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Lake Eutrophication Linked with Watershed land use and Seasonal Variations in Rwanda, East Africa.

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ABSTRACT
The effect of landscape patterns including land use variability and topographic features on lake eutrophication might be tended for more comprehension about intricacy existing between land use and water quality. The research aimed to relate physicochemical variables and chlorophyll a concentration in the Lake Kivu to watershed variables and land use patterns. Eight physicochemical variables and chlorophyll a categorized as gauges of nutrient conditions, gauges of organic matter, gauges of salinity and phytoplankton abundance gauges were sampled from five bays of the Lake Kivu adjacent to five land use types. Geographic Information System (GIS) and Principal Component Analysis (PCA) as well as Pearson correlation were used to ascertain the likely connection between land use types and eutrophication in the Lake Kivu in Rwanda, during the rainy and dry seasons in 2016. Seasonal variations were observed, designating that the link between lake eutrophication and land use patterns was stronger in wet seasons than that in dry seasons. For both wet and dry seasons, farmland manifested a sturdier relationship with water quality variables comparatively to other watershed land use types. As topographic features of land use were engaged for more analysis of these relationships; the results proved certain complexity connections between slope disparity and land use types; where a sturdier impact on lake eutrophication was remarkable from land use in sharper slopes than in flatter ones.
Key words: Land use, Eutrophication, Water quality, Physicochemical, Lake Kivu

I. INTRODUCTION

Water quality deterioration is of significant worry at a time when freshwater supply is confronting quickly expending demand in many countries [1, 2]. Eutrophication described by high nitrogen and phosphorus concentrations in water body and exorbitant development of phytoplankton and other water-growing plant, is a typical result of water quality corruption in lakes, pools and other water ecosystem [3]. Eutrophication has been long caused by numerous excesses of external inputs containing nitrogen and phosphorus issued from adjacent catchments land use. Despite the fact that, on one side, eutrophication is perceived as normal process in the maturing of lakes like mineralization undergone by plant residues and heterocystous phytoplankton fixing the atmospheric di-nitrogen. Human activities (e.g., urban spillover, over-utilization of chemical fertilizers and sewage releases) on the other side can significantly quicken the procedure by expending the rate at which the nutrients enter the marine locations from their bordering watersheds.

External nutrients, loaded to water surfaces causing eutrophication generally come from point and non-point sources. Researchers [4, 5] have specifically demonstrated that catchment land useplays a crucial role in availing nutrients concentrations in surface waters. Thus, lake stakeholders need a comprehension of nutrients sources and the procedures that drive lake efficiency before creating plans to enhance water quality in eutrophied lakes [3]. Furthermore, many previous

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studies demonstrated a surprising variability at watershed scale and an existing link between land use at watershed level and nutrients specifically physicochemical factors flowing to surface waters [3, 6, 7]. Some of this changeability might be caused by intrinsic characteristic in the structure of watershed that influences their capacity to pass on elements that is, a catchment's conveyance aptitude. That is why pragmatic investigation on how watershed characteristics interact to influence nutrient loading to a lake is crucial so that distinction between characteristics that are sources and features related to the rate at which nutrients moves to the lake might be clear. For instance, the proportion of cropland in a catchment as well as the farming systems gives indication to the amount of nutrients issued by agricultural sources obtainable for spread to a lake, while average catchment slope gives indication of the gravitational energy available for the transfer of those nutrients via mechanisms for example overland flow. The complexity related to the covariation of natural and anthropogenic activities (urban overflow, over-utilization of chemical fertilizers, and sewage releases) can lead to confusing assumptions regarding the likely influence of various nutrient sources to external lake nutrients loads [8, 9]. Furthermore, the topographic features (for example averaged slope) of the catchments were much of the time used to get an enhanced comprehension of the connectionbetween land use and water quality.

