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# Managing Fisheries and Aquaculture for Sustainable Food and Nutrition Security in Ethiopia

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## Abstract

*A ten-years fishery and aquaculture master plan (FAMP) spanning from 2024/25 to 2033/34 has been developed by the Ministry of Agriculture to enhance fish production, particularly by leveraging aquaculture potential in Ethiopia. This paper reviewed the current status of fisheries and aquaculture and showed intervention measures required for utilizing the resources in a sustainable manner. Ethiopia's annual capture fisheries production potential is estimated at 127,969 tons from its 16,100 km² of lentic water bodies and 8,065 km of flowing rivers. In recent years, capture fish production grew rapidly from 50,150 tons in 2013 to 101,000 tons in 2022, approaching the country's production potential. On the other hand, the country possesses over 15,158 km² of land highly suitable for aquaculture development with an estimated fish production potential of 402,000 tons by 2034. Although aquaculture production grew from 41 tons in 2013 to 1,070 tons in 2022, mainly due to the expansion of pond aquaculture, it still accounts about 1% of the total fish production in the country. This paper describes major aquaculture practices, the history of fish stocking and fish species for culturing along with their current status and future prospects. The potential of aquaculture in Ethiopia remains untapped, which calls for timely interventions to enhance fish stock in existing water bodies and expand land-based aquaculture using different culture technologies following FAMP strategic approaches.*

**Key words:** Aquaculture, capture fishery, fish stocking, food security, nutrition, reservoirs

## Introduction

Ethiopia is the most populous nation (117 million people) in the Horn of Africa with 2.6% population growth per annum (CSA, 2021). The country often suffers from food insecurity largely due to recurring drought that affects crop production which is the dominant farming system by small scale farmers in the country. Fortunately, the country is endowed with enormous water resource of great fishery potential nationwide. Ethiopia has 12 drainage basins of which 9 basins (8 river and one lake) are wet throughout the year while three are dry most or all year round (MoWE, 2018). In most of these basins, there are several natural lakes, reservoirs, small water bodies and large floodplain areas covering about 16,100 square kilometers suitable for fish production (FAMP, 2024). In addition to fish production, these water bodies provide a variety of services including domestic and industrial water uses, irrigation, nutrient retention, flood control, microclimatic stabilization and habitat for diverse range of resident and migratory avifauna population (Abebe Getahun, 2017). In addition, the highlands of the country (>1500m a.s.l.) have densely networked tributary rivers with optimum environmental and water quality parameters for production of high value fish species such as brown and rainbow trout (NFALRC, 2018) and small indigenous fishes (Aschalew Lakew *et al*., 2024a).

Ethiopia’s fishery comes exclusively from inland water bodies including lakes, rivers, various types of manmade water bodies and numerous wetlands (Gashaw Tesfaye and Wolf, 2014). Although fishing is not equally practiced in all parts of the country, it is the major source of animal protein for many Ethiopians residing in the vicinity of major water bodies (Aschalew Lakew *et al.*,2017). This is demonstrated by the difference in the national per capita fish consumption (about 1kg/year) and exceeding 10 kg/year in areas with sufficient fish production such as Gambela, Lower Omo, Rift Valley and Lake Tana areas (FAO, 2018; MoA, 2022). Moreover, the gap between supply and demand of fish likely influences fish consumption in Ethiopia (Rothuis *et al*., 2012).

To enhance fish production both from aquaculture and capture fisheries, the Ministry of Agriculture (MoA) has developed a 10-years Fisheries and Aquaculture Master Plan (FAMP) spanning from 2024/25 to 2033/34 (FAMP, 2024). FAMP provides strategic framework for advancing sustainable fisheries production and aquaculture development with the goal of achieving food self-sufficiency, improving nutritional security and boosting economic growth in the country. The country's annual fish production potential is estimated at 530,000 tons, with 402,000 tons coming from aquaculture and about 128,000 tons from capture fisheries (FAMP, 2024). The master plan identified key challenges in the development of aquaculture and capture fisheries, and indicated intervention options to ensure sustainable economic growth, social development and environmental sustainability. Moreover, the Ethiopian government recognizes fish as a vital commodity for food and nutrition security and incorporated it into the country’s ten-year National Development Plan (2020/21 – 2029/30). In addition, several development initiatives and programs such as “Yelemat Tirufat”, Food System Resilience Program (FSRP) and Livestock and Fisheries Sector Development Project (LFEDP) have prioritized fish as an important food commodity particularly for the rural communities.

## Water resources and fish production potential in Ethiopia

Ethiopia’s lentic water bodies including lakes and reservoirs cover an estimated area of 16,100 km$^2$, which accounts about 1.4% of the country’s total land area

(FAMP, 2024). Gashaw Tesfaye and Wolf (2014) listed a total of 106 lakes, major reservoirs and swamp areas with their geographical location, altitude, surface area, and depth mainly based on literature. Considering the existing natural and manmade water bodies of the country, the annual capture fisheries production potential is estimated at 127,969 tons of which about 104,015 tons come from lentic water bodies (lakes and reservoirs) and 23,954 tons from lotic water bodies (rivers and streams) (FAMP, 2024) (Table 1).

Table 1. Area coverage and fish production potential of different water bodies in Ethiopia (adapted from FAMP, 2024)

| Water bodies | Area/distance coverage | | Fish production potential (tons) |
|---|---|---|---|
| | km$^2$ | km | |
| Major lakes | 7,740 | | 42,488 |
| Major reservoirs | 3,910 | | 25,701 |
| Small lakes and reservoirs | 550 | | 18,095 |
| Flood plains | 3,900 | | 17,731 |
| Rivers | | 8,065 | 23,954 |
| Total | **16,100** | **8,065** | **127,969** |

Note: Major lakes and major reservoirs are water bodies with an area covering greater than 10 km$^2$ while small lakes and reservoirs are water bodies with an area covering less than 10km$^2$.

