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INVESTIGATION OF THE SPATIAL AND TEMPORAL VARIATIONS IN THE EXTERNAL NUTRIENT LOADS OF LAKE ZIWAY IN RELATION TO THE EFFECTS OF CLIMATIC AND HYDROLOGICAL FACTORS

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ABSTRACT

Excess household wastes from settlements, agrochemical and industrial effluentsfromthe watershed into Lake Ziway can pause a great problem in Lake Ziway. This study was therefore conducted to analysis the amount dynamics, and influences the external and internal household wastes, agrochemical and industrial loads, on Lake Ziway ecosystem. Water samples were collected on a monthly basis from nine sampling sites of the lake for the analysis of some selected water quality parameters in 2014 and 2015 in different seasons. The physicochemical parameters were measured in-situ with portable multimeter and nutrients were according to the APHA [1]. The inflows from Katar and Meki Rivers indicate the main external nutrient sources of the lake ecosystem. The study showed a general trend of higher external nutrient load in the wet than in the dry seasons. These high nutrient loads indicate the susceptibility of Lake Ziway toapproach Eutrophication levels. Person Correlation indicated that precipitation, water level, discharge flow and air temperature had weak to strong positive correlations with SRP, TP, TIN and TN,while DO, pH, EC, total alkalinity (TA) and soluble reactive silica (SiO2-Si) were negatively correlated with water level and discharge outflows. In order to minimize more pollution of the lake water quality and to eventually restore the lake, management of fertilizers and pesticide usage in the lake watershed should be given urgent priority.

Contribution/Originality: This study contributes to existing literature by analysising the amount dynamics, and influences the external and internal household wastes, agrochemical and industrial loads, on Lake Ziway ecosystem.

1. INTRODUCTION

Most tropical African countries, including Ethiopia, are faced with rapid development and population growth that discharge excessive pollutantsinto lakeswithout any conservation measure in place. This has led to the rapid deterioration of water quality in receiving lakes and some lakes are experiencing severe biodiversity losses [2]. External sources of nutrients undergo a series of biochemical reactions, while some nutrients are partially retained when passing through a storage system. Fine particulate nutrients remain in suspension and gradually settle, as the kinetic energy of the inflow is gradually lost in the pelagic area of the lake. Whilst nutrients are not bioavailable, soluble and diffusible nutrients (e.g. SRP, nitrate, ammonia, and silica) can readily be absorbed by phytoplankton and macrophytes through semi-permeable cell membrane. There is increasing evidence that climate change is beginning to have a noticeable effect on lake ecosystems [3]. Developing countries, such as Ethiopia, are currently vulnerable to climate change mainly because of the larger dependency of their economy on rain-fed agriculture. Hence, assessing vulnerability of water resources to climatic and hydrological factors in relation to external nutrient loading is very crucial. Evidence based knowledge on external loads hence provides an opportunity to plan on the appropriate mitigation measures that must be taken ahead of time [4].

Currently many studies indicated that agricultural practices have markedly increased the agrochemical loads on surface waters; mostly because of an increased use of pesticides and fertilizers in agriculture as a result these agrochemicals are the current water quality problems related to the eutrophication [5]. External nutrient load has long been recognized as one of the most important factors controlling the productivity or trophic state of a lake [6]. Under natural conditions, nutrient inputs to lakes are generally low and cause few water quality problems. However, anthropogenic activity within the catchment can increase nutrient inputs to water bodies to a level that degrades water quality and promotes troublesome, and sometimes toxic, cyanobacteria blooms [7].

The seven larger lakes in the Ethiopian Central Rift Valley (CRV) contain an abundant variety of flora and fauna species, being of major importance for Ethiopia's fish industry [8]. However, the CRV, including its lakes, is one of the most vulnerable environmental landscapes in Ethiopia, with its terrestrial and lake ecosystems having been massively deteriorated by human activities. A key problem is irrigation agriculture, including large-scale floriculture enterprises attracted by the suitable climate of the CRV, such as high radiation, long day lengths, cool nights and high daytime temperatures, as well as favorable humidity [9]. Lake Ziway is one of the Ethiopia Rift valley lakes which are subjected to huge inputs of terigenuos and anthropogenic nutrients (phosphorus, nitrogen and silica) from agricultural, industrial, urban sewages and other discharges. These factors made the lake rich with nutrients, resulting in unexpectedly high biological productivity. Based on observations during field visits, the lake is eutrophic, indicating enrichment of nutrients, which is productive in terms of aquatic animal and plant life, but shows signs of water quality deterioration over the course of a few years. The main objectives of this workwere therefore to determine the levels of nutrient inputs and outputs by inflowing and out-flowing rivers and to investigate the spatial and temporal variations in the external nutrient loads of Lake Ziway in relation to the effects of climatic and hydrological factors.

2. MATERIAL AND METHODS

2.1. Description of the Study Area

Lake Ziway is located in the northern part of the Ethiopia at 08^{0}01'N and 38^{0}47'E Figure 1. The *woredas* (local name but comparable to districts) sharing the lake are Tullu, Jido Kombolcha, Dugda Bora, and Ziway Dugda [9, 10] . Table 1 Geographic coordinates of the sample sites.

