ISSN 2455-4863 (Online) www.ijisset.org Volume: 5 Issue: 1 | 2019

The Impacts of Climate Change on the Water Quality in Ethiopia

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Abstract: *This study was aimed to review the impact of climate change on water quality in Ethiopia with support of relevant literatures. In this paper the effect of climate change on water quality is clearly stated. According to the study Climate change adversely affects the quality of surface water and groundwater due to the change of ambient temperature which leads to extreme hydrologic events. Climate change affects the physical, chemical and biological properties of water due to their interaction, mainly affects water quality parameters such as temperature, pH, DO, EC and alkalinity which regulate various abiotic as well as biotic activities in the aquatic ecosystem. Surface water quality is highly vulnerable for climate change due to its interaction with air temperature and ground water is less exposed for climate change. Generally this review points out that climate change is the devastating hazardous phenomenon which highly affects the water quality.*

Keywords: *climate change, water quality, water quality parameters, nutrient concentration*

1. INTRODUCTION

Global climate change is that the hottest worldwide environmental issue nowadays and can continue within the future. This is because of its devastative impact in different ways. Global climate change is caused by both natural factors and human induced causes practically by the emission of greenhouse gases. Warming isn't a brand new phenomena, but the warming is occurring today is extraordinary with respect to the rate of change.

According to the fourth International Panel on Climate Change (IPCC) assessment report the mean surface temperature of the globe would likely increase between 2^{o}c to 4.5^{o}c by 2100 with the doubling of atmospheric carbon dioxide. In Africa, the climate change during this century would very likely be larger than the global average (3^{o}c). In Ethiopia, average annual temperature has increased by 1.3^{o}c between 1960 and 2006, average rate of 0.28^{o}c per decade. The average annual temperature is projected to increase by 1.1^{o}c to 3.1^{o}c by the 2060s, and 1.5 to 5.1^{o}c by 2090s (Zeray etal., 2007). Additionally, climate change estimations suggested an increase in rainfall variability with an increasing frequency of both severe drought and flood hazard as a result of global warming (Habtom M, 2009).

Ethiopia is a country having great geographic diversity. The topography varies and ranges from high peaks of 4550m above sea level to a low depression of 110m below sea level. The predominant climate is tropical monsoon, with temperate climate on the highland and hot in low land areas. Usually highlands receive more and relatively stable rain fall than the lowlands. Average annual precipitation of the nation is 848 mm, varying from less than 100mm over the Afar Lowlands in the northeast to 2000 mm in the southwest highlands. Yet, rainfall in numerous territories of Ethiopia is highly erratic with very high rainfall intensity and extreme spatial and temporal inconstancy.

Ethiopia is considered as the water tower of Africa (Meronet al.,2017), due to its abundant water resources on the surface and subsurface despite its erratic rainfall. It has 12 river basins with a yearly runoff volume of 122 Billion cubic meters of water and an expected inexhaustible ground water potential of 2.6 Bm^{3} (Meron et al. 2017) in which75.5 billion m^{3} is in the Nile basin (Gebremeskel and Kebede, 2017).Even if adequate water resources are available, its spatial and temporal distribution remains uneven (Mekonen D., 2006). This is now more pronounced due to the higher rate of population growth, enhanced living standards, extreme water pollution and climate change effects (IGPCC, 2007).

Different Studies shown that the threat of climate change impacts on the water resources of Ethiopia. Habtom (2009)and Gete (2018) indicated that climate change in the upper Blue Nile basin of Ethiopia would occur and would shift and reshape the annual and seasonal climate patterns and variation in rainfall, reduce reservoir yield and cause erratic rainfall. Similarly, Kebede (2017) indicated that an increasing trend of annual maximum temperature and annual future rainfall with seasonal variations was observed in the Baro-Akobo Basin. Currently, variations in frequency, distribution, and intensity of rainfall are the common phenomenon in the country. Also in Tigray region, where the Werii watershed is located, is similarly affected by climate change, which is indicated through recurrent droughts as a result of the erratic and general shortage of rainfall (Araya, 2011; Gebrehiwot and van der Veen, 2013; Hadgu et al., 2013, 2015).

Water is vital need for the existence of life, but its accessibility at a sustainable quality is endangered with the aid of various factors, of which climate plays a leading role. Climate change affects the additives of water cycle such as evaporation, precipitation and evapotranspiration and thus results inlarge-scale alteration in water quality that found in surface as well as subsurface. Powerful climate-water quality connection was found between the ambient and water temperature and chemical content. Efficient rainfall conjointly seemed to put a substantial effect on water quality. Generally, climate change affects the quality of surface water and ground water directly and indirectly.