## Diversity and utilization of the capture fishery

The water bodies of Ethiopia harbor 191 indigenous and 9 exotic fish species of which about 45 species are endemic to Ethiopia (Golubtsov and Mina, 2003; Abebe Getahun, 2017). Redeat Habteselassie (2012) provided description of 200 fish species belonging to 75 genera, 31 families and 12 orders, and presented a fairly accurate and updated picture of the current fish diversity in Ethiopia. According to Golubtsov and Mina (2003) the highest species diversity is recorded from Baro -Akobo Basin (113 species) while the highest endemicity was recorded from Abay Basin. Abebe Getahun (2017) indicated that high fish species diversity in Baro – Akobo basin is associated with the presence of highly diverse and rich water habitats, and basin connectivity with Central and West Africa drainage systems. The highest endemicity in Abay Basin can be explained mainly by the endemic flock of *Labeobarbus spp.* constituting 18 commercially important species of Lake Tana (Abebe Getahun and Eshete Dejen, 2012)

Table 2. Fish diversity and endemicity in different drainage basins of Ethiopia (Golubtsov and Mina, 2003; Abebe Getahun, 2017)

| No | Name of the drainage basin | Number of Species | Number of endemic species |
|---|---|---|---|
| 1 | Baro-Akobo | 113 | 5 |
| 2 | Omo-Gibe | 79 | 17 |
| 3 | Abay | 61 | 25 |
| 4 | Tekeze | 36 | 9 |
| 5 | Wabe-Shebele and Genale-Dawa | 33 | 5 |
| 6 | Rift Vally Lakes | 32 | 7 |
| 7 | Awash | 15 | 6 |

Previous studies have also categorized the country's fish species into commercially important and commonly available indigenous fish species based on the fish consumption preference of people in the country (Hussien Abegaz, 2010; Gashaw Tesfaye and Wolff, 2014; Aschalew Lakew *et al*., 2016). Numerically, the number of commercially important fish species ranges from approximately 20 in the Gambela and South Ethiopia (Omo-Turkana) regions to fewer than ten in most other lakes and reservoirs across the country (Table 3). In the Gambela and Lower Omo areas of South Ethiopia, local communities rely on a diverse fish species as a primary source of food and animal protein.

Table 3. Commercially important fish species of Ethiopia with local names in Anuak (Gambela) and Dasenech (South Ethiopia) (Hussien *et al*. 2010; Redeat Habtesilassie, 2012; BoA SNNPR, 2018)

| No | Family name | Scientific name | Common name English/FishBase | Local name | |
|---|---|---|---|---|---|
| | | | | Anuak/ Gambela | Dasenech/ South Ethiopia |
| 1 | Cichlidae | *Oreochromis niloticus* | Nile tilapia | Uredo | Kelete |
| 2 | Clariidae | *Clarias gariepinus* | African Catfish | Aguwella | Urif |
| 3 | Latidae | *Lates niloticus* | Nile perch | Gur | Ichi |
| 4 | Bagridae | *Bagrus docmak; Bagrus bajad* | Bagrid catfishes | Udoora | Leshe |
| 5 | Citharinidae | *Citharinus citharus; Citharinus latus* | Moon fish | Abel | Nakuracha |
| 6 | Cyprinidae | *Labeobarbus spp.* | - | Ukura | Kartach |
| 7 | Polypteridae | *Polypterus bichir* | Bicher | Udeela | Charfante |
| 8 | Arapaimidae | *Heterotis niloticus* | African bonytongue | Uluak | Deze |
| 9 | Gymnarchidae | *Gymnarchus niloticus* | Aba | Wit | - |
| 10 | Alestidae | *Hydrocynus forskahlii* | Enlongate Tigerfish | Weari | Mete |
| 11 | Cyprinidae | *Cyprinus carpio* | Crucian carp | | |
| 12 | Mormyridae | *Mormyrus kannume; Mochokus niloticus* | Elephant fish | Dolo | Ochumulo |
| 13 | Malapteruridae | *Malapterurus electricus* | Electric Catfish | Adaenga | Urif |
| 14 | Mormyridae | *Mormyrops anguilloides* | Cornish Jack | Dolo | Golo |
| 15 | Mochokidae | *Synodontis frontosus; Synodontis clarias* | Mandi | Ukok | Ditu |
| 16 | Protopteridae | *Protopterus aethiopicus* | Lungfish | Lyut | Charbaset |
| 17 | Claroteidae | *Auchenoglanis occidentalis* | Bubu | Ukul | Ngangabongos |
| 18 | Mormyridae | *Hippopotamyrus harringtoni* | - | Auaeyt | - |
| 19 | Cichlidae | *Sarotherodon galilaeus* | Tilapia | Uredo | - |
| 20 | Alestidae | *Hydrocynus vittatus; Aleste dentex* | African tetras | - | Lomuar |
| 21 | Schilbeidae | *Schilbe mystus* | Schilbeid catfishes | - | Ente |
| 22 | Clariidae | *Heterobranchus bidorsalis; Heterobranchus longifilis* | Sampa | - | Birgante |

Capture fisheries production over the past decade (2013–2022) indicate Nile tilapia as the most commercially significant species accounting about 45% of the total catch. This is followed by African catfish (23%), *Labeobarbus spp.* (14%), Nile perch (9%), and the exotic carp species (2%) (MoA, 2023). According to data from the MoA, fish production from capture fisheries increased from 50,150 tons in 2013 to 56,130 tons in 2017, reaching 101,000 tons by 2022 indicating more than a twofold increase over the past ten years at the national level (Figure 1).

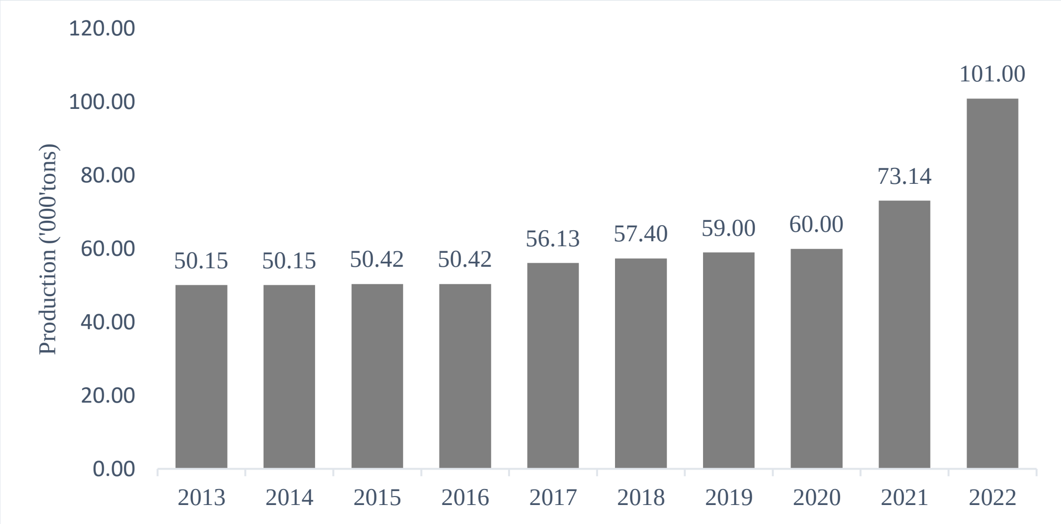

Figure 1. Capture fisheries production in Ethiopia between 2013 and 2022. (MoA, 2023).

