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Floodplains Suitability Assessment for Fish Culture in Central Rift Valley of Ethiopia

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Abstract Though highly important in food and nutritional security of Ethiopia, fish production which usually comes from lakes and reservoirs is low irrespective of the natural and manmade water potentials of the country. Significant amounts of depressed land areas in the Central Rift Valley of Ethiopia are filled with flood during the rainy season, which stay for seasons or year round, where the use of these floodplains for fish production was not assessed in the country. The current study was aimed to assess suitability of seasonal and annual floodplains for fish production in Central Rift Valley of Ethiopia. Water physical-chemical and biological parameters of Sango, the seasonal and Hara-Bata, the annual floodplains were compared with that of Lake Ziway and its wetlands between October, 2017 and January, 2018. Nile tilapia (*Oreochromis niloticus*) fish were also stocked into the floodplains at different times. Data were collected and analyzed to compare the mean values among the water bodies and against the parameter's optimum requirements for fish culture. Water level in the study sites varied, which decreased at faster rate in both floodplains where the Sango lived only for eight months. Water turbidity, conductivity (µS/cm), water temperature, plankton diversity and abundance were significantly different ($P < 0.05$) among the four water bodies. Water pH and conductivity of all the four water bodies were within the optimum range for fish culture. Water turbidity of the floodplains was very high to limit tilapia culture. Diversity and availability of phytoplankton was lower in the floodplains than in Ziway Lake and its wetland; however, zooplankton abundance is higher in Sango floodplain. Nile tilapia thrives in Ziway Lake and its wetlands; survived and reproduced in Hara-Bata though stunted in size but not survived in Sango floodplain due to higher turbidity levels. Water turbidity, depth and durability affect fish culture in the floodplains. Hence, watershed management to minimize erosion and silt load, plantation and conservation around the periphery of the floodplains and dredging refuge area for fish in shallow plains are recommended if fish production is intended in the floodplains.

Keywords Fish culture; Flood plain; Rift valley; Water quality

Introduction

Ethiopia, the land-linked country in East Africa, has a fishery potential with significant amounts of water resources, including around 30 main lakes (7 740 km^2), reservoirs (1 447 km^2), small water bodies (4 450 km^2), and rivers with total length of 8 065 km, distributed in 12 distinct major drainage basins (Tesfaye and Wolff, 2014). Many other dams, including the recently completed Ethiopian Grand Renaissance Dam (GERD), with 1 874 km^2 area and 74 km^3 volume capacity (IPoE, 2013) were added to the resource, making the stagnant water bodies covering over 15 509 km^2 surface area. The country harbors about 200 fish species, of which 194 are indigenous and six are exotic (Desalegn and Shitaw, 2021). Aquaculture is a potential agricultural sector to produce fish which contributes in food security and income generation for poor communities in Ethiopia though the country is producing fish from capture fisheries, mainly from lakes and reservoirs (Abegaz, 2015) which has annual production potential of 94 500 t (Tesfaye and Wolff, 2014). The sustainability of fishery in Ethiopia has been challenged by illegal fishing, use of non-recommended fishing gears, overfishing, lack of/poor fishery management practices, no/poor fish stock assessment activities and limited institutional, technical and financial capacities in the sector (Desalegn and Shitaw, 2021). Aquaculture development in the country looks important in order to increase fish supply and decrease the pressure on capture fisheries.

Fish culturing practice has been started in the country recently using excavated ponds where the farming was challenged by seed and feed limits among other factors. In spite of the infancy of fish culture practice in the country, the business has not been intensified to commercial level because of many factors, of which supply of farm inputs and lower fish prices are the main limits. Moreover, water availability and its required quality parameters for fish growth are the pre-requisite conditions for the establishment of fish farm in a given area. Considering Nile tilapia as a fish of interest in Ethiopian Aquaculture, most of the lowland areas in the country qualify the optimum water temperature required by the fish for faster growth. However, the lowlands have limited access to water even for domestic water use and for agricultural activities except in periphery of main rivers like Awash with its irrigation systems and the Lakes.

There are temporary and permanent floodplains in Central Rift Valley which are inundated with flood water during rainy season as a result of excess rain from surrounding micro-watershed areas and overflows to main drainage system when filled. These floodplains are naturally lower plains formed with different sizes, as large as 60 to 100 hectors, and stay as "Pseudo Lake" for several months after the rainy season or stay year round without drying. Similarly, manmade water harvesting ponds are also found in several villages in the Central Rift Valley but with shorter life spans. These floodplains are very important to the local community for domestic uses, drink for animal, and irrigation purposes while the water harvested in ponds are mainly used for domestic uses (personal observation).

