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Effect of Land Use Activities on Water Quality and Vegetation Cover Change in Nsooba - Lubigi Wetland System, Kampala City

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Agriculture;

Built environment;

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Pollution;

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Research article

ABSTRACT

An assessment of the effect of land use activities on water quality and vegetation cover change in Nsooba - Lubigi Wetland System in Kampala city was conducted between July and October 2020. In order to achieve the set objectives, twelve locations were selected from the Nsooba - Lubigi Catchment. The physico-chemical characteristics of water along the catchment area were determined by standard analytical methods. The average values for Total Dissolved Solids across all the land-use types of wetland, built up areas and agriculture were lower than the National Standard (750 mg/l). A similar pattern of the land-use was observed for the parameters Total phosphorous, Biological oxygen demand, Chemical oxygen demand, Total suspended solids and Total organic carbon, where the observed average values were all below the National Standards of 10 mg/l, 50mg/l, 70mg/l, 50mg/l and 50mg/l, respectively. The Total Nitrogen average value for built-up areas (11.27 mg/l) was higher than the national standard of 10 mg/l while the remaining land use types of wetland (8.05mg/l) and agriculture (5.96mg/l) were below that of the recommended standard. GIS and Remote sensing techniques were used to analyze high-resolution satellite imagery captured during 1998, 2008 and 2018. Wetland coverage declined by approximately 5 hectares (47.2% to 14.58%) from 1998 to 2018. Although most of the measured parameters were below the National standard specified by the Uganda National Environmental Management Authority apart from Total Nitrogen for built-up areas, there is need for close monitoring of the water quality in Nsooba - Lubigi catchment to ensure public health safety. The increased built-up environment in the Nsooba - Lubigi wetland affects ecosystems services of the wetland. The buffer zones for flood control and sewage treatment have been turned into built-up environment. The results from this study suggest a need to protect the Nsooba - Lubigi catchment for its important ecosystems services of flood control and sewage treatment.

INTRODUCTION

The world's growth metrics have been impacted by unchecked expansion in a variety of human undertakings, including industrial, transportation, agricultural, and urbanization (Gavrilescu *et al*. 2015 and Mishra *et al*., 2023). Globally, water quality deprivation is one of the main persistent, and greatly observable signs of anthropogenic impacts. Surface water bodies

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such as reservoirs, river streams and lakes are enormously vulnerable to primary discharges of solid and liquid waste. Extremely dilute water bodies, specifically in headwater regions are vulnerable to impacts caused by atmospheric deposition (acid rain) (Sasakova *et al*., 2018).

In developing countries, the changes in land use are directly and indirectly related to pollution challenges that include sewage, insecticides and pesticides, greatly contaminated water quality, principally near intensive agricultural areas and urban industrial centers (Wang et al., 2015). This alters the ecological landscape, severe strain from anthropogenic encroachment as well as consistent land filling activities for reclamation, water drainage for agriculture and livestock farming, human settlements, clay and sand extraction, brick making, harvesting of papyrus, municipal and industrial waste discharges, unsuitable and illegal solid waste disposal (Peters *et al*., 205, Kayima *et al*., 2018). In the natural ecosystem, heavy metal concentrations differ, human activities alter the distributions and natural cycles of metals creating an unbalanced ratio in the metal cycle leading to accumulation (Edokpayi *et al*., 2018).

Many studies of watershed microbiology focus largely on the detection of indicator microbes such as *E. coli*, *enterococci*, *salmonella* and coliform bacteria and how these might indicate potential risks to human health and environment. Hawumba (2017) indicated that; in Uganda, the leading causes of water quality impairment is high nutrient (phosphorus and nitrogen) discharge to the ground and surface water bodies. The same author further added that, whereas nitrogen is of principal significance in affecting and preventing eutrophication in marine environments, phosphorous is the restraining nutrient in freshwater (or non-saline) ecosystems. According to Ding *et al.,* (2015), studying the correlation among water quality and land use supports to ascertain primary stresses to water quality which are predetermined for efficient water resource and quality control since they can be used to target key land use regions and to incorporate pertinent methods to curtail contamination discharges.

Similar studies on land use have indicated its substantial impacts on water quality (Twesigye *et al.*,2011). Deforestation, urbanization and agriculture mostly alter land topography and characteristics, surface runoff volume, upsurge algal production, generate contamination and reduce concentrations of dissolved oxygen in water resources. According to Wang *et al*. (2015), vegetation cover is an indicator that assesses terrestrial environmental surroundings. Minor alterations of vegetation structures of the landscape inhibit ecological processes. The increasing rates of land-use change over natural habitats like wetlands, lakes, rivers have resulted into the conversion of the natural environment for agriculture, sand mining, fishing and urbanization. Any deterioration of the natural vegetation raises the quantity levels of particulate matter in water, and consequently can directly and indirectly affect water quality (Fierro *et al*., 2017).

According to Sebhatleab (2014), land use change has triggered the decline in both soil physicochemical and biological properties depending on the classification levels across the landscape and soil profile. Constant exposure of top soil can attribute to long-term intensified vegetation deprivation and start a process of land pollution (Marinho *et al*., 2016). The correlation between land use activities and its impact on soils involves studying the drivers of the variations in soil structure and help in illustrating good management processes to prevent desertification and attain conservation goals.