In recent years, the demand for fish in the country has increased significantly primarily due to population growth and increased awareness of the nutritional and health benefits associated with fish consumption (Assefa Mitike, 2013). This growing demand has led to the overexploitation of commercially important fish species in major water bodies (Mathewos Hailu, 2013; Gashaw Tesfaye, 2016; Lemma Abera, 2016; Aschalew Lakew *et al*., 2017; Mathewos Temesgen, 2018). Conversely, small indigenous fish species (SIFS) remain underutilized mainly due to their small size, limited ecological knowledge, inadequate harvesting and processing technologies, and low public awareness regarding their potential use (Gernot *et al*., 2020; Tokuma Negisho *et al*., 2021; Aschalew Lakew *et al.*, 2024a).

## Aquaculture in Ethiopia

Ethiopia's aquaculture has immense potential for development and it is a means to increase fish supply in rural communities and diversify income and livelihood opportunities. Eshete Dejen and Zemnu Mentesinot (2012) indicated that about 15,158 km² (about 1.2% of the total land mass of the country) is highly suitable and 871,731 km² is moderately suitable for aquaculture development. Based on the country's physical, socio-economic and environmental suitability for aquaculture development, FAMP (2024) estimated the potential of aquaculture production at 200,000 and 402,000 tons in 2030 and 2034 respectively although over 60% of the potential was expected from adoption of commercial intensive aquaculture. Fish production from aquaculture was only 41 tons in 2013, 126 tons in 2017 and reached 1070 tons in 2022. Although aquaculture has shown a rapid growth rate over the past decade, its contribution to the country's overall fish production remains insignificant, accounting about 1% of total production since 2020 (Figure, 2).

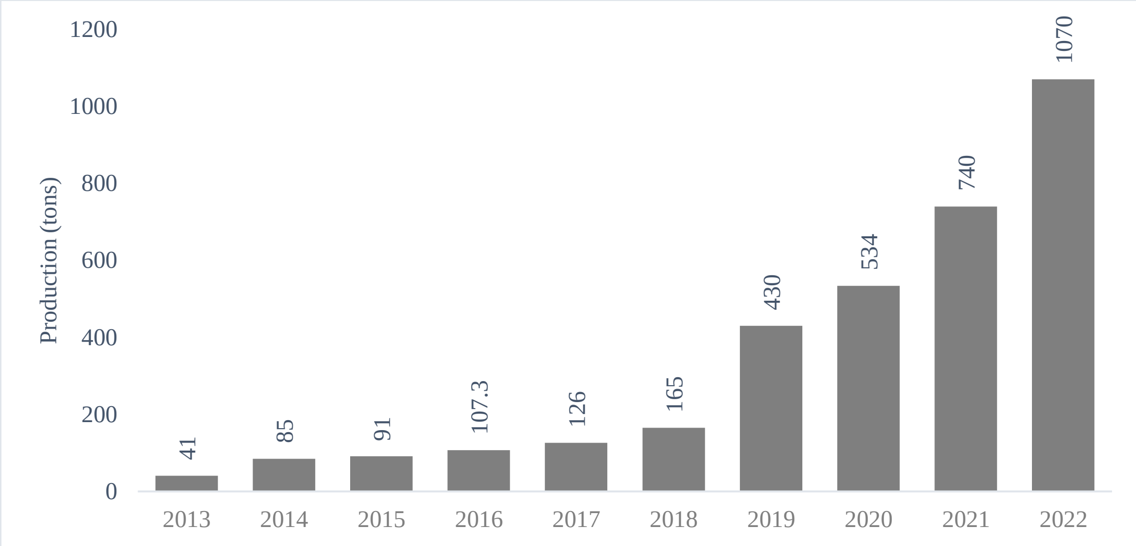


Figure 2. Aquaculture based fish production in Ethiopia from 2013 to 2022. (MoA, 2023).

## Cultured fish species

Nile tilapia, African catfish, common/crucian carp and rainbow/brown trout are known to be the main candidate aquaculture fish species for food production in Ethiopia (Figure 3).

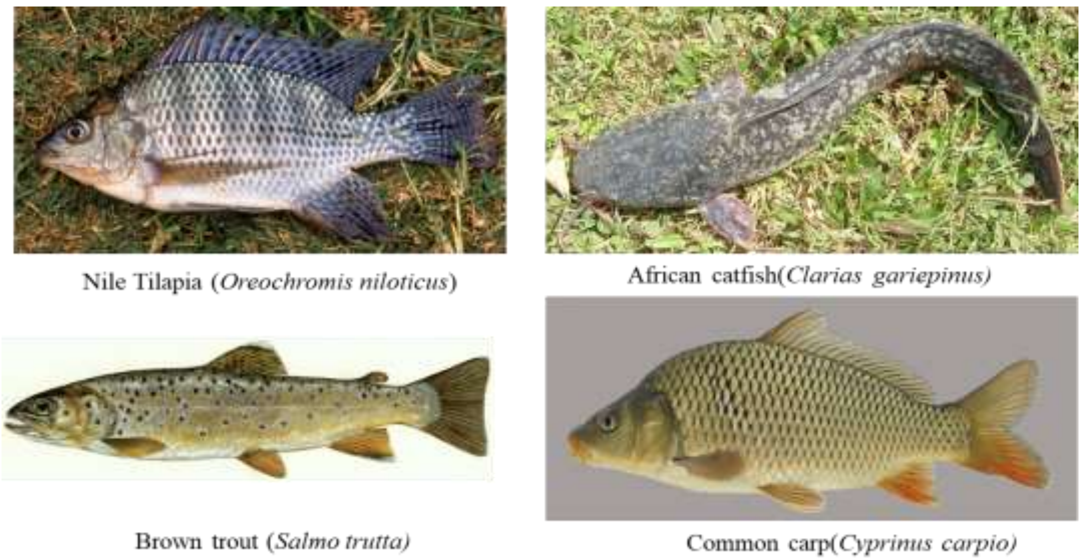


Figure 3. A plate showing aquaculture fish species in Ethiopia.

