Impact of Urbanization on Wetland Degradation: A Case Study of Eleyele Wetland, Ibadan, South West, Nigeria

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Abstract

Nigeria is richly endowed with both coastal and inland wetlands, many of which are being threatened by anthropogenic drivers such as land use activities, urbanization, agricultural activities in addition to the emerging threats of climate change. Therefore, this study highlights the environmental assessment of urbanization land-use impacts on degradation of Eleyele Wetland in Ibadan SW-Nigeria. For the study, a GIS-based remote sensing assessment was employed to characterize the temporal changes in land-use dynamics within the catchment areas of the Eleyele Wetland. In addition, about 40 water samples (from both the main Lake and feeding streams) and 25 bottom sediments samples were collected and subjected to chemical analyses of the major cations and trace metals using inductively coupled plasma mass spectrometer and atomic Emission spectrometer (ICP-MS /-AES) methods respectively. The GIS-based assessment revealed a reduction in the riparian wetland forest of 1.25 km^2 as at 1984 to 0.70km^2 by 2004 with a projected decline of 0.42 km^2 by 2014. These clearly signify considerable impact of human activities with loss of 45-70% of the wetland riparian and light forests due to about 70% increase in build-up areas between 1998 and 2004. The measured physico-chemical parameters of the water revealed relatively higher values in the feeder streams compare to that of the main wetland Lake with pH values of 6.5 to 8.8 and 6.7 to 10.1 and EC of 141 to 1252µS/cm and 142 to 424µS/cm respectively. The average Ca, Mg Na and K concentrations in the lake revealed values of 29.1, 9.3, 29.6 and 13.0 mg/l respectively while those of the feeder streams are 43.9, 9.9, 39.7 and 13.49mg/l respectively. The results of the trace metals such as Cr, Cd, Co, Cu, Pb, Ni, Fe, Al, Mn and Zn also show the similar trend of higher values in the feeder streams over those of the lake samples, a situation which could be attributed to impacts of urban waste water and effluent discharges to the feeder streams. However, the lower concentration in the main lake can be attributed to the dilution effect. The overall results highlight the negative impacts of the human-induced influence on the Wetland ecosystem through land-use and waste effluent discharges with attendant degradation / loss; hence, the need for Integrated Water Resources and Environmental Management in order to safeguard the overall quality of the wetland ecosystem.

Keywords: Urbanization, Wetland degradation, Eleyele Wetland, Ibadan-Nigeria.

Introduction

Wetlands are among the Earth's most productive ecosystems. The significance of wetlands lie in their roles in the hydrological cycle, for flood and biomass production, as refuge for wildlife, biogeochemical functions, as nutrient and pollution filters for water quality improvement among others. However, it had been reported that a large percentage of wetlands have been lost in the last century, apparently due to drainage and land clearance as consequence of agricultural, urban and industrial development activities (Frenken, 2002; Williams et al., 2009). Coupled with these anthropogenic impacts, the degradation of wetlands is being compounded by the emerging reality of climate change and associated impacts.

Wetlands are generally flat-floored, relatively shallow and occupy the lower reaches of watersheds of large rivers, which are either located near the coast and generally do not have large flood plains (Windmeijer and Andriesse, 1993). They comprise of valley bottoms and flood plains, which may be submerged for greater parts of the year. The hydromorphic fringes and contiguous upland slopes contribute water to the valley bottom through runoff and groundwater flow. Wetland ecosystems, including rivers, lakes, floodplains and marshes, provide many services that contribute to human well-being and poverty alleviation (Millennium Ecosystem Assessment, 2005). However, they are increasingly subject to intense pressure from multiple human activities such as water diversion, pollution, over-exploitation of natural resources, and reclamation.

Wetlands are significant ecosystems for two principal reasons: they could be used in a sustainable way and would relieve current pressures on the upland agro-ecoystems, which is being threatened by increasing population pressures as well as desertification. Secondly, physical conditions for cropping within wetland/inland valley are more favorable than uplands since there is more water in this ecosystem. In addition, during the dry season, valley bottom and fringes are almost the only location in most agro-ecological zone where crops can be grown outside irrigated areas. The principal problem posed by these agro-ecoystsems is that for reasons, which are unclear, the potentials of wetlands have remained relatively untapped. According to Brerton, 1988), only 10 and 25 % of these are currently used for agricultural production, although a trend toward a greater use of wetlands is apparent in many areas of Nigeria and West Africa.

Nigeria is a country richly endowed with both coastal and inland wetlands and these wetlands are of ecological, economic, socio-cultural, scientific and recreational significance. Wetlands provide critical functions that are essential for sustainable development in many areas. Wetlands are hugely diverse and these could be ponds, marshes, coral reefs, peat lands, lakes or mangroves. These wetland types share one fundamental feature which is the complex interaction between soil, water, animals and plants.

Furthermore, it should be pointed out that the greatest increases in food production (both during the raining and dry seasons) in Nigeria could come from the wetlands and associated hydromorphic lands. However, with urban populations increasing in Nigeria, food production from the uplands cannot meet increasing population food demand; thus, wetlands may be the most logical environment in which to close this gap. For example, due to their hydrological characteristics, wetlands are favorable ecosystems for rice production during the rainy season and for the cultivation of various arable crops and vegetables during the dry seasons when the water levels have receded. Thus such wetland environment can be described as a small-scale irrigation sites developed through exploitation of shallow groundwater by private farmers, who take responsibility for the investment and management of the farms. It is an alternative to large-scale irrigation system, which failed to meet the food self-sufficiency and security of Nigeria (Baba, 1993). In other words, wetlands cropping afforded peoples some opportunities utilizing the surplus labor during the dry seasons unlike in the rainy seasons when there is labor constraint. However, it should be noted that due to poor land use management soil quality has degenerated resulting in low organic matter content, declining nutrients, fragile topsoil structure and reduced soil moisture coupled with uncontrolled crop cultivation and over grazing. In addition to this, the Nigeria's wetland resources are currently being threatened by some anthropogenic and bio-geophysical factors which are increased population pressure, rapid urbanization, mining and pollution among others. Therefore, at present and for the foreseeable future, human activities will continue to adversely affect wetland ecosystems. The rate at which wetlands are being lost is affecting water supply and water resources management in various parts of Nigeria and especially with the case of Eleyele Wetland in Ibadan metropolis. Hence, there is no gainsaying that the degradation of wetland ecosystems will increase the task and challenges of water resources management in Nigeria.

Climate, topography and soils interact to determine major hydrological processes of the inland valleys and this in turn determine the availability of surface or ground water. Water from the uplands flows towards the valley bottom as surface runoff and just below the soil surface (interflow), or well below the soil surface (groundwater flow). Usually, three hydrological processes characterize wetlands viz: seepage, runoff and vertical fluctuations in the water table (Carsky and Masajo, 1992; Raunet, 1985). These processes are however, determined by indices such as rainfall, soil texture, soil depth, and catchments area as well as valley morphology. Therefore the variability of indices across any section of the wetland ecosystem will in turn affects the hydrologic characteristics of the wetlands. In view of the ecological and hydrological significance of wetlands the negative impacts of such climate change and human-induced degradation on the features of wetlands system (i.e. *components, attributes* and *functions*) will have serious consequences in terms of environmental sustainability. Usually, the *components* of wetlands system are the biotic and non-biotic features such as soil, water, plants and animals, while the *attributes* relate to the variability and diversity of these components e.g. diversity of species. However, the, influence of agricultural land-use and other human activities alongside with climate change-induced hydrological modifications (affecting a biotic factor) are said to affects the attributes and functions of wetlands ecosystem (Gosselink, and Tuner, 1978). These are reflected in terms of storage of runoff water, reduction of peak runoff rates, improvement in the quality of water flowing over and through the lands, provision of habitat for birds and wildlife and the maintenance of biodiversity of plant and animal species.