2. RELATED LITERATURES

2.1. Climate change in Ethiopia

According to the Ethiopian National Meteorological Services Agency (NMSA, 2001) study for 42 meteorological stations, the country has experienced both dry and wet years over the last 50 years. Trend analysis of the annual rainfall show that, there was a declining trend in the northern half of the country and southern Ethiopia, while there is an increasing trend in the central part of the country. However, the overall trend in the entire country is more or less constant.

The study conjointly noted that the minimum temperature is increasing at the next rate than the maximum temperature. Associated with rainfall and temperature change and variability, there was a recurrent drought and flood events in the country. There was also observation of water level rise and dry up of lakes in some parts of the country depending on the general trend of the temperature and rainfall pattern of the regions.

Climate, generally defined by the temperature and precipitation characterizes an enduring average condition of the weather in a given place. Weather can change within a few minutes or hours, but development of changes in climate is over longer time periods, i.e., decades to centuries). The warming of the climate system is undisputable, a statement from the Fifth Assessment Report of IPCC (2014). This is a claim deduced from observations of rising average sea level, prevalent melting of snow and ice and rise in overall average air and ocean temperatures. Precipitation analysis on totally different spatial and temporal scales has been of nice concern during the past century as a result of the attention given to world temperature change by the scientific community.

Assessing precipitation trends and variability is overriding to understanding the variations in house and time. The IPCC (2007) urged that detail analysis is of native precipitation variability. In Ethiopia, many studies are disbursed on rain and temperature trend and variability analysis supported historical information of some chosen weather stations (Baley, 2014, Ayelow et al., 2012, and Hadgu et al., 2013) and over whole the country (NMA, 2007; McSweeney et al., 2008; Koricha et al., 2012; wing et al., 2008). Among the studies NMA (2007) rumored that annual rain remained more or less constant when averaged over the entire country (NMA, 2007). However, mean annual temperature in Ethiopia has raised by 1.3°C between 1960 and 2006, at an average rate of 0.28°C per decade increased (Mc Sweeney et al., 2008). On other hand, Wing et al. (2008) report shows a big decline in main season (June to September) rain was recorded within the southwestern and central parts of Federal Democratic Republic of Ethiopia. Similarly, Baley (2014) findings revealed declined rainfall in central rift valley of Ethiopia. It is terribly tough to notice semi-permanent precipitation trends in Ethiopia, because of the high inter-annual and inter-decadal rainfall variability. Assessing trends and variability in rainfall based on past records helps with better understanding of problem associated with drought, floods and various water uses (Jain et al., 2012).

The highest mean maximum temperatures in the country, about 45^{o}C from April to September and 40^{o}C from October to March are recorded from the Afar Depression in northeast Ethiopia. The other hot areas are the northwestern lowlands, which experience a mean maximum temperature of 40^{0}C in June, and the western and southeastern lowlands with mean maximum temperatures of 35^{o}C to 40^{o}C during April. The lowest mean temperatures, of 40^{o}C or lower, are recorded at night in highland areas over 2,000 masl between November and February (NMSA, 1996).

2.2. Rainfall variability and trend

According to Ministry of water and energy of Ethiopia study (UN-WATER/WWAP/2006/7) trend analysis of annual rainfall show that rainfall remained more or less constant when averaged over the whole country while a declining trend has been observed over the northern half of the country and south western Ethiopia. On the other hand, an increasing trend in annual rainfall has been observed in central Ethiopia. The following figures show the year to year variation of rainfall over the country expressed in terms of normalized rainfall anomaly averaged for 42 stations. Area averaged rainfall anomalies for northern half of Ethiopia, central Ethiopia and south western Ethiopia are also shown respectively. As it may be seen from the figures the country has seasoned both dry and wet years over the last fifty years. Years like 1965 and 1984 were extremely dry while 1961, 1964, 1967, 1977 and 1996 were very wet years.

