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Review Article

Current Ecological Scenario of some Rift Valley Lakes of Ethiopia: A review

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Abstract

Lake Ziway and Abiyata are found in the Central Ethiopian Rift valley area and forms a complex and vulnerable hydrological system with unique ecological characteristics and well-known for their biodiversity. The most important components of the water resources of the lakes are precipitation and river inflow and the lakes are used for smallholder to large scale agriculture, domestic water use, fishery, industrial water use and associated eco-tourism. Based on these facts different organization has been settling down in the area due to suitability of environmental conditions and other infrastructures. The major threats that are common and need due attention are water use conflict; unplanned land use; pollution; deforestation; urbanization and population migration for the demand of resources; wetland interruption without considering their natural environment and others. Recent abstraction of water for irrigation and soda ash production has drastically changed both the lake level and its ecology. Thus, the issues of appropriate management systems are argent needs for the then development of the resources.

Keywords: *Ecology; Lake Level; Water quantity; Ziway-Abiyata Lake watershed*

Introduction

The Ethiopian rift valley is one of the Great East African rift valleys and also called the Afro-Arabian rift, which extends from Jordan in the Middle East, East Africa to Mozambique in Southern Africa and from Kenya border up to the red sea and divides the Ethiopian Highlands in to the Northern and Southern halve. The Ethiopian rift valley is created by volcanic and faulting activities that formed volcano-tectonic depressions in the floor of the rift, which later becomes lakes [1]. The country has a number of lakes and rivers with substantial quantity of fish stocks. There are 10 major lakes with a total area of 7400 km2 and 7185 km of major rivers [2]. Many artificial water bodies are also stocked with fish for fishery [2]. Most of the lakes are located in the Ethiopian Rift Valley depression, which is part of the Great East African Rift Valley system.

The natural resource of the Rift Valley has immense economic and cultural values. These lakes are considered to be centers of biodiversity, corridors of countless migratory birds as well as in ameliorating the effects of drought and protein shortage for the population in the region [3-5]. The ERVLs have also proved their importance to scientific research [6]. The lakes in the rift valley used for multiple purposes like irrigation, fishing, domestic water supply, transportation, recreation and supply of fresh water to Lake Abiyata (eg. Lake Ziway) through the out flowing Bulbula River.

The Central Ethiopian Rift valley is characterized by a chain of lakes and wetlands with unique hydrological and ecological characteristics. Increasing population pressure and economic developments put an increasing claim on the precious freshwater resources. Until recently, water from the lakes mainly supported agriculture and commercial fishery, domestic use, industrial soda extraction and recreation, while the lakes and surrounding wetlands supported a wide variety of endemic birds and wild animals. The interaction of this is its own advantage and disadvantage and therefore the objective of this paper is therefore to assess the current environmental situation of Lake Ziway and Abiyata.

General Overview of the Lakes

Lake Abiyata and Ziway is relatively shallow lakes, located in the Ziway-Shala basin in Central Ethiopia (Figure 1). The climate is humid to sub humid in the highlands and semiarid in the rift valley. The mean annual temperature is around 15°C in the highlands and 20°C in the rift valley. The average annual rainfall ranges from 1150 mm in the highlands to 650 mm in the rift floor [7]. The main rainy season is between June and September and the dry season lasts from October to February [8].