Nonetheless, there are several drivers for wetlands degradation, notable among these lies in the need to expand agriculture to feed growing population, especially in the developing regions of the world, leading to the conversion of wetlands into farmlands. Agricultural activities have been recognized as affecting ground and surface water quality adversely from both point and non-point sources (William et al., 2009). In tropical savanna region wetlands are called *fadamas,* which apart from serving as refuge for wildlife, are primarily utilize to sustain agricultural activities at the local communities. In such tropical region, as in most of the developing countries of Africa, apart from population increase and the attendant competing water needs for agricultural, domestic, and industrial purposes, the surface water regimes are vulnerable to rainfall variability and/or river regulation and abstraction activities. Therefore, ensuring the successful delivery of allocated water to a wetland will require integrated management of associated surface and groundwater resources, at the same time there is the need for better understanding of the agriculture water management in wetland ecosystem.

In summary, there is no doubt as to the increasing impacts of agricultural land-use and other urban human activities on the wetland ecosystem functions on one hand. On the other hand, there is a consensus that climate change is an ongoing phenomenon which will impact negatively on wetland hydrology. Therefore, knowledge of climate variations in space and time as well as knowledge of impacts of land-use activities within the catchment of wetland is vital for adequate assessment of wetland loss and degradation.

Based on the above background, the overall aim of this investigation is to highlight the environmental assessment of land-use impacts and degradation of Eleyele Wetland in Ibadan SW-Nigeria, with specific objectives of:

a) Assessing the effect of the land-use activities on the the wetland ecosystems and
b) Assessing the geochemical characters and contamination of bottom sediments and soils of the Eleyele wetland.

Study Area

Eleyele Wetland

The study location Eleyele Wetland is located in north-eastern part of Ibadan, southwestern Nigeria within longitude N07^{0}25'00" and N07^{0}27'00" and Latitude E03^{0}50'00" and E03^{0}53'00" (Figure 1). The study site is surrounded by Eleyele neighborhood in the south, Apete in the east and Awotan in the north. Eleyele wetland is a modified natural riverine wetland type with area of about 100 km^2 including the catchment area. The elevation is relatively low ranging between 100-150m above sea level and surrounded by quartz-ridge hills toward the downstream section where the Eleyele dam barrage is located. A number of stream channels serve as feeding / recharge streams to the Eleyele wetland basin. In 1942, the quest to create a modern water supply system to meet the challenge of water scarcity for the emerging Ibadan metropolis led to the construction of Eleyele Dam on the main River Ona with a reservoir storage capacity of 29.5 million litres.

Climatic Setting and Vegetation

The study area, Ibadan fall under Tropical Hinterland Climate Zone (about 150–240km northwards from the coast) with 1000 to 1500mm annual rainfall, temperature range of 21–25°C and relative humidity range of 50–80%. The dry season range from 4–5 months between November to March, with December-January characterized by NE-SW dry, cold and dusty harmattan trade wind, from the Sahara Desert. For the study Eleyele Wetland, the adjoining hilly quartzite ridges are covered by forests, while the wetland lowland areas are dominated by light forest, riparian wetland forest most of which had been impacted by human activities.

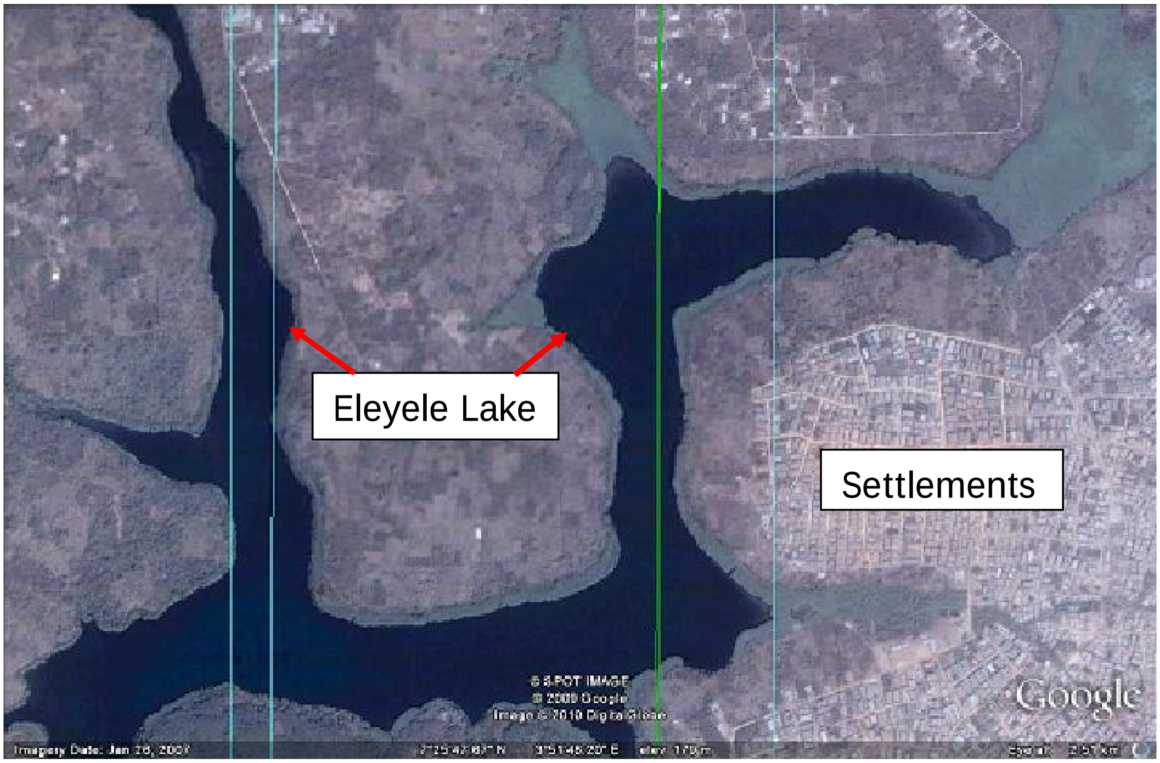

Figure 1: Aerial Photo of Eleyele Wetland catchment showing the agricultural land-use and encroaching settlements (Source; Google Earth).

Geology and Drainage System

Geology of Ibadan and environs, including the catchment of Eleyele Wetland, falls within the Pre-Cambrian rocks of Southwestern Nigeria which is part of the Nigerian Basement Complex. The major rock types are schist-quartzites, granite-gneiss, banded gneiss, augen-gneiss, and migmatites (Jones and Hockey, 1964; Olayinka et al., 1999), while minor rock types such as pegmatite, aplites, quartz veins, and dolerite dykes intruded the main rocks in places (Figure 2). Gneisses are migmatized in places, and characterized by predominantly medium-sized grains while schist-quartzites occur as elongated ridges striking NW-SE (Olayinka et al., 1999).

The drainage system is controlled by the bedrock geology, with characteristic dendritic pattern of the streams and rivulets being structurally controlled. Flash overland flow and drainage discharge is common during the wet season from May through October aided by the hilly nature of the surrounding terrain. The Eleyele Wetland and the associated dam at Eleyele receive water from River Alapata and the headstream of River Ona (see Figure 2). The catchment of the Eleyele Wetland is relatively well drained with network of River Ona and its tributaries (such as Ogbere, Alapata and Ogunpa). River Ona flows roughly in north - south direction.