Despite previous researches which focused on global connection among land use designs and water quality, more comprehension about the relationship hasn't been accomplished in light of the fact that land use types in general really shared impressions on different components, for example, geomorphic characteristics and temporal scale factors. Overwhelming components of temporal scale, including rainfall, temperature and farming practices, are seasonally different due to its side on stream joining process and contaminant influences to water resources. Scientists recommended to deeply thinking about climatic variations during the analysis of water quality deteriorated by land use types. Furthermore Ye et al. (2014) have shown that whereas non-point discharge contamination was transcendent in rainy periods, farming land and forestland indicated more relationship with water eutrophication. The Lake Kivu basin is remarkable for the array and variety of its landscapes and land use types. While land remains comparatively unmodified [10] in some areas of the catchment, there have been significant variations to the environment and degree of the land use and vegetation cover in different areas over past 50 years [11, 12], and changes continue rapidly. Though, the link between land use and related lake eutrophication isn't clear for the Lake Kivu basin, whereas there is interest among social and natural scientists to document designs of land use and understand the impacts of these changes on people and natural biota [13], and recognition of the need for interdisciplinary studies on the linkages between land use , ecology, and economics [14].

Through ten years (since 2008) of monitoring the impact of methane gas extraction on the lake by protecting the lake's stability, a thorough data set has been gathered for the Lake Kivu, encompassing the lake morphology status along with methane extraction [15]. Nevertheless, lake water quality status related to the spatial distribution of watershed is absent. This express how important the availability of data from point source and non-point source contributors will provide an exclusive occasion for further understanding of the connections between watershed features and lake water quality. Thus, this study assumes that by considering external nutrient loading sources which aren't ascribed to diffuse contamination, we will discover more grounded and remarkable critical links between watershed attributes and water quality. Furthermore, the study aimed to relate physicochemical factors and chlorophyll a concentration in the Lake Kivu to watershed variables and land use. This was with the specific goal of assessing the potential impact of catchment status on nutrient augmentation and related water quality of the Lake. It is expected that the greater part of the nutrients improvement would be related positively or inversely to the degree and level of land use status.

II. MATERIEL AND METHODS

2.1. Study area description

The Lake Kivu, situated nearby the active volcanoes Nyamulagira and Nyiragongo lying in the border between Rwanda and Democratic Republic of Congo, is one of the East African great lakes (2370 km^2 surface area, 550km^3 volume) [16]. Due to numerous anthropogenic activities, the Lake Kivu like other African great lakes are considered to be susceptible [17], comparable to Lake Victoria where development activities around the basin created increasing nutrient inputs and eutrophication [18]. Similar to the Lake Malawi, the nutrient stacking to the Lake Kivu may have expanded by half because of agricultural advancement and increasing population density [19]. The lake basin encounters a tropical climate with mean yearly precipitation of 1314 mm, a mean yearly temperature of 19°C and two rainfall seasons per year (March to May and September to December) [20].

2.2. Data collection and analysis

2.2.1. Lake water quality

Water quality factors of the Lake Kivu were obtained from samples collected for one year. Months was classified into rainy season (September – May) and the dry season (June – August) in 2016 from the north (Rubavu district) to the south of the Lake Kivu basin (Rusizi district). The five sampling bays (sites) were selected according to adjacent land useof the Lake Kivu basin (Table1). Sampling took place at various profundities: 0 m, 60 m, 150 m and 350 m. Sampling was repeated four times to get a composite sample at each depth for each place. Samples issued from various profundities were gathered by utilizing a NISKIN bottle on which a RBR 620 CTD probe was appended to record the depth and the physical properties of the water. For depths below 200m, an open valve at the highest point of the NISKIN bottle was topped with an inflatable to keep test misfortune from energetic out gassing upon rising. A strong cord of 400 m length was linked to the RBR test so as to acquire to various profundities of interest in the lake.