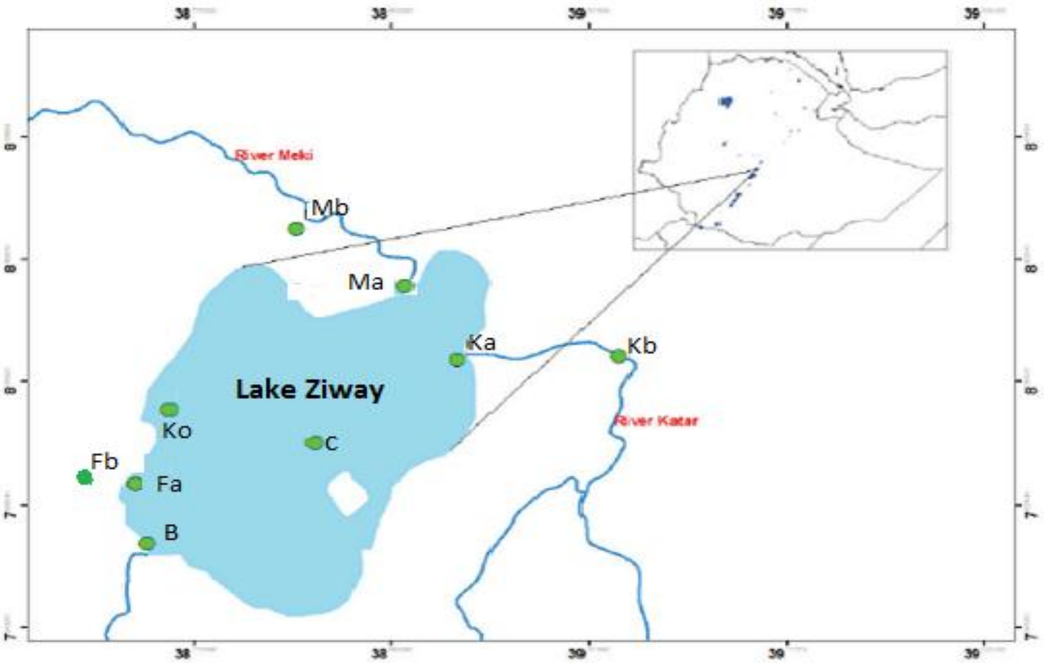

Figure-1. Lake Ziway sampling sites in the lake and its feeder rivers in Ethiopia.

Table-1. Geographic coordinates of the sample sites.

Codes	Sampling Site names	Longitude	Latitude
F_b	Floriculture effluent	38.044020	7.54715
B	Bulbula River mouth	38.743261	7.899822
F_a	Around Floriculture industries	38.740261	7.917644
C	Central part of the lake	38.841453	7.971989
K_a	Ketar River mouth	38.924100	8.031094
M_a	Meki River mouth	38.848733	8.051128
M_b	Meki River at Meki Gage Station	38.835000	8.103000
K_b	Ketar River at Abura Gage Station	39.019033	8.032822
K_o	Korekonch	38.755692	7.995050

During the last few decades, Lake Ziway has begun to show reduction in its water level because of some climatic factors (e.g. evapotranspiration) and water abstraction for irrigation, municipal and industrial purposes [8]. Slight increase in its salinity and mineral contents were observed during the last four decades which were attributed to water abstractions, decrease in rain fall, increase in evaporation rate, and changes in the total rivers outflow and inflows.

2.2. Sample Preparation and Analyses for Physicochemical and Nutrient Analysis

2.2.1. In-Situ Measurements of Physico-Chemical Parameters

Physicochemical parameters were measured after all calibration of equipments according to the manufacturer's specifications:

i. *Temperature, pH, electrical conductivity, total dissolved solid, and dissolved oxygen* were measured with a portable multi meter HACH MM150 model designed for water samples.

ii. *Secchi depth* was measured with a standard Secchi disk of 20 cm diameter with black and white quarters.

iii. *Alkalinity*: Alkalinity was determined by titrating lake water with standard sulphuric acid (0.02 N) according to the Standard Method 2320 B; [1] and using the formula:

$$Alkalinity, \frac{mg\ CaCO_3}{L} = \frac{A * N * 50{,}000}{mL\ sample}$$ Eq. 2.1

Where: *A* is the volume of the standard acid used, mL is the volume is of lake water used and *N is* normality of the standard acid.

2.2.2. Standard Analytical Methods for Nutrient Analysis

In the 24 months sampling periods, the chemical investigation of some selected nutrients were determined for all samples following the standard procedures outlined in [1]. The samples used for the analyses of all nutrients except, total nitrogen (TN) and total phosphorus (TP) were filtered through 0.47 µm diameter glass fiber filters (GF/F). Soluble reactive phosphorus (SRP) was measured colorimetrically using ascorbic acid method, Total phosphorus (TP) was analyzed by persulfate digestion followed by the ascorbic acid method, Ammonia-nitrogen (NH_3-N) was determined by Phenate method spectrophotometrically, Nitrite-nitrogen (NO_2–N) was determined by colorimetric method, Nitrite-nitrogen (NO_2–N) was determined by colorimetric method, Total nitrogen (TN) in water samples was analyzed using Kjeldahl method, and Soluble reactive silica (SiO_2-Si) was determined by Molybdosilicate method (after [1]).

2.3. Data Collection Methods for Climatic and Hydrological Factors

Secondary data for air temperatures, wind speed, sunshine, relative humidity, rainfall and evaporation rate were measured at the meteorological station at Lake Ziway from 1980 to 2014 and the data were collected centrally from the EthiopianMeteorology Agency in Addis Ababa. Hydrological data such as water fluctuations in water levels of the lake and rivers discharge rates were collected from the Ministry of Water, Irrigation and Electricity (MoWIE), Addis Ababa.