ISSN 2455-4863 (Online) www.ijisset.org Volume: 5 Issue: 1 | 2019

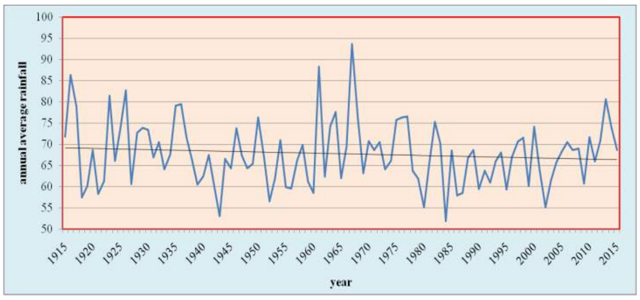

Figure 1: *Trend of rainfall variation (1915-2015)*

2.3. Analysis of trend of temperature variability

In the past years the overall temperature in throughout the country shows an increasing trend for time to time. Based on (UN-WATER/WWAP/2006/7 2006/7) revealed that there has been a warming trend in temperature over the past 100 years. The average annual minimum temperature over the country has been increasing by about 0.7^{0}C every ten years while average annual maximum temperature has been increasing by about 1.1^{0}C every decade. It is interesting to note that the average annual minimum temperature is increasing faster than the average annual maximum temperature.

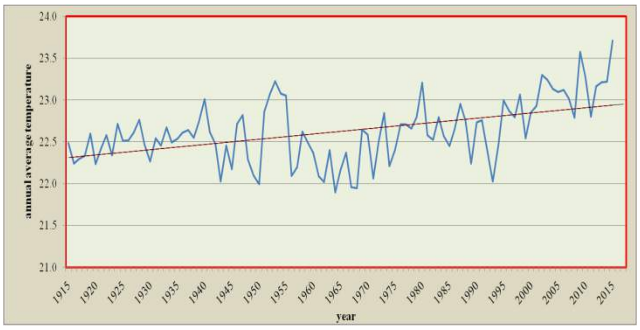

Figure 2: *Trend of rainfall variation (1915-2015)*

3. STUDY AREA

Ethiopia is strategically situated in the northeastern part of Africa continent commonly recognized as "the Horn of Africa". It imparts limit to the North and South Sudan on the west, Somalia and Djibouti on the East, Eritrea on the North and northwest and Kenya on the South. The country lies between the Equator and Tropic of Cancer, between the 30 N and 150N Latitude or 330 E and 480 E Longitude. The total land area is 1,127,127 square km and the area occupied by water bodies is 7,444 sq. km.

The terrain of Ethiopia consists of a diversity Rocky Mountains, flat-toppedplateaus, deep gorges and river valleys. It is erosion, volcanic eruptions and tectonic movements over the ages that have contributed to the nation's diverse topography. The highest altitude is at Ras Dashen (4,620 m above sea level) and the lowest altitude is at Kobar Sink (Dallol depression) (160 m below sea level). A large percentage of the country consists of high plateaus and mountain ranges, dissected by major rivers. As the country is located within the tropics, its physical conditions and variations in altitude have resulted in great diversity of terrain, climate, soil, flora and fauna.

The Great Rift Valley extends across the Ethiopian plateau, which is divided into two by a series of north-south tending escarpments. The escarpments are very steep towards the rift valley on either side. In general, the western high lands have high rims in their western edges, but low lying plateaus and plains to the east and south.

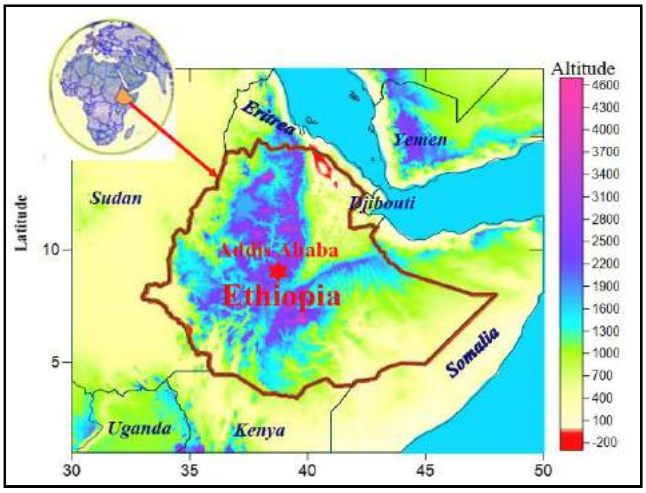

Figure 3: *Attitude and Location map of Ethiopia(source: Seifu Admasu, 2004)*

Ethiopia has four major seasons: Summer 'Kiremet' (June - August); autumn 'Tibe' (September - November); Winter 'Bega' (December -February) and Spring 'Belg' (March- May). However, the coldest month is not always in 'Bega' and the hottest month is not always in 'Kiremet'. Ethiopia lies near the equator where maximum heat from the sun is received. The length of days and nights are almost the same in most regions. There are three principal climate groups in Ethiopia: tropical rainy climate, dry climate and warm temperate rainy climate. Mean maximum and mean minimum temperatures vary spatially and temporally.

