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The Impact of Climate Change and Anthropogenic Activities on Fisheries of Lake Logo, South Wello, Ethiopia

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Abstract

A study was conducted in south Wello zone in Ethiopia to see the impacts of climate change on the fish production of lake Logo. Purposive sampling and focus group discussions were used to generate data on the major anthropogenic activities, and perception of the beneficiaries of the lake about climate change. Besides, meteorological variables were obtained from the National Meteorological Agency and its correlation with fish yield of the lake was calculated. Major anthropogenic activities were identified as deforestation, poor soil and water conservation activities, intensified agricultural activities, urbanization, existence of alien invasive plant species, overfishing, illegal fishing, increased number of fishers, irrigation, and flooding. Fish catch of the lake over the years happened to be in a declining trend. Respondents perceived erratic rain, hotter temperature, flooding, drought and erosion. The meteorological data revealed that the mean annual maximum temperature showed an increasing trend, while the mean annual minimum temperature showed a decreasing trend over the years. Rainfall was found to have an erratic nature. Annual maximum temperature and fish yield had a positive relationship. Mean annual minimum temperature and fish yield had negligible relationship. Mean annual maximum rainfall had a positive relationship with fish catch. However, the mean annual minimum rainfall had no relationship with fish yield. It is highly recommended to apply a holistic and balanced environmental management systems so as to save the loss of aquatic biodiversity in the lake.

Keywords

Climate Change, Anthropogenic, Lake Logo, Fisheries

1. Introduction

Anthropogenic activities and climate change, which are considered as cause for a shift in long term average of climatic variables for a particular geographical location can affect lake fisheries negatively in a wide range of processes, both directly through metabolic and reproductive processes and indirectly through phenology, prey predators and competitors [1]. Climate change poses significant threats to fisheries in addition to major challenges existing in water bodies, like overfishing, habitat degradation, pollution, introduction of new species, eutrophication, over abstraction of water and so on [2, 3]. Its impacts extend to warming of freshwater ecosystems, on organisms across all levels of biological organization resulting in negative effects on the freshwater fisheries that provide food, employment and recreation worldwide in a severe case, species extinctions and extirpations can happen [4-8]. It may also affect fisheries and aquaculture directly by influencing fish stocks and the global supply of fish for consumption, or indirectly by influencing fish species or the cost of goods and services required by fishers and fish farmers [9]. Temperature and rainfall are major climatic factors that can govern fish production in a given water body. Global temperatures continue to rise in the atmosphere as well as on terrestrial and aquatic systems [10]. Warming of freshwater ecosystems, which is considered as sensitive indicators of climate change

have already been reported in different parts of the world and freshwater taxa may be most at risk of extinction due to climate change [4, 11-13]. Apart from air and water temperature, climate change has also modified the global hydrological cycle, resulting in changes in the timing, type, and intensity of precipitation [14]. Climate changes and their impacts have already been detected in many parts of Ethiopia [15-18]. Lake Logo, one of the highland lakes of Ethiopia, is suspected of facing climate variability and anthropogenic activities, which can have a direct impact on its fish production. This study is therefore, planned to assess and document the possible impacts of climate changes and other anthropogenic activities on fish catch/production.

2. Materials and Methods

2.1. Description of the Study Area

The study was conducted in South Wello zone, Tehuledere wereda of the Amhara National Regional State, Ethiopia. Three kebeles, namely Kete, Godguadit and Gobeya that are bordering lake Logo (11^0 15' N, 39^0 57' E) were systematically selected for this study (Figure 1). The wereda has a total human population of 117,877 [19].