The lake water balance and water residence time of Lake Ziway were calculated according to the formula:

2.4. External Nutrient Load Model

The main external agrochemical loads of Lake Ziway are the Katar and Meki Rivers. The yearl agrochemical loads to the lake were estimated by multiplying the monthly concentrations of significant forms of nutrients in the rivers by the monthly average inflows of the two rivers. Therefore, the external agrochemical load of the lake can be computed using the formula mentioned in reference [11] as follows:

$$\mathrm{L} = K\left(\sum_{i=1}^{n}(\mathrm{Ci} * \mathrm{Qi})\right)$$

Where:

L = nutrient load (ton $year^{-1}$).

n = number of samples.

Q_i= discharge ($m^3\ s^{-1}$).

K = a factor to convert from time period of record to annual value.

C_i= amount of nutrients (ton m^{-3}).

The records of monthly discharges of Ketar, Meki and Bulbula Rivers were obtained from Ministry of water, irrigation and energy (MoWIE).

Table-2. Mean, mean standard error, minimum and maximum values of the external nutrients loading (kg day^{-1}) in Katar River (Kb) and Meki River (Mb) in dry season.

Site		TP	SRP	NO_3-N	NO_2-N	NH_3-N	TIN	TN	SiO_2-Si
Kb	$\bar{x}\pm$ Std. Err	86.4 ±21.1	16.4±4.3	60.1±17.2	174.7±74.1	53.6±8.2	288.3±88.3	1558.4±383.8	19526±4515
	Min	37	8	36	45	42	148	733	12149
	Max	154	33	144	536	94	722	3347	41565
Mb	$\bar{x}\pm$ Std. Err	22.3±8.8	11.9±5.0	65.9±47.4	161.9±98.4	44.83±27.2	87.17±34.4	500.1±114.1	5828±1801
	Min	0	0	0	0	0	0	0	0
	Max	62	30	295	590	177	203	798	12399
Total	$\bar{x}\pm$ Std. Err	54.4±14.6	14.1±3.2	63.0±24.0	168.3±58.8	49.2±13.6	187.7±54.4	1029.3±248.8	12677±3104
	Min	0	0	0	0	0	0	0	0
	Max	154	33	295	590	177	722	3347	41565

Table-3. Mean, mean standard error, minimum and maximum values of the external nutrient loads (kg day^{-1}) in Kb and Mb in wet season.

Site		TP	SRP	NO_3-N	NO_2-N	NH_3-N	TIN	TN	SiO_2-Si
Kb	$\bar{x}\pm$ Std. Err	1528±1121	110.8±47.9	1510.5±1220.7	2182.7±1413.5	323.7±258.1	4017±2889	13974±8832	44833±2266
	Min	97	28	45	487	43	584	2117	38453
	Max	4821	245	5159	6378	1098	12634	40041	49170
Mb	$\bar{x}\pm$ Std. Err	1138±626	92.83±46.8	346.3±111.6	1005.3±315	127.2±80.8	1793.2±622.3	8194±3976	29124±5931.9
	Min	146	25	45	434	5	764	1961	21365
	Max	2913	230	515	1782	355	3512	19164	46726
Total	$\bar{x}\pm$ Std. Err	1333±599	102±31	928±608	1594±706	225±131	2905±1431	11084±4615	36979±4178
	Min	97	25	45	434	5	584	1961	21365
	Max	4821	245	5159	6378	1098	12634	40041	49170

Note: *. Correlation is significant at the 0.05 level

**. Correlation is significant at the 0.01 level.

3. RESULTS AND DISCUSSION

3.1. External Nutrient Load

Water quality and quantity data are used to describe the recent loads of TP, SRP, NO_3-N, NO_2-N, NH_3-N, TIN, TN and SiO_2-Si to Lake Ziway over the study period. The results of the study are shown on spatial and seasonal bases in Tables 2 and 3.

3. 1.1. External Soluble Reactive Phosphorus Load

Soluble reactive phosphorus (SRP) load to Lake Ziway ranged from a value of 0.0 to 33 Kg day^{-1} and 25 to 245 Kg day^{-1} during the dry and wet seasons, respectively Tables 2 and 3. Mean SRP loads were 14.1 and 102 Kg day^{-1} during the dry and wet seasons, respectively. SRP loads were significantly different between rivers ($p < 0.05$) in dry season.

An increasing SRP load was seen in Lake Ziway, in which the inflow of K_b contributes higher than M_b Tables 2 and 3. The seasonal variability in SRP loads to Lake Ziway is mostly determined by variability in seasonal inflows of Katar and Meki Rivers, as demonstrated by the relationship between seasonal inflows of the two rivers and seasonal SRP concentration in the two rivers. This indicated that nutrient loads are higher during rainfall period due to agricultural runoff. Similarly, Erik and Brian [4] reported that increasing SRP loading during rainy season is attributed to the increased river flow with precipitation. As Jeppesen, et al. [12] also reported heavy rainfall has significant impact on yearly phosphorus transport from agricultural soils to the lake ecosystem. An higher external agrochemical loading from a number of anthropogenically influenced sources in the lake catchment is indicated as the main reason by other recent studies [13].

3.1.2. External Total Phosphorus Load

The external TP load to Lake Ziway ranged between 0 to 155 Kg day^{-1} and 96.77 to 4821 Kg day^{-1} with mean TPs values of 54.4 and 1333 Kg day^{-1} in the dry and wet seasons respectively Tables 2 and 3. ANOVA (Kruskal-Wallis) result showed that TP values between sampling sites were significantly different ($P < 0.05$) during the dry but not significantly different ($P > 0.05$) during the wet season.