Limited studies have been conducted to study the overall interactions between land use and water quality. The consequences of anthropogenic activities on water quality, soils, and vegetation cover are severe and call for sustainable management. This study examines the relationship between land use and water quality to determine the microbial and physic - chemical attributes of the water, soils integrity, as well as the vegetation cover along Nsooba - Lubigi drainage system. This study,therefore, explores the effect of land use activities on water quality, soil and vegetation cover on Nsooba - Lubigi drainage system.

MATERIALS AND METHODS

Study Area

The study area lies within Nsooba - Lubigi drainage system, stretching from Bukoto hills, the origin of Nsooba - Lubigi to Lubigi wetland in Namungona. It is located between 0° 21'N latitude and 32° 35'E longitude, in Kawempe Division, Kampala City.

The discharge from the surrounding environment to Nsooba - Lubigi drainage system is about 220,000 m^3/day and originates from the daily human activities, industrial and municipal effluent, automotive and mechanical discharge, rainwater run-off, surface and sub-surface water flow from the upstream, as well as the populous slums of Kawaala, Kyebando, Kalerwe, Bwaise, Kanyanya, Nansana and Namungoona (Karabo, 2017). Due to insufficient environmental policies like development of the buffer zone to protect drainage system, Nsooba - Lubigi drainage system has and will continuously receive the initial and direct trickle-down effect of the visually and severely contaminated wastewater from the up-stream storm water draining to the channel as well as the Lubigi Sewage Treatment Plant.

Additionally, Nsooba - Lubigi drainage system has continuously been under serious pressure emanating from human actions and encroachment including unplanned land filling for reclamation, water drainage for agriculture, human settlements and livestock farming, use of agricultural pesticides in management of crops, sand and clay mining, brick making, the harvesting of papyrus for handcrafts, inappropriate solid waste disposal, municipal and industrial effluent disposal and other forms of discharges have led to pollution and contamination of the drainage system thus being a haphazard to the environment and surrounding community.

The area was selected as an ideal site because of the urbanization levels (construction of northern by-road), crowded settlements and the apparent poor sanitation and management of waste water. Further, Nsooba slaughter house also discharges solid and waste water into Lubigi wetland, creating severely contaminated wastewater from the upstream Nsooba - Lubigi water drainage stream and the Lubigi Sewage Treatment Plant.