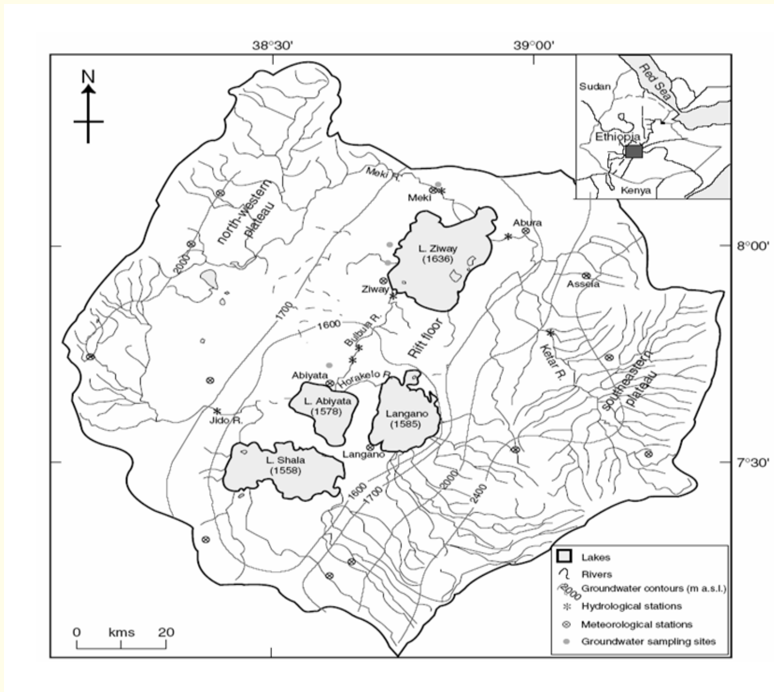

Figure 1 : *General location map, topography, and drainage pattern of the Central Ethiopian Rift lakes [8].*

The Lakes are both located in mid-altitude regions. Mean annual rainfall varies in the valley from approximately 500 mm (weather station at Lake Langano) and 650 mm (weather station Lake Ziway) to 1150 mm on the plateau. There is no clear trend (increase or decrease) in rainfall characteristics in the region during the last 40 years [9]. Highlands flanking both lakes intercept most of the rainfall in the region. Open water evaporation (lake evaporation) is in the order of 1800-2000 mm per year. Actual evapo transpiration depends on the land use and availability of water and varies between 700 and 900 mm per year [10].

Ecology

The CER valley is well-known for its biodiversity. The vegetation of the area is characterized by Acacia open woodland, now extensively overgrazed, while deciduous forests occupy the ridges and slopes [11]. Human pressure in the Rift valley is very high and the natural flora and fauna is disappearing rapidly. Increased human activity has resulted in open vegetation which is floristically poor and uniform. Population pressure during the last three decades has resulted in the conversion of natural vegetation, overgrazing of natural grasslands, removal of natural shrub for fire wood and clearing of forests for construction material. As a consequence of these changes in land use, vulnerable sloping areas in the area face increased erosion and depletion of nutrients required for vegetative growth. Increased erosion and resulting sedimentation elsewhere can have a major impact on the regional hydrology [12].

About 50% of the bird species in Ethiopia have been recorded in the Rift valley area. Current commercial fisheries cover most of the countries freshwater resources, including Lake Ziway which is one of the most intensively fished lakes in Ethiopia with an estimated annual production of 3000 t in the 1960's [10]. More recent data suggest that production has been reduced due to human influences. In Lake Abiyata there is no significant commercial fishing.

Water quantity

As indicated in figure 2, there are different sources for the lakes including rainfall. But due to different infrastructural suitability the water resources are currently over-exploited, especially due to irrigation and water extraction.