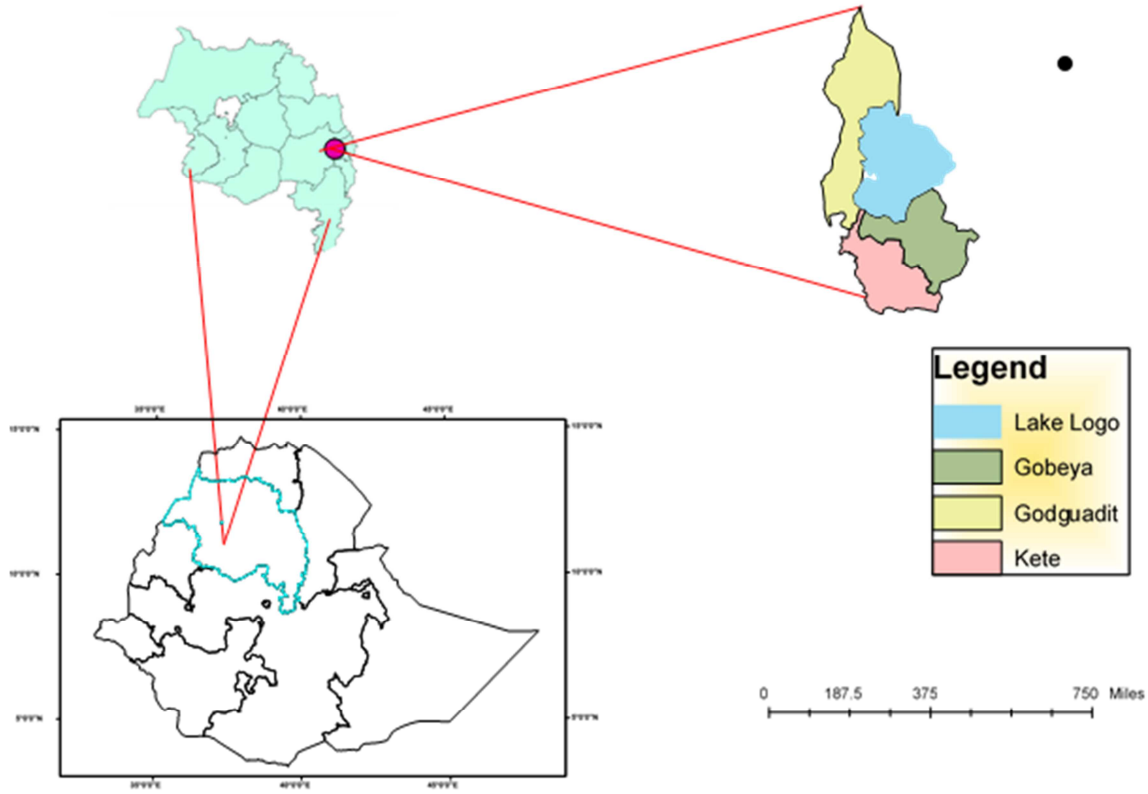

Figure 1. *Map of the study area.*

2.2. Data Collection Methods

Purposive sampling (with structured and semi-structured questionnaire) and focus group discussions were used in order to study the socioeconomic aspects of the respondents, their perceptions about climate change, and fish catch/production of the lake. Purposive sampling was used in order to identify those people who believed to be in a close contact with the lake, and focus group discussions with elderly people applied to obtain data on climate change in relation to what used to be observed in the area before. The climatic data (rainfall and temperature) was obtained from National Meteorological Agency, Kombolcha branch.

2.3. Data Analysis

The data analysis (descriptive statistics, correlations, regressions) was done with SPSS [20]. Mann-Kendal test, which was formulated as non- parametric test for trend detection, was calculated accordingly [21]. The test statistic distribution checks for non- linear trend and turning point [22]. This test was carried out on the climatic data with XLSTAT [23]. Chart showing the trend analysis of fish production and climatic data was sketched with Microsoft Excel [24]. The study area was mapped with ArcGis [25].

3. Result

3.1. Socio-economic Aspects of the Respondents

A total of 189 respondents were participated in this study, of whom 180 (95.2%) of them were males and the remaining 9 (4.8%) were females from Kete (68, 36%), Godguadit (51, 27%) and Gobeya (70, 37%) kebeles. They were grouped into five age groups i.e., 20-30 years (30, 15.9%), 31-40 years (82, 43.4%), 41-50 years (48, 25.4%), 51-60 years (17,