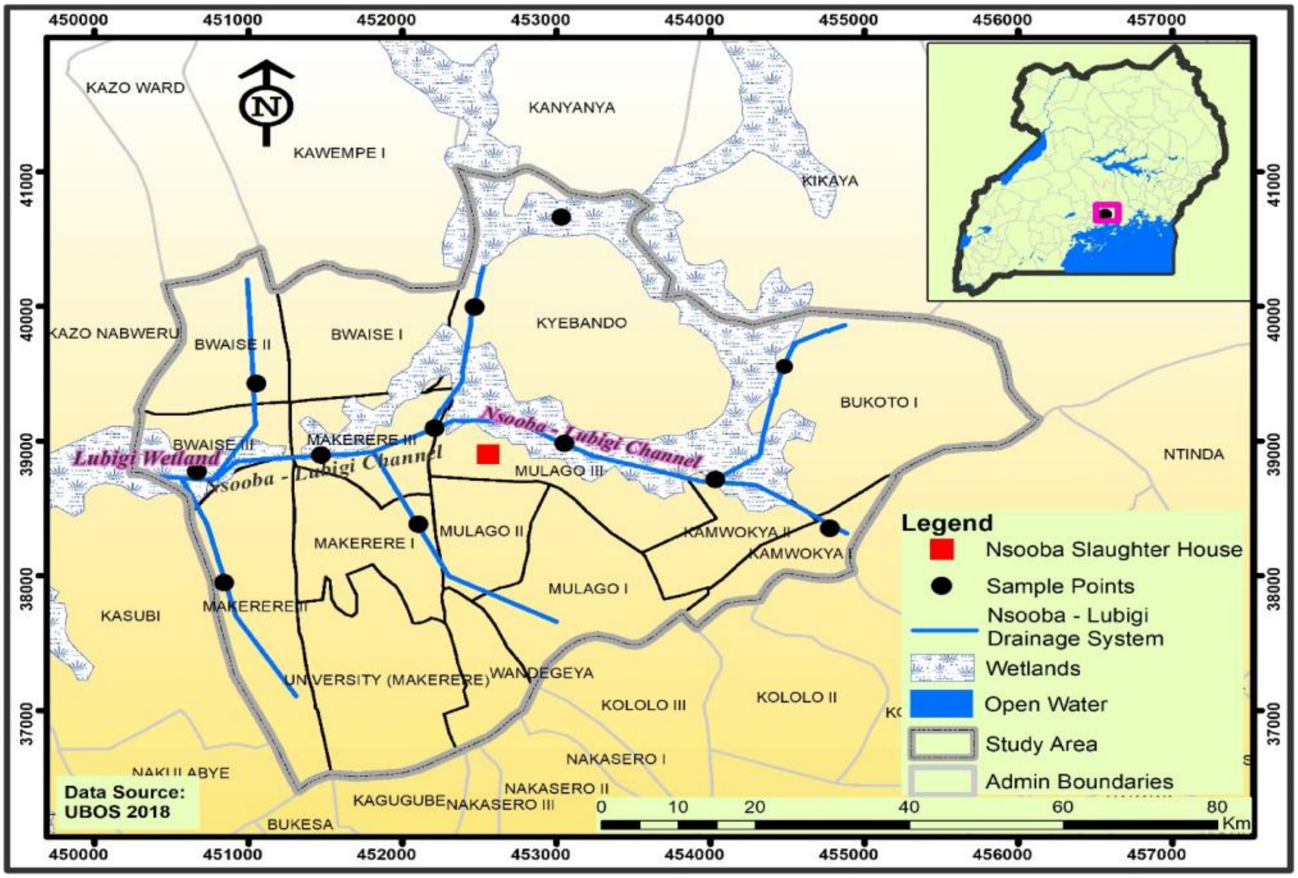

Figure 1: Study sites in Nsooba - Lubigi drainage system, Kampala City

Data Collection Tools and Methods

Land Use Land Cover Change Activities

Landsat-5 TM, Landsat-8, and Sentinel 2 images with a spatial resolution of 30m and 10m for 3 years (2018, 2008, and 1998) were downloaded from an open-source at no cost. These were used for the spatial analysis of land use activities and vegetation cover change in Nsooba - Lubigi.

Table 1: Data specifications

Satellite Data	MM/DD/YY	PATH and Row	Band	Resolution	Source
Landsat 5 (TM)	08/07th/1998	172,059	3,4,5	30m x 30m	USGS
Landsat 7 (ETM+)	09/14th/2008	172,059	3,4,5	30m x 30m	USGS
Landsat 8 (OLI/TIR)	10/07th/2018	172,059	3,4,5	30m x 30m	USGS

A hand held GPS receiver was used for ground verification in evaluating the five land use/ cover classes as indicated in Table 2.

Table 2: Land Use Land Cover (LULC) classification by Anderson method

Land use/cover classes	Description
Agriculture	Subsistence Farming: Mixed farming characterized by crops grown for survival
Small scale farming	Small Scale Farming: Mixed farming, single and multi farming, dry and irrigated farming
Bare Land	Land that is productive and unproductive with no developments activities going on
Wetlands	seasonal and permanent wetlands, swamps, bog
Built-up Areas	Settlements like residentials, commercials, non-residentials, roads

As supervised classification was performed at the study area, each class was calculated while considering the pixel counts and total site (Table 2). Thus, categorizations were made based on area coverage and presented in both hectares and percentage. The five classes included Forestry, Grassland, Wetlands, Settlement, and Small scale farming. Percentages of classes based on these results portrayed land use/land cover events seen in the study area during 1998, 2008, and 2018 respectively.

Sampling Strategy

Water and soil samples were collected from the field for further analysis. A minimum of 48 water samples and 36 soil samples were gathered from 11 sites along Nsooba - Lubigi drainage system. The sites were selected due to the high anthropogenic activities (urbanization, slaughterhouse, industries and road construction) carried out within the wetland area. A minimum of 4 sampling at each sampling site were collected in Duran. Parameters for analysis included pH, EC, TSS, TN, TP, total coliform and *E. coli*, BOD and COD. These constitute the major parameters in measuring the degree of contamination of a water body (Chapman, 1992; Longe and Omole 2008). All the samples were preserved at 4^{o}C using a sampling cooler box and transported to the laboratory for analysis. Sampling was done between 08.00 am and 05.00 pm, the time of peak activities at the Nsooba - Lubigi drainage system in July 2020 and October 2020. During sample collection, sampling containers were rinsed twice with sampled water and, labeled and then taken to the Ministry of Water and Environment laboratory in Entebbe, stored in the refrigerator while maintaining a temperature of 4°C prior to analysis.

Water Pollutants

Water samples were collected between July 2020 and October 2020 in two sets to ensure that the results obtained are more representative. Each set consisted of 24 samples totaling to 48 samples.

Analytical Procedures and Measurement

In order to assess the effect of land use activities on quality of water and vegetation cover of Nsooba- Lubigi drainage system, physico-chemical properties and nutrients loads from upstream and downstream of the Kalerwe abattoir discharge area were evaluated. The physico-chemical characteristics were determined by the American Public Health

Association (APHA) standard analytical methods of water analysis. HACH standard method was used to determine nutrients concentrations by using a DR 1900 spectrophotometer and a DRB 200 digester as defined in the HACH procedure manual for chemical and physical water quality. Total suspended solids were analyzed using a gravimetric method. The Galen Kamp oven was used for drying at 105°C and a Mettlor Toledo weighing scale was used for weighing.

Chemical Oxygen Demand was determined by a standard HACH procedure using a DR 6000 spectrophotometer and DRB 200 digester as described in the HACH procedure manual. A volume of 2mls of the sample were put in the COD vial and digested at 150 °C for 2hrs. The vials were allowed to cool and COD was read. BOD was analyzed using a BOD_5 day test kit. This was used for digestion and monitoring oxygen changes.

Determination of pH & Electrical Conductivity

pH was photometrically analyzed using a thermo scientific Orion star 3 machine whereas Electrical conductivity was analyzed using an Orion star A 222 conductivity meter.