The temporal variability in external TP loads to Lake Ziway is mostly determined by variability in temporal river inflows, as demonstrated by the relationship between temporal river inflow and temporal variability in TP concentrations in a similar trend for SRP present above. The external TP load was maximum in the wet season and minimum in the dry season which might be due to the seasonality of precipitation, land use, and periods when fertilizer is applied on farmlands [7, 14, 15]. In both seasons Katar River TP load was higher than that of Meki River Figures 2 and 3. The result is supported by the data from the reports by FDREMoWR [16]. Ketar River inflow accounts for 63 % of the variability in TP load. In contrast, only about 37 % of the variability in TP load can be attributed to Meki River inflow. The major reason for the lower TP input from River Meki could be either the volume of Meki River decreases extremely in the dry season or it completely dries out at the warmest peak during the dry season, due to excessive water abstraction for irrigation conducted upstream.

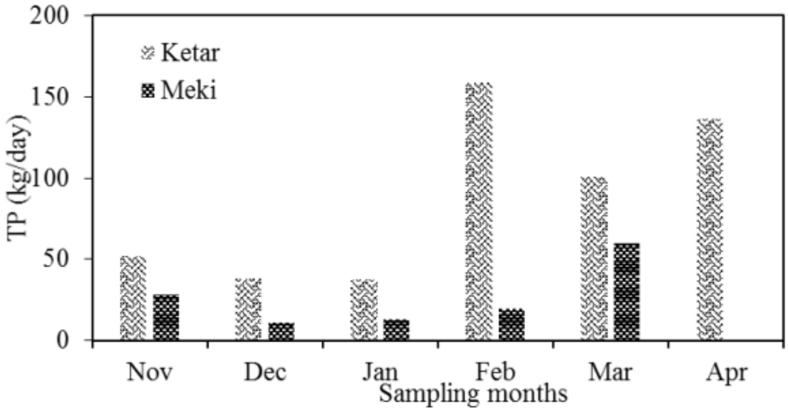

Figure-2. External TP load dynamics from the Meki (Mb) and Katar (Kb) rivers during dry season in 2014 and 2015.

A high source of TP in the lake water can be attributed to runoff fertilizers, pesticides, detergents and domestic liquids. Most of these chemicals contain phosphorous. Environmental Protection Agency (EPA) in US has recommended that TP concentrations should not exceed 0.1 mg L^{-1} in rivers [17]. Therefore, TP concentrations in the two rivers of Ziway are beyond this value.

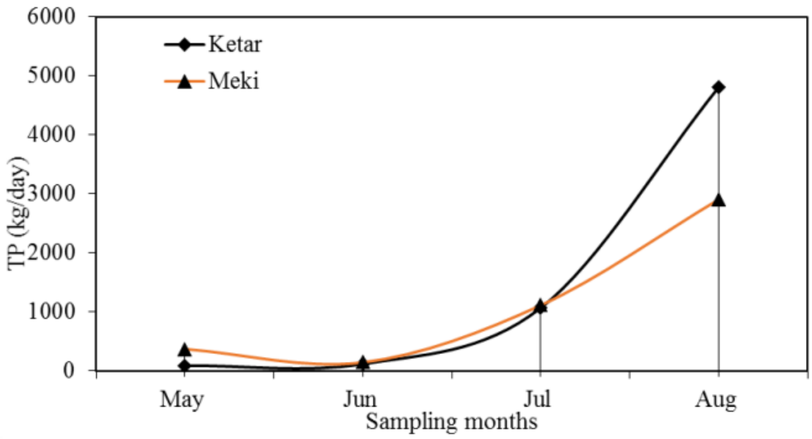

Figure-3. Seasonal variation in external TP load to Lake Ziway from the Meki and Katar rivers in wet season in 2014 and 2015.

The increased anthropogenic developmental activities within the catchment might be the main cause of the higher external TP loading in the lake ecosystem as observed in the Land-use map of the lake Ziway watershed. This spatial variation in external TP load suggests that different management strategies may be needed within the watershed [18].

3.1.3. External Nitrate-Nitrogen Load

The external nitrate-nitrogen (NO_3-N) load to Lake Ziway ranged between 0 to 295 Kg day^{-1} and 45 to 5189 Kg day^{-1} with mean values of 63 and 1928 Kg day^{-1} in the dry and wet seasons respectively. NO_3-N loads were significantly different between sampling sites ($p < 0.05$), with K_b having significantly greater than M_b duringthewet season Tables 2 and 3. The mean NO_3-N loads were higher in the wet season than the dry season. The higher NO_3-N load in the wet season might be attributed to the application of nitrogen fertilizers and pesticides in the Meki and Ketar rivers' catchment during this season. The intensive agricultural practice in the lake catchment area resulting in the excess enrichment of nutrients through agricultural runoff has been reported by other studies [9, 19] in the same lake. Solheim, et al. [3] also reported that extreme precipitation increases the NO_3-N load to the lake ecosystem.

3.1.4. External Nitrite-Nitrogen Load

Nitrite-nitrogen (NO_2-N) load ranged from a maximum of 598 Kg day^{-1} in March to a minimum of 0.0 Kg day^{-1} in April at Meki River during the dry season and a maximum of 6378 Kg day^{-1} in August at Katar and minimum of 434 Kg day^{-1} in May during the wet season in Meki River Tables 2 and 3. The total mean NO_2-N loads were 168 Kg day^{-1} and 1594 Kg day^{-1} during the dry and wet seasons respectively and the mean NO_2-N loads were not significantly different between sampling sites ($p > 0.05$) in both seasons. The higher NO_2-N load during wet seasons was due to agricultural runoff from the catchment precipitation.