Floodplains are critical spawning and rearing habitats for many large-river fish species (Burgess et al., 2012) where fish in main water bodies move into floodplains when water level rose and move back to the main water body as water level falls in the floodplains (Lyon et al., 2010) if there is no barrier for fish movement. Floodplains can also be used for fish production in aquaculture by applying some aquaculture managements (Akter et al., 2013; Lamtane et al., 2017). However, the water quality parameters of the floodplains may vary based on the nature of the floodplain and that of the watershed. With this regard the floodplains found in Central Rift Valley of Ethiopia can also be potential areas to produce fish for food at extensive fish farming level with minimum farm inputs. Volume of water in most of the floodplains of CRV decrease gradually and totally dry out after few months in the dry season; duration depends on the size of the water, volume of water pumped out for irrigation and weather conditions.

Water quality and food availability in the floodplain definitely differs with the flood magnitude, its volume, morphology and weather conditions of the floodplain (Weilhoefer et al., 2008). Fish growth and production in the floodplains are also affected by these factors in the site (Lamtane et al., 2017). Water quality in the temporary floodplains and its potential for fish farming has not been documented in Ethiopia. This study was aimed to test water quality parameters in the temporary and permanent floodplains of the Central Rift Valley in terms of fish production possibility in the floodplains, in addition to its usual uses. The purposes of the study were to assess and compare water Physical-chemical and biological parameters of the Sango and Hara-Bata floodplains with that of Ziway Lake and its surrounding wetlands and to stock Nile tilapia into the floodplains and evaluate its survival and growth performances.

1 Results and Discussions

1.1 Depth of the water bodies

Volume of water in the study areas increase (Figure 1) during the rainy season (June-August months), and reach maximum levels during late September - early October. The depth of the water during the maximum levels varied among the water bodies.

Hara-Bata floodplain was the deepest of all with estimated maximum depth of over 12 m at full level and estimated average depth of 6 m. The flooded surface area of Hara-Bata was as large as over 100 ha at maximum level and gradually shrinks after the rainy season. Decrease in depth of Hara-Bata started from October and decreased by average depth of 80 cm every month (Figure 2).

Figure 1 Water level increasing in Hara-Bata (left), Sango (center) and Ziway wetland during August and early September 2017, end of the rainy season
Note: Red circles indicate reference marks to measure water level decrease

Figure 2 Water level decreases in Hara-Bata floodplain as dry season progresses
Note: Red arrow indicates maximum water level

The maximum depth of Sango floodplain was 1.95 m at full water level. Rate of decrease in water level was also high at Sango floodplain (Figure 3) where the average monthly decrease was 60 cm when the excavated canal allows water outflow to Katar River. The fast decrease in water level happened until level of water in the floodplain became lower than that of the level of excavated outlet canal. Later, gradual decrease in water level was caused by infiltration, evaporation and consumption by animals and local people for construction and other purposes which was measured to be 25 cm each month.

Figure 3 Water level decrease in Sango floodplain as dry season progresses, October to January

Generally, all the water bodies decreased in depth after the rainy season. The rate of decrease was so fast in Hara-Bata floodplain followed by Sango floodplain (Figure 4). Level of Ziway Lake and its wetland was relatively slow in rate of decrease because of its stable lake floor near to ground water table. Inlet rivers also supply water to the lake even after the rainy season to stabilize water level in the lake. In contrast to Ziway Lake, Hara-Bata floodplain inundated large area of grazing and farmlands during the flooding period of the study time; flooding to this maximum level happens once in five to ten years according to the local inhabitants' explanation. The infiltration rate of Hara-Bata floodplain was high to facilitate the decrease in its water level. Decrease in water level of Sango floodplain was also fast when the flood overflows via the excavated canal. But after the water level decreased below the level of the outlet canal, the rate of decrease in water level was slower than that of the Hara-Bata as a result of saturated floor of the Sango floodplain to minimize infiltration loss.