Nile tilapia (*Oreochromis niloticus*) is the second most farmed and popular fish in the world after carps (FAO, 2018). Nile tilapia is candidate fish for aquaculture mainly because of its feeding habits, fast growth rate, ability to adapt at different stocking density, and its adaptation to a range of culture systems including pond systems, cage culture, raceway systems and super-intensive culture systems under a wide range of environmental conditions. More importantly, tilapia incurs relatively low cost of production, high market demand and readily acceptable by many Ethiopian consumers. Nile tilapia stocking has been practiced since the establishment of Sebeta Fish Culture Station (SFCS) in 1977 (the current 'National Fishery and Aquatic Life Research Center' (NFALRC)). Nile tilapia fingerlings have been stocked to farmers ponds, community water reserves, medium and large reservoirs and natural lakes with the intention of enhancing fish production in different parts of the country.

Carp is the most farmed fish species in the world (FAO, 2022) and established its population in different manmade and natural water bodies of Ethiopia. Studies indicated that common carp (*Cyprinius carpio*) was introduced to Abasamuel reservoir from Italy in 1940 while silver carp (*Hypothalmichthys molitrix*) and grass carp (*Ctenopharyngodon Idella*) were sourced from Japan in 1975 to stock Fincha reservoir (Shibru Tedla and Fisseha Hailemeskel, 1981). Common carp and crucian carp have adapted well in reservoirs and natural lakes of the country including Fincha, Koka, Tendaho, Ziway, Langano, Hashengae, Lugo and Ardibo, and constitute about 2% of the total fish catch in the country (MoA, 2022). Currently, carp species adapted a wide range of temperature in lowland and midaltitude areas in Ethiopia (e,g. Tendaho reservoir at 370m a.s.l. and Lake Hashengae at 2440m a.s.l.). In recent years, there is an increasing demand for carp fingerling especially for midaltitude areas (1800 - 2500m a.s.l) in different regions of the country and NFALRC multiply significant number of fingerlings and stock fish ponds and reservoirs mainly in central, northern and south-west regions of Ethiopia (NFALRC, 2021).

African catfish is another important aquaculture species which is widely cultured in different countries mainly in Nigeria, The Netherlands, Brazil, Hungary, Kenya, South African, Cameroon, and Mali (FAO, 2018). Some Asian countries like China, Indonesia and Malaysia also produce significant amounts of African catfish in aquaculture (Dauda *et al*., 2018). African catfish is selected for aquaculture because it grows fast in captivity even at a higher stocking density, highly fecund fish, disease resistant, tolerant to a range of extreme environmental conditions including low water quality (De Graaf, 1996). African catfish is the second dominant commercially important fish species constituting about 23% of fish catch from capture fisheries in Ethiopia (MoA,2023). Few studies indicated that catfish fingerlings were distributed to few fish farmer ponds and reservoirs mainly for controlling the over population of tilapia (Yared Tigabu, 2018). Although Ethiopia has huge potential and suitable environmental conditions to boost production of African catfish from aquaculture sub-sector, its development is hindered mainly due to limited source of quality fingerlings, feed and lack of proper extension services.

Trout is an important aquaculture species particularly in mountainous cold regions worldwide. Trout is typical cold-water fish that require high dissolved oxygen (nearly 100% saturation) for smooth respiration (Bimlendu *et al*., 2021). Although the natural feeds for trout varies based on the age and size of the fish, they are opportunistic feeding on diverse macroinvertebrates, small and large crustaceans, worms, snails, small fish, and offspring of amphibians and reptiles, and formulated fish feed (FAO,2022). Two trout species namely rainbow trout (*Oncorhynchus mykiss*) and brown trout (S*almo trutta*) were introduced to Ethiopia from Kenya (Shibru Tedela and Fisseha H/Meskel, 1981; Redeat Habtesilassie, 2012). Shibru Tedela and Fisseha H/Meskel (1981) reported that rainbow and brown trout were introduced to Bale Highland rivers namely Weib, Denka and Tegona. NFALRC (2018) reported that both rainbow and brown trout are well established self-sustaining population in the upper section of Meribo, Leliso, Weib, Denka, Shaya and Togona rivers in Arsi-Bale highlands. On the basis of temperature and water clarity, streams and rivers originating from Afroalpine and sub-afroalpine regions of Ethiopia are suitable for aquaculture-based trout production. For example, in 2009 a Trout Fish Farmers Private Limited Company has been established as a commercial trout fish farm using water from Meribo river that flows from the Berinda Ridge (3,700 m a.s.l.) of Bale Mountains range. This practice can be promoted to similar ecological regions of the country and enhance production of high-quality cold-water fish for national market as a substitute of import from different countries.

## Production of fish fingerling

The success of aquaculture depends on the availability of farm inputs mainly quality fish fingerlings, quality feeds and proper water management. Following the establishment of NFALRC in Sebata, a considerable number of manmade water bodies have been stocked mainly with Nile tilapia and common carp fingerlings (NFALRC, 2018). Until recently, fish fingerlings of Nile tilapia were collected from natural lakes (mainly from Lake Hora) and distributed to different water bodies (NFALRC, 2018). However, in recent years NFALRC multiplies quality fingerlings of Nile tilapia, common carp and African catfish using its outdoor fish ponds and modern indoor fish hatchery. In addition to NFLARC, Batu and Bahir Dar Fishery and Aquatic Life Research centers have established fish seed multiplication facilities mainly for Nile tilapia while outdoor fish hatcheries were constructed in Hawasa, Arba Minch and Arbegona in the southern part of Ethiopia (Table 4).