3.1.5. External Ammonia-Nitrogen Load

The ammonia-nitrogen (NH_3-N) load to Lake Ziway ranged between 5 to 1098 Kg day^{-1} and 0 to 177 Kg day^{-1} with mean values of 225 and 49.2 Kg day^{-1} in the wet and dry seasons respectively Tables 2 and 3. Through the mean NH_3-N loads were not significantly different between sampling sites ($p > 0.05$) in both seasons; similar results reported by the seasonal variability of the load with maximum values in the wet season and minimum in the dry season can likely be attributed to the seasonality of climatic and anthropogenic activities like precipitation, land use change and periods of fertilizer and pesticides application on farmland [7, 9, 12, 19]. The greatest external NH_3-N loads to Ziway Lake occurred in August at Katar River (1098 kg day $^{-1}$) and the lowest loads occurred in June (5 kg day $^{-1}$) at Meki River during wet season while in dry season highest and lowest NH_3-N load were in March (178 kg day $^{-1}$) and April (0 kg day^{-1}) at Meki River, respectively. In general, Katar River was the dominant source of external NH_3-N load, but there were only for a few months, when Meki River contributed more NH_3-N load than Katar River.

3.1.6. External Total Inorganic Nitrogen Load

Total inorganic nitrogen (TIN) load in the study sites ranged from 0 to 722 kg day^{-1} and 584 to 12634 kg day^{-1} in dry and wet season respectively during the study period Tables 2 and 3. The highest load of TIN in wet season could be due to climate changes in particular to rainfall. The greatest external TIN loads to Lake Ziway occurred in August (12634 kg day $^{-1}$) and the lowest loads occurred in May (584 kg day $^{-1}$) at Ketar River during the wet season while in the dry season the lowest and highest values were in April (0 kg day^{-1}) in Meki and March (261.8 kg day $^{-1}$) at Ketar Rivers, respectively. However, ANOVA (Kruskal-Wallis) result showed that TIN values between sampling sites were significantly different ($P < 0.05$) during the dry season but not ($P > 0.05$) during the wet season.

In general, the results showed Ketar River is the dominant source not only for SRP and TP described above but also for TIN too to Lake Ziway throughout the study period Figures 4 and 5.

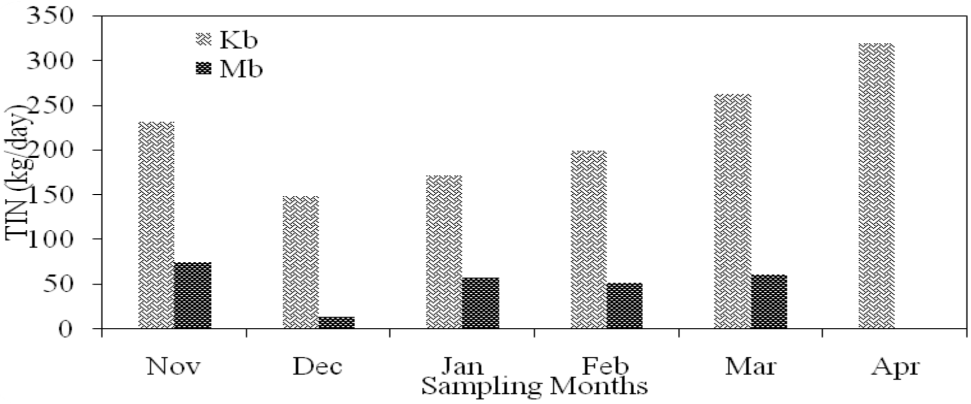

Figure-4. External TIN load dynamics from the Meki (M_b) and Katar (K_b) rivers during dry season in 2014 and 2015.

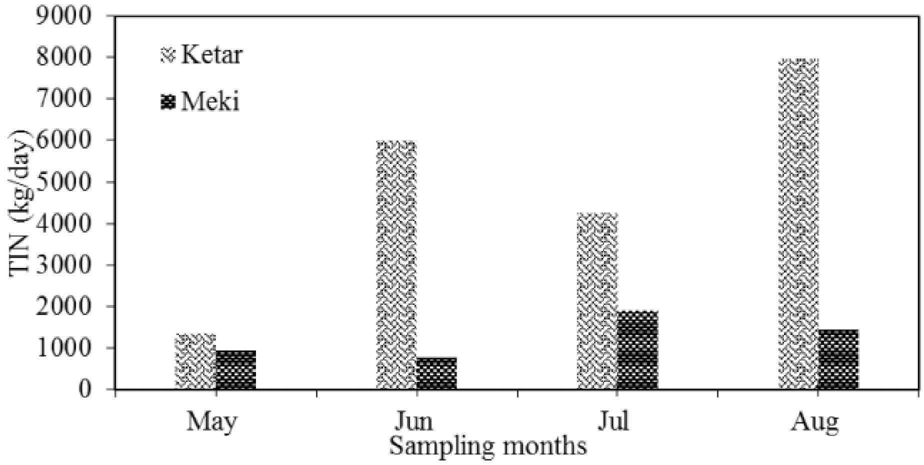

Figure-5. External TIN load dynamics from the Meki (M_b) and Katar (K_b) rivers during wet season in 2014 and 2015.

Higher TIN load in Lake Ziway might be associated with anthropogenic factors around the lake watershed and climate changes. The increase rainfall may cause flushing of upland soils. In the dry season increased temperature, reduced inflow and increased residence time result in high denitrification processes that lead to lower TIN load. However, further downstream, where the input from agriculture and point sources is larger, the effect of reduced dilution in dry season becomes more important than that of increased denitrification, giving increased concentrations also in the dry season [20].