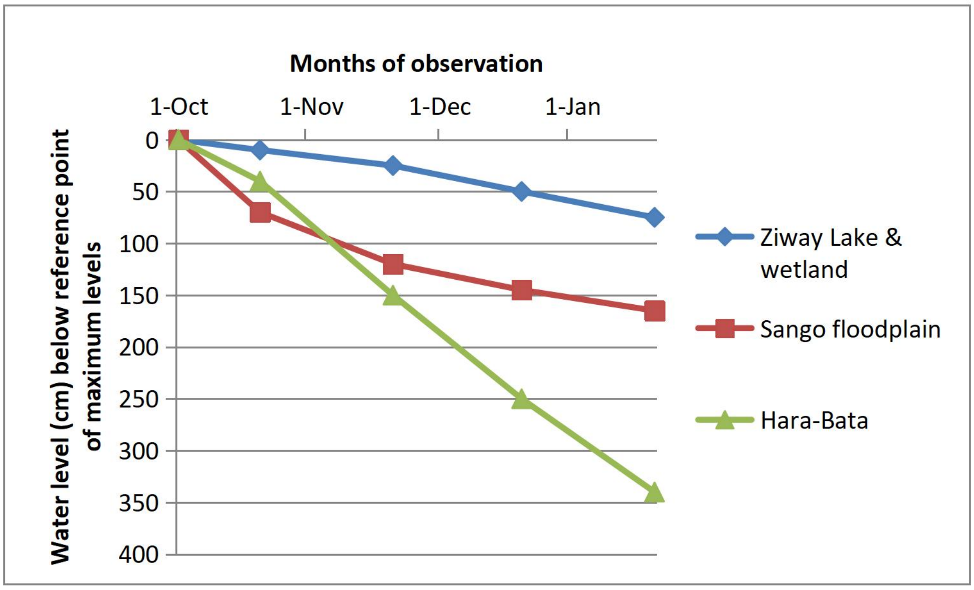

Figure 4 Water depth decrease in Ziway Lake and the surrounding floodplains after rainy season

Eventually, Sango floodplain and Ziway wetland were almost dry at the beginning of February (dry season) because of their shallow depth. Hara-Bata floodplain shrinks to lower area and can pass to the next rainy season without drying because of its higher depth. But, in some years when annual rainfall decreases and river-overflow doesn't happen to flood the area, Hara-Bata dries out during dry season according to information from the local people. However, Lake Ziway is stable except the fluctuation in depth between end of dry (minimum) and end of rainy season (maximum).

1.2 Water turbidity in Secchi depth

Transparency of water is one of the water quality parameters determining fish productivity of the water bodies. Transparency of water is limited by turbidity level which was measured in Secchi depth. Water turbidity is caused by suspended solids which usually consist of silt, stirred up bottom sediment, decaying plant matter, or sewage treatment effluent. The turbidity affects depth of light penetration for photosynthesis. Moreover, higher turbidity due to silt and stirred up bottom sediment affect the activity of fish gill in breathing (Rowe, 2002).

The average Secchi depth readings of each of the four water bodies during the observation months were not so varied within their own system. Sango floodplain tends to remain highly turbid followed by Hara-Bata and Ziway Lake, while Ziway wetland remained relatively clear (Figure 5; Table 1). The average Secchi depth reading was as shallow as 3 cm (873 NTU) in Sango floodplain, followed by Hara-Bata floodplain and Ziway Lake; and as deep as 18.6 cm (72.4 NTU) in Ziway wetland (Table 1). The water transparency level (Secchi depth) was significantly different (P=0.00) between all the four study sites. The higher turbidity (lower transparency) of Sango floodplain resulted from erosion of the immediate micro-watershed areas of surrounding farmlands bringing silt mass to the plain. Moreover, the Sango is shallow and found on flat plain without windbreak that the water was restless with waves and currents agitating the silt making the floodplain deadly turbid. Hara-Bata was deeper and relatively found in low-lying area that the silt got time to settle and turbidity became relatively lower.

Measured in Secchi depth, water transparency range from 30~80 cm is good for fish health; 15~40 cm is good for intensive culture system and < 12 cm causes stress (Bhatnagar et al., 2004). According to the authors, the observed water transparencies at Sango and Hara-Bata floodplains were in the stressing range for fish. Sango floodplain with average Secchi depth of 3 cm was too turbid and by far below the optimum transparency limit for aquaculture.

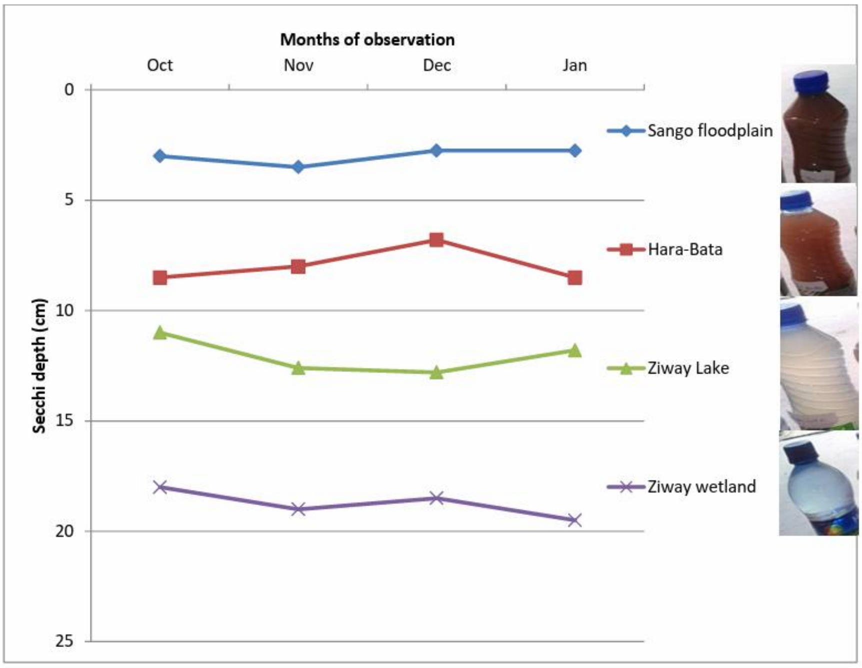

Figure 5 Water transparency as measured in Secchi depth (cm) in Ziway Lake and the surrounding floodplains over four observation months