Table 4: List of fish hatcheries and estimated annual fingerling production potential of target species for aquaculture development in Ethiopia (Source: MoA,2024)

| | Name and location of fish hatchery | Target fish species | Multiplication facility | Annual production potential (millions) | 2022/23 fingerling produced in '000' |
|---|---|---|---|---|---|
| 1 | National Fishery and Aquatic Life Research center, Sebeta | Nile tilapia, African catfish, | Indoor | 5 | 1,049 |
| | | Common carp | Outdoor | 7 | |
| 2 | Batu Fishery and Aquatic Life Research center, Batu/Ziway | Nile tilapia | Outdoor | 0.86 | 72.3 |
| 3 | Batu fish hatchery | Nile tilapia | Outdoor | 8.7 | |
| 4 | Bahir Dar Fishery and Aquatic Life Research center, Bahir Dar | Nile tilapia | Outdoor | 5.3 | 406.2 |
| 5 | Hawasa fish hatchery, Hawasa | Nile tilapia | Outdoor | 3.1 | 69 |
| 6 | Arba Minch fish hatchery, Arba Minch | Nile tilapia, African catfish | Outdoor | 7.5 | 68 |
| 7 | Arba Minch Agricultural research center | Nile tilapia | Outdoor | 1 | - |
| 8 | Arbegona fish hatchery, Sidama region | Common carp | Outdoor | 2.6 | - |
| 9 | Bonga fish hatchery | Nile tilapia | Outdoor | 5 | - |
| 10 | Mekele fish hatchery | Nile tilapia | Outdoor | 0.7 | - |

Note: Actual production in 2022/23 was adapted from FAMP (2024)

Existing fish hatcheries has several technical and input-related limitations that prevent them from operating at their full potential, indicating the urgent need for targeted support and intervention from relevant institutions. For example, while Ethiopia's estimated fish fingerling demand between 2021 and 2030 stands at approximately 234 million, only 4.8 million fingerlings were produced by existing hatcheries during the period from 2021 to 2023 (FAMP, 2024). All fish fingerlings produced were distributed and stocked into different water bodies and farmer ponds across the country.

## Production of fish feed

Fish feed plays a major role in aquaculture viability and profitability, because it accounts about 50 -60% of the total cost of fish production (Jamu and Ayinla, 2003). The existing aquaculture practices in Ethiopia depends on feeds produced on-farm from the locally available feed ingredients of both plant and animal origin (Zenebe Tadesse and Abelneh Yimer, 2021; Abelneh Yimer and Zenebe Tadesse, 2022). Previous research on fish feed has suggested that fish feeds can be formulated using locally available agro-industrial byproducts and alternative ingredients such as duckweed and earthworms to promote the growth of Nile tilapia in pond aquaculture (Zenebe Tadesse and Abelneh Yimer, 2021). A study by Kassahun Asaminew *et al*. (2012) provided a list of locally available plant and animal source ingredients with proximate composition to formulate fish feed for small scale fish farming in Ethiopia. Recently, the use of insect-based-fish feed was examined and a complete replacement of fishmeal with Black Solder Fly larvae (BSFL) enhanced the growth of Nile tilapia in tank culture (Aschalew

Lakew *et al.*,2024b). Commercial feed for fish is not available in the local market; however, Alema Koudijs PLC produces formulated fish feed for Nile tilapia fingerlings and grow out (Rothuis *et a*l., 2012).

## Water quality management

The dominant aquaculture practice in Ethiopia is pond based fish farming, although the role of nutrients and water quality parameters are poorly understood by fish farmers. Poor water quality in fish ponds can lead to common problems, such as excessive algal blooms, overgrowth of plants, noxious smells and fish death. In order to prevent these problems, an understanding of basic physicochemical parameters of the water is necessary. Dissolved oxygen (DO) is the most important water parameter needed by fish and other aquatic organisms in a fish pond system. Most oxygen in water is produced by algae and green plants through photosynthesis and naturally incorporated into water from the atmosphere through surface diffusion and turbulence caused by wind. DO depletion is mainly caused by organic waste decomposition and sudden algal bloom die-off. Control over excessive nutrient loading, removal of aquatic weeds, water refreshing and mechanical aeration are commonly applied mechanisms to maintain the required oxygen level in pond culture system. Fish farmers should also be aware of water turbidity caused by suspended inorganic matters or plankton bloom. To avoid high load of suspended particles that cause turbidity, fish farmers should monitor the source of the water and purify with sand before it enters into the fish pond. However, if the water is deep green in color, it indicates over-production of plankton communities which can be managed by regulating the quantity of fertilizers, manure or nutrient rich feeds applied to the pond. Fish ponds with acidic bottom soils can be neutralized by applying agricultural limestone before filling the pond with water which intern increases the productivity of fish pond.

## Fish culture practices in Ethiopia

Fish culture practices can be described based on culturing facilities and culture techniques used to rear a fish. Culturing facilities include earthen and concrete ponds, plastic tanks and cages while culturing techniques consist of monoculture, polyculture, integrated aquaculture agriculture and aquaponics, using extensive, semi-intensive and intensive production systems. The dominant fish culture technique in Ethiopia is pond based integrated aquaculture which is practiced by 942 fish farmers owning around 4000 fish ponds followed by 300 cages owned by private investors and institutions (FAMP,2024). The common and/or potential aquaculture practices in Ethiopia include the following:

### a. Pond based fish farming

Fish farming in ponds has been practiced in different parts of Ethiopia in recent years. Pond fish farming at farmer's yard has been widely recommended by researchers and agricultural experts because of its low cost of establishment, good soil texture and simplicity of the technology to learn (Figure 4). In a place where the soil with poor water holding capacity, farmers have been encouraged to line the ponds with geomembrane to reduce water loss through seepage, although it is too expensive for the local fish farmers. The size of the fish ponds varies from small dug holes (less than 50 $m^2$) with irregular shape to a well-designed pond with inlet and outlet structure (greater than 200 $m^2$) following the recommendation by different authors (e.g. Aschalew Lakew *et.al*., 2016). The construction cost of concrete ponds is expensive for fish farmers, and as a result, these ponds are mostly found in fishery research centers, fish seed multiplication centers, private fish farms and project-supported fish demonstration sites. Majority of fish ponds are stocked with mixed sex Nile tilapia leading to overpopulation which hampers optimal fish growth and negatively affect the overall fish production. Adamneh Dagne *et al.* (2013) demonstrated high production and productivity of Nile tilapia in fish ponds which are stocked either with all-male tilapia or in a polyculture system (tilapia combined with African catfish).