Among the measured parameters, the pH and temperature were performed in situ utilizing a consolidated pen-type pH/thermometer (ATC Pometer), handheld conductivity tester EC-1382A (Kelilong Electron) and with YSI professional plus handheld multiparameter instrument calibrated with standard solutions, respectively. TN, TP, NO_2-N, and NH_3-N concentrations which were considered as gauges (indicators) of nutrient settings were obtained according to the standard of laboratory procedures [21, 22]. For the standard method on total nitrogen and total phosphorus, the absorbance was resolved at 540 nm for total nitrogen and 880 nm for total phosphorus. Samples of very much blended unfiltered were processed in autoclave at 121°C for two hours with potassium persulfate as the oxidizing reagent to change over all phosphorus to orthophosphate. Then the orthophosphate was analyzed adding the ascorbic acid but for the total nitrogen cadmium was added. The permanganate index (COD_{Mn}), chemical oxygen demand (COD_{Cr}), and BOD_5 have been considered as indicators of organic matters and electrical conductivity (EC) considered as salinity indicator. Finally, chlorophyll (Chla) was considered as indicator of phytoplankton abundance. During the chemical oxygen demand determination, the sample of water was oxidized in reflux by solution of potassium bichromate ($K_2Cr_2O_7$) which is strong oxidant, in sturdy acid medium and in existence of silver sulphate (Ag_2SO_4) as a catalyst. Biological oxygen demand was determined by making incubation during 5 days at 20°C, the samples of water were conserved in anaerobic medium and in dark. And then, the biological oxygen demand (20 °C) has been calculated by making the difference between the quantity of dissolved oxygen initially available, and the quantity of residual dissolve oxygen at the end of incubation period. In order to analyze chlorophyll a; water samples were taken on Whatman GF/F filters afterward screening through 300 µm mesh to remove zooplankton, and kept frozen till analysis. Pigments were taken out in 90 % alkaline acetone and examined using a Sequio Turner fluorometer (Model 450). Chlorophyll a concentrations were deliberated from fluorescence values before and after acidification.

Table 1: Identification of sampling sites and descriptions of adjoining land use

Sites	Land Use	Definitions
Nyamyumba	Farmland	Percentage of agricultural practices, garden, livestock divided by the total area of the catchment.
Mushubati	Forestland	Percentage of forest divided by total area of the catchment.
Mubuga	Grassland	Percentage of grass areas along roads, rivers bank and in residential blocks divided by total area of the catchment.
Gihombo	Shrubland	Percentage of shrub species covering the areas of lake basin.

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Nkanka	Urban	Percentage of residential, public buildings, municipal facilities and roads divided by total area of the catchment.

2.2.2. Land use data

GIS software was used to excerpt lake catchments and elucidate land use information. Usually, external nutrients loading to the lake considered as source of eutrophication are different for numerous land use types [20]. Nevertheless, in specific places, apart from cash crops (coffee and tea) which are intensively farmed, other crops types are hardly distinguished by methods for direct remote detecting symbolism because of agricultural practices which are complex (crop diversity per plot). Subsequently, the assessment of eutrophication extents related to land use and land cover classes has been restricted to five (Farmland, forestland, grassland, shrubland and urbanland) in the lake basin. land use and land cover data for the basin was achieved by using two landsat 8 images with a corresponding path/row (173.61 and 173/62 obtained in March 2017) provided by the USGS global visualization [23]. The images were radiometrically amended, the mist obscurities were disguised, and the holl-filling calculation was utilized to acquire images without clouds utilizing ENVI software rendition 5.2 [23]. Apart from using ArcGIS 10.2 Desktop software to calculate areas corresponding to each land use type within the Lake Kivu basin; it intervened to determine other landscape features including slope and rainfall. Furthermore, to further analyze the impact of topographical features on the link between land use patterns and lake water quality, three categories of slope have been measured including category 1 ($0 – 10^o$), category 2 ($10 – 20^o$), category 3 ($20 – 37^o$) at sub-basin scale. The three categories of slope were then considered after Pearson's correlation investigation on the link between LU and lake water quality.

2.2.3. Statistical analysis

Multivariate analyses were implemented on the data set. Oneway analysis (ANOVA) was accomplished on the log-changed water quality parameters to decide if the difference between the rainy and dry periods were noteworthy. Relationships among gauge of nutrients conditions, gauge of organic matter, gauge of salinity and gauge of phytoplankton abundance, slope and land use were evaluated with Pearson correlation investigation with statistical implications at the $p< 0.05$ level in dry and rainy periods. Data were checked for normality and homogeneity for all the variables before correlation by using Kolmogorov – Smirnov test (K –S test).

