integrity Research Journals

Global Journal of Fisheries Science
Volume 2(2), pages 14-29, December 2020
Article Number: 1FD2F70B1
https://doi.org/10.31248/GJFS2020.017
https://integrityresjournals.org/journal/GJFS

Review Article

Fisheries production and aquaculture development: Current status and future directions in Ethiopia

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Received 8th August, 2020; Accepted 26th October, 2020

ABSTRACT: Nowadays worldwide projected growth of population pressure with a steadily growth of disposable income and urbanization corroborated by global markets corridor are expected to elicit a substantial increase the demands of high value foods. These situation causes to exploit the aquatic ecosystems mainly for fish, the largest single source of animal protein and fastest growing food commodity. Likewise, Ethiopia has enormous potential of freshwater (126.5 BMC) available per year; plus favorable environments considered to be significant scope for fisheries development for fish yield (about 94,509 ton/year + 5.3% as 73,104 ton/year + 3.3% for lentic and 2,1405 ton/year +11.8% for lotic ecosystems). Ethiopian water resources deduced to hold over 180 fish species, freshwater shrimps, crabs, mollusks, commercially important microalgae, and vegetation. However, currently actual fish yield is (about 51,581 ton/year) much far below expected level, which resulted in lower per capita consumption of fish per year (0.216 kg) compared to other African countries. This is attributed to several constraints in which, traditional methods of fish farming and fishing, limited awareness, management skills, skills and technological knowhow; besides the impacts of climate change and global warming, ecosystems degradation, mismanagement, siltation, growing toxic weeds in most lakes, with marked overfishing practices by fishermen are the dominant challenges. To reverse these scenarios into the desired track, urgent intellectual measures should be at hand in Ethiopia. Therefore, this article was studied through the collected 19 years' published and unpublished source materials, data analyzed and empirical models were applied to explore updated fundamental information on current potential of fisheries resources and overall status of aquaculture development, so as to create better understanding, and to suggest scientific strategies and better approaches for the sector contribute in the sources food, employment, and livelihood in Ethiopia. Finally, this paper is recommended to be beneficial to the readers and policy makers for the fisheries and aquaculture development in Ethiopia and the region.

Keywords: Ethiopia, fish production, fishery resources, future strategies, high value foods, major challenges.

Abbreviation: ADP, Agricultural domestic product; **ANAF,** Aquaculture network for Africa; **ARI,** Institute agricultural research; **BMC,** Billion metric cubs; **CIFAA,** Committee inland fisheries and aquaculture for Africa; **EFASA,** Ethiopian fisheries & aquatic sciences association; **EIDP,** Ethiopian industrial development policy; **FAO,** Food & Agricultural Organization; **FAD,** Fisheries & Aquaculture Development; **FDRE**, Federal Democratic Republic of Ethiopia; **FRD,** Fisheries resources development; **FWF,** Freshwater fisheries; **FWFF,** Freshwater fish fauna; **ILCA,** International Livestock Centre for Africa; **ITCZ,** Inter Tropical Convergence Zone, **MDG,** Millennium Development Goals, **MOAL,** Ministry of Agric and Livestock; **MOARD,** Ministry of Agric & Rural Development; **NEPAD;** New Partnership for African Development; **PPCC,** Protein per capita consumption; **PWRFF,** Potential water resource and fish fauna; **RVL,** Rift valley lakes; **WRFF,** Water resources and fish fauna.

INTRODUCTION

The emerging findings have been shown that the world's food requirement by the year 2050 will be double the 2010 (FAO, 2016) and a larger part of this will be emanated from the developing countries on account of the projected growth in disposable incomes, urbanization and of the human population (Mwanja et al., 2011). This condition triggers to exploit aquatic ecosystems by virtue of high productivity, besides to land agriculture efforts to sustain

food security (Hussien, 2010; Hussien et al., 2011).