Integrated earthen fish pond in South-West Shewa, Oromia region

Integrated lined fish pond in South Ethiopia

Concrete fish pond around Bahir Dar city, Amhara region

Earthen fish pond around Bambasi, Benshangul Gumz region

Figure 4. A plate showing pond-based fish farming practice in different regions of Ethiopia. Author's picture

### b. Integrated fish farming system

An integrated fish culture approach combines the agricultural systems with fish farming which allows use of wastes as inputs by another system, thus conserving resources and enhancing productivity (Shoko *et al.*, 2011). Integrated fish farming has immense potential to address the problem of low income, nutritional insecurity, unemployment, and poverty of farmers across East Africa (Ogello *et* *al.*, 2013). Fish farmers engaged in integrated fish farming are impressed with the practice where they use mainly poultry and dairy manure for pond fertilization, and fertilized pond water for irrigating vegetables and forage grass in South west Shewa zone, wonchi woreda (NFALRC,2021). Moreover, previous studies on integrated aquaculture agriculture (IAA) practices in the country demonstrated the importance and benefit of IAA in terms of food diversification, profitability and environmental sustainability (Belay Adugna *et al.*, 2016; Yared Tigabu *et al*., 2018). Integrated fish farming is inexpensive and profitable fish culture practice but unexploited approach in present aquaculture development in Ethiopia. The implementation of integrated fish pond culture system is identified as an appropriate fish culture mechanism for most rural farmers in Ethiopia, provided that proper pond management practices and input delivery systems are in place (Aschalew Lakew *et.al.*, 2016).

### c. Cage culture

Fish rearing in cages is implemented in water bodies including lakes, reservoirs, rivers, ponds and temporary water bodies. The cages are constructed from durable, non-toxic materials in various sizes and installed in proper location that allows free water exchange. Cage culture has been practiced in Ethiopia since the initiation of the BOMOSA project in 2006, with several scientific papers published to promote the technology for both subsistence and commercial fish production in various water bodies (e.g. Ashagrie Gibtan *et al*., 2008; Zenebe Tadesse, 2009, Fasil Degefu *et al*. 2011) (Figure 5). Africa Sustainable Aquaculture (ASA), a Dutch investment company, has been implementing commercial cage fish farming in Koga reservoir near Bahir Dar in 2015 and currently the company is relocated and installed the cage fish farming infrastructure in Gilgel Gibe III reservoir (Personal communication). Although little information is available on the productivity of cage culture, it is an overlooked opportunity to produce and supply fish to central and regional markets in Ethiopia.

Commercial cage culture in Gilgel Gibe III reservoir

BOMOSA fish cage at Yimlo fish pond for demonstration

Figure 5. A plate showing cage culture practice in reservoir (left) and farmer's fish pond (right). Author's picture

### d. Tank based fish farming

Tank based fish farming is suitable culture system in areas where land and water are scarce input resources. Although there is no literature confirming the existence of commercial tank-based fish farming in Ethiopia, several studies conducted at NFALRC have shown that plastic tanks with a capacity over 1000 liters are effective for fish culture (Zenebe Tadesse and Abelneh Yimer, 2021; Aschalew Lakew *et al.*, 2024b). The author of this paper believes that tank-based fish farming is unexploded opportunity to produce fish especially in urban and semi-urban areas of the country.

### e. Aquaponics based integrated fish farming

Aquaponics is a sustainable farming method that combines rearing of fish with growing plants without soil in recycling environment (FAO,2018). In this culture system, fish waste is converted into nutrients for the plants, and the plants purify the water for the fish. Aquaponics is fairly new technology for Ethiopia and only few demonstration units has been established with the project support such as FAO Smart Fish project in Ziway, Methehara, Shewarobit and Addis Ababa University. Currently, small scale aquaponic practices are being demonstrated as a means to diversify food sources and efficient resources utilization (water, land and organic waste) in private farms such as Alpha Fish Hatchery and Supply PLC, and government institutions including EIAR-NFALRC. Although the wider applicability and profitability of the culture technique requires future research and technological inputs, it is unexploited opportunity to address food insecurity issues specifically in urban areas of the country.

## Reservoirs for aquaculture development in Ethiopia

Damming of rivers and water harvesting for various socio-economic benefits such as hydropower generation, irrigation, cattle watering, domestic uses is a common practice in Ethiopia. In recent years, Ethiopia is actively exploiting its water resources by building multi-purpose water reservoirs primarily for irrigation and hydropower generation (MoWE, 2018). The new built reservoirs formed by damming major rivers create opportunities to integrate fish production along with power generation and irrigation of agricultural land. For example, a dam constructed for irrigation usually create new aquatic habitats such as reservoirs, irrigation canals, and irrigated fields suitable for fish production. More importantly, integrating culture based-capture fishery and application of aquaculture technologies such as cage culture can easily boost fish production. The productivity of a newly constructed reservoirs is a function of surface area, depth, the availability of breeding habitats and natural food for the target fish species (Kolding and Zwieten, 2006). The geographical location can also influence in reservoirs productivity as temperature and other topographic features determine growth and reproduction rate of a fish species (Dagnew Mequanent *et al.*, 2022). In the reservoir, the availability of decomposable materials, the dynamics of nutrient and organism fluxes, and other materials transported from the catchment to the reservoir strongly affect the water quality and primary productivity that intern affect food web and fishery production (Kolding and Zwieten, 2006).

Most reservoirs in Ethiopia are characterized by high water level fluctuation due to flooding of the rivers in the rainy season and significantly low flow during the dry season. Usually, the amount of water level fluctuation in the reservoir can also affect productivity and suitability for a fish production (Baumgartner *et al*., 2017). The ecological integrity of reservoirs tends to evolve rapidly in the first few years after impoundment and matures when all abiotic and biotic processes stabilize. Reservoirs become fertile shortly after dam closure as inundated vegetation decomposes and releases nutrients that boosts primary production and create complete food web in the system (Kolding and Zwieten, 2006). In deep reservoirs, the nutrients may sink and making the reservoir less productive at primary stage but as the reservoir matures in age the temperature difference between the surface and bottom water causes stratification that brings nutrients to the surface and increase fertility of the reservoir water (Paul *et al*., 2017). Most reservoirs in Ethiopia receives flowing water from agricultural land and forest area which makes them fertile due to nutrient and detritus washed into the system and thus suitable for both culture-based capture fishery and aquaculture technologies such as pen and cage culture.

