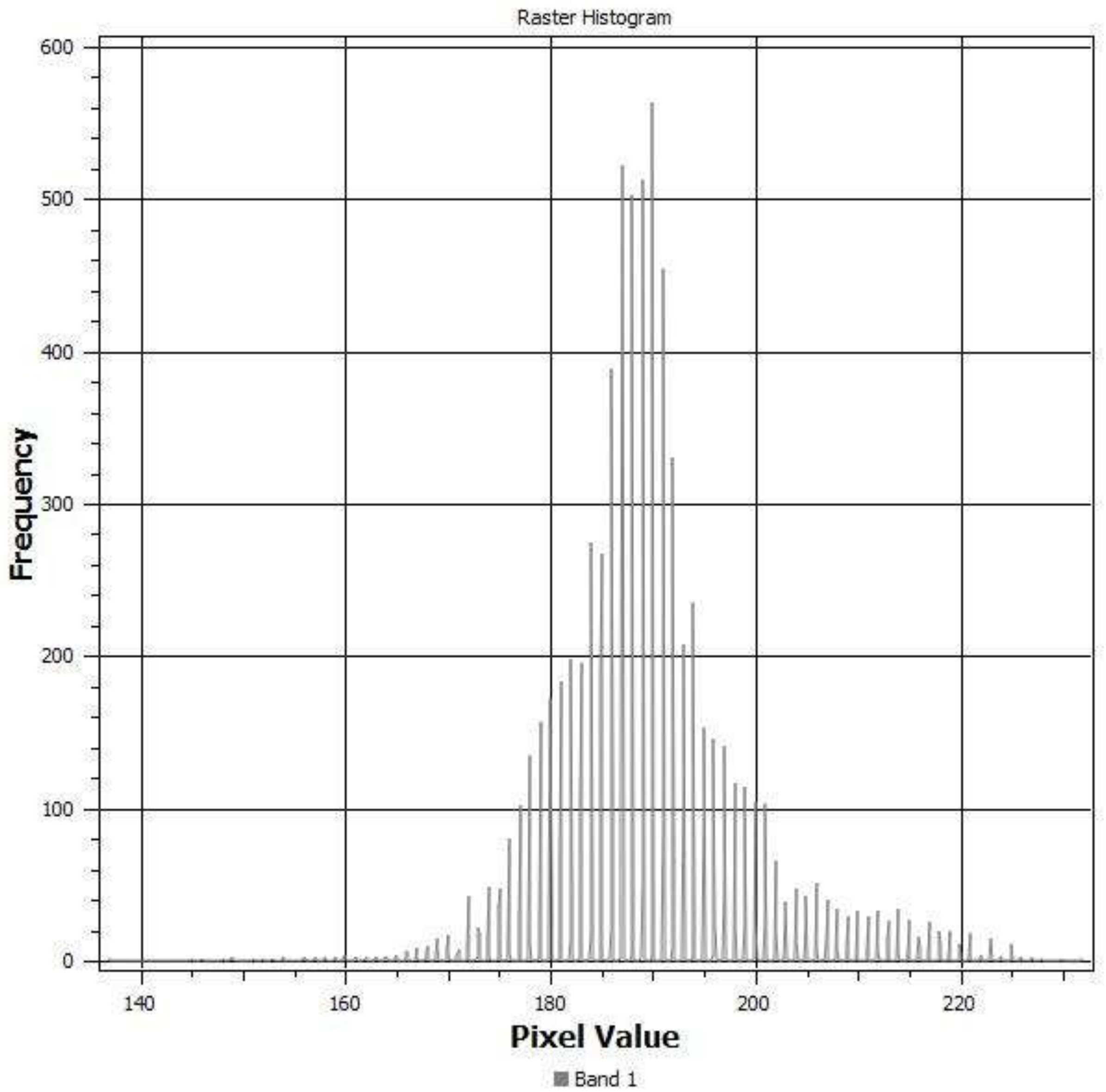

Figure 6: Status of Healthy Vegetation in 1986

Figure 7: NDVI in 1999

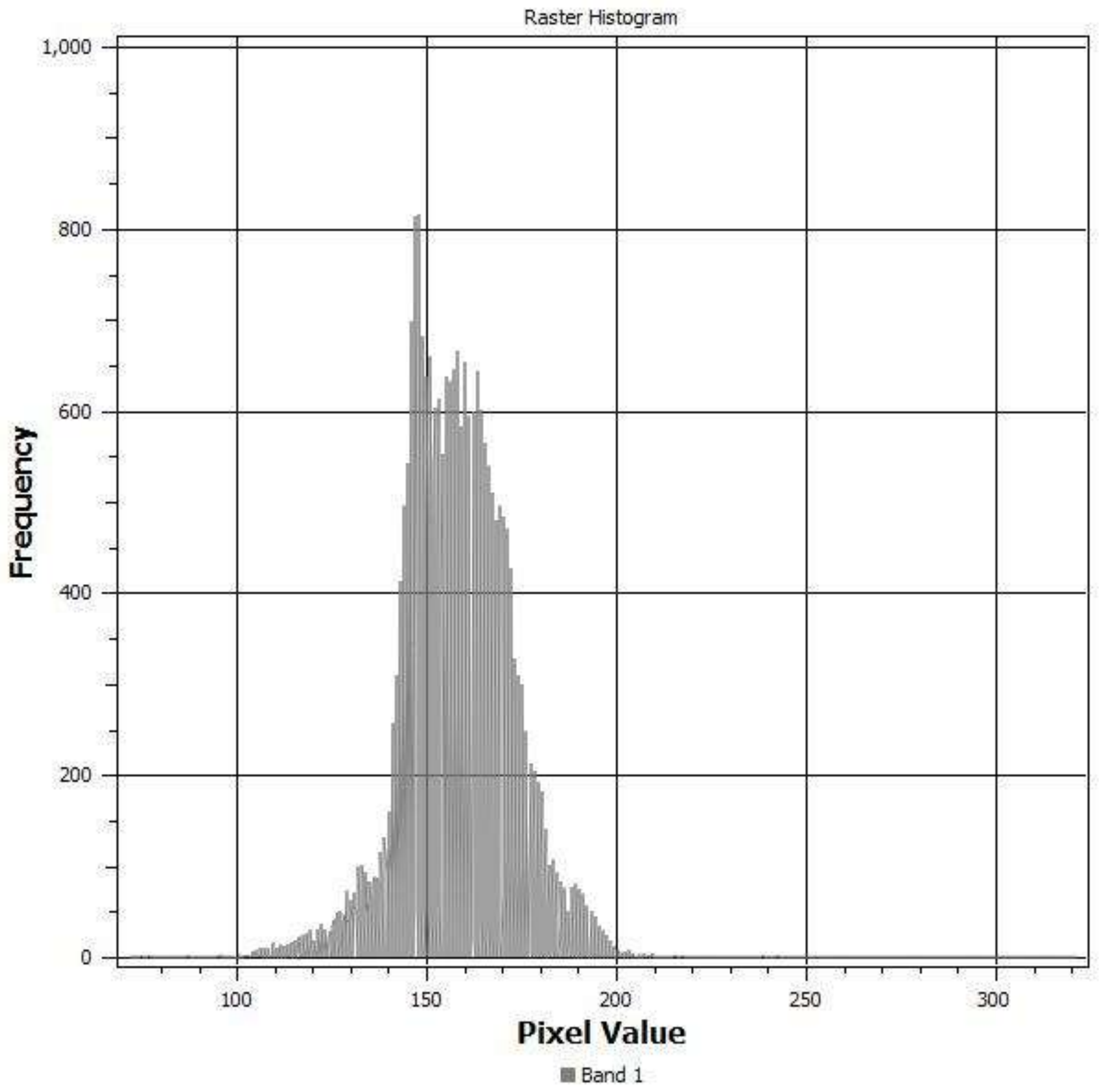

Figure 8: Status of Healthy Vegetation in 1999

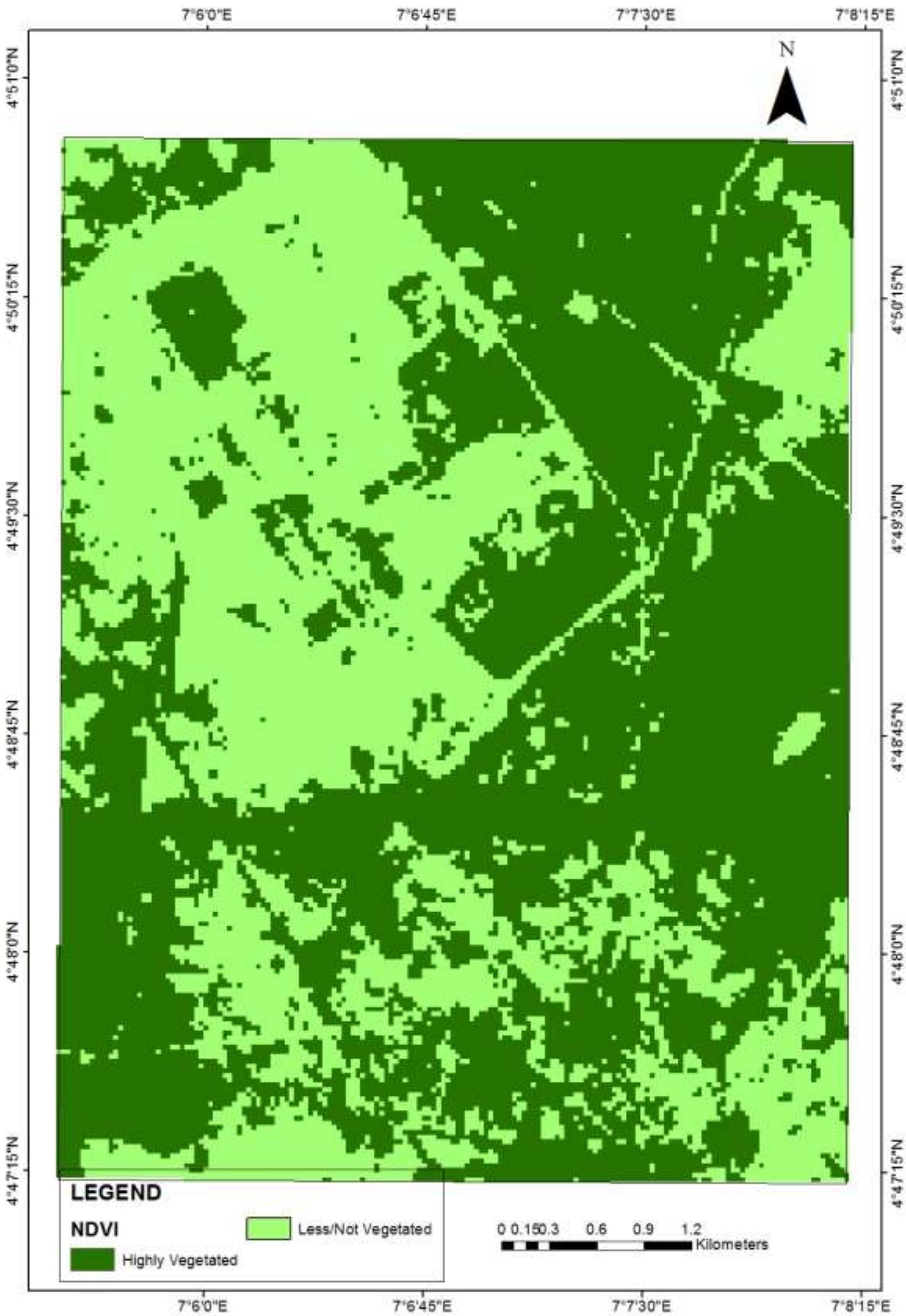

Figure 9: NDVI in 2015

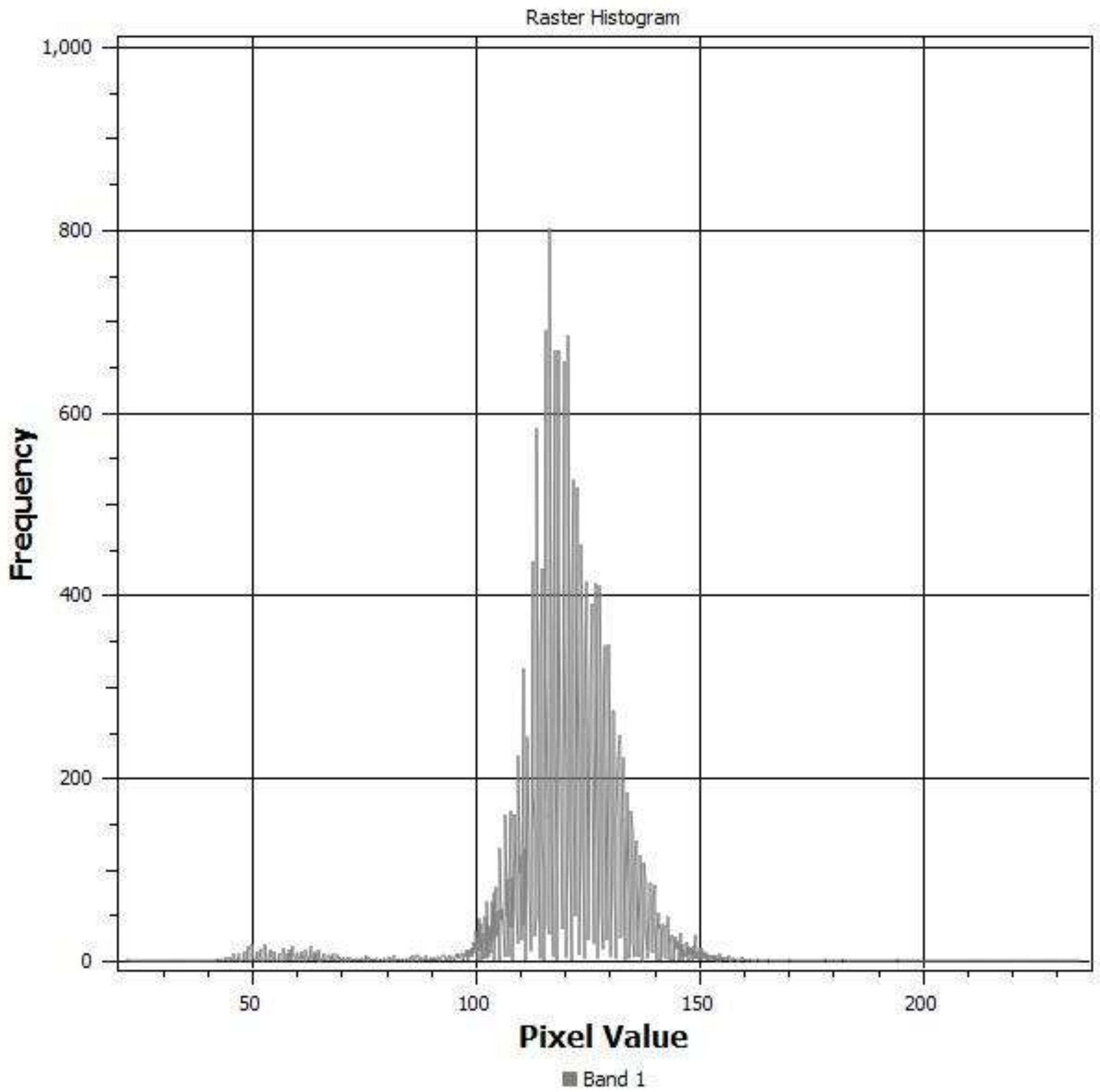

Figure 10: Status of Healthy Vegetation in 2015

Effects of Less/Not Vegetated and Highly Vegetated areas on Soil Physical Properties