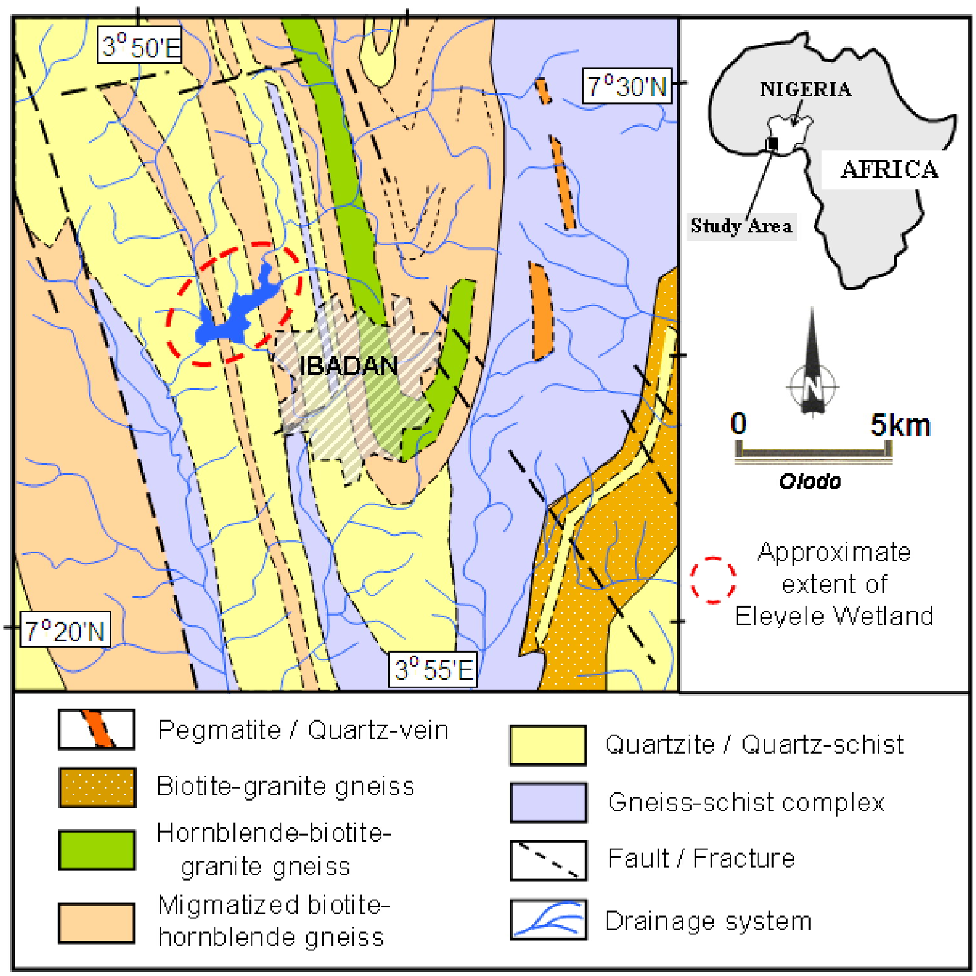

Figure 2: Geological map of the Ibadan showing the location of Eleyele Wetland

Methodology (Sample Collections and Analyses)

Methods employed in this study involved a number of activities, both field and laboratory based, were undertaken in order to generate the necessary data. Initial desk study involved a GIS-based assessment of the sptial and temporal changes in the areal extent of the different land-use in order to assess land use changes and possible attendant impacts of human activities on the Eleyele Wetland ecosystem. Subsequent field in-situ measurements of field physico-chemical properties of water samples from both the main wetland reservoirs and the feeding streams as well as sampling of water and bottom sediment samples along the feeding tributaries and within the wetland reservoir were also undertaken. In addition soil samples from the buffer zones were also collected.

Physico-chemical parameters measured or determined in the field are electrical conductivity (EC), Total dissolved solid (TDS), pH and temperature of the water with the aid of portable pH/Conductivity/Temperature meter (model PC Testre meter). For the field sampling operation, a local boat was used in moving from locations to locations within the make lake while water samples were collected in two separate 50cl polyethelene sampling bottles for cations (acidified) and anions analyses. In addition, the buffer zones soils as well as bottom sediment samples within the lakes and feeding streams were also collected with the aid of hand auger with polythene bags. Figure 3 presents the sampling locations of the different media within the catchment of Eleyele Wetland.

Water samples were preserved after collection before chemical analyses under refrigeration, while bottom sediment samples were air-dried and sieved with sieve of 0.2µm mesh size to obtain the clay portions. Subsequently, cations and trace elements in the water and bottom sediments samples were analyzed at the ACME Analytical Laboratory, Vancouver, Canada, using ICP-MS and ICP-AES method respectively. However, the buffer soil samples were aired dried and subjected to chemical analyses at the soil laboratory of the Agronomy Department at the University of Ibadan, Ibadan, Nigeria.

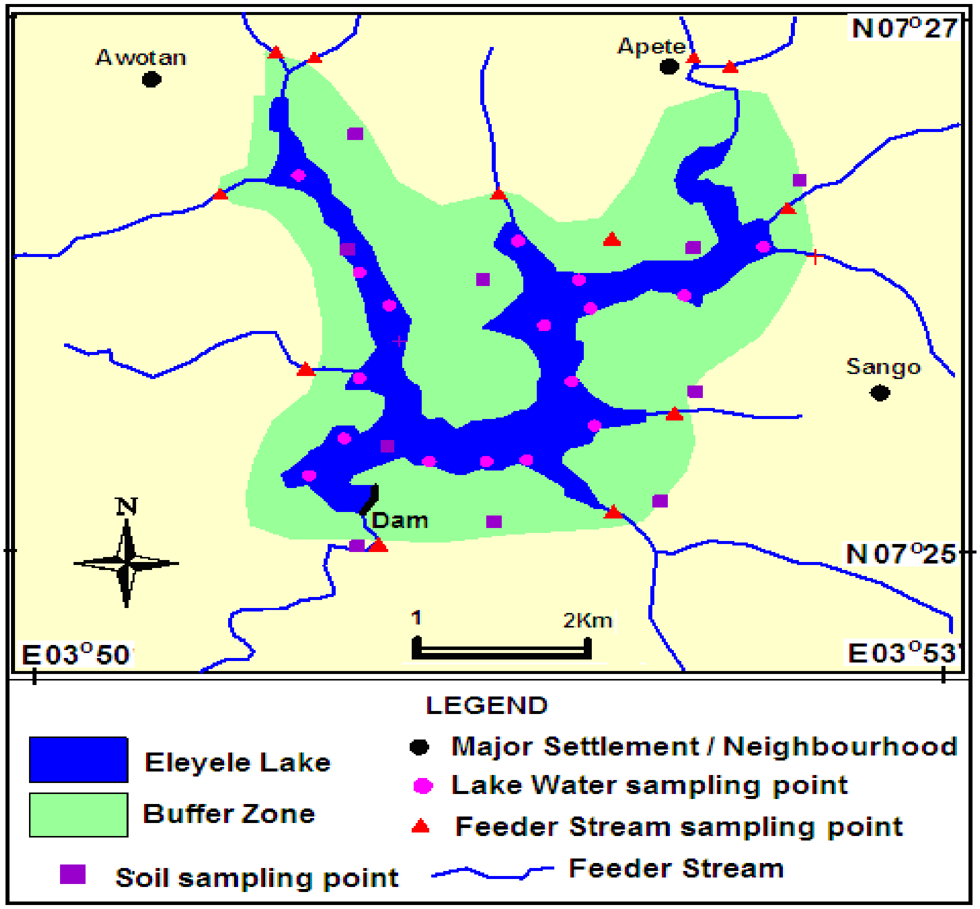

Figure 3: Location map of the Eleyele Wetland Catchment showing the water, soil and bottom sediments sampling points

Finally, as part of data evaluation, the results of the in-situ physico-chemical measurements and laboratory geochemical analyses of the water samples, bottom sediments and soil samples were subjected to statistical evaluation involving statistical summary and correlation to ascertain the interdependence or otherwise of the different parameters. For the assessment and quantification of the level of wetland contamination / degradation with respect to the various media sampled (water, bottom sediments, and buffer soils), some quantitative and qualitative indices were used to describe the concentration trends and also to allow for easy comparison between the measured parameters and a number of standards.