Table 1 Average monthly measured Secchi depth (cm) of the water bodies

Water body	N	Mean Secchi depth (cm)± Std. Error
Sango floodplain	12	3.00^{a}±0.18
Hara-Bata floodplain	12	7.95^{b}±0.40
Ziway Lake	12	12.05^{c}±0.41
Ziway wetland	12	18.75^{d}±0.32

Note: Means followed by different letters are statistically significant at significance level of 0.05

1.3 Water temperature

Water temperature ranged between 13 °C at Sango in December and 26 °C at Ziway Lake in January. Temperature stratification of water column was observed in Hara-Bata, and to a lesser extent in Ziway Lake and Ziway wetland but not in Sango floodplain. Temperature stratification was related to the depth and liability to wave caused by wind to mix-up the column. Diurnal temperature change of the water was observed in all the water bodies except Hara-Bata.

Average water temperature of Sango, Hara-Bata, Ziway Lake and Ziway wetland during the four months of observation were (16.00±3.05) °C, (19.33±3.05) °C, (20.88 ±3.66) °C and (18.92 ±3.09) °C, respectively. The average temperatures were not significantly different among the four water bodies. Overall average temperature decreased from October (21.0 °C) to January (17.0 °C). Temperature of the shallow floodplain, Sango dropped below 18 °C in the months of December and January where this lower temperature influences the growth and reproduction of Nile tilapia (Mirea et al., 2013).

1.4 pH of the water bodies

Monthly average pH value of the four water bodies was analyzed (Table 2). The mean pH value of the four water bodies during the four months of observation was not significantly different (*P*>0.5).

Table 2 Monthly average pH value of water in the four water bodies

Water body	N	pH value Mean± Std. Error
Sango floodplain	12	7.78 ±0.209 34
Hara-Bata floodplain	12	7.69 ±0.237 45
Ziway Lake	12	7.91 ±0.139 37
Ziway wetland	12	7.77 ±0.137 68

The similarity in pH of the water bodies was attributed to their position in the same watershed area which receives more or less similar watershed effect. Rainfall, being the source of the water for the floodplains, is slightly acidic with pH value from 5 to 6.5. However, pH of the floodplains was in the alkaline range above a value of 7 (Table 2) because of the eroded soil and dissolved ions. Suitable water pH for aquaculture generally range from 6.5 to 9.0 (Boyd et al., 2016) while the suitable range for *Oreochromis niloticus* is wider, from 5.5 to 9.0 (Rebouças et al., 2016). The observed pH range of 7.7 to 7.9 in the current study was within the suitable range for growth and reproduction of tilapia and other fish species.

1.5 Electric conductivity (EC)

Electric conductivity (EC) is an index of the total ionic content of water and is the measure of the water's ability to pass an electrical current. Lakes and floodplains carry suspended and dissolved solids including sodium, magnesium, calcium, iron and aluminum ions. Conductivity affects fish's osmotic pressure maintenance and therefore the optimum conductivity for fish production differs from one species to another. In freshwater environment, conductivity values in lakes and streams are typically found to be in the range of 50~1 500 µS/cm (Bhatnagar and Devi, 2013). Conductivity can also be used as indicator of primary production (chemical richness) and thus fish production.

Lower conductivity of (149.75±13.80) µS/cm was recorded in Hara-Bata floodplain, followed by Sango floodplain, Ziway Lake and Ziway wetland (Table 3). The conductivity level of Hara-Bata, Ziway Lake and Ziway wetland were not significantly changed during the four months of observation. However, the conductivity of Sango floodplain changed from 228.0 µS/cm in October to 565.0 µS/cm in January. This significant increase in conductivity of Sango floodplain was due to the decrease in volume of water through evaporation and infiltration losses, leaving the ions of the shallow plain highly concentrated (Figure 6).

Table 3 Conductivity (EC in µS/cm) of the water bodies during four observation months

Months	Sango floodplain	Hara-Bata floodplain	Ziway Lake	Ziway wetland
Oct., 2017	228.0	133.5	450.5	533.4
Nov., 2017	326.6	147.1	477.4	535.5
Dec., 2017	334.2	151.4	454.8	566.5
Jan., 2018	565.0	167.0	471.0	550.0
mean± Std. deviation	363.45 ±142.81	149.75±13.80	463.43±12.83	546.35±15.33