Determination of Vegetation Cover Change

This was determined using Landsat8 and sentinel 2. Landsat enabled the acquisition of old satellite images of 2008 and 1998, whereas sentinel facilitated the acquisition of satellite image of 2018.

Data Analysis

To compare the parameters across land use types, the data were subjected to a non-parametric test known as Kruskal-Wallis *H*-test, because it is more robust and requires smaller samples sizes. The test compares medians among k independent groups ($k > 2$) and is formulated based on ranks rather than actual observations (Daniel, 1990). The test is generally robust to departure from normality and homoscedasticity and is less sensitive to outliers. Kruskal-Wallis *H*-test only indicates that more than two groups are significantly different. It cannot show which specific groups of the independent parameters are statistically different from each other. Dunn test was used to determine which land use types were statistically significantly different from each other. Fisher's exact test was used were the data was categorical in nature and therefore difficult to compute the median.

Image Acquisition

Re-classification process and change detection analysis of various land-use land-cover classes were performed by three Landsat satellite images of 5 TM, Landsat 7 ETM+ and Landsat 8 OLI/TIR all acquired from path 172 and row 059 as indicated in Table1. The satellite imagery data was downloaded from the United States Geological Survey website (USGS) (ftp://ftp.glcf.umd.edu/glcf/Landsat/WRS2 and https://earthexplorer.usgs.gov/). After downloading, the images were all geo-referenced to the WGS 84 datum with the UTM Zone 36N of the coordinate system. All satellite data were analyzed by assigning per-pixel signatures and segregating the land uses to 5 classes based on different landscape elements.

The delineated classes were: Agriculture, Bare land, Wetland and Built up Areas (Table 2). For each of these, a designated land use/ cover category was assigned training samples by defining polygons within each sites, and signatures files created for the particular land use/ cover categories downloaded from the satellite imagery taken by using pixels enclosed by polygons. The unsupervised classification was performed using the ISO Clustering Classification method which was followed by ground-trothing to guide in the performance of the Maximum Supervised Classification for accuracy assessment. All classification processes were executed using ArcGIS 10.2 as explained in the subsequent paragraphs.

RESULTS

Impact of human activity on the water quality

The results for the effect of land use activities on physico-chemical composition of water quality are presented in Table 3 and shows a significant correlation between land use activities and physico-chemical composition of water. According to Table 3, the Kruskal-Wallis test showed p values of less than 0.05 for EC (0.007), TDS (0.022), pH (0.022), TN (0.007), BOD (0.000), TSS (0.003) and TOC (0.010), indicating that they are significantly affected by LUAs. On the contrary, no significant correlation was found between land use activities and TP and COD. The p value was greater than 0.05 with TP recording a p value of 0.317 and COD with 0.203.The results from descriptive statistics indicate that the data from eight out of the nine physicochemical parameters were positively skewed (skewness> 2.0) signifying the presence of large outliers. These values for the parameters EC, TDS, TP, TN, BOD, COD, TSS and TOC are 2.563, 2.700, 2.731, 2.996, 4.400, 6.808, 2.412 and 2.867 respectively. This implied that the median was preferred to the mean as the measure of central tendency of the data and for comparison to the National Standards. The pH value of 0.966 was negatively skewed, signifying accurate correlation.

According to Table 3, the EC values for wetland (537.5 µs/cm), built-up areas (472.5 µs/cm) and agriculture (272.50 µs/cm) remained below the recommended threshold of 1000 µs/cm. The average values for TDS across all the land-use types of wetland, built up areas and agriculture (309.00 mg/l, 352.00 mg/l and 155.00 mg/l respectively) were lower than the National Standard (750 mg/l). A similar pattern of land-use types of wetland, built up areas and agriculture was observed for the parameters TP (0.84mg/l, 0.82 mg/l and 0.53 mg/l respectively), BOD (5.75 mg/l, 14.00 mg/l and 8.75 mg/l respectively), COD (41.00 mg/l,49.50mg/l and 42.00 mg/l respectively), TSS (25.00 mg/l, 42.00 mg/l and 10.00 mg/l respectively) and TOC (16.70 mg/l, 20.50 mg/l and 5.65 mg/l respectively), where the observed average values were all below the National Standards of 10mg/l, 50mg/l, 70mg/l, 50mg/l and 50mg/l respectively. For TN, the average value for built-up areas (11.27 mg/l) was higher than the national standard of 10 mg/l while the remaining land use types of wetland (8.05mg/l) and agriculture (5.96mg/l) were below that of the recommended standard.

