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REMOTE SENSING AND GIS TECHNIQUE IN THE ASSESSMENT OF LAND USE CHANGE AND HEAVY METAL POLLUTION IN SOUTH WESTERN NIGERIA

***ADISA, A.L.[1] AND OLADEJO, S.O.[2]**
[1]Department of Applied Geology, Federal University of Technology, Akure
[2] Department of Remote Sensing and GIS, Federal University of Technology, Akure
Corresponding author: aladisa@futa.edu.ng

Abstract

Land use land cover change is an important contributor to the trace element content of an aquatic system. Therefore, the study of the land use pattern is important in understanding the heavy metal pollution of the sediments of the aquatic system in an area. The aim of the study is to apply LULC pattern to understanding the heavy metal pollution of the stream sediments of River Ala and its tributaries. Geologically, the area is underlain by rocks of the Precambrian Basement complex of Nigeria. The basement rocks are: granite gneiss, granite, quartzite and charnockite. High resolution Landsat imageries were utilized in determining the LULC pattern for the years 2010 to 2016. The Landsat were processed and classified using maximum likelihood algorithm for the LULC classes. Twenty stream sediment samples were systematically collected from the channels of River Ala and its tributaries. The pollution status of the stream sediment were assessed by two pollution indices viz: Enrichment factor (EF) and geo-accumulation index (Igeo). The heavy metal concentrations were also compared with United States Environmental Protection Agency (USEPA) stream sediment quality (SQG) values as well as with other similar studies in Nigeria. Results of the geochemical analysis revealed that the mean concentration of the analyzed elements are Pb (0.47 mgkg^{-1}), Fe (22.9 %), Co (0.395 mgkg^{-1}), Cd (0.014 mgkg^{-1}), Mn (5.109 mgkg^{-1}), Zn (1.233 mgkg^{-1}), Cu (0.549 mgkg^{-1}), Cr (0.28 mgkg^{-1}) and Ni (0.571 mgkg^{-1}). The mean concentrations of all the analyzed elements are lower than both the average world shale and USEPA SQG values except for Fe. Furthermore, both the EF and Igeo indices revealed that the mean concentrations of the elements fall within background concentrations. The LULC patterns also revealed the most dominant LULC trends in 2010 was forestland which covered 28.78 km^2. However, the area occupied by forest had been reduced in 2016. In conclusion, the LULC changes has not had any significant effect on the heavy metal contents of the stream sediment as they are unpolluted with respect to the analyzed elements.

Key Words: *Land use, Heavy metals, Pollution, Landsat 8, NDVI*

Introduction

Rivers and streams form part of hydrologic cycle. They play a vital role in human existence as they serve as source of water for both industrial and domestic purposes for communities within their catchments. Despite this overwhelming importance, rapid population growth and urbanization have constituted threats to river systems (Olorunfemi and Jimoh, 2000). Thus, it becomes imperative that human activities which could adversely affect the quality of water and sediments be assessed (Ayeni *et al.,* 2006)

Land cover, according to Rawat and Kumar, (2015), is the "physical characteristics of the earth's surface which involve vegetation, water, soil and other physical features created through human activities", while land use refers to the human activity associated with a piece of land (Lillesand *et al*., 2004). Rapid and unprecedented growth in human population has been reported to be a major contributor to land use and land cover (LULC) changes. Furthermore, Human activities affect water runoff and chemistry. Such activities include deforestation, agricultural development, biomass burning and human settlements (Calder *et al*., 1995). Consequently, LULC can, therefore, have strong correlation with water chemistry. As a result, information on LULC is necessary not only in the selection of sites for water resources but in the monitoring and management as well.

Anthropogenic activities carried out by different land use types are reported to release varying volumes of heavy metals into water systems. The trace metals of an aquatic system is controlled by geology, chemical reactivity, mineralogy, hydrology, vegetation, land use pattern and biological activity (Albanese *et al*., 2013). These heavy metals have become the leading cause of health problems in humans as result of the fact that they are the most common pollutant of the aquatic environment. Therefore, the study of Pollution of stream water, sediment as well as soil has attracted the attention of researchers.

Satellite remote sensing has been a vital tool in LULC study (Bahadur, 2009). It has also been deployed in the monitoring as well as management of the environment and natural resources. Landsat ETM 7+, Landsat 8 OLI/TIRS, ASTER DEM, SENTINEL radar etc., which are remote sensing tools, have been successfully used by researchers in the study of LULC (Krami *et al*., 2013, Xin *et al*., 2013, Li *et al*., 2017).

Akure, the study area, has had its fair share of rapid population growth. The population of the city had increased by more than 54% in 13 years. It was 360,268 in 2006, according to that year's National Population and Housing Census. The population of the city was expected to be 559,940 people in 2019, at the rate of 3.2 % increase. This population growth could have a devastating effect on both the environment and natural resources including rivers and streams.

A number of research works have been carried out on the LULC changes in Akure (Balogun *et al*. 2011; Owoeye and Ibitoye, 2016). However, there is paucity of research works on the effects of LULC changes on the aquatic environment especially with respect to heavy metal pollution of stream sediment. The objective of this research is therefore to assess the (i) land use land cover pattern of the study area; (ii) heavy metal contents of the sediment, and (iii) pollution status of the stream sediments of River Ala and its tributaries.

Description of the Study Area

Ala River, the study area, is located in Akure, Ondo state, south western, Nigeria. It lies between longitude 07° 14′ 30″ and 07° 17′ 30″ and latitude 05° 14′ 00″ and 05° 18′ 00″ on Akure topographic sheet number 264 (Figure 1). It runs through Akure and the neighbouring villages. The study area is accessible through Oba Adesida Road to Oba Ile where the river cut across the road near Eji-Oba High School.