3.1.7. External Total Nitrogen Load

The total nitrogen (TN) load ranged from 0 to 3347 kg day^{-1} and 1961 to 40041 Kg day^{-1} during the dry and the wet seasons, respectively Tables 2 and 3. The TN load to Lake Ziway was an average of 1029 Kg day^{-1} and 11084 Kg day^{-1} in dry and wet seasons, respectively. ANOVA (Kruskal-Wallis) result showed that TN values between sampling sites were significantly different ($P < 0.05$) in dry season but not in wet season ($p > 0.05$).

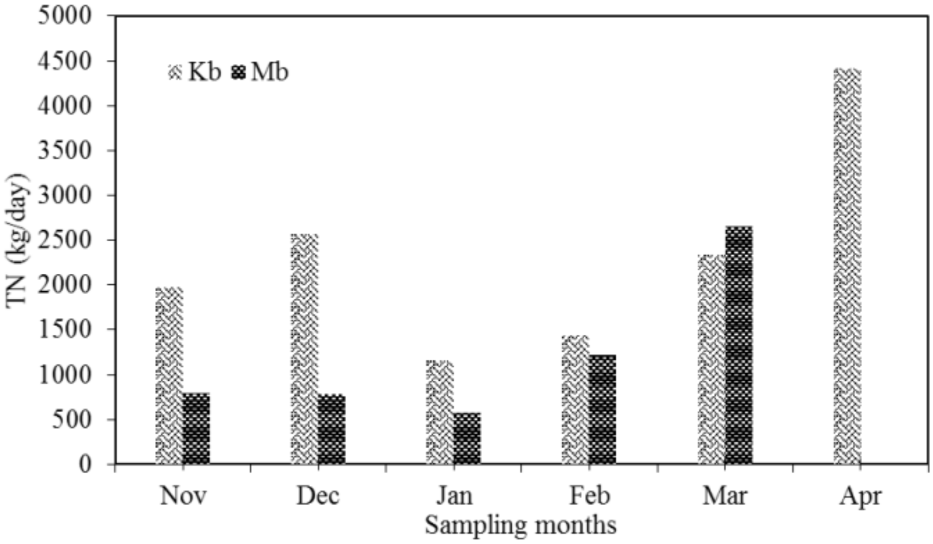

Figure-6. ExternalTN load dynamics from the M_b and K_b rivers during dry season in 2014 and 2015.

Low TN load in Meki River during April Figure 7 is associated with the lowest monthly inflows from the river in dry season due to the river dried out during this month (Personal observation) while high TN load occurred during August in Ketar River in wet season Figure 8. Based on the discharge flow data in this study, Ketar River contributed 56 % and 63 % of the TN load over the study period in dry and wet seasons, respectively.

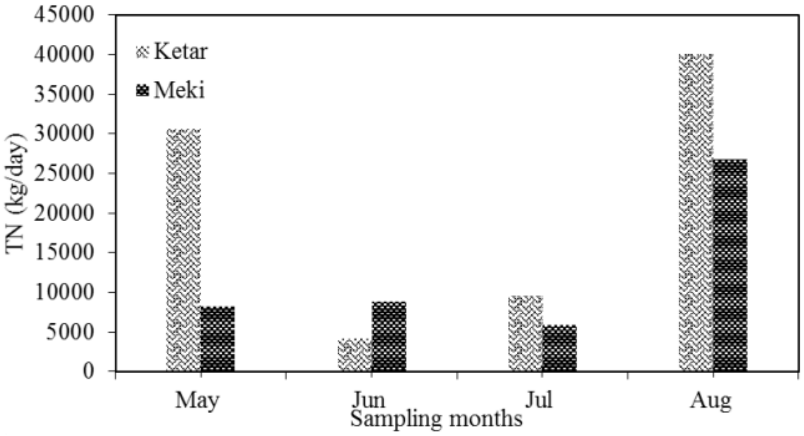

Figure-7. External TN load dynamics from the Meki and Ketar rivers during wet season in 2014 and 2015.

3.1. 8. Soluble Reactive Silica Load

Soluble reactive silica (SiO_2-Si) load to Lake Ziway ranged from 0 to 41565 Kg day^{-1} and 21365 to 49170 kg day^{-1} during dry and wet seasons respectively Tables 2 and 3. The mean SiO_2-Si loads were 12677 and 36979 kg day^{-1} in dry and wet seasons, respectively. SiO_2-Si loads were significantly different between sampling sites ($p < 0.05$) in both seasons.