Table 3: Descriptive summary statistics and test for equality of medians for physic- chemical parameters of water quality by land use

Parameter	Land use Land cover	No. of obs. (n)	Median (homogenous groups**)	Kruskal-Wallis test*	Overall skewness	National standard for waste water discharge, NEMA
Electrical conductivity (μs/cm)	Wetland	8	537.50[a]	H = 9.838	2.563	1000 (μs/cm)
	Built Up Areas	36	472.50[a]	p = 0.007		
	Agriculture	4	272.50[b]			
Total dissolved solids (mg/l)	Wetland	8	309.00[a]	H = 7.612	2.700	750 (mg/l)
	Built Up Areas	36	352.00[a]	p = 0.022		
	Agriculture	4	155.00[b]			
pH	Wetland	8	7.30[a]	H = 7.245	0.966	5.0-8.5
	Built Up Areas	36	7.20[b]	p = 0.027		
	Agriculture	4	7.45[a]			
Total Phosphorus (TP) (mg/l)	Wetland	8	0.84[a]	H = 2.298	2.731	5 (mg/l)
	Built Up Areas	36	0.82[a]	p = 0.317		
	Agriculture	4	0.53[a]			
Total Nitrogen (TN) (mg/l)	Wetland	8	8.05[b]	H = 9.895	2.996	10(mg/l)
	Built Up Areas	36	11.27[a]	p = 0.007		
	Agriculture	4	5.96[b]			
BOD (mg/l)	Wetland	8	5.75[b]	H = 16.666	4.400	50 (mg/l)
	Built Up Areas	36	14.00[a]	p = 0.000		
	Agriculture	4	8.75[b]			
COD (mg/l)	Wetland	8	41.00[a]	H = 3.185	6.808	70 (mg/l)
	Built Up Areas	36	49.50[a]	p = 0.203		
	Agriculture	4	42.00[a]			
TSS (mg/l)	Wetland	8	25.00[a]	H = 11.896	2.412	50 (mg/l)
	Built Up Areas	36	42.00[a]	p = 0.003		
	Agriculture	4	10.00[b]			
TOC (mg/l)	Wetland	8	16.70[a]	H = 9.126	2.867	50 (mg/l)
	Built Up Areas	36	20.50[a]	p = 0.010		
	Agriculture	4	5.65[b]			

[*] National Environment (Standards for Discharge of Effluent into Water or Land) Regulations, 2020.

The effect of land use activities on the vegetation cover in Nsooba - Lubigi drainage system

The results for the effect of land use activities on the vegetation cover for the years 1998, 2008 and 2018 are shown in Table 6..

Table 4: Land Use Land Cover Change from 1998 to 2018

Year	**1998**		**2008**		**2018**		**Percentage Change (%)**
Land Use Land Cover	Area (Ha)	%	Area (Ha)	%	Area (Ha)	%	
Wetlands	6.93	47.21	4.05	27.59	2.14	14.58	-32.63
Agriculture	2.06	14.03	4.55	31	4.47	30.45	16.42
Bare land	2.13	14.51	1.05	7.15	1.04	7.08	-7.43
Built Up Areas	3.56	24.25	5.03	34.26	7.03	47.89	23.64
Total	14.68	100	14.68	100	14.68	100	0

The vegetation cover change from 1998 to 2018 was investigated for the four land use classes namely; wetlands, agricultural activities, bare land and built-up areas. According to results from table 6 wetlands gradually declined from 47.21% in 1998 to 27.59% in 2008 and 14.58% in 2018. Similarly, results for bare land showed 24.5% in 1998, and drastically dropped to 7.15% in 2008 and with no significant change (7.08) in 2018. Seemingly, there was gradual increase in agriculture and built-up areas by 14.03% in 1998 to 31% in 2018 and slowed growth of 30.45% in 2018; and 24.25% in 1998 to 34.26% in 2008 and 47.89% in 2018. The increase in built-up could have resulted into reduced agricultural activities. The Land use/land cover changes and vegetation cover for the years 1998, 2008 and 2018 are shown in Figure 2. LULC types such as Agriculture and Built-up Areas have shown a notable increase for the last two decades (from 1998-2018).

Land use land cover, a, b, c in1998, 2008,2018

Table 4 shows that, the total land area of the study area was 14.68ha with a variation in land use land cover change of the study area. The dominant land use type was wetlands with an area of 6.93ha (47.21%), followed by built up areas at 3.56ha (24.25%). Both agriculture and bare land showed minimal changes having 2.14ha (15.51%) 2,23ha (14.03%) of the land use land cover respectively.

The analysis indicated that the surrounding environment within Nsooba - Lubigi drainage system in 2008 shows an increase in built up areas 5.03ha (34.26%) and agriculture 4.55ha (31%), these are the major anthropogenic activities that result to contamination of water quality and degradation of the Nsooba - Lubigi wetland. There was a deliberately declined to 4.05ha (27.3%) as well as a significant decline in bare land to 1.05ha (7.15%) resulting from urbanization of the city centre.

It was observed that in 2018 the built up areas consistently increased to 7.03ha (47.89%), followed by 4.5ha (30%) of the total land use and the natural vegetation cover especially wetlands to 2.14ha (14.6%) and bare land at 1.03ha (7.08%) respectively.