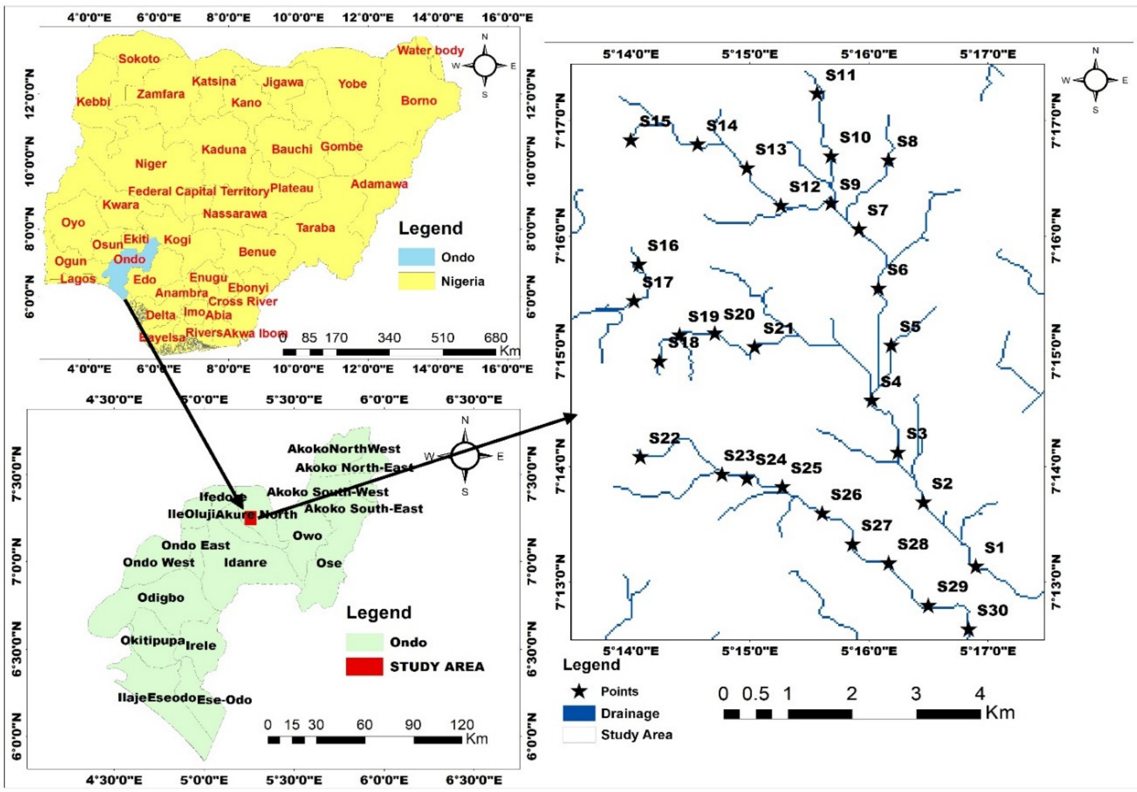

Fig. 1: Location Map of the Study Area

The climatic condition of the study area is the tropical rainforest type, characterized by two distinct season: raining and dry seasons. The raining season spans from April to October. The period is marked by heavy rainfall, reaching its peak around June-July. The dry season starts from November and ends in March. The average annual rainfall in Akure area is 1,400 mm (Ondo State Ministry of Economic Planning and Budget, 2010), while the mean annual temperature ranges from 18^{O}C to 33^{O}C. The drainage pattern in the area is mainly dendritic, the streams and rivers flowing essentially from North to South and occupying the low land areas.

The study area is underlain by the rocks of the Precambrian Basement Complex of South western Nigeria. The basement rocks in the study area are Granite gneiss, granite and quartzite (Figure 2). Intruding into the migmatite-gneiss-quartzite complex and the older granite are the charnockitic rocks. These charnockitic rocks contain intrusive veins of pegmatite, aplite and quartz. According to Olarewaju (2006), they are characterized by dark greenish to greenish grey colour and contains quartz + plagioclase+ alkali feldspar + orthopyroxene + clinopyroxene + hornblende ± boitite ± fayalite. Accessory minerals include zircon, apatite, and iron ores. The granite, a member of the Older granite suite, is the most dominant rock in the area and it occurs as fine-grained biotite granite, medium to coarse – grained, non-porphyritic biotite-hornblende granite and coarse porphyritic biotite-hornblende granite.

Materials and Methods

Sample Collection

Remotely sensed datasets employed in this study are Landsat 7 ETM+ 2010 (Enhanced Thematic Mapper Plus) and Landsat 8 OLI/TIRS 2016 were downloaded from Global Land Cover Facilities (GLCF) website. These dataset lie on path 190 and row 55.

Image Processing

Land Use Land Cover (LULC) changes in the study area in the past 6 years, from 2010 to 2016, were determined using a topographic map and two multidate, nearly cloud free imageries. The satellite imageries are Landsat 7 ETM+ and Landsat 8 OLI/TIRS collected for 2010 and 2016 respectively. The landsat imageries were digitally processed using ILWIS 3.2 software and exported to ArcGIS 10.3 for further processing and analysis. The preprocessing involved the following stages: georeferencing and sub setting in order to extract the study. The images were later displayed in natural colour composite using different band combinations. Others image generated included NDVI (Normalized Difference Vegetation Index) and LULC changes for both 2010 and 2016. The NDVI was calculated using the formulae:

NDVI = (Band 4 – Band 3) / (Band 4 + Band 3)

where Band 3 = red band and Band 4 = infrared band

The processed images were subsequently classified using maximum likelihood classification algorithm for LULC classes. LULC statistics were generated for both the Landsat 7 ETM+ 2010 and Landsat 8 2016 in a manner suitable for change detection analysis. The supervised classification was based on Intergovernmental Panel on Climate Change (IPCC). The IPCC classification was based on five broad land use categories of IPCC Good Practice Guidelines such as Forest land, Wet land, Cropland, bare ground and settlement. A reconnaissance survey of the area was also carried out which assisted in developing an appropriate LULC classification scheme. The reconnaissance survey was conducted with the aid of a topographic map of the study area as well as a Global Positioning System (GPS).

Thereafter, geological fieldwork was carried out in the month of May during which twenty stream sediment samples were collected from the channels of River Ala and its tributaries Figure 3. The samples were collected at a depth of 5 cm and at sampling interval of 500m. The coordinate of the sampling location were determined with the aid of a Global Positioning System (GPS) and later plotted on the field map. The collected samples were put in a pre labelled sample bags. The field sampling exercise was done using a 1:50,000 topographic map.