9%), and 61-70 years (12, 6.3%). The marital status of the respondents, which was seen as married, single, divorced and widowed are 153 (81%), 26 (13.8%), 5 (2.6%) and 5 (2.6%), respectively. The number of household members varied from 1 to 11 with an average of 4.39 (SD 1.715). Analysis of the educational status of the respondents indicated that there are illiterate to university/college level (Annex 1), though the dominating group was at elementary level (74, 39.2%). The respondents are involved in different occupations including fishing and farming (137, 72.5%), farming (20, 10.6%), fishing (20, 10.6%), civil servant (8, 4.2%), trading (3, 1.6%), and engaged in home duties as house wives (0.5%). In order to know their familiarity with the study area, respondents were asked about the number of months/years they lived in the area and grouped into four; less than a year (1, 0.5%), 1–19 years (26, 13.8%), 20 –39 years (93, 49.2%), and greater than 40 years (69, 36.5%), which showed that more than 85.7% of the respondents lived in the area for more than 20 years. The time required to travel from the lake to the respondent's house, that is believed to have an effect on the frequency of respondents' contact with the lake, was also among the questions forwarded to the respondents. The result indicated that the distance ranged from 4 minutes (2, 1.1%) to an hour (4, 2.1%), with an average value of 25.3280 minutes (SD 12.57). The findings of this study indicated that 157 (83.1%) of the respondents to possess land ranging from 0.006 to 2 hectares, with an average of 0.46 hectares (SD 0.38) while the remaining 32, (16.9%) do not have a land. The findings indicated also that 155 (82%) of the respondents are involved in fish related activities while the rest 34 (18%) are not. Responding to the question focusing on the type of fish they prefer to catch and their reason, the respondents put the species according to their preference: Accordingly, the preference put in the order of 125 (66.1%), 15 (7.9%), 10 (5.3%), and 5 (2.6%) for *Oriochromis niloticus, Cyprinus carpio, Clarias gariepinus*, and all available species, respectively. The main reasons for such species preferences were price and accessibilities during fishing. Majority of the respondents (145, 92.4%) indicated that the fish catch/production over the last five to twenty years decreased dramatically, but the other 12 (7.6%) reported that there has been an increase in fish production. They were also requested about the amount of fish catch per trip in Kg, for which their answers ranged from 2kg to 50kg, with an average value of 7.61 kg (SD 6.027). They go fishing on average 4.24 times (Standard deviation 1.36) per week to achieve this. Regarding the type of gear used, 154 (81.5%) of the respondents reported that they usually use hand line and gillnet gears for fishing. All of the respondents who said they are involved in fisheries related activities (155, 82%) unanimously agreed that they are not getting any single support from the government that is related to fishing. When requested about the general activities going on in and around the lake, respondents (N=189) mentioned a number of points. 110 (58.2%) of them disagree with the idea of existence of deforestation around the lake but 41 of them (21.7%) indicated that it is a problem in their area. Soil and water conservation activities around the lake are reported poor by 113 (59.8%) of the respondents, though 47 (24.9%) of the respondents rejected and 29 (15.3%) said they don't know about it. Waste water and domestic sewages originating from the nearby tourist sites and hotels and entering into the lake are another problem raised by 128 (67.7%) of the respondents, but there are 40 (21.2%) who disagree and another 21 (11.1%) who said 'I do not know'. Agricultural activities as a threat is mentioned by 164 (86.8%) respondents, even though 8 (4.2%) considered it as a harmless and 17 (9%) said 'I don't know'. 135 (71.4%) of the respondents agreed on the idea that any grass species around the lake is considered as an input to the traditional coffee ceremony and raw material for housing construction in the study area, but 28 (14.8%) of them rejected it and the remaining 26 (13.85) reported that they don't know. Urbanization around the lake is another point which is raised as a recent phenomenon by 115 (60.8%) of the respondents even though there are 51 (27%) who said it is not and 23 (12.2%) that they don't know. The existence of invasive alien plant species in the area was confirmed by 124 (65.6%) of the respondents, but the idea was rejected by 46 (24.3%) of the respondents. There are also 19 (10.1%) respondents who said that they have no idea about its existence. Overfishing in the lake is reported by 116 (61.4%) but rejected by 35 (18.5%) of the respondents, while 38 (20.1%) of them reported that they don't know. The presence of illegal fishing activities in the lake are another issue reported by 116 (61.4%) and its existence denied by 41 (21.7%) of the respondents. 32 (16.9%) of the respondents reported that they don't know. An increase in the number of fishers in the area is reported by 111 (58.7%) of the respondents even though 50 (26.5%) rejected its presence and other 28 (14.8%) replied they have no knowledge of it. 142 (75.1%) of the respondents confirmed that there is an irrigation activity around the lake, 22 (11.6%) of them said there is no irrigation and the other 25 (13.2%) indicated that they don't know. The lake is also serving the community as a watering point for their livestock, a point agreed by 162 (85.7%) and rejected by 12 (6.3%). There are also respondents, 15 (7.9%) who said they don't know. Responding to a question on flooding in the study area, 142 (75.1%) of the respondents said that there is a problem of flooding, while 26 (13.8%) said it doesn't occur and the remaining 21 (11.1%) reported that they don't know. Regarding the lake volume 145 (76.7) of the respondents agreed that it is decreasing, however, this is not accepted by 22 (11.6%) of them, and the remaining 22 (11.6%) said they don't know.

3.2. Respondent's Opinions/Views on Fish Production Status

Responding the question focusing on the status of current fish production vis-à-vis when they first start fishing at the lake, 108 (69.03%) of the respondents agreed on a decreased fish production while the remaining 49 (30.97%) said that there is no change in production. The main reasons given by those who said production decreased varied from pollution

(45, 41.67%), illegal fishing (28, 25.92%), overfishing (22, 20.37%) to increased number of fishers (13, 12.04%). The status of fish production in the coming five years is predicted to decrease by 177 (93.7%) of the 189 respondents, while a person (0.5%) predicted an increase. However, 9 (4.8%) respondents predicted that there will be no change in fish production and the rest of the respondents 2 (1.1%) said they have no idea. As an intervention for the current problems observed in the lake, respondents were requested if they agree on an idea that there is a closed season/time when fishing is not allowed, and 162 (85.7%) agreed, 22 (11.6%) disagreed and 5 (2.6%) said they have no idea about it. They were also requested if they agree on an intervention to limit the number of people who should be allowed to fish, and 161 (85.2%) agreed, 23 (12.2%) disagreed and 5 (2.6%) said they don't know. Limitation on the mesh size is raised as a solution for the ongoing problems in the fishing activity, and 176 (93.1%) respondents agreed, and 13 (6.9%) disagreed. The other point considered was licensing the fishers, and 178 (94.2%) respondents agreed and 11 (5.8%) of them disagreed on this idea.

3.3. Perception of Respondents on Climate Change

In order to interpret the perception of respondents on climate change, a number of points related to climate change have been forwarded to them. The first was if they have noticed any climate change related issues in their environment over the past five to twenty years, and 157 (83.1%) of them said yes we have observed and the remaining 32 (16.9%) said no. Regarding the climate change related issues 60 (38.2%) of the respondents reported to have observed a less rain, 6 (3.8%) more rain, 67 (42.7%) erratic rain and the rest 24 (15.3%) said there was no change in the pattern of rain. Moreover, 90 respondents have reported hotter (57.3%), 9 cooler (5.7%) temperatures while 37 said no change (23.6%) in temperature but 21 (13.4%) said they don't know. The existence of change in frequency of flooding was reported by 108 (68.8%) of the respondents in the study area, even if 49 (31.2%) of them rejected it. The other point was drought, which is reported to be observed in a varying frequency by 126 (80.3%) respondents. However, 31 (19.7%) of them disagree with the existence of drought in the area. Presence of soil erosion in the surrounding of the lake is also indicated by 114 (72.6%) of the respondents, and opposed by 43 (27.4%) respondents. 121 (77.1%) respondents confirmed that intensified agricultural activities are going on around the lake, but 36 (22.9%) of them rejected its existence.