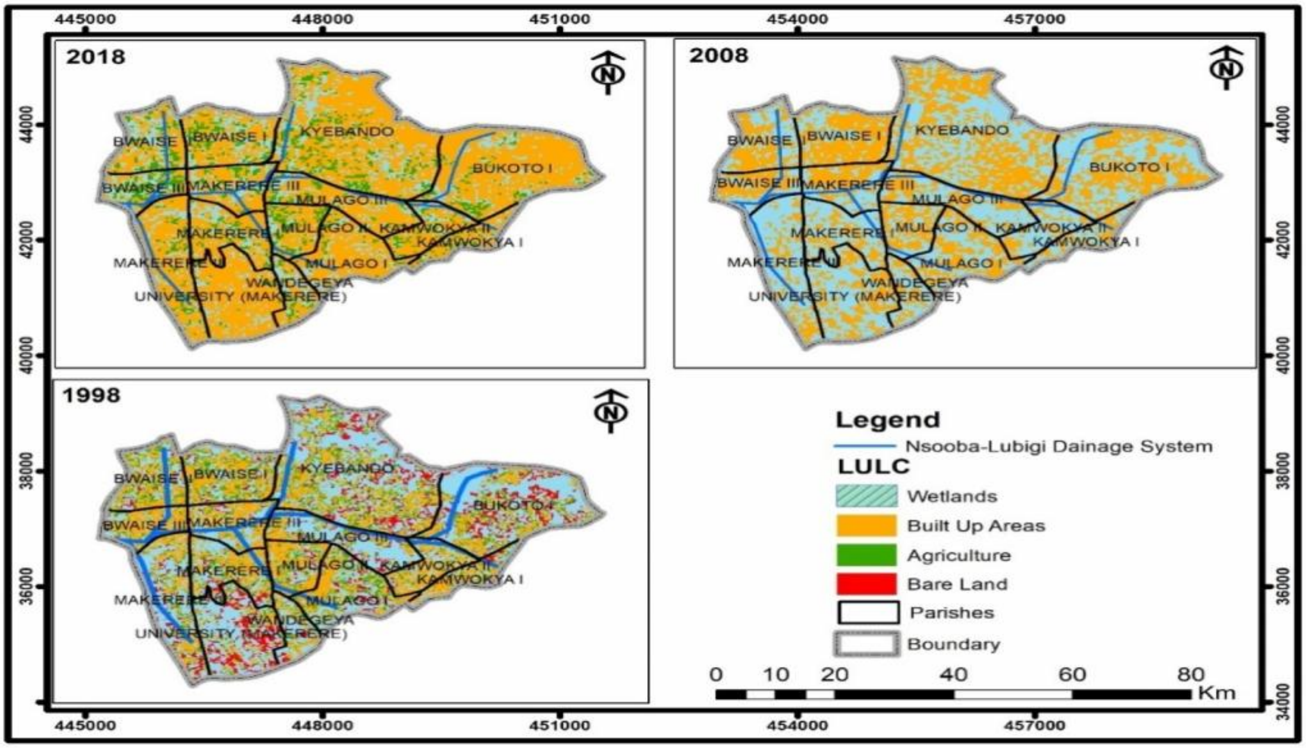

Figure 2. Land use/land cover changes and vegetation cover

Land use land cover change

The high levels of built up areas at 23.64% and agriculture to 16.43% of the total percentage land use change between 2018 and 1998 meant intensive pressure is on the natural resources especially the wetlands thereby altering the water quality levels to -32.63% between 2018 and 1998, leading to expansion of urban agriculture along and on marginal lands as well as encroachment into protected Nsooba - Lubigi wetland.

DISCUSSION

While determining the impact of land use activities on water quality and vegetation cover along the Nsooba - Lubigi drainage system, it was noticed that there are various activities and variations in past land use as compared to the current land uses and activities. The previous style of land use prevailed on both sides of the Nsooba - Lubigi drainage system in the form of road structures, communication networks, settlements (planned and unplanned), and farmlands. Evidence shows that the land and vegetation cover has deliberately changed compared to the past years. The Nsooba - Lubigi drainage system has been seriously affected by mainly human activities evidenced by the on-going developments of the multi-trillion road construction of the Kampala-Entebbe express way for easy accessibility to the Entebbe international airport which has greatly affected the natural vegetation cover thereby endangering the species diversity within the study area.

The physico-chemical Parameters that were analyzed in water include, Electrical conductivity, Total dissolved solids, pH, Total nitrogen, Total phosphorous, BOD, COD Total suspended solids and Total organic carbon. These were selected because they bring about severe pollution and eutrophication if not controlled or regulated which subsequently impacts on the receiving ecosystem. Electrical conductivity and Total dissolved solids contribute to an ion influx which consequently increase the saltiness of the water. This makes it hard for the water born species to survive. pH, on the other hand increases the alkalinity or acidity of the water hence affecting the aquatic life since they have specific pH in which they survive. Total nitrogen and total phosphorous are nutrients that bring about excessive growth of the algae and the other green plants in the water. This overtime inhibits direct light penetration into the water and also inhibits atmospheric re-oxygenation of the water which consequently leads to suffocation of the fish and other water borne species.

Further, land use activities in the study area range from agriculture which includes animal husbandry, horticulture, floriculture in the Lubigi wetland, road construction, settlement both planned and unplanned. Construction of northern bypass has attracted more development and population increase, this later led to creation of slums in the wetlands for example Bwaise and Kalerwe. National water and sewerage cooperation has also constructed a sewage treatment plant which encroached on the vegetation cover of Lubigi wetland. All these land use activities have led to degradation of the wetland and loss of vegetation cover.