Principal component analysis has also been used and the best minimum data set was interpreted by principal components with the highest eigenvalues and variables with the highest eigenvectors [24, 25]. In order to perform statistical analysis and draw figures, statistical package for the social sciences 22.0 and OriginPro 9.0 (Originlab Inc., USA) for windows were used.

2.3. Results and discussions

2.3.1. Physicochemical properties of water quality in the studied sites

No significant seasonal variation was seen in the ANOVA test ($p> 0.05$) for measured factors during the dry and rainy periods. As shown in Figure 2, the mean concentrations of TP, TN, NO_2-N, NH_3-N, COD_{Mn},COD_{Cr}, BOD_5, EC and Chla were somewhat higher in the rainy period than that in the dry period.

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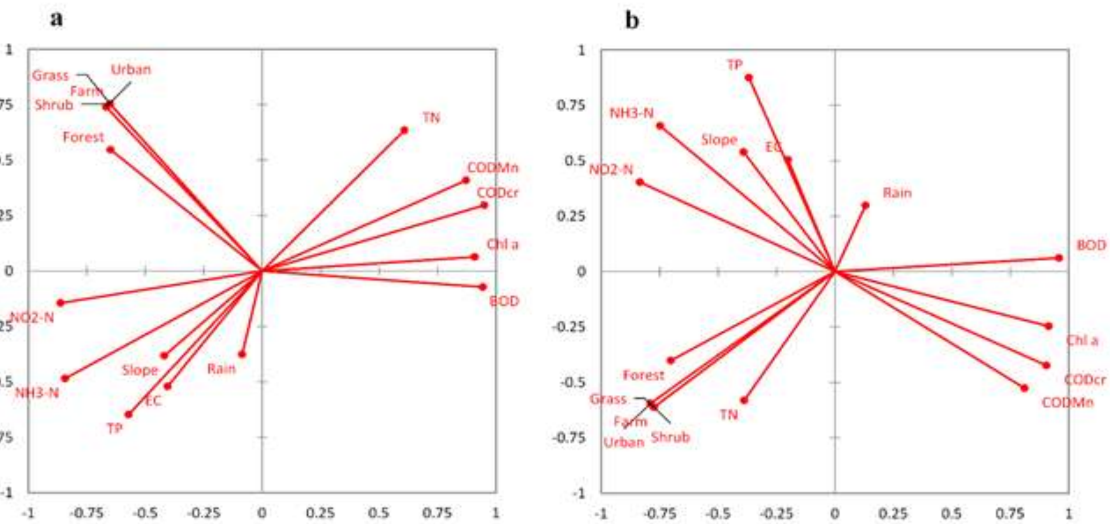

Figure 1: Ordination diagram for the PCA of physicochemical variables, land use and slope in rainy season (a) and dry season (b).

The mean concentration and standard deviation of physical and chemical factors and chlorophylla of lake water were ascertained at various scales, as appeared in table 2. By considering the influence of scales on water quality variables, spatial patterns variability has been observed. For instance, the mean concentrations of nutrient elements like TP, TN, NO_2-N, NH_3-N, COD_{Mn}, COD_{Cr} and EC were 1.56 mgL^{-1}, 2.38 mgL^{-1}, 0.67 mgL^{-1}, 0.83 mgL^{-1}, 8.52 mgL^{-1}, 7.61 mgL^{-1} and 1047 µs cm^{-1} correspondingly and were much higher in the Nyamyumba site than that in other four sites, showing that farming non-point contaminants had sturdily negative relations with water quality. It is for the most part because of different reasons including percentage farmland, population density and other landscape of the catchment. About the percentage of agricultural lands which is more than the other four sites (33 %, 25 %, 9 %, 3 %, 0.55 % within Nyamyumba site, Mushubati site, Mubuga site, Gihombo and Nkanka site, respectively). These results are congruent with other many researches where farming practices presented noteworthy relationships with physicochemical variables of waters in different areas like Africa, America and India [26-29].