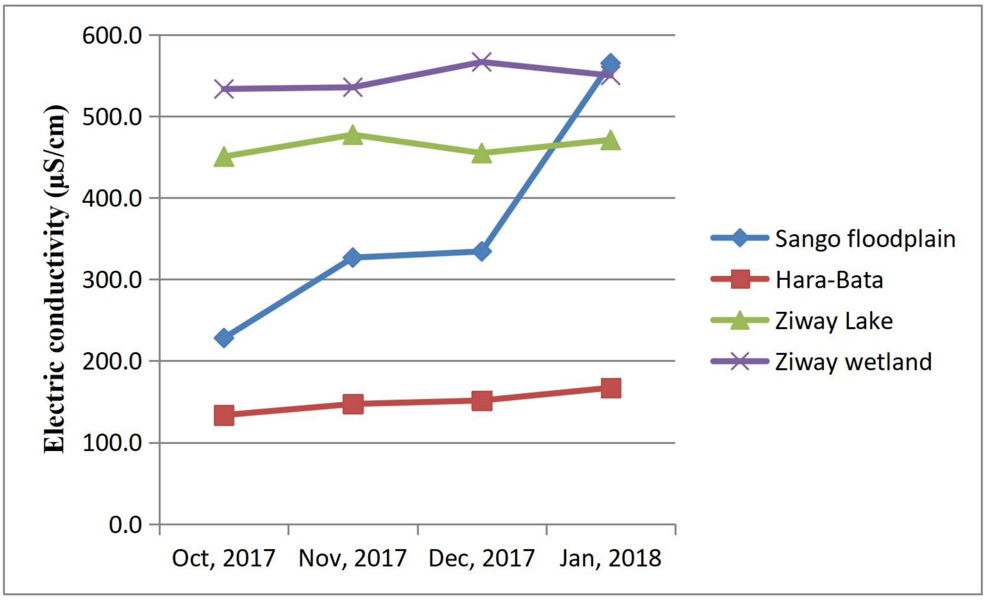

Figure 6 Electric conductivity (EC) of the water bodies during four months of observation

The mean conductivity of the water bodies were significantly different (P = 0.00) where conductivity of Hara-Bata floodplain was significantly lower than all the three water bodies and Sango floodplain was significantly lower than that of Ziway wetland. The mean conductivity of Ziway Lake was not significantly different ($P > 0.05$) from Ziway wetland and Sango floodplain.

Higher conductivity of water in the wetland was due to shallow water depth having high water interaction with ground and surface runoff from surrounding watershed as a source for ions concentration (Yimer and Mengistou, 2009).

Conductivity of water in the studied water bodies (Table 3) lies within the range for freshwater lakes and streams (Bhatnagar and Devi, 2013). Water conductivity of between 150 and 500 μS/cm is ideal for fish culture (Reviewed in Makori et al., 2017) while Stone et al. (2013) put wider range of conductivity between 100 and 2 000 μS/cm for fish ponds. Hence, the conductivity of Sango floodplain, Hara-Bata floodplain and that of Ziway Lake and Ziway wetland was within suitable range for fish and other aquatic organisms.

1.6 Plankton diversity and abundance

1.6.1 *Phytoplankton*

Samples of water taken from the off-shore water column from depth of 0 to 50 cm were examined in lab under microscope and consisted of diversified phytoplankton species. The major algal colonies found in Ziway Lake were *Microcystis spp.*, *Pediastrum spp. Cryptomonas spp.*, *Scenedesmus* colonies, *Peridinium spp., Closterium*, *Euglena*, and others. Ziway wetland consisted filamentous algae and few colonial algae at lower frequency than the lake. Sample of Hara-Bata and Sango were also investigated for phytoplankton. Both floodplains were deficient in phytoplankton abundance. Hara-Bata consisted of colonial algae, microcystis at lower frequency of appearance while Sango consisted of *Scenedesmus* and *microcystis* algae also at lower frequency of appearance in the water samples. Sample of Sango was so muddy that it was hard to isolate and identify organisms from the suspension. The lower diversity and concentration of algae in the floodplains was the high turbidity levels which limited light penetration for photosynthetic activity. The situation in the floodplains limited fish survival and growth especially filter feeders like tilapia.

1.6.2 *Zooplankton*

Water samples from Ziway Lake were dominated by rotifer species (five to eight organisms per drop of sample), followed by ciliates and few copepods while samples from the wetland consisted rotifer species and few ciliates, both at lower frequency of appearance than that of the lake. Water samples from Hara-Bata consisted rotifer species (two to three organisms per drop of water sample) while other zooplanktons were not observed. However, the water sample of Sango consisted of several hundreds of rotifers and dense bacterial colonies in the highly turbid water samples; floodplains normally support diversified species of rotifers (Sharma, 2005).

Zooplankton species diversity was high in Ziway Lake and less in the floodplains, while abundance, especially for rotifers was high in Sango floodplains. Decomposition of mass of organic matter in Sango at shallow aerated depth has supported the bacterial and rotifer biomass to dominate the plains. Hundreds of migratory birds were filtering in the shallow floodplain of Sango during, the dry season in December and January.