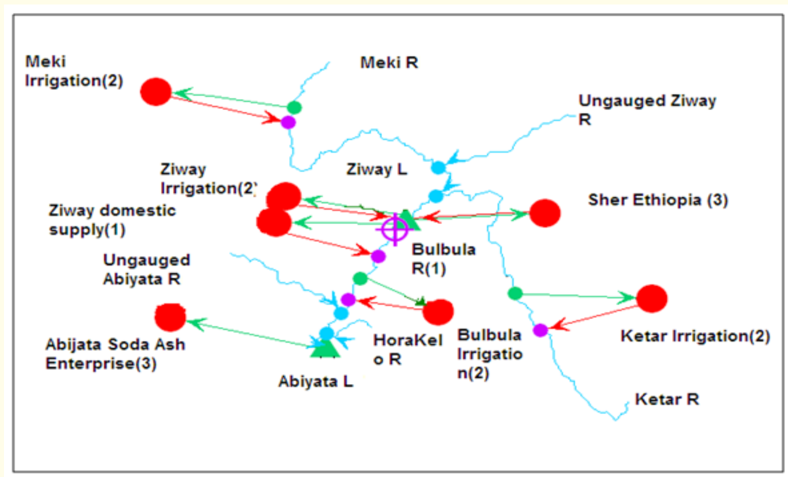

Figure 2: *Different water sources of Ziway-Abiyata Catchment.*

Lake Ziway and Abiyata are situated in a closed basin. The major incoming rivers for Lake Ziway are Ketar and Meki River (Figure 2). The Meki River discharges the runoff from the plateau west of Lake Ziway. The Ketar River discharges the water from the eastern and south-eastern plateaus. The catchments of these two rivers cover 5610 km² [8]. A major part of the water inflow of Lake Abiyata originates from Lake Ziway through the Bulbula River. Hence, both lakes are hydrologically connected. Considerable less water is discharged from Lake Langano to Lake Abiyata through the Hora kelo River (Figure 2).

The groundwater system in the Ziway/Abiyata catchment is largely determined by the East African Rift Valley, being a major structural feature with a width of 40-60 km and at places a depth down to 1000 m below the flanking plateaus. The groundwater flow is to the lowest point of the Ziway/Abiyata catchment. It was estimated that groundwater contributes approximately 20% of the total inflow into Lake Abiyata [11].

In general, the groundwater is largely controlled by the rift faults it is a major source for domestic water supply, supplementary to surface water of Lake Ziway.

Lake Ziway

The maximum depth of the lake is 9 m, while the average depth is only 2.5 m. The volume of the lake is approximately 1.1 billion m^3 [13]. Lake Ziway contains fresh water, which principally originates from the two incoming rivers, being the Ketar River and Meki River (Figure 2), and rainfall. Both rivers are perennial rivers. They used to have substantial base flows, which have, however, reduced as a result of uncontrolled water abstractions for small-scale irrigation schemes in the upper reaches of the catchments.

The major portion of the inflowing water from the Ketar River and Meki River returns to the atmosphere by evaporation. Only a small portion discharges through the natural outlet towards Lake Abiyata. It is estimated that under natural conditions approximately 10% of the inflowing water (110 million m-3) discharge towards Lake Abiyata through the Bulbula River [14]. The present discharge is, however, reported to have decreased [15].

Lake Abyata

The maximum depth of the lake is 13m, while the average depth is 7.6m. The volume of the lake is approximately 750 million m^3 [13]. Hence, the average depth of Lake Abiyata is approximately three times the depth of Lake Ziway [16]. [10] Tenalem. (2004) report the level of the lake has decreased after 1985, when water abstractions and land use changes increased dramatically. Since the 1970's the lake level has dropped about 5m [9]. Water consumption for domestic use and smaller irrigation schemes along the Bulbula river is unknown but [8] Legesse., *et al.* (2004) estimated total extraction at about 59 million m^3, which is about 38% of the mean annual Bulbula river discharge recorded over the past 30 years. Annual water use for soda extraction from Lake Abiyata through an artificial evaporation basin is estimated at 2.25 million m^3 [8] and 15 million m^3 [10].

Water quality

Lake Ziway

It is a fresh water lake, having a low salt concentration. The total dissolved solids range between 200 and 400 mg l^{-1} [17,18]. The total dissolved solids in the Bulbula River which is outflow from the lake and Meki River are similar (300-400 mg l^{-1}), the salt concentration of the water in the Ketar River is less than 200 mg l^{-1} [18]. The pH is neutral to slightly alkalic. The predominant ions in the Meki and Ketar River are calcium and bicarbonate.

The Bulbula River and Lake Ziway have a relative abundance of sodium and bicarbonate. The different water composition can be explained by the geology of the area. The main source for sodium is the dissolution of sodium containing rock minerals. The contents of silica in the river water is, relatively, elevated (30-50 mg l^{-1}). This is, most probably due to the dissolution of feldspars in the weathered ignimbrites. The silica concentrations in Lake Ziway are lower than in the rivers, which can be explained by the relatively low temperature of the lake compared to the temperature of the inflowing rivers and the extraction of silica by organisms for shells and skeletons [18].