3.4. Fish Catch/Yield

The fish catch/yield data of the lake, though not complete, was obtained from Tehuledere wereda/district (Haik town) and South Wello Zone (Dessie city) Livestock and Fisheries Development Offices [26]. Available secondary data of fish catch/yield was also used from literature [27]. However, it was not possible to obtain fish catch/yield data for the year 2013 in any source, hence a gap has been created in the fish production trend of the lake indicated in Figure 2.

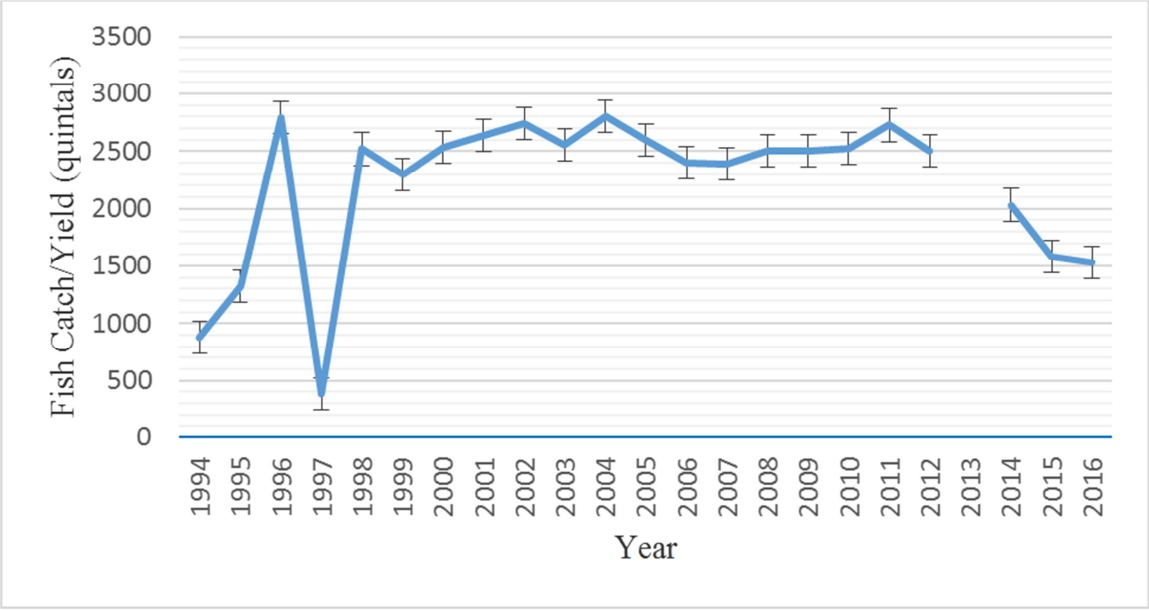

Figure 2. *Fish Catch/Yield (in quintals) of lake Logo, 1994 – 2016.*

3.5. Meteorological Data

In the present study, trend analysis of meteorological data has been done by using non parametric Man-Kendall test. The temperature and rainfall data, which was recorded over 23 years (1994-2016) in order to compare the trend in every 7 – 8 years data were classified into three categories (1994-2000, 2001-2008, and 2009-2016). Results indicated that there was a shift in mean annual minimum temperature towards lower (long term average of 7, 8 and 8 years, respectively). The least mean annual minimum temperature was being 9.9°C (Standard deviation 2.9) in the last class, i.e.

2009 - 2016. The mean annual maximum temperature showed an increasing trend over the years 1994-2016, the last class (2009-2016) being the hottest with a value of 26.7°C and a standard deviation of 1.87°C. However, the total annual rainfall values fluctuated over the years, between 23 mm (Standard deviation 18.5mm) in the first class (1994-2000) and 26.2 mm (standard deviation 20.7mm) in the second class (2001-2008) (Table 1).

Table 1. *Descriptive Statistics (Mean Annual Minimum and Maximum Temperature in ^{0} C, and Total Rainfall in mm).*

Years, categorized into classes	Mean Annual Minimum Temperature					Mean Annual Maximum Temperature				Total Annual Rainfall			
	N	Min	Max	Mean	Std. Deviation	Min	Max	Mean	Std. Deviation	Min	Max	Mean	Std. Deviation
1994-2000	7	6.0	14.3	11.2	2.874	23.4	29.6	26.1	1.753571	0.92	54.44	23.0	18.501
2001-2008	8	5.3	13.9	10.5	2.932	23.8	29.9	26.4	1.731125	1.20	66.05	26.2	20.741
2009-2016	8	5.0	13.5	9.9	2.870	23.7	30.01	26.7	1.867375	1.29	66.73	25.1	21.039

3.6. Mann Kendal Trend Analysis of the Climatic Data

The Mann Kendall Test, which is a nonparametric test used to identify a trend in a series, has the null hypothesis (Ho) "there is no trend in the series", and alternative hypotheses of negative, non-null or positive trend. It was applied to the climatic data (mean annual maximum and minimum temperature, Rainfall) and an increasing trend in mean annual maximum temperature observed especially in the years 2007, 2008, 2012, 2014 and 2015, with P-value (2-tailed) of 0.045, 0.023, 0.033, 0.007, 0.023, respectively at 0.05 significance level. However, a decreasing trend in the mean annual minimum temperature was detected as indicated in (Figure 3).