Results and Discussion

GIS-based Mapping of Land Use Changes

The GIS-based assessment of the temporal changes in the areal extent of the different land-use type involved evaluation of remotely sensed satellite imagery for the period of 1984 and 2004, while the resulting evaluation were used to obtain scenario for the intervening period of 1994 and the future projection for the period of 2014. The composite map of the spatial didtribution and areal coverage of the different land use types for the periods of 1984 and 2004 are presented in Figure 4a and b, while the evaluated results is presented in Table 1.

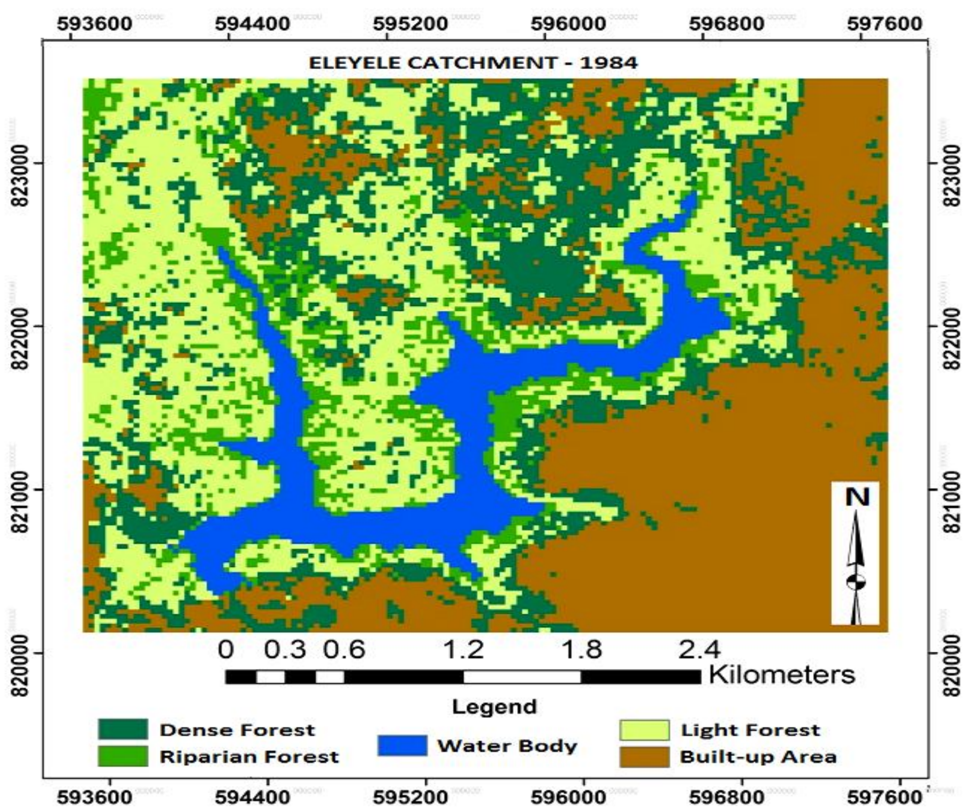

Figure 4a: GIS-based imagery map of spatial distribution of the land-use type as at 1984.

As presented in Table 1, a critical interpretation and evaluation of the imageries revealed that the dense forest within the catchment area had reduced in extent from 3.38km^2 in 1984 to 3.01km^2 by 2004 with a projected decrease to 2.52km^2 by 2014. Similarly, the riparian wetland forest of 1.25 km^2 as at 1984 was reduced to 0.70km^2 by 2004 and also projected to decline to 0.42 km^2 by 2014.

The water body, however, experience comparatively little change with an areal extent of 1.25 km^2 as at 1984 and 1.14 by 2004.

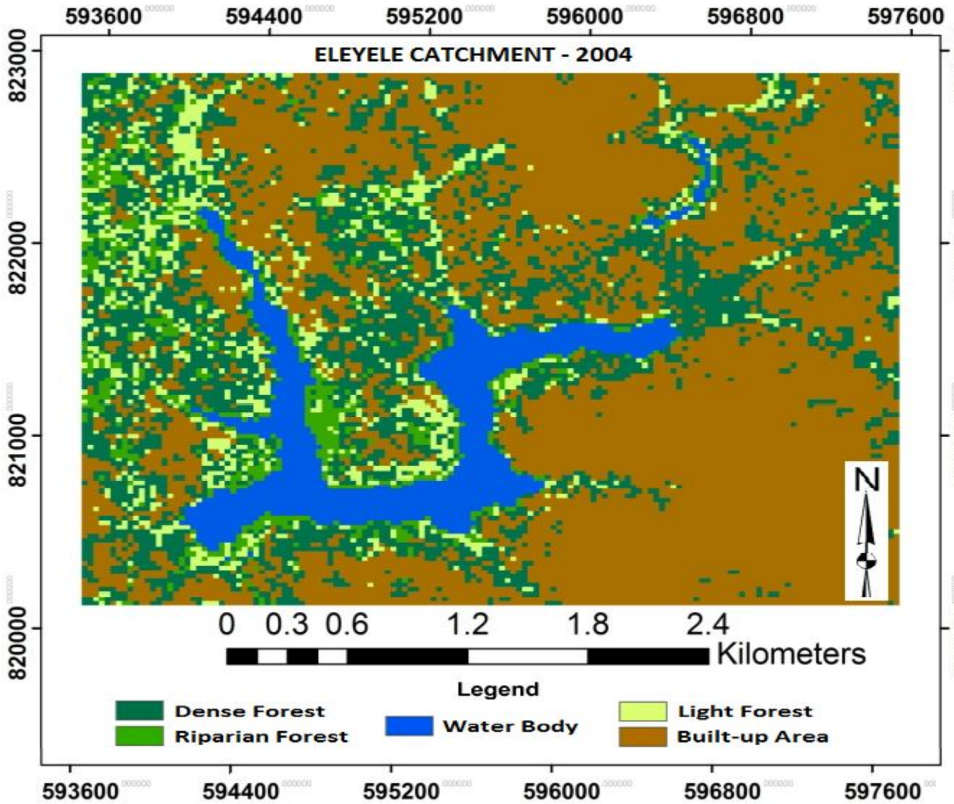

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Figure 4b: GIS-based imagery map of spatial distribution of the land-use type as at 2004.

Nonetheless, considerable impact of human activities within the Eleyele catchment is reflected in the considerable decline in areal extent of the light forest from 3.84 km^2 in 1984 to 1.09 km^2 by 2004 apparently giving way for the built-up area which had expanded from 4.47 km^2 in 1984 to 7.52 km^2 by 2004 (see Table 1).

Table 1: GIS-based estimated and projected temporal changes in the spatial extent of land use types (in km^2) within the Catchment of Eleyele Wetland

Land Use Type (km^2)	1984^+	1994*	2004^+	2014*
Dense forest	3.38	3.20	3.01	2.52
Riparian (wetland) forest	1.25	0.98	0.70	0.42
Light forest	3.84	2.46	1.09	0.01
Water body (River)	1.25	1.19	1.14	1.09
Built-up Area	4.47	5.99	7.52	9.04

+ = Estimated * = Projected

Furthermore, the temporal and spatial changes in land use pattern are clearly evident as highlighted in Fig. 5. The riparian wetland forest and the surrounding light forest witnessed significant loss or degradation (of 45-70%), due to urban development activities resulting in increase of about 70% in build-up areas as at 2004 compared the situation in 1984. This is no doubt a clear indication of anthropogenic activities or impact of urbanized activities within the catchment of Eleyele Wetland with attendant degradation and loss. However, unlike the riparian wetland forest and the light forest, the Eleyele wetland water body and surrounding dense forest are less affected with about 10% loss as at 2004.

This may be attributed to the fact that most of the so-called dense forests are located on the surrounding hilly quartzite ridges with poor accessible for development compared to the light forest area at the low lying plains, in addition to the fact that some are planted forest reserves. Nonetheless, the observed minimal change in the extent of the wetland water body despite the obvious encroachment implies that the feeding channels are still kept open and that water, as usual, do find its level.