Table 2: The mean concentration and standard deviation of the physicochemical factors and chlorophyllastudied sites

	Nyamyumba	**Mushubati**	**Mubuga**	**Gihombo**	**Nkanka**
TP (mgL^{-1})	1.56 ± 0.40	0.30 ± 0.38	0.21 ± 0.04	0.28 ± 0.04	1.16 ± 0.13
TN (mgL^{-1})	2.38 ± 0.14	0.51 ± 0.15	1.29 ± 0.07	1.39 ± 0.08	2.03 ± 0.48
NO_2-N (mgL^{-1})	0.67 ± 0.08	0.09 ± 0.04	0.13 ± 0.05	0.41 ± 0.08	0.51 ± 0.03
NH_3-N (mgL^{-1})	0.83 ± 0.07	0.23 ± 0.05	0.27 ± 0.08	0.39 ± 0.08	0.57 ± 0.08
COD_{Mn} (mgL^{-1})	8.52 ± 0.71	3.7 ± 0.74	4.93 ± 0.04	6.43 ± 0.71	6.91 ± 0.06
COD_{Cr}(mgL^{-1})	7.61 ± 0.06	3.22 ± 0.04	4.49 ± 0.04	5.14 ± 0.04	6.71 ± 0.05
BOD_5 (mgL^{-1})	9.87 ± 0.05	5.29 ± 0.04	7.89 ± 0.07	6.29 ± 0.05	8.23 ± 0.04
EC (µscm^{-1})	1047 ± 6.32	6021 ± 6.32	7180 ± 7.91	8101 ± 12.7	9231 ± 14.5

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Chla (µg L^{-1})	3.25 ± 0.08	1.97 ± 0.02	2.65 ± 0.08	2.91 ± 0.05	3.03 ± 0.04

For the population density which is generally high for the Lake Kivu basin; it has been specific in Nyamyumba than in other sites (37,941; 25,822; 18,485; 24,817; 18,438 within Nyamyumba, Mushubati, Mubuga, Gihombo and Nkanka respectively) (NISR 2012). Farmer's activities in these densely populated catchments may cause degradation of soil material which ends up by running away in downwards. These results showing the influences of population density to agriculture activities and its potential impact to water quality are in line with previous studies in which population density influenced farming practices in significant ways [30, 31]. At the same time, biological oxygen demand and electrical conductivity were considerably higher than that in the other sites, suggesting the presence of a thoughtful soil erosion issues, as extensively revealed by many researchers [12, 32]. Apart from the physicochemical and chlorophyll a status observed in Nyamyumba site, Nkanka has been the next one to show the differences. For instance, the average concentrations of nutrients like TP, TN, NO_2-N, NH_3-N, COD_{Mn}, COD_{Cr}, EC and Chla were 1.16 mgL^{-1}, 2.03 mgL^{-1}, 0.51 mgL^{-1}, 0.57 mgL^{-1}, 6.91 mgL^{-1}, 6.71 mgL^{-1}, 8.23 mgL^{-1}, 9231 mgL^{-1} and 3.03 mgL^{-1} correspondingly and were accentuated in the Nkanka site than in other three sites (Mushubati, Mubuga and Gihombo).

Most forgoing studies have revealed the status of physicochemical variables of lake water linked with adjacent land use on large scales, fluctuating over numerous catchments, or have considered only few catchments with strongly contrasting land use designs (e.g. farmland, bareland, urban) [33-35]. This study extended these approaches by comparing relatively heterogeneous and highly diversified land use in the watershed at the lake basin. It has been discovered that the amount of physicochemical variables and chlorophyll a was high in site adjacent to farmland except electrical conductivity. This suggests that farmland affects lake eutrophication differently and that erosion and sediment distribution processes might be highly influenced by agricultural practices in the watershed.
In addition, the status of physicochemical factors and chlorophyll a of the lake should be analyzed looking on land use changes in watershed which are mostly linked with societal and economic advancement mostly recognized to be the utmost significant promptly cautioning indicator of the lake eutrophication [36, 37]. Agricultural practices, which necessitates larger uptake of nutrients than does forestland, prairie, shrubland and urban, destroy the edifice of the upper part of soil which is mostly fertile therefore bringing about the stacking of chemicals and soil particles during precipitation [38, 39]. The existence of forestland might enhance the buffering aptitude of soil and the net main productivity of a biological community, and it assumes a key part in blocking contaminants that would in one way or another enter water bodies. The increasing loads of land-based contaminants (for example nutrients, sediment, and pesticides) produced by land use changes can bring about exacerbating water quality [40, 41].