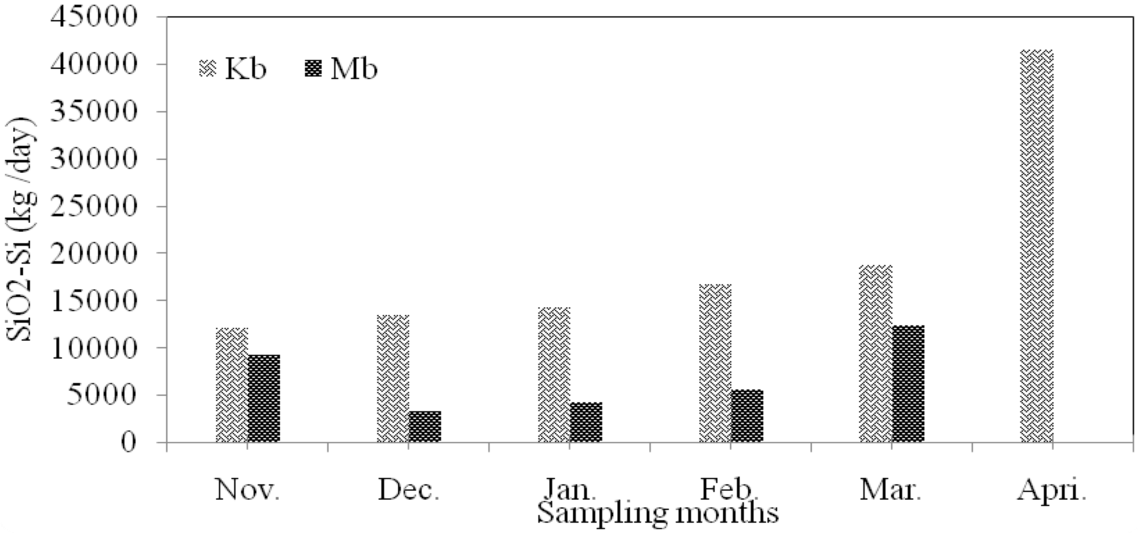

Figure-8. ExternalSiO_2-Si load dynamics from the Meki River (M_b) and Katar River (K_b) during dry season in 2014 and 2015.

The SiO_2-Si load is highest in April at Katar River and the lowest in the same month at Meki River Figure 8 during the dry season. The nutrient load patterns in the two rivers have low values during the dry season and an extended rainy season which was high load. When compared the SiO_2-Si load for the two rivers, is very low in Meki River in all sampling months except July in which both have similar external SiO_2-Si load Figure 9.

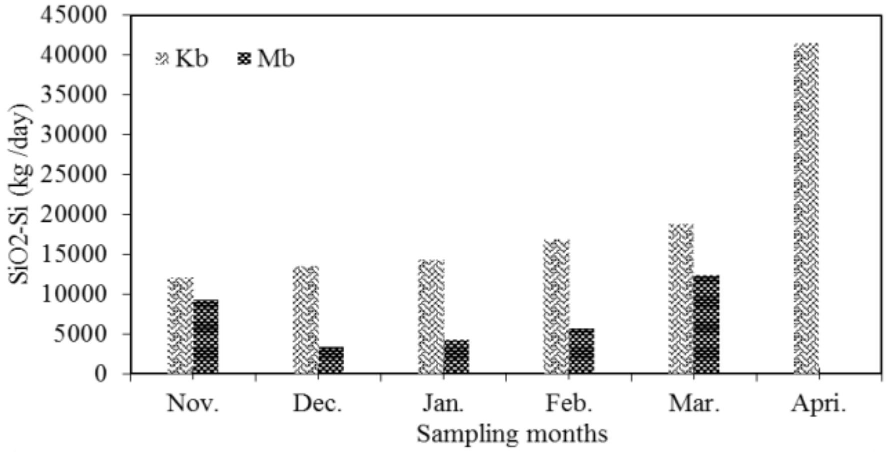

Figure-9. External SiO_2-Si load dynamics from the Meki River (M_b) and Ketar River (K_b) during wet season in 2014 and 2015.

The two major rivers showed systematic variations in SiO_2-Si loads as a function of inflow with higher loads under flow conditions and the lowest loads at low inflows. Therefore flow rate seems parameter that increases external SiO_2-Si load. Similarly, flow rate as a function of nutrient load is reported in temperate lakes in the study by Amisi [21]. The annual external SiO_2-Si load in Lake Ziway is estimated 8938 t yr^{-1} which is closely similar to the external SiO_2-Si load of Lake Kivu, Congo (7200 t yr^{-1}) as reported by Amisi [21].

In conclusion, this study showed the direct entrance of the two rivers, Meki and Ketar, effluents from floriculture and high human interference around korekonch sites of Lake Ziway imposed a significant effect on the high nutrient loads to the lake. Other reports on the same lake have also reported that these factors have a decisive effect on the high nutrient loads to the lake [8, 9, 19]. Comparisons with other lakes Table 4 showed that, theexternal TP and TN load in Lake Ziway is higher compared to some Tropical Lakes like LakeLewisville [22] and Ibirité reservoir [6] however, lower than that of Chaohu Yan, et al. [23] and Mnyanga, et al. [24]. TP loads for Lake Ziway is similar with the TP loads of Lake Kasumigaura [25] and Okeechobee [25] however its TN load is lower than that of the mentioned lakes. TN load of Lake Ziway is comparable with the TN load of Lake Donghu [25]. All lakes listed in Table 4 are under eutrophic conditions.

Table-4. Comparisons of the external nutrient loads (t yr^{-1}) of different lakes.

Lakes	**TP**	**TN**	**References**
Victoria (Rivers total loading)	9270	38828	Mnyanga, et al. [24]
Chaohu	2700	4350	Yang, et al. [26]
Kasumigaura	220	3890	Havens, et al. [25]
Donghu	95	1480	Havens, et al. [25]
Okeechobee	426	5550	Havens, et al. [25]
Lewisville	9.26	57.3	Gain and Baldys [22]
Ibirité reservoir	97	1526	Antonio, et al. [6]
Ziway	208	1817	This study

3.1.9. Analysis of the Relationship of Climatic, Hydrological Factors and Surface Water Quality Parameters

Tables 5 and 6 revealed that there are high correlations of hydrological, climatic, and some selected water quality parameters. Precipitation had strong positive correlations with water level, discharge flow and fair positive correlation with mean air temperature; however had weak negative correlations with rate of evaporation in both dry and wet seasons. Increase in temperature generally results in an increase in potential evaporation largely because the water holding capacity of air is increased [27]. Mean water level and discharge flow showed the strongest positive correlations compared to the other parameters Tables 4 and 5. According to the hydrological cycle, when precipitation increases, it results in accumulation of rainfall in rivers [28]. High water level is followed by increasing flow velocity and discharge [28].