In large reservoirs with shallow or deep depth, the culture-based capture fish productivity depends on biological processes mainly microbial, planktonic and benthic organisms' life cycle and physico-chemical conditions (Meynell, 2014). On the contrary, small and shallow reservoirs are well mixed and oxygenated with enhanced primary production that makes them generally more productive in fish production. In small reservoirs fish production is almost dependent on repeated stocking of fish fingerling which can be done annually or twice a year with selected species such as tilapias, African catfish and carps (Baumgartner *et al*., 2017). For example, in large reservoirs like Koka, Fincha, Melkawakena, Gilgel Gibe I and Tendaho, unless catastrophic fish kills occur, the reservoirs can create self-sustaining fishery. However, fish production in such reservoirs can be enhanced by periodic stocking of fish fingerlings and protecting newly flooded areas during the rainy period for temporal fish migration to breed and feed (Kolding and Zwieten, 2006). Moreover, islands created in the reservoir may provide additional feeding and breeding habitat in their vegetated edges and serve as fish refuge to establish sustaining fish population like the case in Koka and Grand Ethiopian Renaissance Dam (GERD). Fish stocking provides significant socio-economic and environmental benefits such as food production, income generation, job creation, and ecological stability. However, it should be carried out based on scientific knowledge and expert recommendation to minimize any adverse impacts on wild fish populations, biodiversity, and overall health of aquatic ecosystems.

Fish stocking in reservoirs has been practiced since 1977 and this has significantly contributed to the overall fish production in Ethiopia (Table 5).

Table 5. Fish fingerlings stocked in some natural and manmade water bodies of Ethiopia (Shibru Tedela and Fisseha HaileMeskel, 1981; Aschalew Lakew *et al*. 2016; Yared Tigabu, 2018; NFALRC, 2018;2021)

| Category | Water body | Fish species | Status |
|---|---|---|---|
| **Natural lakes** | Hashngie | *O. niloticus, Cyprinus carpio,* and *Carassius Carassius* | √ |
| | Haik, Ardibo, Golbo, Maibar, Zengena, Bahiregorgis, Lai-bahir,Tach-bahir, | *O. niloticus, T. zilli, Cyprinus carpio* | √ |
| | Small Abaya, Bishoftu lakes, Hararobi, Haromaya, Tirba and Bishanwaka | *O. niloticus* and *T. zilli* | √ |
| | Ziway | *Cyprinus carpio, Carassius carassius* and *Clarias gariepinus* | √ |
| | Langano | *Cyprinus carpio* and *Carassius Carassius* | √ |
| | Tana | *Esox lucius, Gambusia holbrooki* | × |
| | Wonchi, Dendi | *Cyprinus carpio, Carassius carassius* and *Oncorhynchus mykiss* | × |
| **Streams/rivers** | Meribo, Leliso, Furna, Danka, Weib, Shaya, Togona, Micha | *Salmo trutta* and *Oncorhynchus mykiss* | √ |
| | Chacha, Beriso, | *Salmo trutta* and *Oncorhynchus mykiss* | × |
| **Reservoirs (>10 sq.km)** | Koka, Melka wakena, Borta, Sorga, | *O. niloticus*, *Cyprinus carpio* and *Carassius Carassius* | √ |
| | Finicha, Amerti | *O. niloticus*, *Cyprinus carpio, Clarias gariepinus* | √ |
| | | *Ctenopharyngodon idella* and *Hypothalmichthys molitrix* | × |
| | Tendaho, El-bayehi, Gilgel-Gibe I | *O. niloticus* | √ |
| | Wodecha | *O. niloticus* and *T.zilli* | √ |
| **Reservoirs (<10 sq.km)** | Abasamuel, Geferasa, Legedadi, Yeboba | *Cyprinus carpio* | √ |
| | Birati, Washa, Anguamesk, Chacha, Gumero, Yayo, Bedele, Enda-Medehaniam, Rubafelege, Degeme, Gomi, | *O. niloticus, Carassius carassius* and *Cyprinus carpio* | √ |
| | Tolay | *O. niloticus, Carassius auratus* and *Cyprinus carpio* | √ |
| | Korir, Sesela, Mai-nigus, Dur-anbesa, Lahai wukro, Shilanat, Gerbemehese, Gerbebeati, Gebete, Boji, Shakiso, Chile-chefa, Areket, Damte, Geray, Belbela, Dembi, | *O. niloticus* and *T.zilli* | √ |
| | Midmar, | *O. niloticus* | √ |
| | Maila, Derekwa | *T.zilli* | √ |
| **Fish ponds** | Private fish ponds in different regions of the country (Tigray, Amhara, Oromia, Sidama, Centeral/South-west/South Ethiopia | *O. niloticus, Cyprinus carpio* and *Clarias gariepinus* | √ |

√ - well adapted to the ecosystem/habitat × - No evidence for fish adaptation

In addition to culture-based capture fishery, large reservoirs have a huge potential for commercial cage fish farming (FAMP,2024). Cage culture offers a practical opportunity for private investors and youth cooperatives without access to land-based fish farming. Moreover, cage farming is an important means of fish production that create new job opportunities for the local youth and women especially for those displaced local communities due to reservoir construction.

## Fisheries management in major water bodies

The future development of fisheries resource in different water bodies of the country depends on sustainable utilization and management of the aquatic resources. Fisheries management combines a set of legal frameworks and its effectiveness depends on the support gained from the resource users and their involvement in decision-making process. At federal level, the country has Fisheries Development and Utilization Proclamation No. 315/2003 with the objectives to conserve fish biodiversity and its environment as well as prevent and control overexploitation of the fisheries resource; to increase the supply of safe and good quality fish and ensure a sustainable contribution of the fisheries toward food security, and to expand the development of aquaculture (FDRE, 2003). Following the federal proclamation, Amhara and Oromia regional states adapted the fisheries proclamation considering the aquatic resources in respective region in proclamation No. 92/2003 and proclamation No. 178/2013 respectively. The legislation provides broad guidelines relating to the control of overfishing, fishing gear, introduction of exotic species, and regulates the market of fishery. It also puts a considerable emphasis on regulation, permission, and the role of fishery inspectors (Hussien Abegaz *et al*., 2010). Mathewos Temesgen and Abebe Getahun (2016) identified a list of challenges in fisheries management including types of fishing gears and fishing methods employed, socio-economic factors, poor facilities and infrastructure, ineffective administration setup, shortage of expertise, poor land use around fish habitats, and lack of scientific data were observed as the major fishery management and conservation challenges.