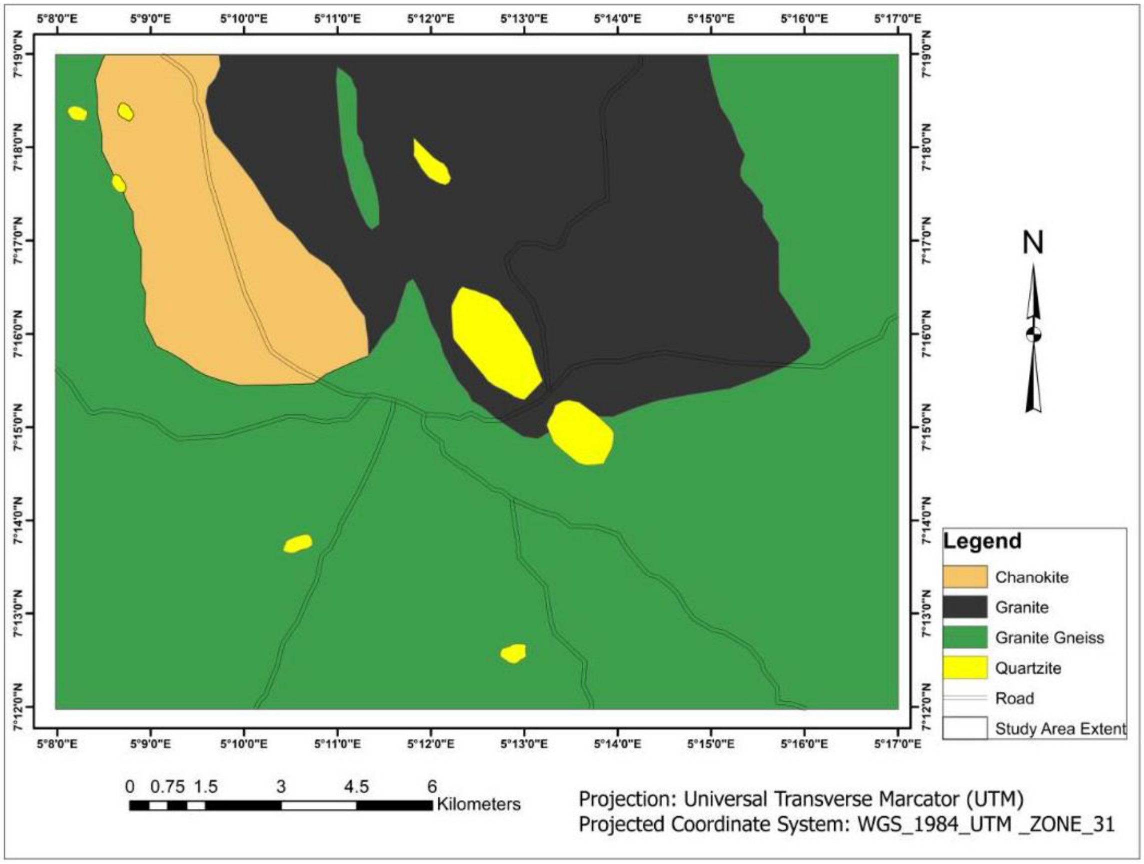

Fig. 2: Geological Map of Akure
(Adapted from Nigeria Geological Survey Agency (NGSA), 2006)

Sample Preparation

The laboratory work involved two stages: sample preparation, sample digestion and sample analysis. Sample preparation involved drying the samples at room temperature. The dried samples were then disaggregated and sieved using 63micron nylon sieve in order to avoid contamination of the samples. The fraction passing through the 63 micron were later digested prior to analysis.

Sample Digestion

2g of the sieved samples were later sent to the laboratory for analysis. The samples were first digested using aqua-regia. The concentrations of nine elements viz: Pb, Fe, Co, Cd, Mn, Zn, Cu, Cr and Ni in the samples were determined using Atomic Absorption Spectrometry (AAS) Buck Scientific 210/211 VGP version. Sample digestion and analysis were done at a commercial laboratory.

Statistical Analysis of Data

Univariate statistical analysis such as mean, median, minimum and maximum of the stream sediment geochemical data were computed. This was done to assess the nature of the data. Other univariate analysis computed are 1st quartile, 3rd quartile, coefficient of variation, skewness and kurtosis. All these analyses were then presented in form of box plots.

Assessment of Heavy Metal Pollution

In this research work heavy metal pollution of River Ala and its tributaries were assessed by using Enrichment factor (EF) and Geoaccumulation Index (Igeo).