2.3.2. Relationship between water quality and land use types.

The Kolmogorov – Smirnov goodness of fit test indicated that TP, COD_{Mn}, COD_{Cr}, NH_3-N and EC variables were not dispersed normally ($P< 0.005$) during the rainy period; and for the dry period, TN, NO_2-N, NH_3-N and EC didn't meet the ordinariness of distribution. Therefore, these factors were log-changed for further scrutiny. The log-changed results demonstrated that all of the log-changed water quality parameters were normally distributed ($p> 0.05$). As shown in Table 3, the statistical analysis indicated correlation status between physicochemical, chlorophyll a with land use types (farmland, forestland, grassland, shrubland and urban areas) and slope for rainy season and dry season.

Notably positive relationships in both rainy and dry season have been noticed between all studied water quality factors and the slope. For example the highest positive relationship was 0.86 and 0.66 with TP and NH_3-N respectively during rainy season and 0.77 and 0.64 with TP and NH_3-N during dry season. On the other side,biological oxygen demand demonstrated high negative correlation (-0.83) with urban area. Furthermore, PCA showed that the BOD_5, COD_{Mn}, COD_{Cr}, TN and chla were positively linked and these factors were linked negatively to the farmland, forestland, grassland, shrubland and urban area during the rainy season (Figure 1a). For the dry season the TN is related negatively to the BOD_5, COD_{Mn}, COD_{cr} and chla (Figure 1b).

This study showed that farmland had a positive connection with most water quality factors (TP, TN, NO_2-N and NH_3-N) under the research area. This agrees with previous researches[42-44], who mentioned that compared with other land use types, farmland was the main cause of non-point source pollution loading into the lake water.

Moreover, the results showed that TP, TN, NO_2-N and NH_3-N originated from farmland areas, which is consistent with [45]. However, different articles discussing on the sources of TP and TN, contended that TP comes from urban land use and TN from farmland sources [46, 47]. While farmland had the largest influence on lake eutrophication, urban areas also had a negative impact on water. Particularly, urban areas were positively related to TP, TN, NO_2-N and NH_3-N. However, this relationship was substantial in the proximity of the lake (150 m buffer). While the buffer size increased, the connection between land use types and water quality decreased. Forestland was found to have a clear beneficial effects on lake water quality in both rainy and dry periods.

Table 3: Pearson correlations between the physical and chemical factors, chlorophyll a and land use patterns.

	Farm	Forest	Grass	Shrub	Urban	Slope
Rainy season						
TP	0.22	-0.11	-0.11	-0.11	0.10	0.86
TN	0.04	-0.26	0.02	0.04	0.04	-0.44
NO_2-N	0.43	-0.27	0.41	0.41	0.42	0.48
NH_3-N	0.23	0.18	0.16	0.16	0.17	0.66
COD_{Mn}	-0.27	-0.20	-0.24	-0.24	-0.24	-0.41
COD_{Cr}	-0.41	-0.40	-0.39	-0.39	-0.39	-0.47
BOD_5	-0.70	-0.65	-0.69	-0.69	-0.69	-0.13
EC	-0.07	-0.08	-0.09	-0.09	-0.09	-0.23
Chla	-0.53	-0.35	-0.51	-0.51	-0.51	-0.39
Dry season						
TP	0.20	-0.08	-0.22	-0.22	0.10	0.77
TN	0.55	-0.11	0.55	0.55	0.55	-0.23
NO_2-N	0.36	-0.23	0.34	0.34	0.34	0.57
NH_3-N	0.19	0.21	0.16	0.16	0.16	0.64
COD_{Mn}	-0.29	-0.21	-0.27	-0.27	-0.27	-0.56
COD_{Cr}	-0.46	-0.45	-0.44	-0.44	-0.44	-0.56
BOD_5	-0.83	-0.78	-0.82	-0.82	-0.82	-0.22
EC	-0.07	-0.08	-0.08	-0.08	-0.08	-0.23
Chla	-0.54	-0.35	-0.52	-0.52	-0.52	-0.37