Fish is a crucial source of high value protein for the livelihoods of people in the world. Likewise, more than 500 million people are depended on fisheries for their livelihood in developing countries (Kundu et al., 2010; FAO, 2012). Similarly, Shimada (2013), FAO (2016), Dagne et al. (2008) reported that more than 48,000 Ethiopians are living with fishing and fish marketing operations of the fisheries industry for their sustainable income sources and livelihoods. Besides, many more communities, nearby the major lakes and reservoir dams, are also used for subsistence. However, the sector has been challenged by several hindrances. Among which poor policies and institutional setups and inadequate technical backups are the most underlined (FAO, 2016; FAO, 2012; Kundu et al., 2010). Thus, the objectives of this article may include: exploring fundamental information for creating better awareness on the cases of existing situation of fisheries production and aquaculture development; current status of potential fisheries resources; current status of commercial fish resources, fish consumption trends; and the major challenges on fisheries and aquaculture development; and finally, to suggest helpful intellectual approaches and draw important conclusions and recommendations in Ethiopia.

METHODOLOGY

A range of literature sources about the fishery resources in Ethiopia was used for this review including journal articles, books and book chapters, workshop proceedings, FAO reports, bulletins, legal documents, and documents from the Internet. Information was reviewed on catch composition, temporal trends and spatial differences in harvest rates, estimates of potential production, processing techniques, marketing and socio-economic aspects, management, and legal and regulatory frameworks. Information on the extent of water resources was also updated using the literature sources. Nineteen years (from 2003 to 2018) of fisheries data were analyzed to evaluate the state of fishery production and aquaculture development in Ethiopia.

GEOGRAPHY AND CLIMATIC PROFILES OF ETHIOPIA

Geography

Ethiopia is located in the Horn of Africa. It surrendered its Red Sea coastline to Eritrea in May 1993 and is now landlocked (MoA, 2010). Ethiopia's topography consists of a central high plateau that is bisected by the Great Rift Valley into northern and southern highlands. The plateau is surrounded by lowlands, which are more extensive to the east and southeast than to the south and west. The plateau varies from 1500 to 3000 m and features mountainous uplands separated by deep gorges and river valleys, especially in the north. The highest point is Ras Dashen (4620 m), in the northern highlands. In the east, the Denakil Depression (part of the Rift Valley) is in places 115 m below sea level and is one of the hottest places on earth. A chain of lakes lies in the southern Rift Valley, but the largest inland body of water is Lake/Tana in the northwest. The diversity of Ethiopia's terrain determines regional variations in climate, natural vegetation, soil composition and settlement patterns (Leykum, 2003).

Climate

Rainfall and temperature patterns vary widely because of Ethiopia's location in the tropics and its diverse topography (Desese et al., 2010). The major factors that influence rainfall are the seasonal migration of the intertropical convergence zone (ITCZ), the northerly trade winds and the southerly monsoon, while the temperature is greatly influenced by changes in altitude (Tesfaye and Wolff, 2014).

Temperature

Latitude, altitude, winds and humidity all have a significant impact on temperature in Ethiopia. Although there are considerable differences between the highlands and the lowlands in the average monthly and annual temperatures, they are more or less similar in their small annual range and large daily range of temperatures (MoA, 2010). Ethiopia lies within the tropics, a zone of maximum insolation in which every spot has the sun directly overhead twice a year. However, 43% of the country consists of highlands, and tropical temperatures are not experienced everywhere except in the lowlands (Tesfaye and Wolff, 2014). In Ethiopia, temperature is greatly influenced by changing altitude. Extremes in temperatures range from the mean annual temperature of 34.5°C in the Danakil Depression at 180 m below mean sea level, to mountain slopes of over 4000 m, where minimum temperatures fall below 0°C (Hussien et al., 2011). As the sun is always high in the tropics, seasonal variation is not as distinctly observable as it is in the temperate zone of the northern hemisphere. However, there is a slight temperature increase in summer. In most places, the highest temperatures are experienced between March and September, as this is when the sun is at its highest. As the relative position of the sun shifts, southern Ethiopia has its highest temperatures in autumn and spring when the sun is directly overhead (BOMOSA, 2009)