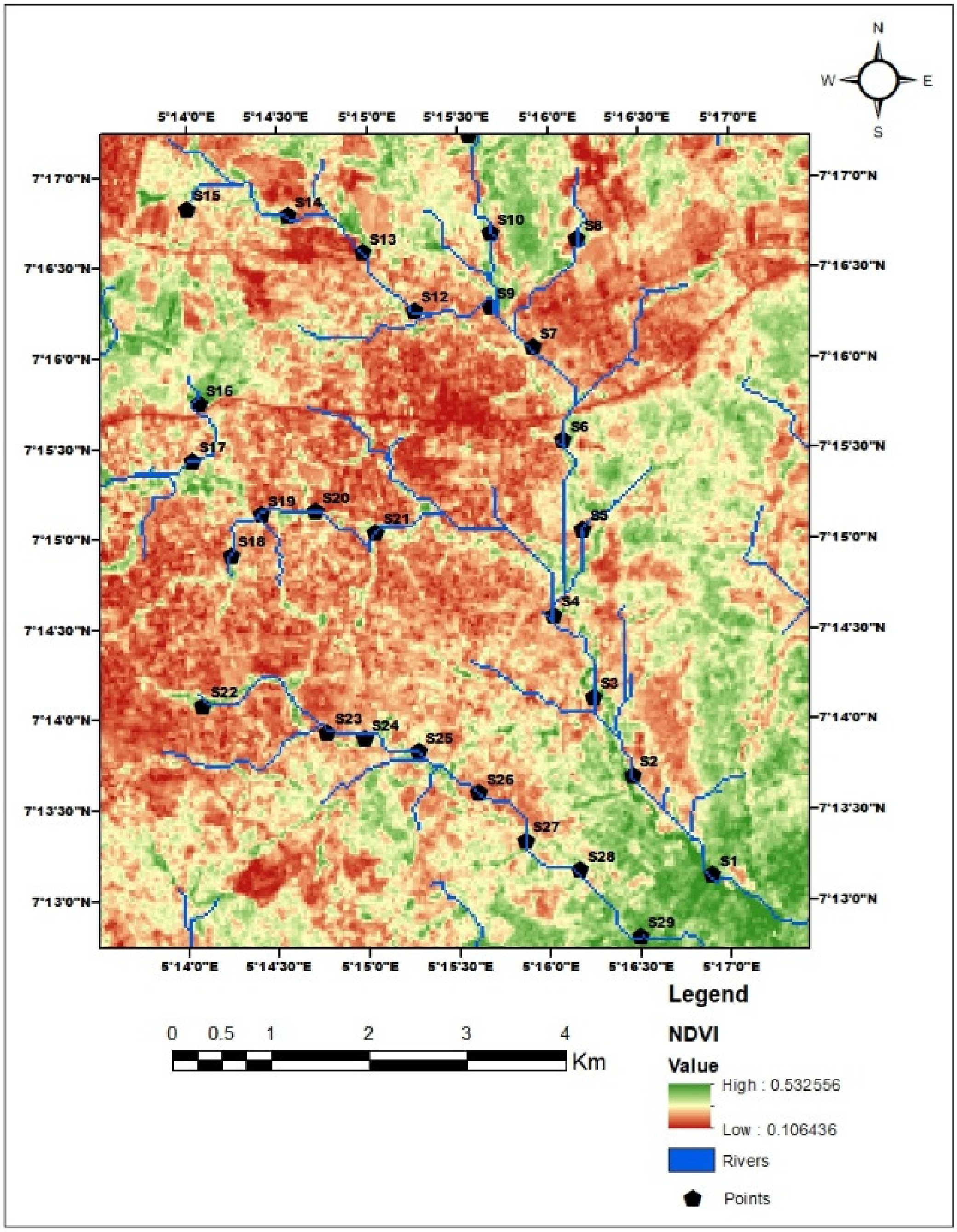

Fig. 3: NDVI Map of the Study Area showing River Ala and Its tributaries with the sample locations (Landsat 8, 2016)

Enrichment Factor

The Enrichment factor (EF) is determined by using the formulae:

$$EF_m = \left(\frac{Cn}{Fe}\right) sample / \left(\frac{Cn}{Fe}\right) background$$

where:

C_n= Concentration of trace element in the sample;

Fe_{sample}= Concentration of the reference element in the sample;
$C_{n\ background}$ = Clarke value or average shale value of the element; and
$Fe_{\ background}$= Clarke value or average shale value of the reference element.

The Enrichment factor (EF) is defined by Hernandez *et al*. (2003) as "the relative abundance of a chemical element in soil (or sediment) compared to the bedrock".

The Average world shale value by Turekian and Wedephol (1961) is the background value while Fe is the normalizing element adopted in this study in the computation of EF. The EF values were computed using Excel software and they were presented in form of box and whisker plots.

Geoaccumulation Index (Igeo)

The level of anthropogenic pollution in the stream sediment of River Ala and its tributaries was also assessed by computing the Geoaccumulation Index (Igeo) using the formula:

$I_{geo} = \log_2 (Cn/ 1.5B_n)$

where:
C_n = the measured concentration of analyzed metal (n) in the geological sample (i.e. sediment);
B_n = the geochemical background concentration of the metal (n); and
1.5 is the background matrix correction factor due to the lithogenic effects.
The Igeo values were presented in form of Bar chart using Excel software.

Results and Discussion

Land Use/Land Cover Studies (2010 – 2016)

The LULC classification for both 2010 and 2016 is shown in Figures 4a and 5a. Five LULC classes were identified. This included bare land, light cropland, dense forest, settlement and wetland. As of 2010, forestland dominated the land cover of the area, which covered 35.72 km^2 (46.67 %). This was followed by settlement (23.78 km^2), bare ground (8.02 km^2), light cropland (5.34 km^2) and wetland (3.67 km^2) (Table 1, Figure 4b). However, by 2016, the forestland had reduced to 27.9 km^2 from 35.72 km^2 while there had been increase in areal extent of light cropland from 5.34 km^2 to 8.8 km^2 (Table1, Figure 5b). Therefore, some part of the forested areas in 2010, as a result of anthropogenic activities, had been cultivated. Consequently, this has led to an increase in the area of light cropland.

Heavy Metal Distribution

The result of the stream sediment geochemical data revealed that the analyzed elements vary widely in composition. Pb concentrations ranged from 0.184 $mgkg^{-1}$ to 0.826 $mgkg^{-1}$, with a mean concentration of 0.474 $mgkg^{-1}$. Fe ranged from 9.992 % to 26.308 %, the mean and median concentrations are 22.909% and 24.4 % respectively. Co has a minimum concentration of 0.103 $mgkg^{-1}$ and a maximum concentration of 0.642 $mgkg^{-1}$ with a mean of 0.395 $mgkg^{-1}$. The range and mean concentrations of Cd, Mn, Cu, Cr and Ni are as follows: Cd range 0.001 $mgkg^{-1}$ to 0.034 $mgkg^{-1}$, mean concentration 0.014 $mgkg^{-1}$; Mn range 3.614 $mgkg^{-1}$ to 5.841 $mgkg^{-1}$, mean concentration 5.109 $mgkg^{-1}$; Zn range 0.84 $mgkg^{-1}$ to 1.649 $mgkg^{-1}$, mean concentration 1.233 $mgkg^{-1}$; Cu range 0.059 $mgkg^{-1}$ to 3.245 $mgkg^{-1}$, mean concentration 0.549 $mgkg^{-1}$; Cr range 0.199 $mgkg^{-1}$ to 0.4 $mgkg^{-1}$, mean concentration 0.28 $mgkg^{-1}$ and Ni range 0.258 $mgkg^{-1}$ to 0.779 $mgkg^{-1}$, mean concentration 0.571 $mgkg^{-1}$ (Table 2, Figure 6). The raw geochemical data also revealed that all the analyzed elements have very low Coefficient of Variation (CV) values indicating homogeneous spatial distribution of these elements. This is evident in both the mean and median concentration having similar concentrations.