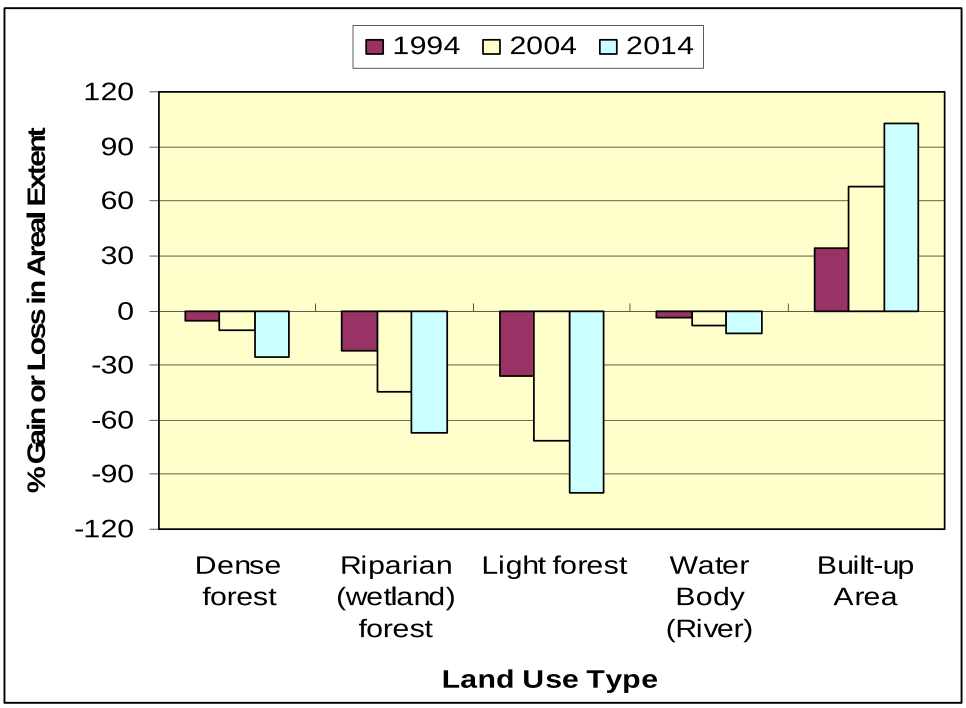

Figure 5: Temporal variation in the estimated percentage loss / gain in the extent of the different land use within Eleyele Wetland with reference to 1984 situation.

Physical and Chemical Characteristics of the Wetland Waters

The summary of results of field physico-chemical data and chemical analyses of the water samples from the Eleyele wetland lake and feeding streams within the catchment of Eleyele wetland are presented in Tables 2.

The results revealed water pH range of 6.7 – 10.1 for the main wetland lake indicating neutral to alkaline in nature compared the values of 6.5 – 8.8 for the feeding streams. Also the water temperature of 28.6 – 32.7°C (av. 31.0°C) for the main lake reflects a tropical lake setting influenced by solar heat exchange compared to the cooler temperature of the riparian feeding steam (25 – 30.9^{o}C). Also the distribution of the electrical conductivity (EC) varies between 250 – 344µS/cm (av. 316µS/cm) with corresponding TDS values of 213–334mg/l (av. 242mgl) within the main Lake indicating low variability. However, as graphically presented in Figure 6, the observed higher values and variability of EC (141 – 1,252µS/cm) and the corresponding TDS (106 – 9,39mg/l) in the feeder streams can be attributed to anthropogenic point sources discharges of untreated waste effluents within the catchment area. The trend is consistent with the results of Tijani et al., 2007 as well as that of Tijani and Onodera, 2009.

Table 2: Statistical summary of physical and chemical composition of water samples from the main lake and feeder streams of Eleyele Wetland.

	Main Lake (N=26)			**Feeding Stream (N=15)**		
Parameters	**Min.**	**Max.**	**Mean**	**Min.**	**Max.**	**Mean**
Elev (m)	173	201	183.5	174	192	184.8
EC (uS/cm)	250	344	316.9	141	1252	426.5
TDS (mg/l)	213.8	334	241.5	105.8	939	319.9
pH	6.7	10.1	8.3	6.5	8.8	7.3
Temp. ^{o}C	28.6	32.7	31	25.8	30.9	28.1
Ca (mg/l)	8.94	71.83	25.26	10.68	152.49	45.96
Mg (mg/l)	3.87	16.00	8.73	3.18	18.50	9.90
Na (mg/l)	11.05	31.83	28.13	10.36	98.97	39.72
K (mg/l)	3.21	15.10	13.01	4.32	34.75	13.49
Si (mg/l)	0.92	27.53	3.39	1.39	14.24	11.06
Al (mg/l)	0.01	0.56	0.09	0.03	0.30	0.13
Fe (mg/l)	0.01	1.13	0.45	0.38	3.77	1.34
Mn (mg/l)	0.03	0.45	0.15	0.10	1.93	0.63
Ba (mg/l)	0.02	0.36	0.10	0.08	0.30	0.14
Sr (mg/l)	0.13	0.45	0.18	0.06	0.36	0.19

In general, it can be deduced that the observed profiles of the in-situ physical parameters of the water from the main lake and the feeder streams of the Eleyele Wetlands clearly demonstrate the impacts of human activities (direct discharge of household effluent and at times waste dumps) especially on the feeding stream, in terms of wetland water quality and the overall ecosystem quality. Nonetheless, it should be pointed out that the relatively low but uniform profile within the lake does not necessarily imply lack of contamination from the catchment area; rather it is an indication of possible dilution/volume effect.

As summarized in Table 2, the water quality results for the main lake revealed average concentration of 25.3 and 8.7mg/l for Ca and Mg and 28.1 and 13.1mg/l for Na and K. With exception of is with average concentration of 3.4mg/l, other major elements (Al, Fe, Mn, Ba and Sr) have concentrations of less than 1mg/l. For the feeding streams, the concentration profile follow similar trend with Ca and Mg having average concentration of 46 and 9.9mg/l respectively compared to 39.7 and 13.5mg/l for Na and K respectively. Similarly, with the exception of dissolved silica and Fe, other elements have concentration less than 1mg/l.