Rainfall

In Ethiopia, there are 5 broad climatic zones recognized based on the altitude and temperature, namely: wurch (cold climate at >3000 m), dega (temperate climate – highlands between 2300 and 3000m), weynadega (warm, 1500 to 2300 m), Kola (hot and arid–climate: <1500 m) and

bereha (hot and hyper-arid climate in lowlands). These are typically subdivided into three according to distribution of rainfall such as wet: >1400 mm/year; moist: 900 to 1400mm/year; dry: <900 mm/year (Tesfaye and Wolff, 2014). The wettest part of a country is in the southwest, where average annual rainfall exceeds 2200 mm; for instance, in Lubabor zone rainfall decreases in all directions as one moves from the south-western highlands, with the driest areas averaging <200 mm, particularly in the Danakil Depression, the lower Awash River Basin and in Eastern Ogaden (MoA, 2010). Even though climate conditions are classified into generalized areas of specific types of climate, there are significant microclimatic variations over relatively small areas due to micro-relief variations (Leykun, 2003). Precipitation is determined by differences in elevation and seasonal shifts in monsoon winds. The highlands receive by far the most rainfall, most of it between mid–June and mid–September; lower elevations receive much less. In general, relative humidity and rainfall decrease from south to north and vary from scant to negligible in the eastern and south-eastern lowlands (Leykun, 2003).

According to Tesfaye and Wolff (2014) and MoA (2010), the short and long rains occur from February to April and mid–June to mid–September, respectively, starting in the north and moving southward. In the region of the headwaters of the Sobat, the rains begin earlier and last longer. The rain is heaviest in the Tekezé Basin in July and August. In the former provinces of Gojjam and Welega, heavy rains continue till the middle of September, and occasionally into October. There are also spring and winter rains; in fact, rain often falls in every month of the year. The rainfall varies from about 750 mm a year in Tigray and Amhara, to over 1000 mm in parts of Oromia (Hussien et al., 2011). The rainy season is of great importance not only to Ethiopia but also to the countries in the Nile Valley, as the prosperity of the region is largely dependent upon the rainfall in Ethiopia (Demese et al., 2010).

OVERVIEW OF FISHERIES DEVELOPMENTS IN ETHIOPIA

Scholars declared that Ethiopia possesses enormous potential of fertile and rich water ecosystems, commercially important fish fauna with diverse microalgae and water plants. Against which in the country is characterized by lower economic development, inadequate foods supply, rapid population growth, is one of the most acute challenges besides to the natural and manmade calamities. Ethiopian fish resources could undoubtedly offer the solutions to the problem of food shortage (EIDP, 2013). The ecological diversity and climatic variation explained to a large extent by its highly variable topography, which implies that Ethiopia is a country of enormous habitat diversity. Ethiopia, with its different geological formations and climatic conditions, endowed with considerable water resources and wetland ecosystems, including river basins, major lakes, many swamps, floodplains and manmade reservoirs. Hence, the water bodies support a diverse aquatic life including more than 200 fish species of which about 40 are endemic (FAO, 2016).

In Ethiopia, fish is almost harvested from wild by artisanal methods for consumption, the actual fish production potential is estimated to about 52,541 tons annually for the main water bodies, of which only around 38,400 (Table 1) were exploited very recently (EIDP, 2013). Similarly, according to Hirpo (2012), although some form of fisheries practiced in most freshwater bodies in Ethiopia, commercial fishery is concentrated at Lakes Tana, Chamo, Ziway, Abaya, Koka, Langano, Hawassa and Turkana. The major fish supply to the major cities and towns in Ethiopia are captured from Rift Valley Lakes (RVL) (40%) and Lake/Tana (50.2%) in the north (MOARD and FAO, 2009) and the remaining percentage going to riverine fisheries. For instance, the rivers and floodplains in Gambela Region are estimated to have annual fish yield potentials of 15000 to 17000 tons (Hussien et al., 2011), while rivers and floodplains in Benishangul Gumuz Region are estimated to have potentials of 2400 ton/year (Awulachew et al., 2007).

Freshwater fisheries resources in Ethiopia

Ethiopia has been acknowledged for huge potential of physically available freshwater resources: 12 river basins with 122 Billion metric cub (BMC) total mean annual flow; 4.5 BMC underground, Lakes: 11 freshwater and 9 saline water, 12 major marshes and a lot of craters, most of which are establish in the Rift Valley Basin (Tesfaye and Wolff, 2014; Gordon et al., 2007). According to Tesfaye and Wolff (2014), most of the lakes except Ziway, Tana, Langano, Abaya and Chamo have no surface water outlets, i.e., they are endhoric. Compared to surface water resources, Ethiopia has lower ground water potential. However, by many countries' standard the total exploitable groundwater potential is high.