The mean concentration values of the analyzed elements in the stream sediment were also compared with the corresponding "average world shale", United States Environmental Protection Agency Sediment quality guidelines (USEPA SQG) values as well as other similar studies carried out in Nigeria. Table 3 revealed that the concentrations of all the elements are less than their corresponding average world shale and USEPA sediment quality values except for Fe. Fe with a mean concentration of 22.909 % is higher than the corresponding average world value of 4.7 %. Therefore, when the average world shale and USEPA stream sediment guideline values are used as the basis for determining the pollution status of the sediments, River Ala and its tributaries are unpolluted by Pb, Fe, Co, Cd, Mn, Zn, Cu, Cr and Ni. These elements, therefore, do not pose any environmental risk.

Table1: Areas and rate of change of the five LULC between 2010 and 2016

LU/LC Types	2010 LULC Areal Extent		2016 LULC Areal Extent		Change between 2010 and 2016
	Km^2	%	Km^2	%	
Wetland	3.67	4.80	4.3	6.16	+0.63
Bare Ground	8.02	10.48	8.02	11.49	0
Dense Forest	35.72	46.67	27.9	39.96	-7.82
Settlement	23.78	31.07	20.8	29.79	-2.98
Light Cropland	5.34	6.98	8.8	12.60	+3.46
Class Total	76.53	100	69.82	100	