The physical properties of soil under less/not vegetated and highly vegetated land use types are shown in Table 4.4. The mean sand content under the less/not vegetated was 92.63% under less/not vegetated while it was 92.40% under highly vegetated land use. The mean silt content was 3.10% ranging from 2% to 7.4% under less/not vegetated land use type while the mean silt under highly vegetated land use type was 4.20%. The clay content ranged between 2.6% and 6.8% with mean value of 4.27% under less/not vegetated land use type while the clay content ranged between 2.80% and 4.80% with a mean clay content of 3.30% under highly vegetated land use.

Table 3: Physical Properties of Soil under Less/Not Vegetated and Highly Vegetated Land use Types

Soil Properties	Less/Not Vegetated		Highly Vegetated	
	Minimum-Maximum	Mean±SD	Minimum-Maximum	Mean±SD
Sand (%)	87.8-95.2	92.63±2.8	87.80-95.20	92.40±3.2
Silt (%)	2.0-7.4	3.10±2.1	2.00-8.40	4.20±2.5
Clay (%)	2.6-6.8	4.27±1.6	2.80-4.80	3.30±0.8
Textural Class	Sand		Sand	

Source: Research Analysis, 2016

Effects of Less/Not Vegetated and Highly Vegetated Land use on Soil Chemical Properties

The soil chemical properties under the less/not vegetated and highly vegetated land use types are shown in Table 4.5. The mean soil pH under the less/not vegetated land use was 5.40 ranging between 5.30 and 6.2 while the mean soil pH under highly vegetated land use was 5.90 ranging between 5.40 and 6.30. The analysis shows that the soil pH in the entire study area was acidic. The level of acidity under highly vegetated was relatively lower than the less/not vegetated land use type.