Research findings have indicated that the country also possess many lakes and reservoirs, many small water bodies and large floodplain areas distributed all over the country that jackets a land area of about 13,637 km^2 (Table 1), about 1.2% area of the Ethiopian territory (Tigabu et al., 2007; Wang et al., 2018). Major lakes and rivers (Figure 1), and small water bodies include lakes and manmade reservoirs or micro dams, ponds and irrigation canals with an area of less than 10 km^2, and swamps and floodplains (FAO, 2003). However, numerous of such water bodies in Ethiopia could not be looked at yet and many of these are mysterious to scientists and researchers. Besides, a total of 106 major lakes and marshes, and major reservoirs in Ethiopia including Eritrea as well as 73 Ethiopian wetlands with their unlisted location (Minelik et al., 2012; Wang et

Table 1. Commercially exploited lakes, landing area and potential fish yield (Alemayehu, 2017; Tesfaye and Wolff, 2014).

Water bodies	Main landing site	Area (Km^2)	Fish Yield Possible (ton/year)
Tana	BahrDar	3,500	10000
Lugo	Lugo	25	400
Koka reservoir	Koka	255	700
Ziway	Ziway	434	2941
Langano	Oittu	230	240
Awassa	Awassa	91	611
Abaya	Arba Minch	1,070	600
Chamo	Arba Minch	350	4500
Turkana	Ethiopian (1.3% total area)	94	750
Total		6477	23,342

Table 2. Fish diversity in six drainage systems (Vadacchino et al., 2011)

Drainage systems	Number		
	Family	Genera	Species
White Nile (Baro Akobo)	26	60	113
Omo Turkana	20	42	76–79
Blue Nile (Abay)	16	37	77
Atbara Tekeze	10	22	34
Rift/Valley	11	18	28–31
WabeShebele and Juba	12	21	33

al., 2018).

Major freshwater fish species in Ethiopia

The Ichthyo faunal families, genera and species that are occurring in Ethiopian drainage basins are summarized in Table 2. Accordingly, the Baro Akobo appeared the most species rich (113 species) in 60 genera and 26 families (Shimada, 2013; Hirpo, 2017). The same report revealed that the basin harbors 6 fish families (Protopteridae, Notopteridae, Cromeridae, Nothobranchidae, Anabantidae and Channidae) which have not been described from the other basins. The Gibe/Omo and Blue Nile basins have more/less comparable species richness (Adewumi et al., 2012). The former was reported to harbor 76 to 79 species in 42 genera and 20 families, and the latter has 77 species in 37 genera and 16 families (Table 2) (Kundu et al., 2010). Similarly, Tekeze and Shebele drainage basins are comparable with 34 species (22 genera and 10 families) and 33 species (21 genera and 12 families) respectively. Families Anguillidae and Gobiidae were described only from the Shebele system so far (FAO, 2003).

The main commercially important fish species contributing to the total landing are *Oreochromis niloticus, Labeohori, Clarias gariepinus, Barbus and Latesniloticus* (Gabriel et al., 2007). Besides to its captured fisheries importance, Tilapia is one of the most important Genus for 21 century aquaculture and is produced in <100 countries (Tesfaye and Wolff, 2014; FAO, 2003). Tilapia is the leading species fished and consumed in Ethiopia. Researchers concluded that Nile Tilapia (*Oreochromis niloticus*) is the most dominant species landings (Gordon et al., 2007).

The catfishes mainly Chrysichthys, are widely distributed in salty and freshwaters in Africa where there are commercially important fish (Vadacchino et al., 2011; Daw and Helfrich, 2012). The freshwater fish fauna of Ethiopia is identified as a mixture of Nilo Sudanic, east African and endemic forms (Kundu et al., 2010). The highland east African forms are found in the northern rift/valley lakes (Awassa, Ziway and Langano) and lighland lakes (lake/Hayk and lake/Tana). The genera include *Barbus*, *Clarias, Garra*, *Oreochromis* and *Varicorinus*. They are related to fishes of Eastern and Southern Africa, and Arabian Peninsula. Ethiopia widely distributed *Lintermedius*is subdominant. However, 5 species occurred in 3 or more Lakes: *Oreochromis niloticus* (Nile tilapia), *Labeobarbus intermedius* (common large barb), *Clarias gariepinus* (African catfish), *Garradem becha* and *Cyprinus carpio* (common carp) (Hirpo, 2017). With the exception of Lake/Tana, all fish communities showed a low (6) species richness (Wang et al., 2018).