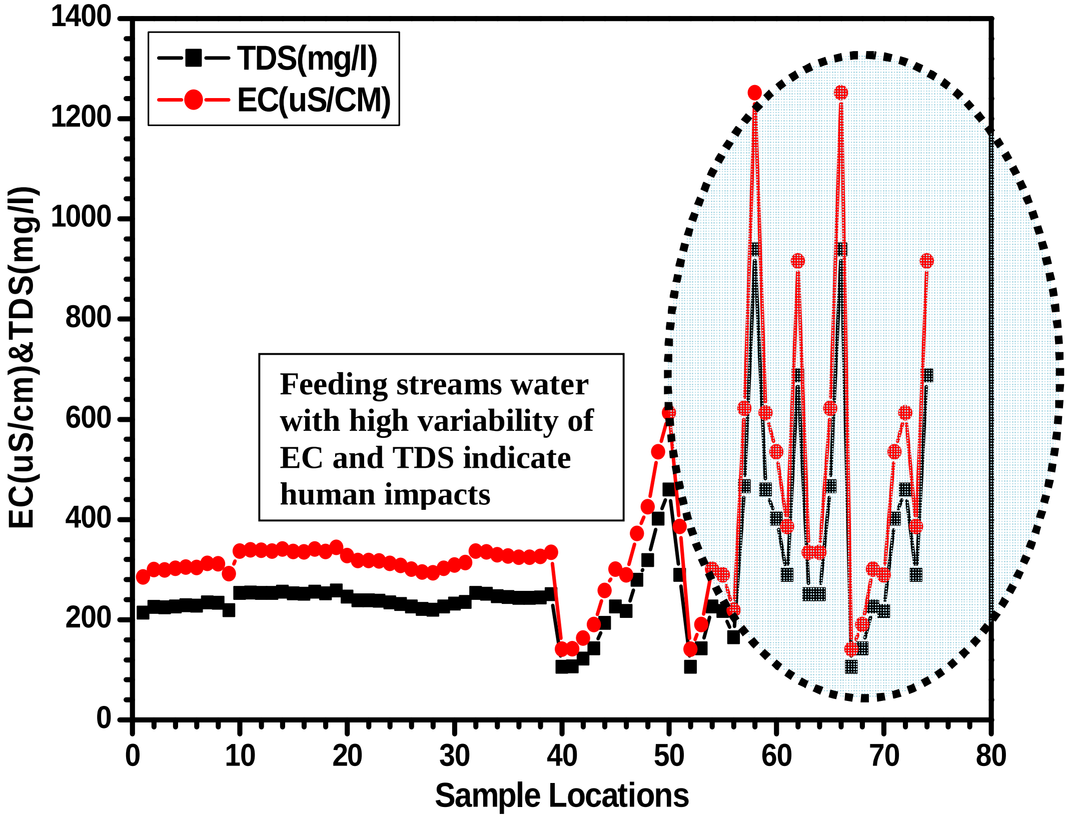

Figure 6: Plot of EC and TDS against the sampling locations highlighting the impacts of human land use activities on the feeding streams of the Wetland.

In general, the relatively concentration of the major cations (Ca, Mg, Na, K) in the Eleyele wetlands is a reflection of the relatively soluble nature of these elements as weathering products. However, a closer look at the data graphical plots of the major elements as presented in Figure 7a and b revealed more or less higher variability of the metal concentrations in the feeding stream compared to the mail lake waters. This can be attributed to possible anthropogenic discharges at the feeding streams on one hand and due to possible dilution effect at within main lake.

Nonetheless, the overall trends in the chemistry Ca>Na and K>Mg is generally a reflection of the chemical characteristics of the underlying bedrocks, the weathering of which release these elements as soluble components of weathered soil profile. Apparent dissolution of these, either by surface run-off or recharge infiltration into the shallow groundwater system, control or influence the observed chemical characters of the analyzed water samples from the Wetland Eleyele Wetland.

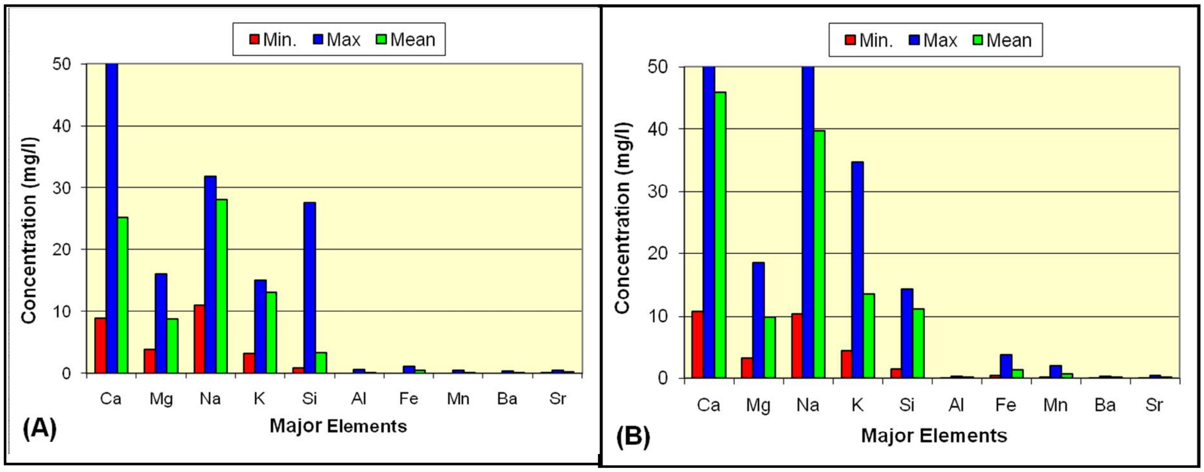

Figure 7: Profiles of major elements concentrations in water samples from (a) the main lake and (b) feeding stream.

Trace Elements in Waters of Eleyele Wetland

Due to the focal position of wetland in any landscape, usually at the receiving end of contaminant input from the catchment areas, an assessment of possible trace metal contamination of the urbanized Eleyele wetland was also undertaken. As summarized in Table 3, trace metal concentration of the main lake revealed a wide range with average of 1.97 – 3.9 ug/l for Cd, Pb and Cu, while Zn and B have higher values of 39.8ug/l and 22.5ug/l respectively. In addition, for the feeding streams, the trace metal concentration revealed similar trend with average value of 2.4 – 5.2 ug/l for Pb, Cu, Cd, and Co, while like in the lake waters, Zn and B have higher average value of 80.4ug/l and 24.8ug/l respectively. However, Ni exhibits similar concentration with average value of 7.9ug/l in the main lake and feeding streams.

Table 3: Comparison of the Trace metals concentrations with average (total) baseline / background concentrations of trace elements in Lakes and Rivers

Parameters	**Main Lake Water (N=26)**			**Feeding Stream Water (N=15)**			**Lakes/ Rivers***
	Max	**Mean**	**Median**	**Max**	**Mean**	**Median**	**Median**
Pb (μg/l)	9.90	2.63	2.30	19.70	5.18	3.60	0.022
Zn (μg/l)	173.0	39.80	23.55	513.20	80.40	37.60	0.116
Cu (μg/l)	7.90	3.92	3.45	15.80	5.08	3.70	0.058
Cd (μg/l)	5.16	1.97	1.69	4.91	2.37	1.43	0.005
Co (μg/l)	1.10	0.32	0.27	9.61	3.28	1.73	-
Ni (μg/l)	91.6	7.91	4.10	18.30	7.95	5.40	0.058
Cr (μg/l)	2.50	0.90	0.85	3.30	1.60	1.60	0.074
B (μg/l)	75.0	22.46	21.00	58.00	24.82	23.00	-

*Calculated average (total) concentrations of trace elements in Lakes and Rivers (Nriagu, 1990).

A closer evaluation of the data revealed higher trace metals concentrations in the feeding stream, like the major elements, as highlighted in Figures 8a and b. For example, the average concentrations of Pb, Zn, Cu and Cr in the feeding streams are 2-fold higher than those of the main lake. Co is about 6-fold enriched while B, Ni and Cd exhibit similar level of concentration in waters from both feeding streams and the main lake. The observed enrichment trend of most of the metals in the feeding stream is a clear confirmation of the urban anthropogenic waste (effluents) inputs into the feeding streams.

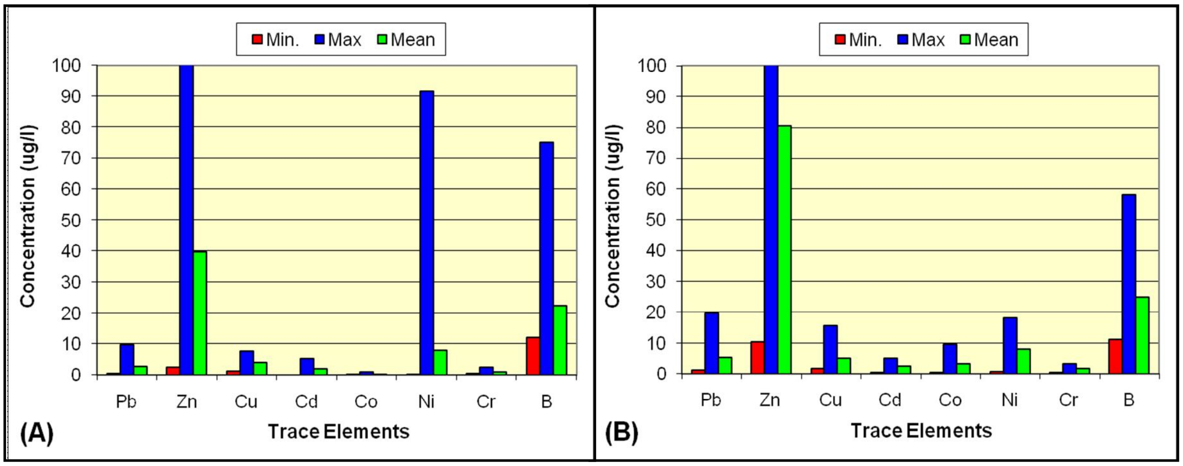

Figure 8: Profiles of trace elements concentrations in water samples from (a) the main lake and (b) feeding stream.