The federal and regional proclamations and regulations issued by the government are important instruments in managing the fishery resources although none of these instruments are currently being effective due to poor implementation. Among others, the ineffective implementation of the legal frameworks is linked with lack of commitment to implement, lack of enforcement guideline, poor collaboration among key stakeholders, poor consultation of resource users, and limited skilled manpower in the sector are few to mention. The new fishery management approach such as ‘co-management system’ which consists of resource users, policy makers and all stakeholders in the sector is promising for sustainable fishery management in Ethiopia as it is also indicated in the ten years fisheries and aquaculture master plan (FAMP, 2024). Fisheries co-management is also identified as useful fisheries management approach for cross-regional water bodies such as Tekeze reservoir (FAO, 2020) and trans-boundary water bodies such as Lake Turkana bordering with Kenya. (https://ecofish-programme.org/sustainable-fisheries-beyond-borders/).

## Contribution of fish production for food and nutrition security

Hunger is rising and affecting an estimated 821 million people worldwide (FAO, 2019). In the United Nations Sustainable Development Goals (SDGs), Goal 2 targets to end hunger, achieve food security and promote sustainable agriculture in 2030. Moreover, a food-based approach includes food production, dietary diversification and food fortification to achieve food and nutrition security (FAO, 2019). The contribution of fishery is significantly high in food and nutrition security. For example, FAO (2018) reported that fish is an important source of animal protein providing about 17% of world's meat consumption and about 7% of global protein intake. Fish is a nutrient-dense animal source of food for many nutritionally vulnerable people residing in the potential fish producing areas. Studies indicated that stunting rates reached 80% in some drought prone areas in Ethiopia (Hana *et al*., 2020). The government of Ethiopia proclaimed the 'Sekota' declaration named after Ethiopia's worst famine -stricken area, Sekota, to eradicate the underlying causes of malnutrition and end stunting among children under two by 2030. Therefore, enhancing the production and productivity of the fishery sector and feeding children with nutritious fish food undoubtedly minimizes the problem of stunting nationwide.

In addition to high bioavailable protein, vitamins and mineral content, fish contains polyunsaturated fatty acids (PUFAs), including docosahexaenoic acid (DHA) and eicosatetraenoic acid (EPA) in high proportion (Youn *et al*., 2014). Moreover, fish fillets are known to be rich in quality lipids mainly the omega 3 polyunsaturated fatty acids (PUFA) which are beneficial to human health. PUFAs are crucial for cardiac health and promote cognitive development and function (Zhao *et al*., 2016). Studies on commercially important fish of Ethiopia have confirmed the presence of high levels of PUFA in fish fillets and highlighted the health benefits of consuming fish food (Zenebe Tadesse *et al*., 1998; Zenebe Tadesse, 2010). Recent studies on nutritional content of small indigenous fish species (SIFS) showed the presence of high mineral and fat contents which are limiting nutrient in the diet of local people especially the rural communities (Bezuayehu Gutema and Fikadu H/Michael, 2021; Tokuma Negisho *et al*., 2021; Aschalew Lakew *et al*.,2024a). For example, Bezuayehu Gutema and Fikadu H/Michael (2019) indicated that incorporation of fish powder prepared from small *Barbus sp.* significantly improved the nutritional content of *Enset ventricosum* (Kocho) which is a carbohydrate rich food commonly consumed in southern Ethiopia.

In Ethiopia, most fish production practices in major lakes and reservoirs use non-motorized vessels, traditional fishing and processing methods, local transportation mechanisms and sold at nearby towns which gives fish food access to the local community. In some parts of Ethiopia including Gambela, central Rift Valley areas, lower Omo and lake Tana, there is a higher reliance on wild caught fish than other terrestrial animals indicating fish as a major, accessible and affordable animal source food for people residing close to water bodies. For example, lower rate of children stunting has been reported in Gambela (23.3%) compared with others parts of the country (up to 80%) which confirming the importance of fish to improve food and nutrition security in the country (Hana *et al.*, 2020). Moreover, the open and ease access of inland water bodies in Ethiopia gives additional advantage for the poor and landless local people to capture fish for household consumption and income generation.

## Conclusion and Recommendations

Natural and manmade water bodies of Ethiopia have a huge potential to produce fish and support food and nutrition security programs in the country. Over 16,100 $km^2$ lentic water bodies and major rivers stretching about 8065 $km^2$ have an estimated potential of producing about 128,000 tons of fish per annum. However, the capture fisheries of the country faced several challenges including overfishing in major water bodies, lack of updated data for informed decision making, poor fisheries management practices, expansion of illegal fishers, and weak coordination and lack of commitment among stakeholders to implement fishery legislatives. The country owns 15,158 $km^2$ of land highly suitable for aquaculture with estimated production potential of 402,000 tons annually; of which about 60% is produced from commercial intensive aquaculture. However, this potential is underutilized mainly due to limited inputs (quality seed and feed), undeveloped fish culturing practices, limited technical skill, poor extension services, and limited promotion and support to involve the private sectors. Nile tilapia is widely used for pond-based aquaculture and stocking of reservoirs and fish ponds followed by common carp in the country. Pond based fish farming is dominantly practiced by rural fish farmers while cage culture remains unexploited opportunity to supply fish for the nation. The following recommendations are provided for sustainable fisheries and aquaculture development in the country

- In addition to commercially important fish species from major water bodies, promote the development of riverine fishery and utilization of small indigenous fish species in the country.
- Implement stock enhancement activities through re-stocking of overexploited lakes and reservoirs and stocking of newly constructed water bodies.

- Promote and practice fisheries co-management approach which involves resource users and different stakeholders, and support with the regulations of the country.
- Establish and strengthen fish hatcheries and fish feed production facilities with proper equipment and technical capacity.
- Encourage private sector involvement in aquaculture development such as cage culture and pond-based fish production and advanced culture techniques such as recirculation aquaculture system and aquaponics.
- Building the technical skill of experts and extensionist for proper adaptation and transfer of aquaculture technologies and practices in rural and semi-urban areas of the country.

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