According to Tesfaye and Wolff (2014) and Shimada (2013) endemicity is the highest and lowest in drainage basins of Blue Nile , and Baro Akobo and Gibe/Omo

Table 3. Summary of the various water bodies production estimates in Ethiopia (Kundu et al., 2010)

The water bodies	Area (km^2)	Length (km)	Potential yield estimates (tons/year)	
			Mean	Per unit length
Major lakes	7740	-	39,262	5.8 ± 0.6
Major Reservoirs	1447	-	7879	6 ± 0.6
Small water bodies	4450	-	25996	4.1 ± 0.4
Rivers	-	8065	21,405	2.4 ± 0.9
Total	13,637	8065	94,541	

respectively, despite their highest fish diversity (Table 5). Similarly, Hirpo (2017) reported that the highest species endemicity in Blue Nile could be attributed to high cyprinid (18 species) endemicity for Lake/Tana. This is probably due to forms of geographical barrier, which isolate lake fauna from lower part of Blue Nile basin (EIDP, 2013).

Wabe Shebelle system of the Ethiopian territory is reported to have 10 to 12 endemic species (Shimada, 2013). According to Kundu et al. (2010) and Tesfaye and Wolff (2014), the species lower endemicity in otherwise high species diversity basins (Baro Akobo and Gibe/Omo) could be due to insufficient exploitation capture possible endemicity. Ethiopian endemics are so far represented by a few species like *Danakilia franchetii, Nemacheilus abyssinicus, Garra ignesti* and large number of *Labeobarbus* species (Table 4) (Alemayehu 2017). Some of commercially important species in Ethiopia include *Oreochromis niloticus*, *Labeobarbus* spp., *Lates niloticus*, *Clarias gariepinus, Bagrus docmak*, and *Cyprinus carpio* (Vadacchino et al., 2011; Lemma, 2008; Gabriel et al., 2007).

CURRENT STATUS OF COMMERCIAL FISHERIES

Commercial fisheries refer to the profitable harvested aquatic organisms for human consumption. The case that apparently all fish consumed in Ethiopia are collected from the wild using artisanal methods (Adewumi et al., 2012; Awulachew et al., 2007). In Ethiopia, the major consumable fishery resources to the big cities and towns are mainly captured from lakes of the main rift valley basins (40%) and Lake/Tana (50.2%) in the north and some of the freshwater bodies (Table 5) (Alemayehu, 2017; Shimada, 2013).

The Ethiopian Rift/Valley contains a series of small to medium sized lakes, few of which are saline such as Lake Shalla, Lake Abiyata. Scientific findings indicated that the most highly productive lakes where regular fishing is conducted include *Ziway, Langano, Awassa, Chamo* and *Abaya* (Tigabu, 2010). Likewise, FAO (2016) reported that fishing is highly practiced in the two large reservoirs, namely, Fincha and Koka. Riverine fishing activities, mostly for local consumption, are performed in Baro River and its tributaries (located in Gambela and Benishangul Gumuz, south western Ethiopia) and Omo River systems, going as far as the Kenyan border (Janko, 2014; Cumberlidge, 2009).

At present Ethiopia has been constructing reservoirs dams with huge potential of holding large water volume intended to generate hydroelectric power to the domestic as well as consumption of the neighboring countries for foreign currency in one hand and also to produce foods of high quality like fish and other aquatic products (Tigabu, 2010). Some of the dams being constructed include: Dam of Gibe I, II, III, IV, V, VI, and VII, Tekeze, and Great Ethiopian Renascence Dam (with actual water holding capacity of 74 billion metric cub) build on the Nile river are believed to be used for fish production, and irrigating large area of fertile soil (EIDP, 2013; FAO, 2016).

Fishing gear technology

Gears commonly utilized in Ethiopian fisheries include gillnets, beach seines, long lines, hook and line, and cast nets (Tesfaye and Wolff, 2014). Various forms of traps, scoop nets and baskets made of plant materials and wires are also used, particularly in the rivers of Ethiopia (FAO, 2016). Gillnets are used almost on all Ethiopian lakes and account for most of the commercial production (Table 3). Beach seines are used for commercial catches in the northern Rift Lakes such as lake/Ziway and lake/Langano and Koka Reservoir. In Lake Abaya both the bottom and surface long lines are used to catch *Bagrus* and Nile perch, respectively (Shimada, 2013).