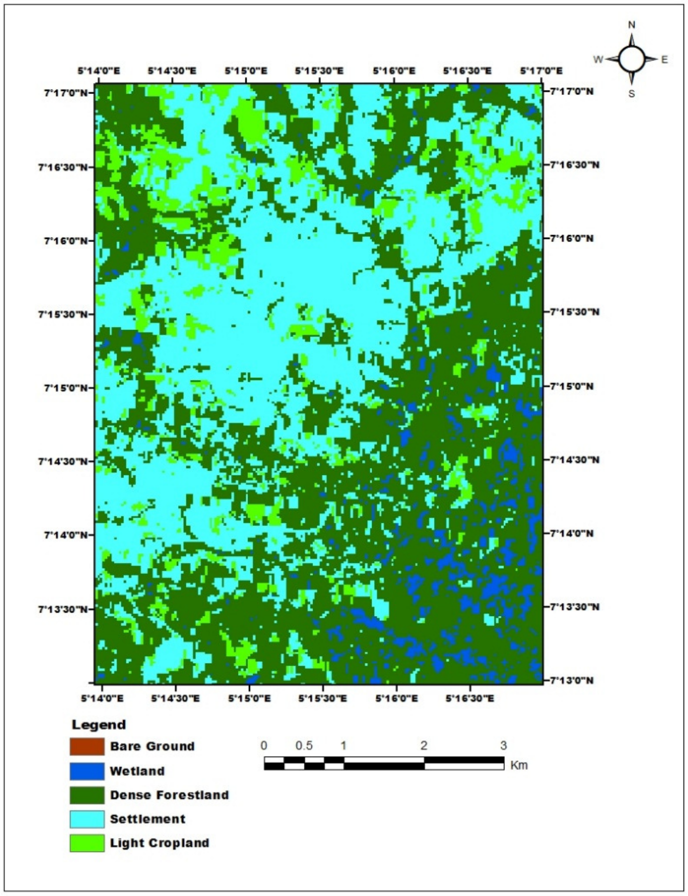

Fig. 4a: Land Use/Land Cover Map of the Study Area based on Landsat 7 ETM+ 2010

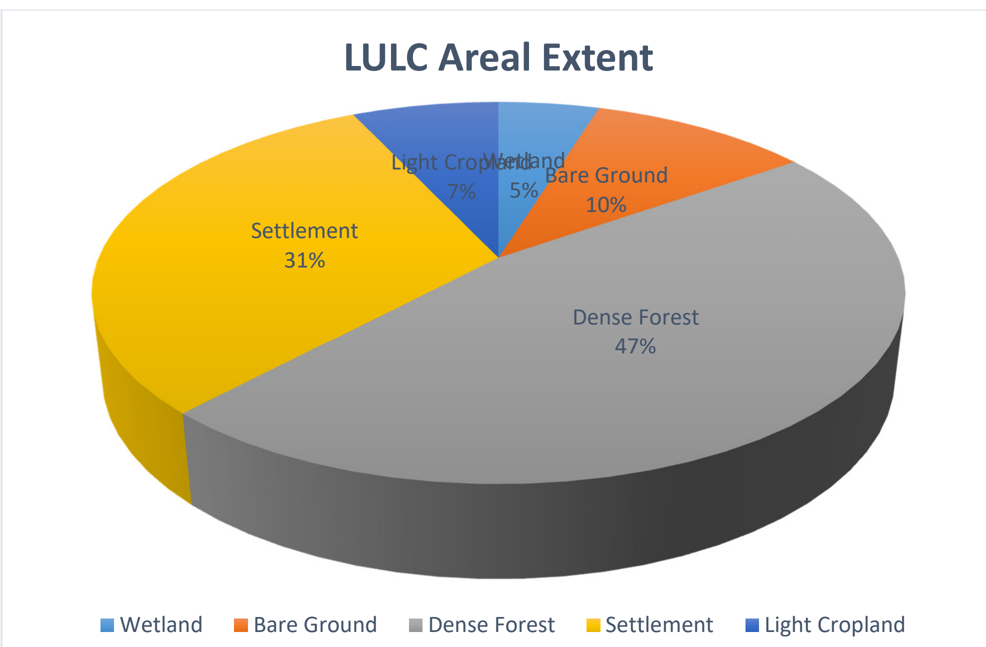

Fig. 4b: Land use land cover areal extent based on Landsat 7 ETM+ 2010

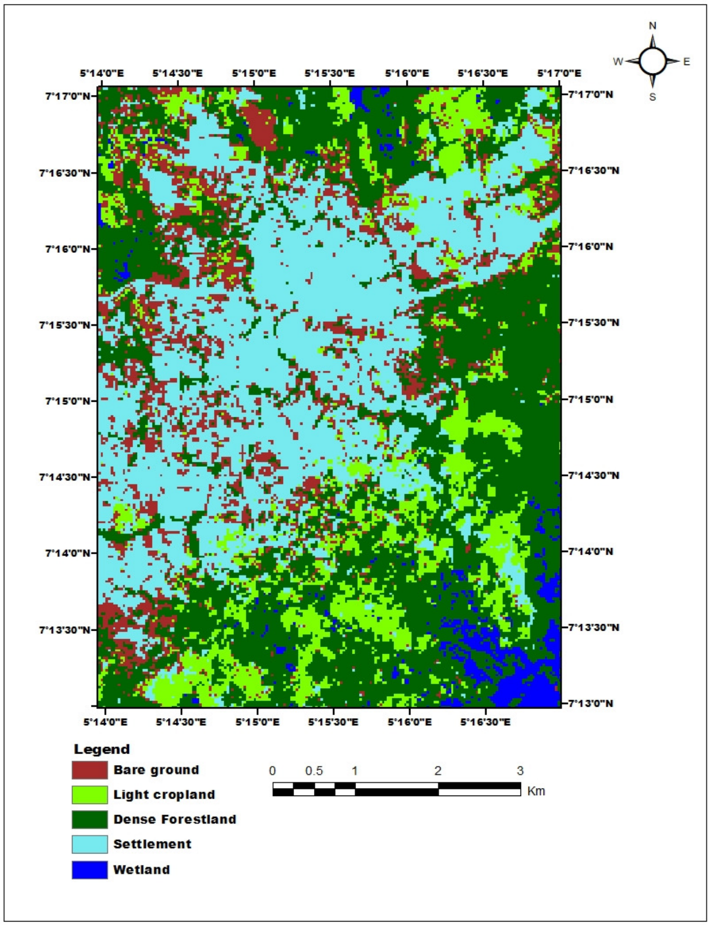

Fig. 5a: Land Use/ Land Cover Map of the Study Area based on Landsat 8 2016

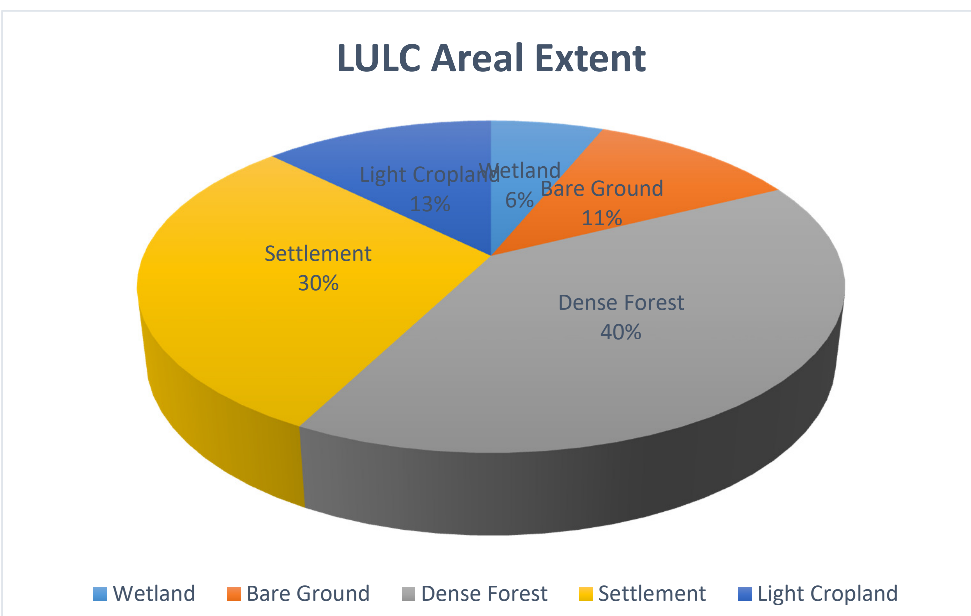

Fig. 5b: Land use land cover areal extent based on Landsat 8 2016

Table 2: Summary Statistics of the analyzed elements

	Min.	Max.	Median	Mean	1st Qrt.	3rd Qrt.	SD	Variance	CV	Skewness	Kurtosis
Pb	0.184	0.826	0.447	0.474	0.290	0.700	0.210	0.044	0.442	0.347	-1.064
Fe	9.992	26.308	24.400	22.909	23.638	25.442	4.452	19.819	0.194	-2.055	3.382
Co	0.103	0.642	0.257	0.395	0.193	0.347	0.143	0.020	0.363	1.068	0.880
Cd	0.001	0.034	0.014	0.014	0.005	0.024	0.010	0.000	0.725	0.356	-1.166
Mn	3.614	5.841	5.251	5.109	4.823	5.488	0.580	0.337	0.114	-1.188	1.154
Zn	0.840	1.649	1.165	1.233	1.010	1.465	0.257	0.066	0.209	0.151	-1.388
Cu	0.059	3.245	0.338	0.549	0.212	0.487	0.694	0.482	1.264	3.417	12.997
Cr	0.199	0.400	0.280	0.280	0.236	0.311	0.050	0.002	0.177	0.406	0.304
Ni	0.258	0.779	0.574	0.571	0.476	0.674	0.130	0.017	0.227	-0.344	0.319