The effect of land use activities on the physico-chemical properties of water

Figure 2 presents the Median (homogenous groups**) of EC, TDS, pH, TP, TN, BOD, COD, TSS and TOC parameter values for the land use activities. Figure 2 revealed that EC and TDS were significantly impacted by land use activities while COD, TTS and TOC were moderately impacted. On the contrary, pH, TP, TN and BOD were minimally impacted by land use activities. Further, wetlands and built-up areas presented the highest significant impact on water quality, specifically EC and TDS, while agriculture presented the lowest impact on water quality and this could have been attributed to the low farming activities carried out in the sampling areas. Despite, the substantial effect of LUAs on the water quality, all the EC, TDS, pH, TP, TN, BOD, COD, TSS and TOC parameter values for wetland, built-up areas and agriculture activities were below the National Standard for wastewater discharge set by National Environmental Management Authority, 2020. This indicates that the results from wetlands, built-up areas and agricultural areas have minimal impact on the water quality.

The agriculture activity recorded the lowest EC compared to built-up areas, which further increased significantly in the wetlands. Similar trends were obtained by Wachu (2018) who presented that EC is highest in urban sites compared to cultivated areas and forested areas. The studies concluded that high EC concentrations in wetlands is due to the increased input of ions from industrial effluents including car garages in Masanafu and slaughterhouse in Kalerwe and domestic wastewater. This conquers with the findings attributed by Ochuka *et al.* (2019); who stated that anthropogenic activities such as application of agro-chemicals and waste disposal are associated to higher EC in built-up areas.

In regard to TDS, the concentrations from wetlands, built-up areas and agriculture were attributed to different minerals dissolved in water which include potassium, sodium, magnesium, bicarbonates, these can be connected to numerous other compounds which can be water contaminants as well. However, the results of this study differs from recent studies conducted earlier within the drainage system by Hawumba (2017) and Ochuka *et al*. (2019) who stated that increased concentration of TDS results in noxiousness through heightened salinity and change in the ionic composition, influencing water taste, odour, colour and hardness. Water with TDS less than 600 mg/L is considered pleasant; nevertheless, extremely low TDS reduces the flavor of drinking water.

The average values of pH obtained under the three land uses fell within the acceptable range of the national standard (5.0-8.5), signifying that land-use did not impact the water pH. Total phosphorus (TP) had negligible impact on the water quality, since the activities indicated very low quality characteristics in comparison to the national standard. This could have been attributed to the low BOD levels that are recognized to favor phosphorus discharge to the freshwater ecosystem (Shafie *et al*., 2017). It was observed that Total nitrogen (TN) is moderately higher in all the 3 activities (though below the national standard). Large increases in organic matter from wetland areas and built-up areas (domestic - household wastewater, sewage, detergent waste, etc.) areas might have led to an increase in the factors affecting moderate concentrations. This is also supported by moderate concentrations in TOC from both the wetland and built-up area activities. This similar trend was also observed in the study conducted by Özdemir *et al*. (2022)who indicated that wastes from agricultural and tourism activities in the field of study could affect nitrogen and its derivatives.

Built-up areas presented the highest TSS and this could be attributed to poor waste management practices through littering and discharge of unhealthy effluent from both domestic and industrial activities. This is in agreement with the studies conducted by Grimm *et al*. (2005) and Shafie *et al.* (2017) who highlighted that bare soil at building sites has frequently resulted in large sediment inputs to the drainage streams through rainfall runoff events. The studies further indicated that the extent of fine particulate was generally higher in drainage streams around residential areas.

Other physico-chemical parameters including BOD, COD TSS and TOC were moderately high though below the National Standard, as observed within the sampling areas. This clearly shows that the high values could be attributed to the undigested materials and animal solid waste released from the Nsooba slaughterhouse. It therefore implies that there is need for huge amount of oxygen to synthesize all of these organic materials into CO_2 and water, which in turn, cause high concentrations of COD and BOD within the study area which could clarify on the linear correlation between solids, COD and BOD. This is in line with Hawumba (2017) who stated that, the subsequent highly concentrated discharge further adversely affects the water quality of Nsooba channel as detected by the increase in COD and microbial overload, revealing of significant nutrient quantities. The sedimentation of some suspended solids, and the mineralization of the organic loads as the water flows away from the discharge points, should partially describe the reduction in COD linked to what other researchers have studied.

The effect of land use activities on the vegetation cover

From Table 4 it was observed that built-up areas and agriculture are the activities with the lowest stability as they are developing activities in the drainage system. This means that the transitions of wetlands and bare lands types are oriented towards urbanization and developing farming activities. The percentage changes for wetlands, agriculture, bare land and built-up areas between 1998 and 2018 were observed to be -32.63%, 16.42%, -7.43% and 23.64% respectively as shown in table 4.

Further, it was observed that Nsooba - Lubigi drainage system has been subjected to a gradual process of reclamation and presently experiences some of the most dangerous threats and pressures, especially on the wetlands. The sites around the drainage system, including Nsooba channel and Lubigi wetland are observed as major sites for urbanization due to their proximity to the city center and industrial district. The land use land cover (LULC) results showed that Nsooba - Lubigi drainage system was under several anthropogenic uses including industrialization, increased agriculture, road construction among others has increased the rate of loss of vegetation cover. This is agreement with Twesigye *et al*. (2011) who stated that increased development such as urbanization and industrialization, and other anthropogenic practices have led to the decline in vegetation cover and its loss. Kayima *et al*. (2018) also presented that rapid urbanization coupled with increasing population growth are one of the major driving factors of land use along Nsooba - Lubigi drainage system. This proportionately relates to Ding *et al.* (2015) who elaborated that, in most urbanized areas, land use largely contributes to nitrogen and phosphorus emanating from point source and non-point source pollutants. Ribolzi *et al.* (2011 found that most urban households are the common point source to pollution in waste water contamination, these contain pathogens which harbor low dissolved oxygen conditions in ground water supply leading to high metal concentration in the wetlands and other aquatic plant life.