The latter is also used in Lake/Chamo to catch Nile perch (Tesfaye and Wolff, 2014). The use of hook and line is often restricted for subsistence fishing (Janko, 2014). Many other traditional gears are also employed on various lakes and rivers of the country's drainage basins. For instance, scoop nets in conjunction with fences are used in Gumara River of Lake/Tana (Kefale and Chinnan, 2012). The traditional gears account for most of the fisheries in Baroakobo Basin in Gambella region (FAO, 2016). Moreover, there are uses of poisons, extracted from various types of plants including *Millettia ferruginea* (Daw et al., 2012; FAO, 2016).

Fish healthcare

Disease problem might be one of the factors that hinder

Table 4. Diversity of the fish families in White Nile in Ethiopia (Alemayehu, 2017; Tesfaye and Wolff, 2014).

Family	Common name	Genera	Species
Amphiliidae	Loach catfishes	2	2
Anabantidae	Climbing gouramies	2	3
Bagridae	Bagrid catfishes	1	2
Balitoridae	African stony loach	1	1
Centropomidae	Nile perch	1	1
Channidae	Snakehead	1	1
Characidae	Characins	4	7
Cichlidae	Cichlids	4	5
Citharinidae	Abeles	1	2
Claroteidae	Claroteid catfishes	3	4
Clariidae	Air-breath catfishes	2	5
Cromeriidae	Naked shellear	1	1
Cyprinidae	Carps	7	21
Distichodontidae	Purus	4	9
Gymnarchidae	Aba	1	1
Malapteruridae	Electric catfishes	1	2
Mochokidae	Squeakers	5	15
Mormyridae	Elephant fishes	8	15
Notopteridae-African	Knife fishes	1	1
Nothobranchiidae	African ivulines	2	3
Osteoglossidae African	Bony tongue	1	1
Poeciliidae	Poeciliids	1	2
Polypteridae	Bichirs	1	2
Protopteridae African	lungfish	1	1
Schilbeidae Schilbeid	Atfishes	3	5
Tetraodontidae	Puffer	1	1
Total		**60**	**113**

fish production in countries similar to Ethiopia. Apart from postharvest production loss, diseases are known to cause mortality both in aquaculture and capture fisheries, and some are also causes for human diseases in many parts of the world (Wang et al., 2018). It must be noted that most parasitic diseases occur as a result of poor water quality. Most parasitic organisms are opportunistic and may be present all the time in the tank or on the fish in low numbers, and only cause disease when the fish is stressed (Janko, 2014). The amount of fish present in a tank, the water temperature, pH, lighting, type of filtration system and water chemistries all influence the health of fish. Since research is the base to undertake intervention measures many studies have to be conducted in this area for the future. However, there are a few reports concerning fish health in Ethiopia (Gordon et al., 2007; Leykun, 2003).

Generally, in Ethiopia, fishes are not the serious problems of human health, but important in relation to aquaculture development. There are some upsetting risks to public health safety in a badly managed culture system. Therefore, according to Wang et al. (2018) and Vadacchino et al. (2011) based on these facts, it is very crucial to control fish disease to avoid the above risks, to prevent costly losses in production from aquaculture, to prevent transmission of diseases among culture systems when eggs or fry are transferred from culture to a new area and to prevent hazardous effects of a disease control measures if treated fish are sold as food.

Preservation and transportation

Fish is one of the most perishable foods, mainly in tropical climates of less developed nations (Daw et al., 2012). If proper care is not taken immediately after capture, it can be spoiled in a few hours. Even using traditional methods, fish could still be subjected to various forms of spoilages (Nandlal and Pickering, 2004). Fish handling in Ethiopia is at its lowest level and remains traditional stage. Starting from the fish's collection by net/hooks, fish are thrown on to floors of boats, canoes/rafts.

Most of the lakes cached fishes reach the market by the traditional means of transportation without any preservation facilities (EIDP, 2013; Mwanja et al., 2011). Some fishermen hook some of the fish together with a string and carry them by hand to the market for immediate

Table 5. Estimates of the potential fish production in Ethiopian Rivers (Alemayehu, 17; Tesfaye and Wolff, 2014).