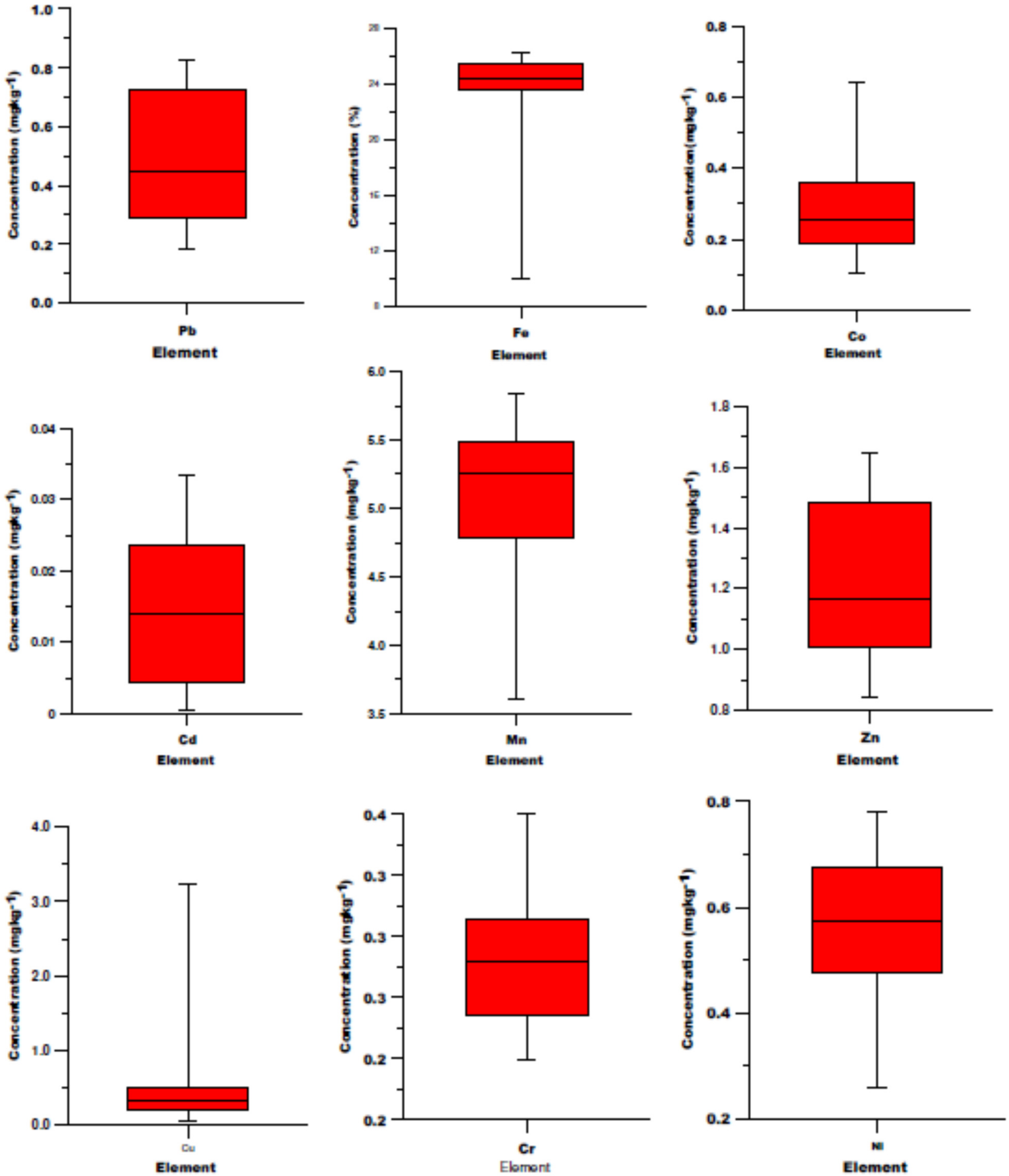

Fig. 6: Box Plots of the Concentrations of Analyzed Elements in the Stream Sediment of the Study Area.

Assessment of Stream Sediment Pollution

Enrichment Factor

The enrichment factor (EF), for the analyzed geochemical elements in the stream sediment of River Ala and its tributaries, is presented in Figure 7. The range of EFs for the analyzed elements are as follows: Pb (0.0017-0.0194); Co (0.0011-0.0074); Cd (0.0005-0.0283); Mn (0.000823-0.00264); Zn (0.0016-0.00816); Cu (0.00025-0.0133); Cr (0.00043-0.00159); Ni (0.000726-0.0036).

In interpreting the EF values, this research has adopted the classification of Sutherland (2000). Sutherland (2000) classified EF values into six categories Table 4. The EF values of all the analyzed elements are all less than 1 (i.e. EF < 1). This implies that the EF values fall within the range of background concentrations. Therefore, these elements pose no risk of contamination or pollution in the stream sediment and the associated medium (water). River Ala and its tributaries are not enriched with respect to the analyzed heavy metal when EF is used as an index of assessing the pollution status. The sources of the elements could be attributed to the underlying geology. For example, the source Pb may possibly be from the K-feldspar in the underlying granite/granite gneiss. Pb has been reported in K-feldspar structure in which it replaces K (Wedepohl, 1970). Co is often found in association with Ni in mafic and ultramafic rocks (Rose et al., 1979). The low concentrations of these elements could be attributed to the paucity of these rocks in the study area. Co could be found in pyroxene, olivine and biotite in acid and intermediate rocks. Therefore, the source of Co and Ni could possibly be from granite. Cu is a chalcophile element. It is found concentrated in biotite, pyroxene as well as olivine in intrusive rocks (Krauskopf, 1979). The source of Zn could from the underlying rock in the study area. Zn could substitute for Mg and Fe in silicate structure. It could, as well, be found in minerals like plagioclase, K-feldspar, muscovite and quatz. These mineral constitute the rocks underlying the study area.

Geoaccumulation Index (Igeo)

The geoaccumulation index (Igeo) values for the analyzed heavy metals were interpreted using the classification by Muller (1981) (Table 4). The Igeo values for Pb, Co, Cd, Mn, Zn, Cu, Cr and Ni are all less than zero (i.e. Igeo < 0) except Fe where the Igeo values range between 0.503 and 1.9 (Figure 8). Therefore, on the basis of Igeo, the stream sediment of River Ala and its tributaries are uncontaminated with respect to Pb, Co, Cd, Mn, Zn, Cu, Cr and Ni. Furthermore, the sediment is moderately contaminated by Fe.

Table 3: Comparison of Mean Concentration of Heavy Metals from this Study with USEPA SQG, Average Shale and Similar Study in Nigeria

	Mean	USEPA	Average Shale	*Odo-Owa	**Eastern Niger
Pb	0.474		20	11.74	56.51
Fe	22.909	30	4.7		
Co	0.395		19		
Cd	0.014		0.3		1.85
Mn	5.109	30	850		
Zn	1.233	110	95	151.3	108.77
Cu	0.549		45		
Cr	0.280		90	2.3	
Ni	0.571	16	68		7.03

*Mustapha and Lawal (2014)
**Ekwere *et al.*, (2013)