Evidence from other lakes in Ethiopia show that the longer term impact of human induced changes like deforestation increases the risk of flooding such as Hawassa Lake or even complete degradation of the lake like in the case of Haramaya [19]. According to [3] Zinabu Gebremariam. (1998) population pressures and urbanization significantly affect cities near lakes and the lakes themselves were among the greatest potential causes of change in water quality and quantity (e.g. L. Ziway). Hence, the current population pressure around the lake, cause pollution and water scarcity. The 'clear water' condition reported seven decades ago is now visibly replaced by a brownish turbid Lake Ziway. Different factors have been forwarded that could change the trophic state of a lake (e.g. nutrient, waste disposal, morphometric features, other biota, turbidity etc).

Lake Abiyata

Lake Abiyata is a saline, soda-type lake which is typical for the Rift Valley. The water in Lake Abiyata has a pH of around 10 [14,4]. Being the terminal lake, Lake Abiyata is subject to evaporative conditions, resulting in increased salinity and increased alkalinity. The increase of alkalinity is a result of the disequilibrium between bicarbonate and earth-alkali elements. Hot springs that discharge directly or indirectly into the lake also contribute to the elevated salinity and alkalinity. The salinity ranges between 12000 and 24000 mg l^{-1}. However, the salinity may have increased further since 1994 (comparison: sea water has a salinity of approximately 35000 mg l^{-1}) [17].

The salinity and alkalinity of the lake have been increased by a factor of 2.6 and 4, respectively, between 1926 and 1991 [17]. The seasonal fluctuation may only account for a factor 1.6 in alkalinity. The increase of salinity with a factor 2.6 cannot be explained by the evaporative process of the terminal lake. The salinity in 1926 and 1938 was around 8000 mg l^{-1}**.** The present salinity is more than 2000 mg l^{-1}. Over 75 years evaporation can account for a salinity increase of a few grams per liter only [20]. Increased extraction of water along the Bulbula River and extraction of water for soda ash production are most likely the main causes of this increase in salinity.

Mean Monthly River Discharge

Meki River

On the average monthly basis of long data, maximum flows occurs in August with a minor secondary peak in April and minimum flows between December and February (Figure 3). As it can be observed from the hydrograph of the Meki River, discharge at Meki town near the confluence to Lake Ziway, during December-January the river bed may dry. It can be said that the base flow of the river dry out during the savior dry years which is impossible to depend on runoff the river throughout the year for irrigation and domestic water supply. The total annual contribution of the Meki River to the Lake Ziway is 277.81MCM [15].