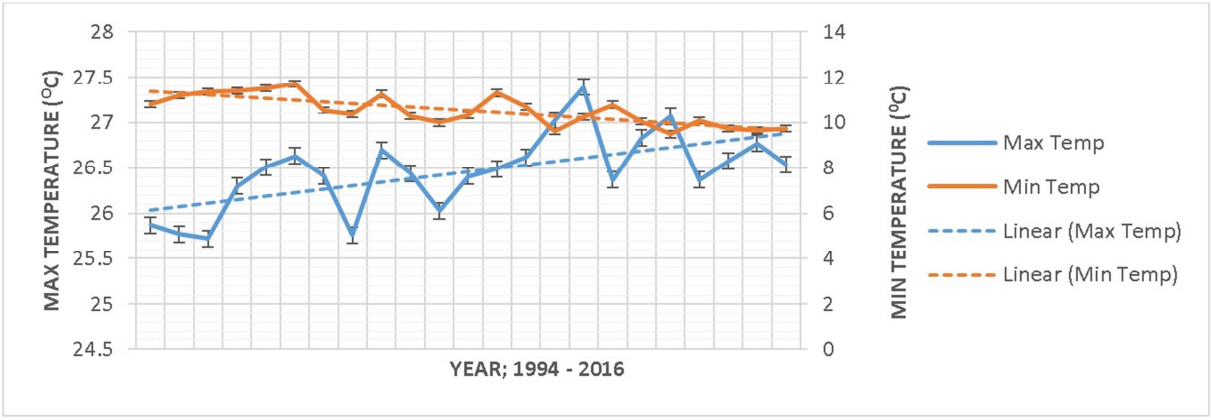

Figure 3. *Mean Annual Maximum and Minimum Temperature.*

The mean annual maximum rainfall data gave no trend. The highest amount of rainfall recorded in 2001 (104.2mm, standard deviation 34.75mm) and the lowest in 2007 (42.4mm, standard deviation 14.5mm). The Sen's magnitude of slope in the Mann-Kendall trend analysis of the rainfall data is given in Table 2.

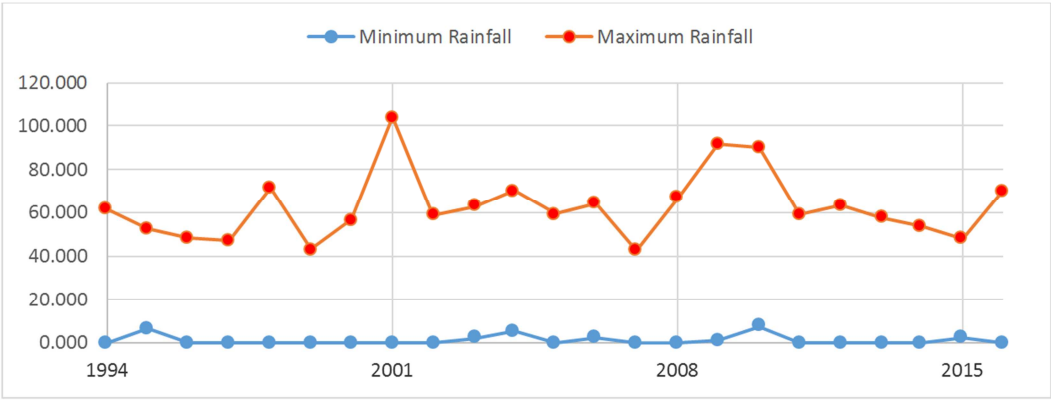

Figure 4. *Mean Annual Maximum and Minimum Rainfall.*

Table 2. *Mann-Kendall trend test of rainfall (Sen's slope).*

Sen's Slope	-0.496	1.471	-1.610	-0.796	-2.311	1.022	0.904	-1.074	1.619	1.483	0.376	-1.842
Year	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005

Table 2. *Continued.*

Sen's Slope	**-1.133**	**-0.208**	**1.193**	**1.993**	**-1.190**	**-0.292**	**-1.145**	**-0.149**	**-0.610**	**0.415**	**1.793**
Year	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016

3.6.1. Maximum Temperature and Fish Catch/Yield

The relationship between fish yield (in quintals) and maximum temperatures is analyzed through correlation with the null hypothesis (Ho), that there is no statistically significant correlation between fish yield and maximum temperature for Lake Logo. The correlation coefficient is found to be 0.197. The significance 2-tailed gives P value of 0.393 which is greater than 0.05, hence Ho retained, that this study doesn't provide enough evidence to conclude that there is statistically significant correlation between fish yield and maximum temperature for the lake. In terms of regression, Ho is that, there is no supported relationship between fish yield and maximum temperature (b=0). The result give R value of 0.197 which shows a positive correlation between the two variables and R^2 of 0.039 meaning maximum temperature explains only 3.9% of variation in fish yield. The regression equation is:

$$Y=a+b*X$$

$$Y= -1836+136.9 * \text{Maximum Temperature}$$

3.6.2. Minimum Temperature and Fish Catch/Yield

Fish yield (in quintals) and mean annual minimum temperature correlation provides coefficient of 0.063. The significance 2-tailed shows 0.787, hence, Ho is maintained since 0.787 > 0.05. The regression analysis indicates R value of 0.063 and R square of 0.004 implying that minimum temperature accounts for only 0.4% of variation in fish yield. The regression equation is;

$$Y = 818.3 + 60.4 * \text{Minimum Temperature}$$

3.6.3. Rainfall and Fish Catch/Yield

Fish yield (in quintals) and a Maximum Rainfall relationship gives correlation coefficient of 0.345. The significance 2-tailed is 0.125, hence, Ho is accepted. The regression result provides R value of 0.345 and R square is 0.119 meaning Maximum Rainfall accounts for 11.9% of variation in fish yield.

$$Y = 1369.9 + 14.051 * \text{Maximum Rainfall}$$

Fish yield (in quintals) and Minimum Rainfall linkages by correlation provide coefficient of -0.044 interpreted as no or negligible relationship. The significance 2 - tailed is 0.850, hence, Ho is retained. The regression coefficients are R value of 0.044 and R square is 0.002 suggesting that only 0.2% of variation in fish yield is explained by Minimum Rainfall.

$$Y = 2266+ -12.746 * \text{Minimum Rainfall}$$

4. Discussion

The fish production of the lake, which showed a dramatic drop in 1997 has been relatively stable from 1998 to 2012. There are two probable justifications for the reduced fish yield in 1997, the first is related to the previous year production whereby 2796 quintal of fish was harvested that might have resulted in loss of parent stock, hence reduced production in 1997 (Figure 1). The second reason for the drop in the fish yield in 1997 might be attributed to improper registration of fish yield of the lake (perhaps recklessness in recording and keeping data) that resulted in unrealistic information (e.g. there was no fish production data recorded for 2013), which is still a major problem related to fish production in many lakes of the country. A dramatic decrease in fish catch/production was reported (in the past five to twenty years) by almost all of the respondents (145, 92.4%), and in the coming five years, production is predicted to decrease even more. The average fish catch per trip is only 7.61kg, with an average fishing time of 4.24 times (standard deviation 1.36) per week. As a result, fishermen have started abandoning the lake and shifting to the other nearby lake Ardibo as an alternative, which will have the same fate, if things remain the same. The increasing human population of the area and the high number of people who are involved in fish related activities even among those participated in this study (155 out of the total 189 respondents) in lake Logo, can indicate the pressure that is being exerted on the lake and hence resulting lower fish production [19]. In line with this, the respondents also raised points, in one way or the other, related to the current decreased fish production of the lake vis-à-vis ownership of a fragmented land (average 0.46ha, standard deviation 0.38) forcing people to look for other alternative economic activities like fishing, not getting any support from the Government. As confirmed by 155 (82%) of the respondents, therefore, overfishing, illegal fishing activities, and ever increasing number of fishers are the major threats of the lake fisheries. As primary measures to be considered to save the lake and the biodiversity it supports, some points were raised to check the respondents' reaction, and 162 (85.7%) agreed on a closed season/time a specific breeding and brooding time in a year where fishing is strictly prohibited, 161 (85.2%) agreed to limit the number of people who fish, 176 (93.1%) agreed on limitation on mesh size, and 178 (94.2%) agreed on licensing the fishers, indicating how willing the respondents are to see the above points to be implemented. A change in climatic conditions of an area can be determined by a number of indicators. Temperature and rainfall are the major variables which can clearly show the existence of relatively different or unusual climatic conditions in a specific area as compared to what was used to be observed. The mean annual maximum temperature of lake Logo is being changed towards the highest values. The Mann