Urbanization has additionally stretched to water-resistant areas larger volumes of runoff. Impervious rainfall runoff drains all types of pollutants including point and non-point source pollutants into rivers, which intensifies nutrients concentrations into surface waters. The strategic location of Nsooba - Lubigi drainage system means that it offers an exclusive and significant set of amenities to the residents within Bukoto, Kyebando, Bwaise and Kawempe among others. It serves as a buffer through which much of Kawempe division's and part of Kampala industrial and domestic effluents pass before being discharged into River Mayanja which eventually drains into River Kafu. Partially treated sewage from NWSC Lubigi treatment plant is mixed with the untreated wastewater present in the Nsooba Channel before entering the Lubigi wetland.

The current rise in settlements around Nsooba - Lubigi drainage system especially in the areas of Bwaise, Kalerwe, Kyebando and Makerere among others is largely due to the high demand for affordable accommodation by people who work in the motor vehicle garages, Kalerwe market and other markets around, petrol station fuel attendants and small companies located within Kawempe division. This is in line with Zhang *et al*. (2011), who stated that macroeconomic activities such as industrialization and other businesses, contributing to the growth of GDP often require large areas also contribute to the transition of forest/shrub land/grassland into buildup areas. These results are in agreement with Omagor and Barasa (2018) who reported that the wetland extent was narrowing at a high rate due to settlements. Similar trends in the degradation of wetlands in Kampala city have been reported by Warsame *et al*. (2022) and Karabo (2017). The study by Karabo further reported that the buffer zones/spaces for flood control, sinking sediments, silt, nutrients, pollutants, toxins and sewage treatment have been turned into built-up environment which explains the growing problem of flooding and water quality in the wetland catchments (Karabo, 2017).

A significant number of low income earners find affordable and cheap temporal housing along Nsooba - Lubigi drainage system and wetland. Some of the residents around Masanafu, Sentema, Namungoona and Bulaga settlements depend on harvesting of papyrus materials from Lubigi wetland as a way of making the ends meet. The degraded natural and cultural characteristics of the Nsooba channel and Lubigi wetland show lack of clear channel management policies. The location of Nsooba - Lubigi drainage system makes it suitable for providing exceptional and important ecological services to the residents of Kawempe division and Kampala City at large. Nsooba - Lubigi drainage system is consequently meant to play an important role in preserving the quality of both water supply and open waters. This signifies that areas made of urbanization, bare land, as well as farming activities are characterized by a significant population size that could be partly contributing to water quality and soil quality deterioration in the area.

CONCLUSION & RECOMMENDATION

The analytical concentrations of land-use types of wetland, built up areas and agriculture was observed for the parameters EC, TDS, TP, BOD,COD , TSS, TOC , where the observed average values were all below the National Standards of 1000 µs/cm, 750 mg/l, 10mg/l, 50mg/l, 70mg/l, 50mg/l and 50mg/l respectively. For TN, the average value for built-up areas was higher than the national standard of 10 mg/l while the remaining land use types of wetland and agriculture were below that of the recommended standard.

There was a significant decline in land coverage for wetlands and bare land from 1998-2018 attributable to rapid urban development involving infrastructural development, farming activities and rapid population growth. Wetland coverage declined by approximately 5 hectares since 1998 which represents an average decline of 2 hectares per decade. Bare Land was also observed to have declined from 14.5% in 1998 down to 7% by 2018, signifying a rapid decline of about 50% from 1998 to 2008. The percentage changes for wetlands, agriculture, bare land and built-up areas between 1998 and 2018 were observed to be -32.63%, 16.42%, -7.43% and 23.64% respectively.

The Nsooba - Lubigi drainage system, with its natural status is potentially susceptible to land use changes attributed to anthropogenic pressures. The physical and chemical examination of water quality revealed that built up area (Kalerwe) had the highest level of pollution attributed to rapid population growth and human activities including Nsooba slaughter house that discharges untreated effluents to Nsooba channel. The findings of this research can offer scientific orientation for land use management and water pollution regulation as well as guide in the creation of strategies for managing the water and other natural resources. However, other factors associated with water quality, such as the weather, precipitation, and density of population call for further research. From the findings of this study, a degraded land cover pattern in the Nsooba - Lubigi catchment is evident. The study concludes that the people settling around Nsooba - Lubigi Wetland System are victims of the Lubigi wetland system environmental degradation challenges and must be involved in finding solutions to these problems. This calls for the communities in the study area to assume responsibilities in guiding and controlling its development with the help of responsible government institutions like NEMA and research institutions. Our results suggest an urgent need for formation of community based management committees and by-laws to protect the fragile wetland ecosystems in Kampala city which are critical in biodiversity conservation, flood control and waste wastewater treatment.

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