Rotifers are primary freshwater invertebrates (Balian et al., 2008) consisting over 2 000 species and are natural food for fish especially at young age. The floodplains and Ziway Lake and its wetland can harbor zooplankton that can support fish.

1.7 Fish stock in the floodplains

Selected strain of Nile tilapia fish species from Batu Fish and Other Aquatic Life Research Center was stocked into the locally isolated and idle Hara-Bata floodplain in February, 2015, following the request from the Livestock development office of Dugda district. The fish were established in the site three years after stocking and became a tilapia seed source site for fingerling distribution in the Aquaculture development of the region. Though the water quality at Hara-Bata was stressful, *Oreochromis niloticus* was able to thrive and reproduce to large quantity providing hundreds of thousands of fingerlings in a year. Length distribution of tilapia sample showed that the tilapias of Hara-Bata ranged from 7 cm (the lower size caught by the seining net) to maximum of 19 cm, with average of 12.1 cm TL out of over 2 600 fish caught by the seine. The maximum size limit shows that it is less likely for the fish to grow fast to size of over 20 cm. The retarded growth of Nile tilapia in Hara-Bata was likely due to the turbidity stress and limited production of phytoplankton in the turbid water system.

For the tilapias stocked at Sango floodplain, The destination water, Sango was shallow, found on a flat field without any windbreak in the surrounding and no macrophytes in the water to retard water waves which agitated the water. As a result, the water in the floodplain was deadly turbid (Secchi depth of 3.0 cm) to support the life of tilapia. About 25% of the tilapia was found dead (Figure 7) one day after stocking into the floodplain, and mortality continued to the second, third and fourth days, when it was decided not to stock fish anymore.

Figure 7 Water turbidity in Sango floodplains measured by Secchi disc, fish stocking into the floodplain and fish death after stocking

Silt and suspended sediment at levels of hundreds to hundreds of thousands mg/L is acutely lethal to fish while sub lethal effects are manifested in the tens and hundreds of mg/L sediment (Rowe et al., 2009) as it was fatal in the current stocking at Sango floodplain. Though the fish survived, the high water turbidity observed in Hara-Bata was not suitable for Nile tilapia to attain optimum growth rate. The highest water turbidity and the shallow depth of Sango cannot support culture of *Oreochromic niloticus* unless the water turbidity is minimized by filtering periphery vegetation and water depth as a refuge corner for fish is created.

2 Materials and Methods

2.1 Study sites

Ziway Lake (Figure 8) is located in the Ethiopian rift valley between 7° 52’ to 8° 8’ N and 38° 40’ to 38° 56’ E at an altitude of 1 636 m above sea level with maximum length of 32 km and maximum width of 20 km (LFDP, 1997). The lake having an area of 434 km^2 and shore line length of 137 km with maximum and mean depth of 8.95 m and 2.5 m, respectively (LFDP, 1997). The lake has two feeder rivers, Meki River from Northwest and Katar River from East side, and has one outlet river in its southern part, the Bulbula River which flows into Abijata Lake.

There are several temporary (last for about three seasons) and permanent (stay year round) floodplains (Figure 8) of different sizes; water of which stay from few months to few years in the plains within Ziway Lake's drainage system. Among the floodplains, Hara-Bata and Sango floodplains (particularly Chalalaka in Sango) are larger and durable to stay for several months to several years without drying.