Table 4: Correlation of slope classes of each land use type with water quality factors

	Farmland			Forestland			Grassland			Shrubland			Urban		
	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III
Rainy season															
TP			0.39							0.05			0.06		
TN			0.45	-0.13			0.08								
NO_2-N		-0.11									0.03		0.14		
NH_3-N			-0.31												-0.11
COD_{Mn}					0.06			0.26							
COD_{cr}						-0.12			-0.04					-0.02	
BOD_5	0.08										-0.08				
EC		-0.06										0.31			
Chla		-1.18			0.23		-0.08		0.23						
Dry season															
TP			0.37							0.04			0.05		
TN			-0.41	-0.14				0.05							
NO_2-N		0.09											0.13		
NH_3-N			0.32												
COD_{Mn}							0.27								-0.12
COD_{cr}					-0.05	0.11			-0.03					-0.03	
BOD_5	0.07										0.07				
EC		0.05										0.32			
Chla		-1.17			0.22				-0.22						

2.3.3. Contribution of seasonal variations and topographic patterns on the complex correlation

The prominence of topography has been renowned in several previous studies. It has been seen that slope can perform as sinks or origin for particulates, as areas with high erraticism may also perform as sinks and abrupt slopes can rush runoff to the lake, grabbing up particulates along the way [48-50]. The link between land use and the lake water quality was more investigated by considering the existing slope in the catchment (Table 4).

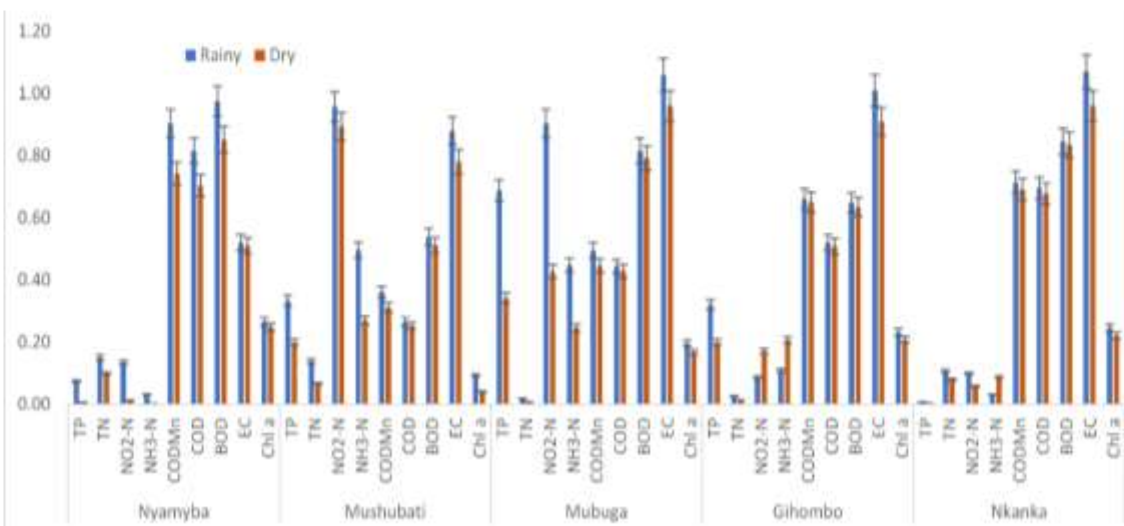

Figure 2: Physicochemical and chlorophyll a properties during both the rainy and dry period in the Lake Kivu