The mean total organic carbon under less/not vegetated land use type was 1.73 % while it was 1.87% under highly vegetated land use type. Also, the mean total nitrogen was 0.10% and 0.13% under less/not vegetated land use and highly vegetated land use types respectively. The available phosphorus under less/not vegetated land use type ranged between 21.67 mg/kg and 91.69 mg/kg with a mean of 59.50 mg/kg while the mean available phosphorus was 36.91 mg/kg under highly vegetated land use type.

Furthermore, the exchangeable bases which include Mg, Ca, K and Na were also analysed under both less/not vegetated land use type and highly vegetated land use type. The mean magnesium under less/not vegetated land use type was 0.32 $Cmolkg^{-1}$ while it was 0.27 $Cmolkg^{-1}$ under highly vegetated land use type. The concentration of calcium ranged between 0.33 $Cmolkg^{-1}$ and 1.05 $Cmolkg^{-1}$ with mean calcium of 0.52 $Cmolkg^{-1}$ under the less/not vegetated land use type. The mean calcium concentration under highly vegetated land use type was 0.42 $Cmolkg^{-1}$. However, mean potassium was 1.29 $Cmolkg^{-1}$ under the less/not vegetated land use type and 1.35 $Cmolkg^{-1}$ under highly vegetated land use type. The concentration of sodium ranged between 0.40 $Cmolkg^{-1}$ and 1.43 $Cmolkg^{-1}$ with mean sodium of 0.89 $Cmolkg^{-1}$ under less/not vegetated land use type while mean sodium under the highly vegetated land use type was 0.93 $Cmolkg^{-1}$. The mean TEA was higher under less/not vegetated land use type(1.13±0.3) $Cmolkg^{-1}$ than the highly vegetated land use type (1.11±0.2) $Cmolkg^{-}$1.The mean CEC was higher under less/not vegetated land use type (4.14±1.7) $Cmolkg^{-1}$ than the highly vegetated land use type (4.06±1.6) $Cmolkg^{-1}$.The C:N ratio ranged between 13.04% and 19.75% with mean C:N ratio of 17.23% under less/not vegetated land use type while mean C:N ratio under highly vegetated land use type was 14.74%. The mean C:N ratio was higher under less/not vegetated land use type(17.23±2.3)% than the highly vegetated land use type (14.74±1.9)%.

Table 4: Chemical Properties of Soil under Less/Not Vegetated and Highly Vegetated Land use Types

Soil Properties	Less/Not Vegetated		Highly Vegetated	
	Minimum-Maximum	Mean±SD	Minimum-Maximum	Mean±SD
pH (H_2O)	5.3-6.2	5.88±0.3	5.40-6.30	5.90±0.3
Total organic carbon (%)	1.5-2.18	1.73±0.2	1.58-2.10	1.87±0.2
Total Nitrogen (%)	0.08-0.13	0.10±0.01	0.11-0.17	0.13±0.02
Available Phosphorus (mg/kg)	21.67-91.69	59.5±23.2	16.67-80.02	36.91±26.7
Magnesium ($Cmolkg^{-1}$)	0.08-0.87	0.32±0.3	0.05-0.63	0.27±0.19
Calcium ($Cmolkg^{-1}$)	0.33-1.05	0.52±0.2	0.20-0.80	0.42±0.2
Potassium ($Cmolkg^{-1}$)	0.60-2.17	1.29±0.5	0.47-2.41	1.35±0.9
Sodium ($Cmolkg^{-1}$)	0.40-1.43	0.89±0.4	0.58-1.50	0.93±0.4
TEA ($Cmolkg^{-1}$)	0.93-1.64	1.13±0.3	0.85-1.23	1.11±0.2
CEC ($Cmolkg^{-1}$)	2.43-7.16	4.14±1.7	2.44-6.01	4.06±1.6
C/N (%)	13.04-19.75	17.23±2.3	11.42-16.80	14.74±1.9