Kendal trend Analysis test proved that there is an increasing trend of this variable in the study area. An increase of 0.6^0 C was observed during the years 1994 – 2016. This increase in temperature has a positive relationship with fish catch/yield of the lake even though the correlation is not statistically significant, and the change in mean annual maximum temperature explains 3.9% of the variations in fish yield observed over the years, and the remaining 96.1% being governed by other environmental factors and genetics. This result is in line with what has been predicted before, in which the temperature across Ethiopia could rise between 0.9°C and 1.1°C by 2030 [28]. In addition, the field survey result revealed that 90 of the total 189 respondents (57.3%) indicated that there has been a hotter temperature in their area in the past twenty years, which is in agreement with the climatic data analysis result. In the same way, an increased temperature of 1.3°C was reported for Lake Tanganyika and an increase in air temperature between 2.2°C and 5.1°C is expected to be observed in the Mediterranean basin [29, 30]. South east Asia already has seen an increase between 0.1 and 0.3°C in the last half of the 20^{th} century, with India showing an increase of 0.7°C during the 20^{th} century and 0.6-1.0°C rise in mean temperature in coastal area of Pakistan since the early 1900s [31]. Studies indicates also that warming of air temperature in tropical Africa by 0.26°C per decade since the 1970s was recorded [31]. On the other hand, extended increase in mean annual maximum temperature may have an indirect negative effect on Ankwarka, the only feeder river of Lake Logo by increasing evapotranspiration. An increase in air temperature increases the rate of evaporation, resulting in water availability being further reduced [33]. It may also have an impact in the reproductive success and biology (maturation, hatching periods…etc.) of the fishes. An increased water temperature stresses fishes and facilitates occurrence of diseases and parasites [33]. Moreover, a decrease in oxygen level and water quality can happen which may result in a reduced survival rate and growth of fishes, in the worst scenarios. In the same way, it has been indicated that increased water temperatures, decreased dissolved oxygen levels and increased toxicity of pollutants, in lentic system, can cause exacerbated eutrophication and pronounced stratification which could alter food webs and change habitat availability and quality [35]. The mean annual minimum temperature showed a drop from 11.2^0 C (standard deviation 2.874) in the first class to 9.9^0 C (Standard deviation 2.870) in the last, a decrease of mean annual minimum temperature by 1.3^0 C from 1994 – 2016. The Mann-Kendall trend analysis test also showed a decreasing trend of this variable. Based on the result of analysis of the fish yield (suspected of unreliability because of the existence of illegal fishing activities which are unaccounted for) and climatic data, the decrease in annual minimum temperature has a negligible relationship with fish catch/yield and accounts for only 0.4% of variation in fish yield over the years. However, such a drop in mean annual minimum temperature can have a direct negative impact as well on the primary producers, hence, resulting in a shortage of feed that in turn would results in stunted growth of fishes. If it goes far beyond the cold tolerance level of fishes, mass kill may happen in the same way as the case of the 1987 fish kill at lake St Lucia, caused mainly by a drop in water temperature and near marine salinities [36]. The mean total annual rainfall fluctuated a lot (erratic rain), the highest (26.2 mm, Standard deviation 20.7) of it recorded in the second class (2001-2008) and the lowest (23.0mm, standard deviation 18.5) in the first class (1994-2000). In the non-parametric Mann-Kendall test, trend of rainfall for 23 years has been calculated, together with the Sen's magnitude of slopes. The outcome revealed the trend of the series for 23 years to be both positive and negative in the study area i.e., -0.496, 1.471, -1.610, -0.796, -2.311, 1.022, 0.904, -1.074, 1.619, 1.483, 0.376, -1.842, -1.133, -0.208, 1.193, 1.993, -1.190, -0.292, -1.145, -0.149, -0.610, 0.415, and 1.793, respectively. For the years 1995, 1999, 2000, 2002, 2003, 2004, 2008, 2009, 2015 and 2016, there is an evidence of rising trend while a negative trend (decrease) is observed for the other years (13 years). However, there is a positive correlation coefficient (0.345) for the mean annual maximum rainfall and fish catch/yield which indicates the existence of strong positive relationship between these two variables, so a change in the amount and/or frequency of rainfall would have a direct effect on the fish production of the lake. The same influence of rainfall on non-estuarine dependent species, mackerel, catch has been reported [37]. After studying the changes in rain fall and rainy days in Ethiopia, it has been reported in the same way as this study's result, there was no trend in the annual total rainfall, seasonal total rainfall or rainy days over central, northern and north-western Ethiopia in the period 1965-2002 [38]. Similarly, no trend in annual precipitation was reported in a French Mediterranean region in the context of climate change [39]. The mean annual maximum rainfall in this study accounts for 11.9% of variations in fish catch/yield, hence its absence or delayed onset will have a profound negative impact on the fish production. The mean annual minimum rainfall has no relationship with fish yield and accounted only 0.2% of variations in fish catch/yield over the years.

The analysis of meteorological data revealed that there are changes in climatic patterns (temperature and rainfall) in lake Logo. The local community's perception from the results of questionnaire based interviews and focus group discussions also revealed that there are changes in climatic conditions, confirming the actual climate change that is happening in the area. Like the result of the meteorological data analysis, which showed an increase in mean annual maximum temperature and existence of erratic rainfall, the local community also perceived the same. Out of the 150 respondents, 90 (57.3%) reported a hotter temperature and 67 (42.7%) of the respondents reported an erratic rainfall in their area in the last 5 to 20 years. However, there is a difference in mean annual minimum temperature shift as perceived by the local community and as derived from the meteorological data. Only 9 (5.7%) of the respondents reported a cooler temperature, but a meteorological data showed a sharp drop in mean annual minimum temperature. A considerable