Nonetheless, comparison of the trace metal profiles in both the main lake and feedings stream with the average (total) baseline / background concentrations of trace elements in Lakes and Rivers (Adriano, 1986; Nriagu, 1990) as presented in Table 3, revealed considerable enrichments of most of the metal, suggesting urbanized anthropogenic inputs and degradation of the Eleyele Wetland as pictorially presented in Figure 9.

Figure 9: Photo images of urban effluent and waste dumps on a feeding Stream and Wetland buffer zone as a waste Dump site.

Nonetheless, the lower concentration in the water of the main lake can be attributed to dilution effect or most likely preferential partitioning into the bottom sediments within the lake. Hence, the need to assess the chemical characteristics of the bottom sediments, as presented in the section below.

Assessment of the Wetland Bottom Sediments and buffer zone soils

Usually, riparian soils and bottom sediments are of importance in respect of water quality function of wetlands. As surface water flows into wetlands, the eroded soils and water-borne sediments with adsorbed nutrients and pollutants have the opportunity to settle out the water column phase. However such preferential partitioning of contaminants in the solid phase is an indication of potential contamination threat, through possible biogeochemical-induced re-mobilization into the water phase in response to changes in physico-chemical conditions (Tijani and Onodera, 2009). As part of further assessment of the impact of the urbanized catchment on quality and degradation of the Eleyele Wetland, 26 bottom sediments samples from the main lake and 16 surrounding buffer zone soil samples within the catchment area were analyzed for possible metal contamination.

The overall results of the physico-chemical data for bottom sediments (Table 4) revealed similar trends with water soluble pH of 6.0-7.5 indicating slightly acidic to neutral conditions. However, the lower electrical conductivity (EC) values of 49 - 454µS/cm (av. 194µS/cm) for the wetland lake bottom sediment can be attributed to the sandy nature of most of the sediments which in turn is a reflection quartz-schist bedrock setting of the catchment area of the wetland. In addition, loss on ignition of 5.1 – 31.2% is a reflection of the total carbon content (1.1- 9.3%) of the analyzed bottom sediments. A higher correlation factor of 0.75 between LOI and total C compared to 0.26 with respect to total S suggest that organic matter decomposition and related biogeochemical processes within the lake are related to an oxidizing environment rather that a reducing environment. This may also be an indication of self purification and buffering capacity of the wetland.

As summarized in Table 4, the chemical character of the bottom sediments of the wetland lake is dominated in the decreasing concentration order by Si, Al, Fe and K with average concentration of 2.8, 6.7, 4.3 and 1.7mg/kg respectively. Other elements such as Ca, Mg, Na, Mn and P revealed average concentration of less than 1.0 mg/kg, an indication of their relative mobility/solubility in the course weathering processes. The observed chemical profile is a clear reflection of the catchment geology dominated by quartz-schist units on one hand. On the other hand it is a clear indication of the fact that the bottom sediments are products of catchment weathering and erosion.

However, the concentration profiles of the trace metals revealed enrichment of Zr, Ba, Sr, Nb, and Y with average concentration of 1,918; 658; 122; 19.7 and 108mg/kg respectively. Unlike the case of Ca, Na, Mg and others, the enrichments of these minor elements is due to the weathering resistance of their procusor minerals that have ability to survive erosion and transportation processes. However, some of the minor/trace elements especially Ba, Ni, exhibited values closer to the threshold concentrations defined by the Netherland Standards for uncontaminated soils (see Table 4). Nonetheless, the overall concentration profiles suggest low anthropogenic impacts from the urbanized catchment, with respect to metal accumulation in the bottom sediments of the Eleyele Wetland Lake.

In summary, it can be inferred that the geochemical or compositional characters of the bottoms sediments of the Eleyele Wetland lake are predominantly geogenically controlled; reflecting the geochemistry of the weathered catchment bedrock units. Though low trace metal enrichment in the sediments may be attributed to low clay contents and/or self biogeochemical purification process within the Lake ecosystem.

The quality of a soil is largely defined by the ability of soils' physical, biological and chemical properties to carry out specific or multiple functions, within natural or managed ecosystem boundaries, to sustain plant and animal productivity, maintain or enhance water and air quality, and support human health and habitation (Doran *et al.*, 1997). However, in wetland environments, soils functions are mainly ecological relating to biomass production, buffering / filtering and biochemical transformations and as biological habitat for soil organisms. Soil performs its functions by supporting plants structurally and supplying elements (both as micronutrients and macronutrients) essential for plant growth (Wild, 1988). Consequently, as part of further evaluation, soil quality assessment was employed for the rating of the wetland soil fertility in the study area based on the measured hydraulic and physical characteristic as presented in Table 5.

Table 4: Summary of the results of chemical analyses of major ions in the Lake bottom sediments (N=26)

Parameters (mg/kg)	Minimum	Maximum	Mean	Median	St. Dev.	*NL Standards
pH	6.9	7.4	7.2	7.0	0.1	
EC (uS/cm)	49.0	454.0	193.5	148.6	88.3	
LOI %	5.10	31.20	13.82	13.00	6.19	
Tot. C %	1.07	9.26	3.66	3.08	2.21	
Tot.S%	0.02	2.68	0.24	0.10	0.53	
Ca	0.11	1.10	0.52	0.46	0.29	5,000 – 30,000
Mg	0.07	0.32	0.19	0.19	0.06	1,000 – 15,000
Na	0.07	1.29	0.39	0.29	0.32	500 – 15,000
K	0.65	4.06	1.74	1.54	0.90	1,000 – 30,000
Si	18.65	38.13	28.88	30.30	4.81	
Al	3.02	12.59	6.70	5.96	2.47	
Fe	1.35	12.31	4.31	3.55	2.39	10,000 –
Mn	0.02	0.15	0.06	0.05	0.03	20 – 3,000
P	0.03	0.24	0.10	0.10	0.04	
Zr	501.0	4640.0	1917.8	1728.0	850.6	
Ba	311.0	1518.0	658.6	556.0	321.6	200 – 400
Sr	37.0	398.0	121.7	101.5	87.0	
Cr	5.0	20.0	10.4	9.5	4.0	100 – 250
Nb	10.0	31.0	19.7	20.0	6.0	
Ni	20.0	38.0	24.5	20.0	5.8	35 – 100
Y	30.0	254.0	107.8	101.0	54.4	
Ti	0.30	1.06	0.63	0.64	0.19	20 – 50
Sc	5.0	19.0	9.0	8.0	3.5	

*Netherlands Standard: Minimum values represent the natural baseline concentration, while the maximum values imply upper threshold limits (Source: HESS II, 2008).

Generally, the result of the physical properties rating of Eleyele wetland soils show varied class from prime to marginal quality status with bulk density of 1.5-1.8 g/cm3 indicates sandy-silt loam soil within medium to marginal class. High bulk density may imply compact soil with negative impact on root penetration or inadequate aeration (Arshad et al., 1996). In addition, this may also enhance runoff and erosion losses of soil and nutrients can be caused by excessive bulk density when surface water is restricted from moving through the soil (Evanylo and McGuinn, 2009).

Infiltration is important for storing water in the soil profile for plant growth and for reducing runoff and erosion (Lowery et al., 1996). In this study, hydraulic conductivity of 7.5 – 48cm/hr (see Table 5) implies well drained buffer zone soils with medium to marginal quality rating, especially in the western portion with quartz-schist bedrock setting. Also water-holding capacity of 29 – 41%

(av. 34.6 %) suggests mostly sandy loam soils that had been influenced by cover removal and tillage which is said to reduces the content of organic matter and reduces pore volume (Evanylo and McGuinn, 2009).