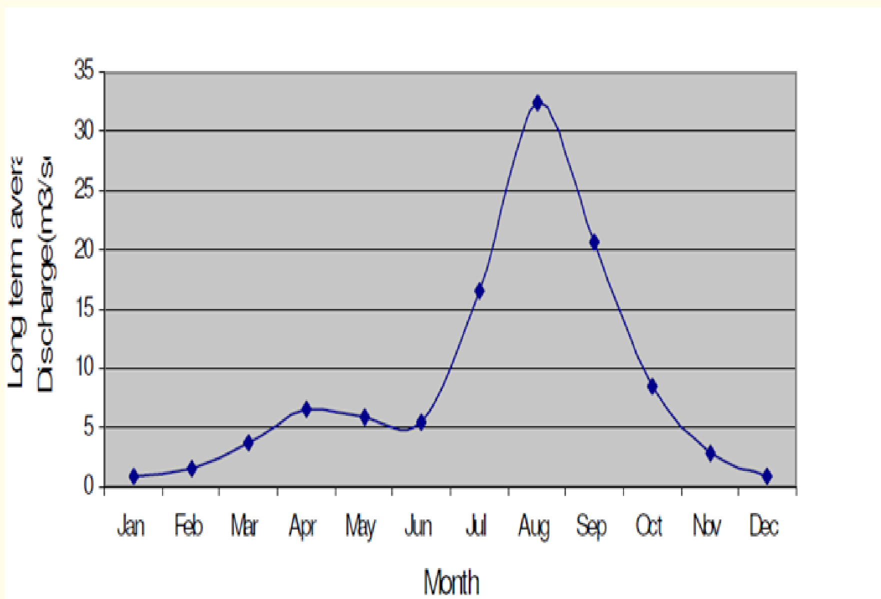

Figure 3: *Mean Monthly Meki River Discharge.*

Katar River

The Katar with a large catchment of 3400.km^2 rises in Arsi High lands to the East of the lake. Consequently, the gradient of the river is generally steep throughout its course to Lake Ziway, and it is often deeply incised up to 50 m below the surrounding. As it observed by [10] Tenalem. (2004), the hydrograph of the river at two stations, the discharge measured at Katar Fitee (sagure) is greater than the discharge at Katar Abura and the difference is very pronounced during the high rainfall months of the country i.e. August (Figure 4). This due to an abstraction either through the faults or evapo-transpiration between the two observation stations and equal discharge measurements observed at the two stations in the month of October & November. The annual inflow of the Lake Ziway from the Katar River is 401.3MCM gauged at Abura (confluence to Lake Ziway) and 562.20MCM gauged at Katar fite at mid of Katar River [15].

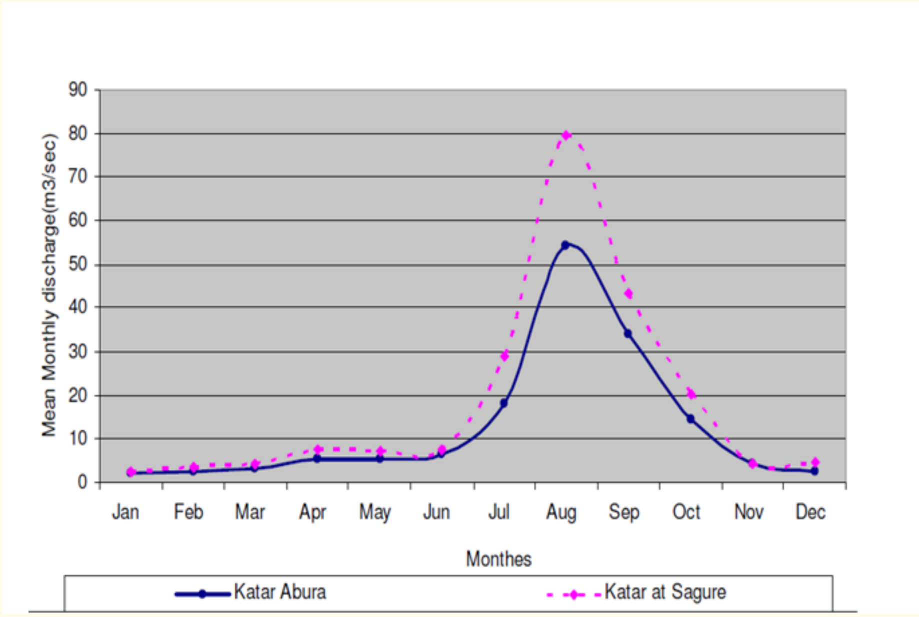

Figure 4: *Comparision of Mean monthly Katar river discharge at Abura and Sagure [15].*

The overall Katar River discharge is appears to be decreasing. Although the overall pattern of flow of Katar is similar to that of the Meki, the peak flow are more clearly defined, the base flows in the dry seasons are rather higher and it seems most unlikely that the Katar would never dry up.

Bulbula River

The entire outflow from Lake Ziway is carried by the Bulbula River, which flows south for 30 km before discharging to Lake Abiyata, a terminal lake. Except periodically during the wet season, the flow in the Bulbula usually derives entirely from Lake Ziway. However, the Bulbula does have significant catchments of its own with ephemeral tributaries from the east occasionally contributing to the flow.