There are positive correlations between precipitation and discharge flow Tables 4 and 5 some other factors within in the lake watershed that influence the precipitation–stream flow relationship include the area of the basin, the slope of the ground, the permeability of the soil, and the area of impervious surface within the basin [28].

DO had weak and strong negative correlations with mean precipitation, water level and discharge flow during the dry season and the wet seasons, respectively Tables 4 and 5. This might be possibly explained by the transportation of different organic and inorganic matter by high discharge flow of rivers which could decrease DO [28].

The nutrient parameters (SRP, TP, TIN and TN) in this study showed strong positive correlations with climatic (PPT and AT) and hydrological (WL and DF) parameters except evaporation for which the correlation was weak negative in the dry and strong negative in the wet season Tables 4 and 5. For instance, these nutrient parameters showed strong positive correlation with discharge flow in both seasons [29]. The nutrient parameters showed strong positive correlations with precipitation. Studies also proved that an increased frequency of heavy rainfall would adversely affect water quality by increasing pollutant loads flushed into the river [28]. In a Similar way,Ventela, et al. [30] reported that high nutrient loads occur in the wet season which is caused by high precipitation. From the study, there were fair to strong negative correlations of TA with the mean water level, discharge flow and precipitation in the dry season and weakly negative correlation with discharge flow and water levels but weak positive correlation in precipitation during wet seasons. Similar findings have been reported by the study by [31]. Their studyfocusedon simulation of future stream, TA under changing deposition and climate scenarios and they found that stream water TA continued to decrease for all scenarios of climate change except where climate is gradually warming and becoming moister.

Electrical conductivity (EC) has strong negative correlations with the mean water level and discharge flow and precipitation.Most scholars agreed that the EC of the water generally increases as the levels of dissolved pollutants (such as nitrate, ammonium, phosphate, sulfate and potassium) increases. The negative correlation of EC with water level, discharge flow and precipitation might be due to dilution effect. Similarly, Zinabu [32] reported that the EC of the Ethiopian Rift Valley lakes generally have lower values during the rainy season than the dry season; which is due to dilution by rain and less evaporation during the rainy season.

4. CONCLUSIONS AND RECOMMENDATION

According to the results of this study, the vertical nutrient profiles of Lake Ziway showed no significant variability, making it difficult to rely on the observed nutrient concentration profiles to understand the nutrient dynamics in the lake. As expected, there is a general trend of higher nutrient load in the wet than in the dry seasons in Lake Ziway for the study periods. The long term effects of high nutrient load and decreased water level in the lake could bring severe negative consequence which might be difficult to reverse unless immediate possible measures are taken on the lake water management, such as a resumption of the natural flow practice around the Lake Watershed and mobilization of overall stakeholders to conserve the lake. There were significant correlations between climatic, hydrological and water quality parameters of Lake Ziway. Precipitation, the mean water level, discharge flow and the mean air temperature had weak to strong positive correlations with nutrients. Negative correlations of DO, pH, EC, TA and SiO_2 were found with all of the hydrological parameters. Since the lake watershed is an intensive agricultural site, it is high time to develop the lake watershed protection management practice in order to reverse control the change.

Table-5. Pearson correlations of climatic, hydrological factors and some water quality parameters of Lake Ziway in dry season.

	PPT	WL	AT	Evp	DF	TP	SRP	TIN	TN	SiO2	WT	DO	pH	EC	TDS	TA
PPT	1	.933**	.430	-.138	.942**	.930**	.965**	.922**	.499	-.562	-.691	-.218	.857*	-.729	-.795	-.829*
WL	.933**	1	.364	-.365	.900*	.879*	.817*	.917*	.647	-.565	-.755	-.288	.640	-.585	-.617	-.669
AT	.430	.364	1	.022	.118	.502	.543	.493	-.377	.322	.290	.128	.510	-.218	-.487	-.794
Evp	-.138	-.365	.022	1	-.140	.027	.045	-.069	-.173	-.093	.198	.178	.205	-.484	-.380	-.135
DF	.942**	.900*	.118	-.140	1	.872*	.861*	.868*	.719	-.781	-.847*	-.195	.725	-.756	-.732	-.635

Note: *. Correlation is significant at the 0.05 level
**. Correlation is significant at the 0.01 level.

Table-6. Pearson correlations of climatic, hydrological factors and some water quality parameters of Lake Ziway in wet season.

	PPT	WL	AT	Evp	DF	TP	SRP	TIN	TN	SiO2	WT	DO	pH	EC	TDS	TA
PPT	1	.540	-.278	-.434	.457	.652	.670	.762	.442	-.240	-.766	-.611	-.729	-.423	-.423	.195
WL	.540	1	-.452	-.930	.763	.620	.864	.766	.777	-.083	-.751	-.464	-.926	-.876	-.873	-.022
AT	-.278	-.452	1	.736	-.921	-.909	-.793	-.801	-.912	.911	.805	-.464	.663	-.034	-.040	.864
Evp	-.434	-.930	.736	1	-.936	-.792	-.942	-.855	-.946	.406	.844	.119	.933	.648	.643	.387
DF	.457	.763	-.921	-.936	1	.936	.956*	.924	.999**	-.700	-.920	.123	-.890	-.356	-.350	-.628

Note: *. Correlation is significant at the 0.05 level
**. Correlation is significant at the 0.01 level.

Abbreviations:-PPT-precipitation; WL-water level; AT-air temperature; DF-discharge flow; Evp-evaporation, TP-total phosphorus, SRP-soluble reactive phosphorus, TIN-total inorganic nitrogen, TN-total nitrogen, WT-water temperature, DO-dissolved oxygen, EC-electrical conductivity, TDS-totals dissolved solid, TA-total alkalinity

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