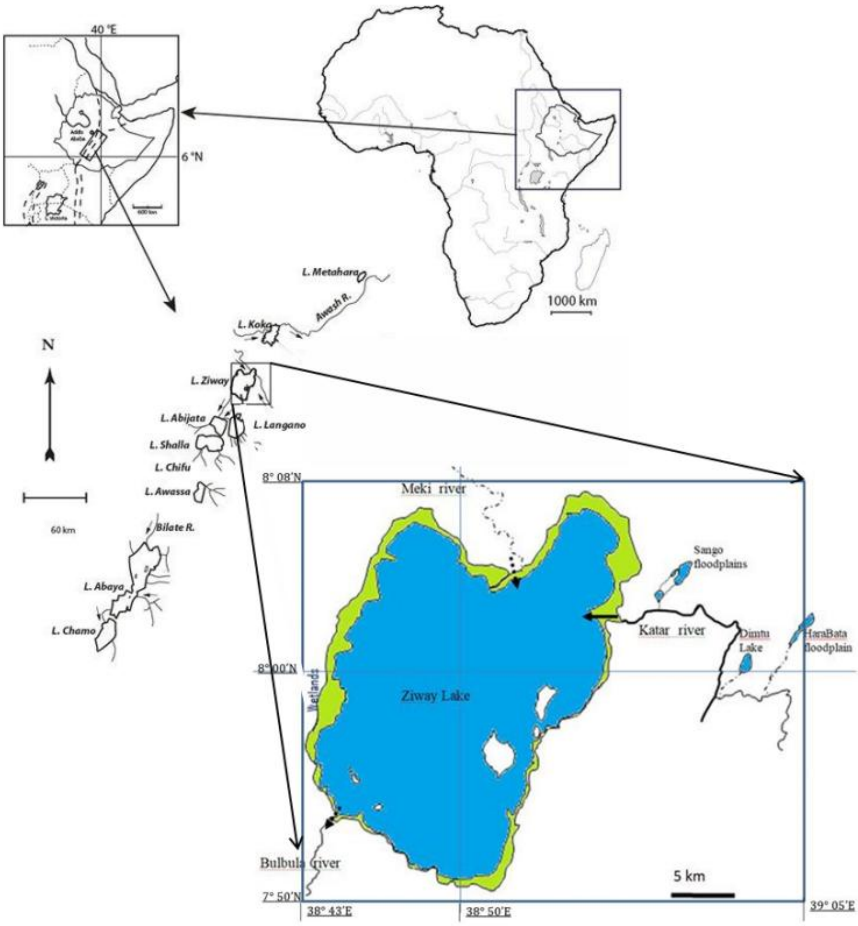

Figure 8 Ziway Lake, surrounding wetlands, inlet and outlet rivers and associated floodplains

Hara-Bata is administratively found in Arsi Zone, Ziway-Dugda ditrict, between Deneba and ToyaLamaan kebeles at altitude of 1 730 m above sea level. It is an isolated area of depression with the water staying year round (at least for the last eight years) forming flood-filled "lake" of about 25 ha at low water level and usually over 100 ha at full water level, but also can totally cover the entire depression of 260 ha as in year 2020. Origin of the flood is Haraxa River which comes from Arsi highland and flowing west wards to join Katar River, which finally ends up in Ziway Lake. Following heavy rain in the upstream, usually in late rainy season, the river floods out of its bank, runs North wards and inundates large area of Hara-Bata, the terminal depression. Hara-Bata, in year of high precipitation, is flood filled in all the depression area and feed-back to the Harax River, falling over irrigation dam to flow downstream to join Katar River which has intern a natural fall at Habura limiting fish upstream movement.

Livestock development workers and local inhabitants informed that, fish were stocked into Hara-Bata four decades ago and the "lake" supported fish production for few years, after which it went dry. Later in 2010, Hara-Bata “lake” was revived to stay year round and checked for presence of fish in 2015 when there were no fish species of fishery target, except the low value fish such as *Garra* spp. and straightfin barb (*Enteromius paludinosus*).

Sango floodplains (Figure 8) in Ogolcho area are within the Katar river drainage system and found in Ziway Dugda administrative district of Arsi zone in Cetral Rift Valley. The Sango floodplains are naturally inundated with flood water coming from the surface runoff in the catchment area. During rainy season, the floodplains are interconnected through surface overflows and manmade drainage canals excavated to mitigate flooding disasters in crop fields of Ogolcho area. Many of the Sango floodplains stay with flood temporarily for one to three months after rainy season except Chalalaka which in some years stay year-round without drying. Chalalaka is the largest floodplain in Sango floodplain system and occupy area of over 60 ha at its full size and hence Sango refers to Chalalaka in this paper.

After heavy rain, excess water from the Chalalaka floodplain pass through the chain of Sango floodplains to join Katar River through manmade drainage canal, after which the river joins Lake Ziway in short distance down the stream. The Sango floodplains have no fish stock because of natural barrier (fall) between the floodplain and the river gorge which limited the upstream movement of fish from Lake Ziway and Katar River. Water in Sango floodplain was usually pumped to irrigate horticulture farms of the surrounding area in dry season during past years before the drainage outlet canal was excavated. In recent years, the water level of Sango gradually shrinks to dry-up between February and April depending on the weather condition and irrigation pressure.

2.2 Fish stocking to the floodplains

2.2.1 Fish stocking to Hara-Bata

Batu Fishery and Aquatic Life Research Center restocked about 200 Nile Tilapia of Chamo "strain" into Hara-Bata in February, 2015 (three years before the current study) based on request from livestock and fishery development office of Ziway Dugda District. They were observed reproducing and found to school at shores of Hara-Bata after a year. The tilapias were adapted to the floodplain, reproduced and enough to be used as a seed source in three years after stocking. Hara-Bata has been used as a tilapia multiplication site for the Batu Fish and Other Aquatic Life Research Center, where the locally organized and trained youth group works on fingerling collection in collaboration with the research center to stock the fingerlings into Aquaculture ponds in the region.

A group of eleven members from local youth were organized into a cooperative in order to harvest the tilapias from Hara-Bata. These members help in fingerling collection from the shore when needed but harvesting of fish for consumption was not efficient because of the smaller sized fish. Fish were collected from three different accessible sites near shore in Hara-Bata when fingerlings were hauled for distribution and also for stocking to Sango floodplain, during the current trial.