The mean annual rainfall ranges from less than about 100mm over the northern parts to an excess of 2800mm over the southwestern parts of the country. The rainfall decreases from the southwest to the northeast. The rainfall is largely concentrated during the summer months of June, July and August.

In general, the climate is moderate, except in the lowlands of the Danakil Desert and theOgaden, which are hot all the year. The highlands are temperate with night frost in the mountains. A single rainy season in the west brings twice as much rain as the wet seasons in the east.

4. RESULT AND DISCUSSION

4.1. Climate Change and Water Resource

Climate variability and change are expected to alter regional hydrologic conditions and results in a variety of impacts on water resource systems throughout the world. Like the other world, the water resource of Ethiopia is highly affected by climate change in terms of quantity as well as quality which results from the extreme hydrological events. The alarming impacts may include changes in hydrological processes such as Evapotranspiration, soil moisture, water temperature, stream flow volume, timing and magnitude of runoff, and frequency and severity of floods, all of which would cause changes in other environmental variables such as plant growth and sediment and nutrient fluxes in to water bodies (Xu, 2000).

Since hydrologic conditions vary from region to region, the influence of climate change on local hydrological processes will likely differ between localities, even under the same climate scenarios. Studies in recent years have been shown important regional water resource vulnerabilities to changes in both temperature and precipitation patterns (Zeray et al., 2007). It is primarily at the regional and local scales that policy and technical measures could be taken to avoid or reduce the negative effect of climate change on the natural environment and society.

4.2. Water Quality Parameters

The quality of water is generally assessed by a range of water quality parameters, which express physical, chemical and biological composition of water (Medudhula et al., 2012). Adak et al. (2002) reported that different physico-chemical parameters of water are very important for effective management of water through their appropriate control. In the understanding of the ecology off resh water systems, analyses of physicochemical parameters are very essential. For instance, DOis a function of temperature, pressure, salinity and biological activity in the water body (Radojevic and Bashkin, 2006). Kaul et al. (1980) stated that nutrients have been used as the most reliable parameter of Lake Eutrophication. According to them a change in the trophic status of a lake is associated with an increase in its nutrient status, thus, an increase in conductivity values indicates a tendency towards higher level of eutrophication. According to Krishnan (2008) nutrients are a governing factor for growth of the aquatic plants but its excess amount causes water pollution. Water quality parameters such as temperature, pH, DO, EC and alkalinity are major factors that regulate various abiotic as well as biotic activities in the aquatic ecosystem (Ojha, 2004; Radhika et al., 2004; Camacho et al., 2015).

4.3. Impacts of climate change on Water Quality

Climate change is one important factor that is known to affect ecosystems. According to previous studies, the water quality can be directly affected through several climate-related mechanisms on both short and long term (Park et al. 2009). This includes impacts on ambient temperature increase, as well as changes in hydrological factors and others (Murdoch et al. 2000). The most immediate reaction to climate change is expected to be in surface water temperatures (Hammond and Pryce 2007). This is due to interaction between surface water temperatures with air temperature, air temperature is a key variable affecting water temperature in most biological systems, strongly influencing water chemistry, biochemical reactions and growth/death of biota (Blackener et al. 2007; Malmaeusa et al. 2006).Increases in water temperatures result in reduced oxygen solubility thus reducing dissolved oxygen (DO) concentrations and DO concentrations at which saturations occurs. Reduced DO concentrations will have an impact on the duration and intensity of algal growth (Cheng Shubo, 2010; Xia, et al, 2014). Several studies point out that higher water temperatures and lower flow rates during summer may cause impairment to water quality directly in surface water and indirectly in groundwater (Bansal J., 2018).However, lower flow and summer may result in increases in nutrient concentrations and biological oxygen demand (BOD) and decreases in DO concentrations in the water body(Xia, et al, 2014) which, in turn, can lead to accelerated algal growth (Shubo, 2010). Under reduced flow in summer, ammonium concentrations decrease due to an increase in the nitrification rate with consequent increase in nitrate concentrations (Xia,et al, 2014).

The extreme events, the frequency of flood which is predicted to increase, also modify water quality through direct impacts of dilution or concentration of dissolved substances. More intense rainfall and flooding could result in increased loads of suspended solids (Lane et al. 2007) and contaminant fluxes (Long field and Macklin 1999) associated with soil erosion and fine sediment transport from the land (Leemans and Kleidon2002). Surface runoff is one of the major causes of water pollution because it carries different pollutants from point source and non-point source.