number of respondents (126, 80.3%) have also indicated that drought has been observed in a varying frequency in their locality, witnessing the increased temperature. A number of climatic change indicator points and anthropogenic activities affecting the lake's ecosystem have been reported by the local community; among them extreme flooding is the first. Land use change, development activities and climate change can be considered as the main cause of flooding in many parts of the world. Climate change induced impacts on land use change and regional development are highly relevant and may even amplify the complex interactions [40]. In particular; cropland, forest, water area, urban, and grassland are more sensitive to these changes than unused land. Majority of the respondents (121, 77.1%) in the study area agreed that there is an intensified agricultural activities going on near the mouth of the lake, exposing the area for flooding during the rainy seasons. The existence of frequent flooding was confirmed by 68.8% of the respondents. Increased deforestation rate, which is also a phenomenon in lake Logo area, can be a cause to increased sediment accumulation rate in the lake affecting the breeding area/site of fishes, lake water level, amount of oxygen…etc., because of increased turbidity which by nature decreases primary production, hence reduced growth of fish and total lake faunal communities (decreased fish biomass of the lake). In the same manner, lake Logo was referred to be threatened by overfishing, catchment degradation, encroachment, siltation and water withdrawal [41]. Moreover, it has been reported that the impact of sediment pollution on biodiversity in Lake Tanganyika, which is similar to the case of lake Logo, caused rapid erosion resulting in high sediment discharge into the lake [42]. Species richness patterns among ostracodes, fish and diatoms showed the level of the impact of sedimentation in such a way that ostracodes and fish were more affected by sedimentation because they require clear water habitats, whereas the benthic diatoms species in the lake are largely cosmopolitan and in many cases also occur in turbid affluent rivers [42]. According to the respondents of the present study, chemical pollution as a result of oil that was being discharged (seven years ago) directly to the lake, from heavy machineries of road construction company's garage near by the lake, is considered to be one of the main causes for the current reduced fish production of lake Logo. This however, requires further water chemistry studies, if at all its negative impacts still exists. In the same manner, pollution is also reported to be a factor that exacerbates the impact of climate change by decreasing dissolved oxygen concentration [43]. Generally, all the non-climate stressors, which are driven by human activities pointed by the respondents in this study have already been reported in the same way by other scholars in different parts of the world; e.g. invasive species, changes in land use, pollution, hydrological regulation, over extraction of water and over exploitation of resources including over-fishing [44, 45, 46, 13, 47, 3].

5. Conclusion

This study identified the major anthropogenic activities, perception of the beneficiaries of the lake about climate change, and relationships between meteorological parameters and fish yield. The following major anthropogenic activities have been identified to be the main threats to lake Logo; Deforestation, poor soil and water conservation activities, intensified agricultural activities, urbanization, existence of alien invasive plant species, overfishing, illegal fishing, increased number of fishers, irrigation, and flooding. Even though there is a shortage/absence of properly recorded data, it has been tried to study fish catch/yield of the lake over the years, which was happened to be in a declining trend. The respondents in the study area perceived a number of climatic change indicator variables, among which, erratic rain, hotter temperature, flooding, drought, and erosion are the major ones. Based on the meteorological data analysis result, the mean annual maximum temperature showed an increasing trend, while the mean annual minimum temperature showed a decreasing trend over the years. Rainfall is found to have an erratic nature. Annual maximum temperature and fish yield had a positive relationship (correlation coefficient = 0.197) though the relation was not statistically significant, and it explains only 3.9% of variation in fish yield. Mean annual minimum temperature and fish yield had negligible relationship, the former accounting only 0.4% of variations in fish yield. Mean annual maximum rainfall, which had a positive relationship (correlation coefficient = 0.345) with fish catch/yield accounts 11.9% of variation in fish yield. However, the mean annual minimum rainfall had no relationship and controls only 0.2% of variation in fish yield. Generally, the study found out the major anthropogenic activities and climatic factors affecting the fish production of the lake.

6. Recommendations

Lake Logo is suffering from the impacts of anthropogenic activities and climate changes. In order to halt the ongoing destruction in and around the lake, there is a strong need of development of appropriate conservation strategies that ensures sustainable use of the resources by considering a balanced approach to sustainably utilize the fish resource and the ecosystem while fulfilling human needs.

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Appendix

Table A1. *Socioeconomic data of the respondents.*

	No.	Percent (%)	Occupation involved in**;	No	Percent (%)	Remarks
Sex			Fishing/Farming	137	72.5	
Male	180	95.2	Farming	20	10.6	
Female	9	4.8	Fishing	20	10.6	
Total	189	100	Civil servant	8	4.2	
Kebele*			Trading	3	1.6	
Kekewa	68	36	Housewife	1	0.5	
Godguadit	51	27	No. of years***			
Gobeya	70	37	< 1 year	1	0.5	
Age Group			1-19 years	26	13.8	
20-30	30	15.9	20-39 years	93	49.2	
31-40	82	43.4	> 40 years	69	36.5	
41-50	48	25.4	Time Required;****	4 min. to 1 hour, Average 25.3 min. (SD 12.57)		
51-60	17	9	Participation in Environmental conservation activities			
61-70	12	6.3	Yes	111	58.7	
			No	78	41.3	
Marital Status			Land possession			
Married	153	81	Yes	157	83.1,	0.006 to 2 ha, Average 0.46 (SD 0.38)
Single	26	13.8	No	32	16.9	
Divorced	5	2.6	Fish species prefer to catch	125	66.1	*Oriochromis niloticus*
Widowed	5	2.6		15	7.9	*Cyprinus carpio*
No. of Household members	1 – 11, Average 4.39 (SD 1.715)			10	5.3	*Clarias gariepinus*
Educational status				5	2.6	All available species
Informal schooling	70	37	Fish catch per trip in kg	2kg-50kg, Average, 7.61kg (SD 6.027)		
Elementary	74	39.2	Average fishing time/week	4.24 times (SD1.36)		
Secondary and preparatory	31	16.4	Govt. help they are getting			
College/University	11	5.8	Yes	34	18	
Illiterate	3	1.6	No	155	82	

Note; * = Locality, ** = Respondent's occupation, *** = No. of years respondents lived in the area, **** = Time required to cover the distance from respondent's home to the lake

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