Table 5: Comparative assessment of physical characteristics of Eleyele wetland soils with respect to soil quality/fertility rating standards

Soil Quality Class	**Class 1 (Prime)**	**Class 2 (Good)**	**Class 3 (Medium)**	**Class 4 (Marginal)**	**Class 5 (Unsuitable)**	**Eleyele Wetland**
Bulk Density (g/cm^3)	<1.25	1.25-1.3	1.3-1.5	1.5-1.65	>1.65	1.5 – 1.8
Porosity Vol. %	>53	51-53	43-51	38-43	<38	35 – 43
WHC (%)						29 – 41
Ksat (cm/hr)	50-80	40-50	10-40	<10	<10	7.5 – 48
Org. C mg/kg		<1.7	1.7-2.6	>2.6		6.7 – 33.7
pH		<5.5	5.5-7.0	7.0-8.0		4.2 – 6.8
CEC cmol/kg		<10	10-20	>20		5.3 – 25.3
N mg/kg	>300	200 - 300	100 - 200	100 - 50	<50	70.0 – 350.0
P mg/kg	>250	180-250	100-180	50 - 100	<50	127 - 150
K mg/kg	>300	175-300	100-175	50-100	<50	150 – 1630
Mg mg/kg	>180	80-180	40-80	20-40	<20	7.4 – 324.0
Fertility Class	**Very High**	**High**	**Medium**	**Low**	**Very Low**	

Source: FAO 1992; Roming, et al., 1995; McGrath et al.*, 2001.*

As presented in the table, the organic carbon and CEC also revealed concentration that are consistent with medium to high fertility rating. However, the pH-(KCl) revealed a relatively acidic soil with values of 4.2 – 6.8 compared to the typical range of (6.5 – 7.5) in pristine agricultural soils. Such low pH values can cause plant nutrient deficiencies (especially Ca, and Mg) and possible metal enrichment with respect to Mn and Al with negative effects on crop yield. Nitrate and phosphorus have values of 700 – 350mg/kg and 15.5 – 127.0 mg/kg respectively which compare reasonably well with typical range of values for uncontaminated arable soils and at the same time suggest soil fertility rating of medium to high quality. Nonetheless, the overall rating implies that the riparian buffer zone soils of the Eleyele wetland still in position to sustain 50–80% crop yield without any amendment application.

In addition to the above assessment of the soil fertility rating, quality degradation in terms of metal contamination was also undertaken. This is consequent to the fact that soils are the ultimate sink for pollutant metals in the terrestrial environment. In other words, quality degradation in terms of contaminant enrichments wetland can be better appreciated using the soil media. Usually, detection of such anthropogenic metal contamination may be difficult where large background of trace metals exist; except in urban soils and near major point sources of pollution (Nriagu, 1990).

Wetland soil contamination / degradation in this study was assessed based on the Netherlands soil contamination standards of three levels of contamination/pollution whereby A-values imply low or background concentrations of contaminants, B-values represent slight to moderate but permissible concentrations of contaminants and C-values imply high concentrations of contaminants above the permissible level (Table 6).

As highlighted in Table 6, selected trace metal concentrations (i.e. Mn, Fe, Cu and Zn) in the wetland soils revealed very low to slight contamination with respect to Cu and Zn with respective maximum concentrations well below the respective A-values. However, higher concentrations of Mn and Fe may be attributed to the natural weathering-induced ferruginization typical of tropical soils in the study area.

Table 6: Comparison of Metal Concentration in Eleyele Wetland Soils with NL-Standards

	Netherlands Standards (mg/kg)			**Eleyele Wetland Soils (mg/kg)**		
Metals	**A**	**B**	**C**	**Min**	**Max**	**Mean**
Mn	50	100	500	7.4	324.01	153.94
Fe	50	100	200	104.03	484.21	219.28
Cu	36	100	500	3.48	9.83	6.33
Zn	200	500	3000	6.26	109.12	23.86

A-values = low or background concentrations of contaminants,
B-values = slight to moderate but permissible concentrations of contaminants
C-values = high concentrations of contaminants above the permissible level.

Summary and Conclusions

In general it can be deduced that the observed profiles of the in-situ physical parameters of the water from the main lake and the feeder streams of the Eleyele Wetlands clearly demonstrate the impacts of human activities (direct discharge of household effluent and at times waste dumps) especially on the feeding stream, in terms of wetland water quality and the overall ecosystem quality. The observed chemical characteristic of the major elements of the water in Eleyele wetland is more or less a reflection of the geogenic induced weathering pedological processes of the catchment area as defined by the bedrock geology. However, the geochemical or compositional characters of the bottoms sediments of the Eleyele Wetland reflect the geochemistry of the weathered catchment bedrock units suggesting geogenic control. Nonetheless, the low trace metal enrichment in the bottom sediments may be attributed to low clay contents and/or self biogeochemical purification process within the Wetland Lake ecosystem.

Like in many developing countries, urban environments have greatly changed in Ibadan with increasing population leading to increasing pressures on agricultural lands as well as wetland and green areas. As highlighted earlier in the intervening period from 1984 to 2004, the built-up area within the catchment of Eleyele Wetland has increased by almost 70%. This has resulted in a reduction or lost of forest and agricultural areas around the Eleyele Wetland to be more than 60%. While this increase in urbanization may not have resulted in total loss or degradation of wetland soils in the study area, there are clear influence of urban catchment activities on water and bottom sediments of the feeding stream and the main wetland lake. The overall implication of the study is that there is the need to control the increasing encroachment of farming and building activities around the wetland to avoid removal of the vegetation and degradation of the ecosystem within buffer zone. Hence, the study recommends the adoption of Integrated Water Resources and Environmental Management (IWRM) in order to ensure proper ecosystem functioning of such urbanized wetland and thus safeguarding the overall quality of the wetland ecosystem.

Nonetheless, the quantification of the extent of the observed urban development activities on the water resources and bottom sediments quality warrant clear definition of associated quality indicators. This aspect of information gap can be regarded as one of the issues requiring further evaluation as part of future research study. Hence, there is the need for definition of soil and water quality indicators which can measure changes in these critical environmental media in Wetland ecosystems. Such indicators is expected to provide information for policy makers, planners, regulators on one hand and the soil-users (farmers), water users (water works, fishermen) and other stakeholder (land-use developers) on the other hand with overall intent of sustainable water resources management. However, such soil and water quality assessment indicators should not only highlight the “good” or “bad” quality, rather should depend on the applicability or useage to match a particular land use (Sparling and Schipper, 1998) and the status of the soil relative to a particular standard (Larson and Pierce, 1994). However, it should be pointed out that the selection of a set of soil and water quality indicators should be based on physical, biological and chemical attributes relevant to the ecosystem functioning of the wetlands.

The overall results highlight the negative impacts of the human-induced influence on the Wetland ecosystem through land-use and waste effluent discharges with attendant degradation / loss on one hand. On the other hand it also highlights the fact that wetland serves as purifier, buffer and sink for the dissolved contaminants from the feeding urban drainage water system. The overall implication of the study is that there is the need to control the increasing encroachment of farming and building activities around the wetland to avoid removal of the vegetation and degradation of the ecosystem within buffer zone. Hence, the study recommends the adoption of Integrated Water Resources and Environmental Management in order to ensure proper ecosystem functioning of such urbanized wetland and thus safeguarding the overall quality of the wetland ecosystem. Furthermore, there is the need to develop a list of soil and water quality indicators that should be considered in developing future quality assessment for urban wetland like Eleyele. Nonetheless, the selection of a such soil and water quality indicators should be based on physical, biological and chemical attributes relevant to the ecosystem functioning of the wetlands.

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