4.3.1. Impacts on Surface Water Quality

Natural processes influencing water quality include precipitation rate, weathering processes, and sediment transport, whereas anthropogenic activities include urban development and expansion and industrial and agricultural practices. These activities often result in the degradation of water quality (Bansal J., 2018). Seasonal variations in precipitation and surface runoff have a strong effect on river discharge and subsequently on the concentration of pollutants in surface water (Palma et al., 2010). There is increasing evidence that climate change is beginning to have a noticeable effect on lake ecosystems (Solheim et al., 2010). The effect of climate change can vary depending on geographical location, regional climate, land use in lake basins and variations in lake characteristics, such as surface area and depth. Besides the expected effects of changes in temperature and precipitation, more projected frequent extreme events also potentially affect ecosystem stability by enhancing mismatch of species distributions and interactions which lead to greater sensitivity to increasing nutrient load (Bansal, J., 2018.; Jeppesen et al., 2014).

According to the IPCC report by 2100 global average air temperature would rise between 1.4 and5.8 °C and precipitation would vary up to ± 20 % from the 1990 level (Zeray et al., 2007). Beingone of the very sensitive sectors, climate change can cause significant impacts on water resources. According to White head et al., (2009) nutrient loads are expected to increase under climate change and hydrological factors potentially resulting in eutrophication problems. The accumulation of nutrients in the lakes causes the growth of aquatic plants and grass which leads to eutrophication of the water body, for example Lake Alamaya, Lake Tana, and Lake Abaya.

For example, the excessive growth of water hyacinth in lake tana due to high concentration of nutrients and climate change causes water quality problem as well as decrease in water quantity. The weed (water hyacinth) highly spreads at extreme temperature between 28°c-33°c. the water hyacinth protect free circulation of oxygen and decreases DO level in the water which leads to water quality problem.

Extreme flood events carry discharges from point sources like effluents of the industries, waste disposal and waste water treatment facilities and non-point sources such as agricultural, urban surface runoff, and other land uses are the major pollution sources of dissolved and particulate nutrients tosurface water, for example Lake Abaya is one of the turbid water bodies due to runoff. At the same time the spatial and temporal distribution of these contaminants are the results of numerous anthropogenic activities developed in the impacted watersheds. Unfortunately, in many parts of the world, such contributions lead to the development of eutrophication of many water bodies (Ismail and Naji, 2011; Jonathan, 2012).

4.3.2. Impact on groundwater quality

Ground water is a vital component of hydrologic cycle and existing natural resources providing for potential use for different human uses. It is currently a remarkable wellspring of water for human utilization, providing almost 50% of aggregate savoring water the world (WWAP, 2009).Climate change is not expected to only affect input (recharge) or output (discharge), but also to influence the quality of groundwater. Ground water quality is of concern essentially with the various constituents found in water and their relations to water use. In additions ground water comes from rainfall which infiltrates beneath the ground surface into the soil zone, at this process the water will be contaminated with different minerals and trace elements that leads to water quality degradation. in the rift valley region of Ethiopia the ground water is dominantly known by high concentration of salts, fluoride's, iodine, arsenic and other trace metals. The concentration of fluoride increases when the temperature increases. Gizaw (1996), reported fluoride concentrations up to 60 mg/l in hot springs and ground waters from deep geothermal wells (temperatures in excess of 40ºC), and fluoride in excess of 200 mg/l in some of Ethiopia's alkaline, saline lakes (Lakes Chitu, Shalla and Abayata). Generally, climate change affects the ground water quality directly as well as in directly due to the interaction of surface water.

5. CONCLUSION

Climate change refers to future variations of temperature, rainfall, wind and various components of Earth's climate system. it's a modification of climate that is attributed directly or indirectly to human action that alters the composition of the country and/or local atmosphere. The historical climate data from 1915 - 2015 in the country showed variation of temperature and rainfall. The country during this period experienced both dry and wet seasons and years over the last 100 years. The findings indicate that a country will most likely be more vulnerable to climatic change because of its particular climatic, hydrologic, and economic circumstances. At the present time, the water resources of the country were faced challenges from climate change and its extreme hydrologic effect. The variation of temperature and rainfall affects the physical chemical and biological water quality parameters. Increases in water temperatures result in reduced oxygen solubility thus reducing dissolved oxygen (DO) concentrations and DO concentrations at which saturations occurs. The extreme events, the frequency of flood which is predicted to increase, also modify water quality through direct impacts of dilution or concentration of dissolved substances. More intense rainfall and flooding could result in increased loads of suspended solids and contaminant fluxes associated with soil erosion and fine sediment transport from the land. Generally, climate change adversely affects the quality of surface water and subsurface water directly or indirectly.

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