2.2.2 Fish stocking to Sango floodplain

To evaluate fish survival and growth performance in temporary floodplain in central Rift Valley (Chalalaka part of the Sango floodplains), 2 650 tilapia were collected from Hara-Bata floodplain. The fish at average size of (12.1±2.2) cm were stocked into Sango floodplain in three consecutive days. During transportation, fish were packed in oxygenated polyethylene bags for the distance of about 25 km and acclimatized to the destination water by gradual water mixing before release. Inspection was made every morning after stocking at the destination floodplain.

2.3 Data collection

Water quality parameters including transparency (using Secchi disk), pH and conductivity (measured using portable multi-meter, SX723 pH/mV/Cond meter, Xi'an, China) were measured *in situ* from three representative sites, inlet, middle and outlet/opposite side to inlet regions of Sango and Hara-Bata floodplains; and three sites between Meki and Bulbula rivers (namely Girisa, Abosa and Batu) in western part of Ziway Lake and Ziway wetland, each sampled every month starting from October, 2017 to January, 2018. Water transparency of the study water bodies was measured using a standard Secchi disc, a white metallic disc of 20 cm diameter having six circular holes around, making contrast for observation in water. Measurements were taken as average depth of the disappearance and reappearance of the disk (Figure 7). Later, a calibration curve was made to convert the Secchi depth reading into the standard NTU unit using water of different turbidity levels in the study area by the Author in 2023. The following conversion equation was developed.

$y = 3912.4x^{-1.365}$, $R^2 = 0.9702$

Where "x" is Secchi depth (cm) reading; "y" is its corresponding NTU (Nephelometric turbidity units) and R^2 is the measure of goodness of fit.

The data was collected for a period of four months, from October, 2017 to January, 2018. Water temperature was measured by using min/max analog water thermometer (-30 to 50 °C range) from surface 0~15 cm and depth of 50~60 cm in morning 8:00 ~10:00 am and afternoon 2:00 ~ 4:00 pm from each of the study water bodies.

Water samples were taken from three representative sites of the water bodies using water sampler for plankton analysis in lab. Microscopic investigation was made in the laboratory of Batu Fishery and Other Aquatic Life Research Center. The water samples ware filtered by using a 30 µm plankton net to concentrate the organisms. Fresh samples were used for identification of live organisms under microscope while identification keys for phyto- and zoo-plankons to genus level. Their relative abundance in the samples was estimated by numbers of organisms counted on the slide grid.

In Hara-Bata, fish were sampled from beach seine catch and total length in cm was measured. Length distribution was also summarized to estimate their size distribution. Fish sampling was attempted from Sango for two months.

The data of water quality parameters of the flood plains, Ziway Lake and Ziway wetland were summarized in months. Mean values of the parameters at the floodplains were compared with the values recorded at Ziway Lake and Ziway wetlands in One-Way-ANOVA and mean separation were made at 0.05 significance level. The values recorded at the water bodies were also compared against the optimum requirement for fish (with special focus to Tilapia) growth.

3 Conclusions and Recommendations

The floodplains, Sango and Hara-Bata were both inundated with flood. The Sango flood plain is filled by surface runoff coming from the surrounding watershed while Hara-Bata is inundated by river overflow coming from distant watershed. Water pH and electric conductivity in Sango and Hara-Bata were within a suitable range for *Oreochromis niloticus* production as Ziway Lake and its surrounding wetlands do. The average water temperature recorded during the study period was lower than the optimum requirement for *Oreochromis niloticus* culture at both floodplains but still can support growth and reproduction of the fish as temporal temperature variation is wide enough where the daily maximum temperature of the water bodies are in optimum range.

Water turbidity was the main limiting factor of fish growth in the floodplains where the water in Hara-Bata, the deeper floodplain was relatively less turbid because of the inlet river self-purification process along the distance flow and better silt settlement in the stable deep water. Though its turbidity was stressful to fish to grow and reach at marketable size unlike it does in Lake Ziway, the *Oreochromis niloticus* was able to reproduce and dominate the floodplain which indicates Hara-Bata can support reproduction of fish.

However the Sango floodplain was short lived, shallow, agitated by strong wave, and fatally turbid that it cannot support *Oreochromis niloticus* production, regardless of its higher zooplankton availability for fish feed.

Perhaps, *Clarias* species like African catfish and common carp can tolerate the high turbidity and make use of the worms and zoo planktons to grow well in the muddy floodplains which needs further study.

In Sango, if the periphery of the floodplain is covered by vegetation such as dual purpose fodder plants, the turbidity of water can be treated as the wetland vegetation of Ziway does. This plantation in the surrounding also helps to supply quality feed and better water for the cattle of the area. It is also better to dredge and make some refugee area for fish in the floodplain to collect fish in one place as the floodplain approaches drying if fish production is planned.

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