The Mean Monthly Bulbula River Discharge at Kakarsitu in actual sense the discharge at Bulbula town should greater than the discharge at Kakarsitu during the rainy seasons since there are many ephemeral rivers between the two stations which drains the runoff to the river from the catchments of Bulbula river. However on figure 8, discharge observed at Kakaritu station is greater than measurements taken at Bulbula town throughout the observed years. This is due to the river loss, abstraction, along the stretch of the river and evaporation even during the rainy seasons. The total mean annual outflow from the Lake Ziway measured at Kakarsitu and Bulbula Town is 161.33 MCM and 127 MCM respectively [15].

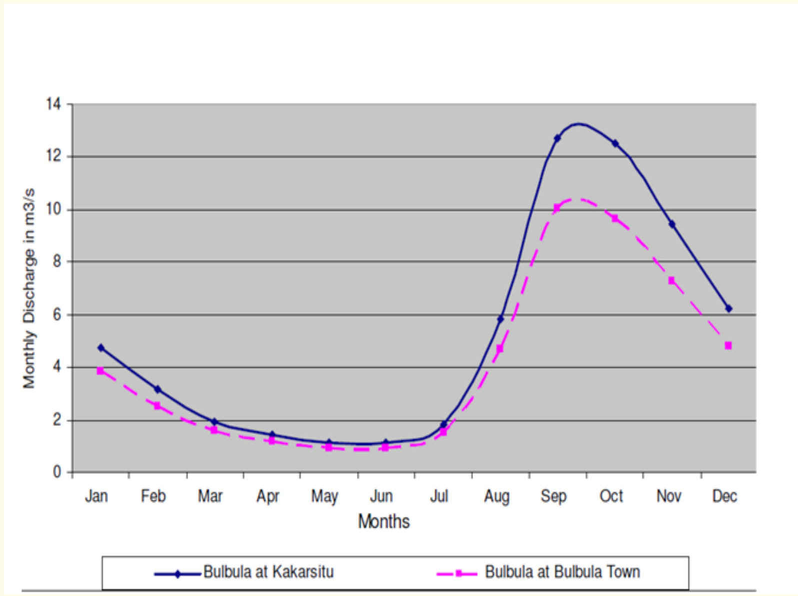

Figure 5: *Mean Monthly Bulbula River Discharge at Kakarsitu and Bulbula town [15].*

Lake Level

The physical regimes and the levels of lakes are governed by many natural and anthropogenic factors. Climatic, hydrological and man-induced factors control lake levels in many ways [21-23]. Changes in lake levels result from a shift in the water balance or the net steady-state removal of water via various surficial and subsurface processes. In particular, closed terminal lakes fluctuate significantly in response to climatic changes but tend to maintain equilibrium between input and output [24].

Some of the Ethiopian Rift lakes, particularly those located in a terminal position, have undergone significant lake level changes since the 1970s. In the last few decades, the ever-growing utilization of water resources in the rift and adjacent highlands has induced salinization of irrigation fields and lake level changes [25,7].

Lake Ziway

The level of the lake is not regulated. The annual fluctuation of the water level of the lake was reported to be 0.8 m [26], but larger fluctuations, up to 2 meters, may occasionally occur [10]. Current total surface water abstraction from the Ketar River and Meki River is in the order of 28 million m3 per year, which is used for irrigation [10]. Due to the sedimentation problem of the lake the mean annual water level time series of Lake Ziway seems an increasing. However, after an adjustment made for the sediment deposited in the lake using the bathymetric surveys of 1976 by Over Land Seas Development and 2005/2006 by Ministry of Water Resources the annual water level of time series of the Lake is decreasing.

Lake Abiyata

The level of Lake Abiyata is influenced strongly by the input into Lake Ziway, which transfers water through the Bulbula River. However, the monthly gains of Lake Abiyata to storage are meager and less than 5% in most dry months. There was a considerable reduction in the volume of Lake Abiyata in 1985 and 1990, amounting to about 425 x 106 mJ, or 51% of its present volume [24]. The reduction of the level of Lake Abiyata is reflected in the changes in its ionic concentration [27].