Discussion of Findings

Findings show that the mean sand content in the highly vegetated land use was slightly lower than that of less/not vegetated land use type, this is probably due to partially decayed plant materials and activities of undisturbed soil microorganisms present in highly vegetated areas (Hallet et al 2012; Robinson et al 2012). The higher sand content in the less/not vegetated land use could be attributed to erosion caused by human activities and based on the fact that the study area is mainly dominated by sand (USDA, 2007). The mean clay and silt contents of soil in the entire study area also varied slightly; hence textural properties of the soil appear homogenous under both less/not vegetated land use type and highly vegetated land use. The similar textural properties may be as a result of the same parent material (Awotoye *et al*., 2009).

The soil pH in the entire study area was slightly acidic. This means that the soil pH was not toxic and closer to neutral. This may be due to chemical weathering of the soil parent materials this is in conformity with Babalola et al (2007)

The mean total organic carbon and mean total nitrogen were slightly higher in soils under highly vegetated land use than less/not vegetated land use. The findings may be attributed to the accumulation of more labile soil organic matter arising from the accumulation of litter-falls in the highly vegetated land use type (Awotoye et al., 2011). Exchangeable potassium and sodium were slightly higher in the highly vegetated land use than the less/not vegetated land use. The findings may be attributed to low nutrient demand of potassium and sodium by natural forest as compared to a tampered forest land (Michelsen et al, 1996).
However, the mean exchangeable magnesium and calcium were slightly higher in soils under

less/not vegetated land use than highly vegetated land use type. This could be linked to their relatively low mobility being divalent cations (Hodges, 1995).

Recommendations

Based on the findings obtained from this study, the following recommendations are made:

1. Further depletion of highly vegetated land use should be discouraged because of its roles in conserving essential soil nutrients such as soil organic carbon, total nitrogen, potassium and sodium.
2. The expansion due to urbanization should be done with carefulness and with adequate legal backings. This would prevent the forest cover to be conserved for soil, wildlife and biodiversity management.
3. Environmental education should be put in place for individuals on the effects of land use on soil physical and chemical properties.
4. More research should be carried in the entire Eleme LGA so that comparison in the land use types and soil properties under the land use can be clearly explained.

References

Chaurasia, R. Closhali, D.C, Dhaliwal S.S, Minakshi, Sharma, P.K, Kudrat. M, Tiwari, A.K 1996. Land use changes Analysis for Agricultural Management: a case study of Tehsil Talwandi Sabo, Punjab. J. India soc.Remote sensing 24(2), 115-123

Gessesse, B. (2007): Forest Cover Change and Susceptibility to Forest Degradation Using Remote Sensing and GIS Techniques: A Case of Dendi District, West Central Ethiopia. An unpublished thesis submitted to the School of Graduate Studies of Addis Ababa University.

Hoffbeck , S.P. and Landgrebe D.A,..1996. Classification of remote sensing images having highspectral resolution. Remote sensing of environment 57,119-126

Rawat J.S, Biswas V, Kumar. 2013. Changes in land use/land cover using geospatial techniques; a case study of Ramanagar town area, district Nainital, Uttarakand India. Egyptian Journal of Remote sensing and space sciences.pp 16, 111-117

Ruiz-luna,.. A Berlanga Robles.. C.A. 2013. Land use, Land cover changes and coastal Lagoonsurface reduction associated with urban growth in Northwest Mexico. Land Ecol.18, 159-171.

Schowengerdt, R.A. (2007). Remote sensing model and methods for image processing.3rd Ed. Academic press. pp 2. ISSBN 97801236 94072.

Selcuk R, Nisanci R, Uzun B, Yalcin A, Inan H, Yomralioglu, T (2003). Monitoring Landuse changes by GIS and Remote sensing technique; a case study of Trabzon,

Turner..M.G, Ruscher C.L 2004. Changes in Landscape patterns in Goergia. USA Land Ecol.1(4), 251-421

Uchegbulam, O. and Ayolabi E.A. (2013): Satellite Image Analysis using Remote Sensing Data in Parts of Western Niger Delta, Nigeria. Journal of Emerging Trends in Engineering and Applied Sciences (JETEAS) 4(4): 612-617