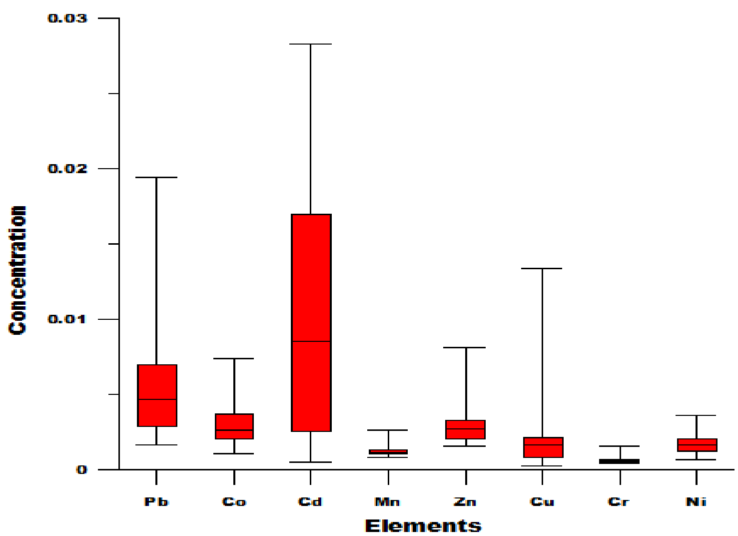

Fig. 7: Box plots of Enrichment Factors (EF) of the trace elements in the stream sediments

Table 4: Classification of Enrichment Factor (EF) and Geo-accumulation Index (Igeo)

Index	Value	Degree of Contamination
EF	<1	Background concentration
	1-2	Depletion to minimal enrichment
	2-5	Moderate enrichment
	5-20	Significant enrichment
	20-40	Very high enrichment
	>40	Extremely high enrichment
Igeo	<0	Uncontaminated
	0 – 1	Uncontaminated to moderately contaminated
	1-2	Moderately contaminated
	2-3	Moderately to strongly contaminated
	3-4	Strongly contaminated
	4-5	Strongly to extremely contaminated
	>5	Extremely contaminated

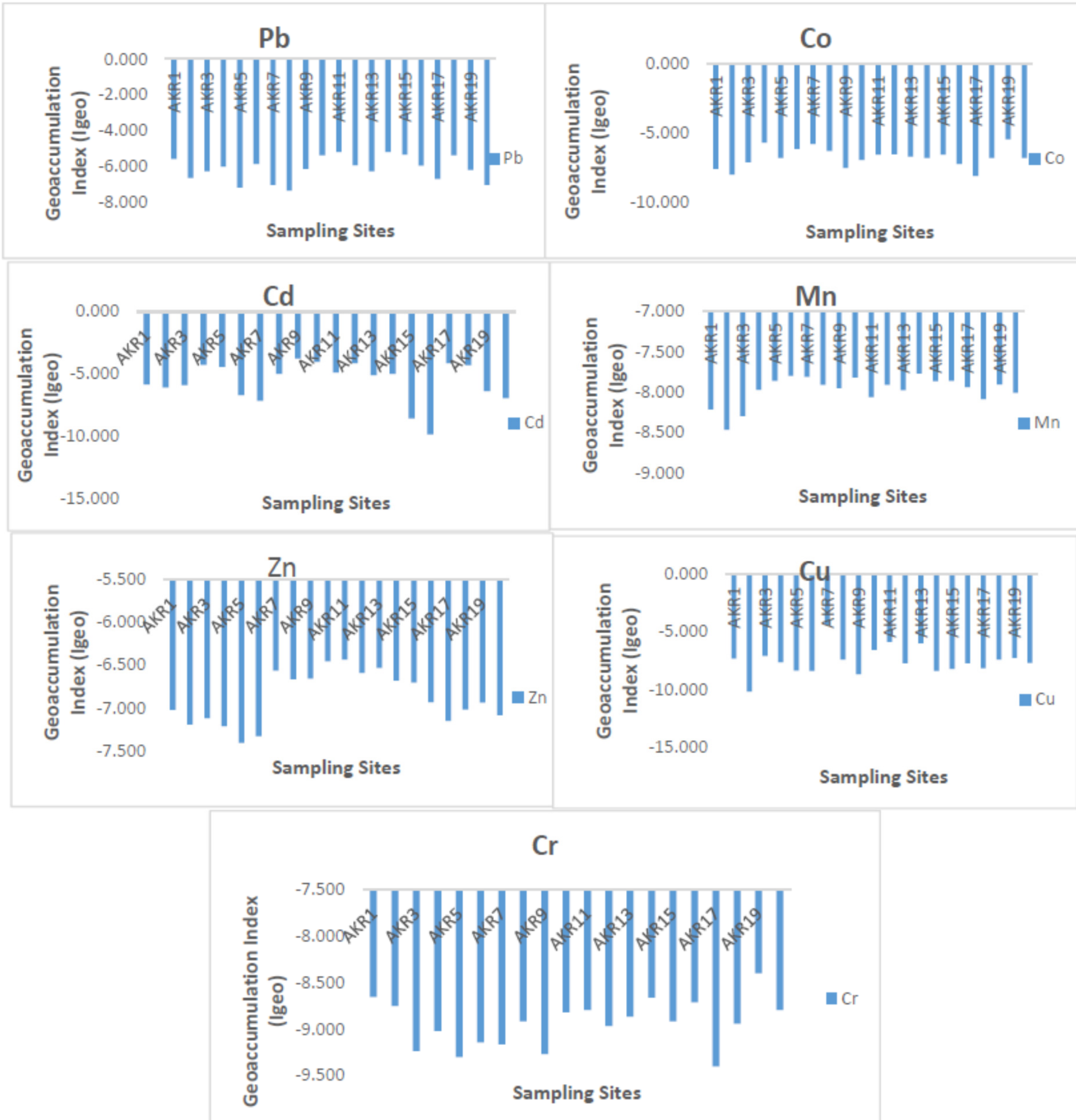

Fig. 8: Geo-Accumulation Index for the Analyzed Heavy Metal from the Stream Sediments of River Ala and Its Tributaries.

Conclusion

This study has investigated the effect of land use changes on the heavy metal pollution of stream sediments using River Ala in Akure as an example. The study revealed that the dominant LULC trend in the area was forest in 2010. Some part of the forestland had been cultivated by 2016 causing a reduction in the area extent of the forestland and increase in the area of cropland. This land use change, however, do not have a significant negative impact as regards the pollution of the stream sediments by heavy metals. The concentrations of Pb, Fe, Co, Cd, Mn, Zn, Cu, Cr and Ni are background concentrations. The mean concentrations of these elements are less than the corresponding USEPA SQG and Average world shale values. The EF and Igeo values of the heavy metals indicated that the stream sediment is unpolluted by these heavy metal.

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