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Almost all studied physicochemical factors and chlorophyll a highly correlated either positively or negatively with slope except biological oxygen demand and chlorophyll a in both rainy season and dry season (Table 3). Most seasonal variations in surface water quality including lakes are determined by climatic and biotic features and thus, largely commended by the processes that are happening in the terrestrial part of the catchments like natural or anthropogenic induced land use change [51]. The results pointed out seasonal variations in the eutrophication status of the Lake Kivu. Water quality was better elucidated by interaction with the land use types in dry season rather than in rainy season. This may have been the outcome of relatively complex discharge within watersheds of the Lake Kivu basin between rainy and dry seasons as well as dense nutrient spiraling [52]. This is additionally strengthened by general lesser concentrations of nearly all nutrients and pollutants within the basin in dry season. The notably higher concentrations of nutrients in the rainy season also correspond with the agricultural activities (tilling, fertilizing, sowing, and weeding) in the area. Nutrients are effortlessly conveyed to the downward through surface overflow and subsurface movements during this period [53, 54].

On the other hand the role of topographic features is of utmost contribution on the water quality. This has been supported by obtained relationship between slope and lake water quality for all land use types in the Lake Kivu basin. The high effect of slope on water quality (Table 3) justified by high positive correlation (0.86) with total phosphorus during rainy season shows erosion status in the area. These results presuming the existence of erosion are in consistent with wearing awayapproximates in most of tropical zones with alike elevation (slopes) and climatic situation. For example, the Lake Kivu basin has been observed to be greatly susceptible of overflow extent of 360 t. ha $^{-1}$ .year $^{-1}$ because of two foremost characteristic elements, comprising increasing average precipitation of 1285 mm/ y and average sheer elevation of 27% [12, 55]. The Lake Kivu basin is mostly distinguished by steep slope (>30 %) therefore, in rainy season this topography generates flows of water from neighboring rivers that willingly flush fertilizers and sediments from both sides into the lake. The results (Table4) demonstrated that a high slope had more notable connections with water quality factors in rainy and dry periods inside the lake Basin. This has been confirmed by [56] that the slope was a basic factor to forecast the extent at which water flow crosswise over surfaces. In the comparatively thinly vegetated catchments on the lake coast, water can speedily gather on sheer slopes and the subsequent surface overflow can apply sturdier scrubbing influence on the surface [57]. As outcome, enormous amounts of nutrients will be directly loaded to the lake from adjacent surface. The connection coefficients between the farmland and urban area of the watershed with the lake water quality indicators also confirmed this phenomenon.

Furthermore, the impact of proximity on the intricate relationship have been considered by previous researchers [58-61] with a specific end goal to know whether the average interval of land use to the outlets of the catchment is another sensible indicator of water quality other than land use types themselves. The findings suggested that the land use types close to the lake water was mostly a good indicator for the efficiency in influencing water quality. However, numerous elements can likewise impacts the connection between the lake water quality and nearby land use other than closeness, and there were counterintuitive findings in our results. While urban land was nearer to the lake than farmland, the relationship of farmland with water quality was as yet sturdier than urban area. This congruent with [62] who infered that when land use was categorized at the level of the whole catchment, the link between land use and water quality was contrariwise sturdier than if just 150 or 300 m cradle strip was contemplated.

2.4. Conclusions

The research aimed to relate physicochemical factors and chlorophyll a concentration in the Lake Kivu to watershed factors and land use in order to evaluate the possible impact of catchment status on nutrient augmentation and related water quality of the lake. The results revealed the connection between land use types and lake water quality throughout rainy season and dry period. Statistical investigation exhibited diverse connection designs in both wet and dry seasons, presenting that physicochemical factors and chlorophyll a concentration of the lake water were more affected by all various kinds of land use as well as slope. Consequently, seasonal disparity was detected, demonstrating that the land use types had a more notable connection in rainy season than in dry periods on water quality. The topographic attributes of land use, like the average slope and nearness of land use to lake water, were observed to be significant variables influencing the influence of land use to lake water quality. Moreover, the investigation proved that periodic dissimilarity also appeared in the multifaceted connection and sharper land usually had a sturdier impact on the lake water quality than flatter area. The present research doesn't just regard the connection between land use and water quality, yet in addition, the link between land use and periodic dissimilarities from one perspective, and land use and topographic features on the other hand. Therefore, the findingsbolster the proposal that water quality can be enhanced by better land use management.

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