In general the level of Lake Abiyata fluctuates according to the precipitation trends in the highlands. However, the recent drastic decline in its level and the increase in salinity coincide with the time of large-scale water abstraction. The current and future uncontrolled water abstraction will have obvious environmental repercussions, which are thought to bring grave consequences to the lacustrine environment in the foreseeable future. Changes in Lake Abiyata should be perceived jointly with the abstraction of water for irrigation around Lake Ziway.

Impact of decreasing Lake Ziway level on Lake Abiyata

If all the proposed irrigated areas are developed, the estimated annual water requirement will be 365.9MCM. This would result in a 0.822m reduction in the level of Lake Ziway which is -0.24m below the level to which the Bulbula River is flowing to Abiyata [9]. Ultimately this will lead to a drastic reduction in the level of Lake Abijata and drying up of the feeder Bulbula River which is the source of domestic water supply (Figure 6).

Figure 6: *River Bulbula as domestic users.*

The apparent decreasing of Abiyata Lake level and Bulbula runoff is parallel this shows that the Abiyata Lake level depends on the Bulbula runoff which spills out from Ziway Lake.

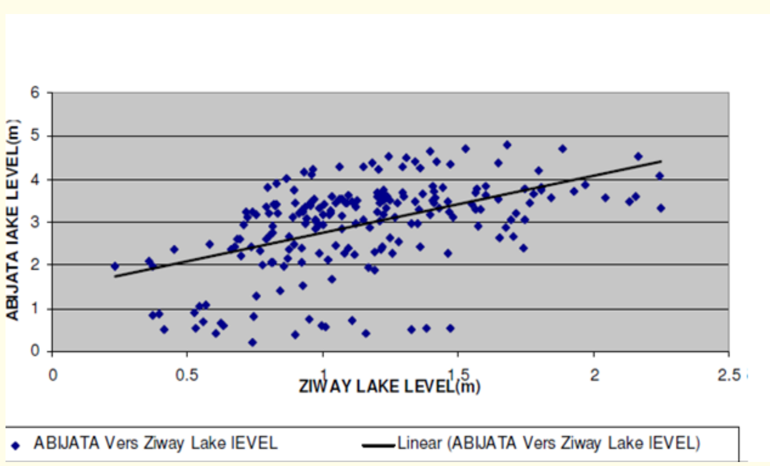

Figure 7: *Abiyata verses Ziway Lake Level [15].*

Hence, the level of Lake Abiyata is influenced strongly by the input into Lake Ziway, which transfers water through the Bulbula River. Therefore, any decrease of the inflowing water discharged from Lake Ziway to Lake Abiyata will have a direct environmental impact. Changes in land use and increased water abstractions along the Bulbula river have resulted in lower inflows to Lake Abiyata and, consequently, lower water levels, and increased lake water salinity and alkalinity (Figure 7)[28].

Conclusion and Recommendations

This review work addressed the current situation of the lakes, with a special focus on the potential impact of Lake Ziway for Lake Abiyata. Surface water extraction for irrigation, industrial and domestic use is continuously increasing in the CER valley. The limited available data indicate that the limits of sustainable water extraction have been reached.

The abstraction scenarios in the Ziway-Abiyata Lake watershed affect not only the Abiyata Lake but also the domestic water users along the river since it is the only fresh water available in between the two lakes. Hence, based on all these the following recommendation is forwarded: Detailed resource assessment of water should be done, including sustainable abstractions and the special variability of water quality and quantity; Measures should be taken to reduce loss of water due to evaporation in lakes; Since the large trees are almost cleared out for the fuel woods and charcoal production, any wind breakers are almost absent. Hence growing tall trees on the windward side of the water bodies is recommended which act as wind breakers and hence reduce evaporation; Develop program of erosion control measures in the basin; Give environmental education for the community through various associations, organization, schools and etc.; and irrigation activities should combined in an integrated approach to sustain future development activates based on the lake water resources.

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