Rivers	Catchment Area(km²)	Length within Ethiopia (km)	Potential yield estimates			
			Literature	Model 1	Model 2	Per Unit length (ton/km)
Baro	38,400	285	916	839	232	2.3
Akobo	21,890	203	653[a]	487	119	2.1
Gillo	13,050	252	810[a]	295	182	1.7
Alwero	8098	321	1032[a]	185	294	1.6
Pibor	4300	96	309a	100	27	1.5
Blue Nile	176,000	800	2133[b]	3675	1792	3.2
Awash	112,696	1200	4800[b]	2385	3999	3.1
Wabishebele	202,697	1000	3333[b]	4215	2787	3.4
Genale	171,042	480	768[b]	3575	652	3.5
Omo	79,000	760	1925[b]	1690	1619	2.3
Tekeze	82,350	608	1232[b]	1759	1041	2.2
Mereb	5900	440	645[b]	136	549	1
Angerib	23,812	220	161[b]	528	139	1.3
Miscellaneous small rivers	196,259	1400	6533[b]	4085	5426	3.8
Total	1,135,494	8065	25,250	23,954	18,855	2.4 ± 0.9
Average			21,405[a]			

cash income. Others put the fish in a basket, cover them with fresh leaves and carry them by hand. Still others collect their catch in sacks and carry it to the market by hand or on donkeys, taxis or pickup trucks (Wang et al., 2018). The most common forms of fish storage are the use of deep freezers of varying sizes and cold rooms in some cases such as the FPME fish collection centers at ArbaMinch, BahirDar, Zwai and Addis Ababa. All shops of the same Enterprise in different towns and cities have mostly deep freezers and in some rare shops cold rooms as well (Shimada, 2013; Wang et al., 2018). It should, however, must be noted that all these fish storage facilities do not get regular supply of power to keep the freezers and cold rooms running around the clock. Most fish retail shops and fish collection or storage facilities do not have backup diesel generators (Shimada, 2013; FAO, 2016).

Although Ethiopian consumers have preference to whole fresh fish, traditional drying of fish is performed on remote fishing sites. Sun drying is the simplest way of preserving fish and is practiced to some extent in some rift valley lakes. Salting as a preservation tool could be best used in areas where salt is available and cheap (Shimada, 2013). Smoking is not a traditional method and only some trials have been carried out at the FPME receiving station at Ziway Town (Tigabu, 2010).

CURRENT STATUS OF FISHERIES IN ETHIOPIA

Aquaculture refers to the rearing of fish in the water bodies for the benefits of human being. It also deals with farming of aquatic organisms such as fish, crustaceans, mollusks and water plants. Aquaculture involves cultivating fishes of the freshwater and saltwater under controlled conditions, which date back to 1955 in Ethiopia, when a few small experimental ponds were constructed to grow *Tilapia zilli* into Ethiopia (Tigabu, 2010; Hech, 2005). Recently, regional research institutes, agricultural bureaus and farmers associations that do water harvesting for irrigated agriculture are showing interests to integrate aquaculture into their farms (Tesfaye and Wolff, 2014; Lemma, 2012; Adewumi et al., 2012). Given this scenario, aquaculture could be quite feasible in Ethiopia, given the diversity in climate, and the availability of aquatic systems inhabited by over 180 fish species (Vadacchino et al., 2011; Gordon et al., 2007).

Recently, capture fishery is in a constant hazard due to illegal fishing and overfishing, corroborated by a rapidly growing population in Ethiopia putting more pressure on the food security problems. This condition provoked the experts to continue aquiculture in irrigated agriculture and water harvesting in dams to supplement the food production system (Vadacchino et al., 2011). As a result, administrative regions like Tigray and Amhara Agric Bureaus have made concrete plans to include aquaculture components into irrigated projects (Adewumi et al., 2012) in Oromia region raised in different systems: water based (cages), Land based (Ponds) mono culture and poly culture system. In addition, Integrated Aquac–Horticulture started to scale up in some areas and using the recycled byproducts of one as inputs (fertilizers, food) for another (Daw et al., 2012).

Potential of culture fishes

A number of factors considered before deciding on species for use in aquaculture. The standard criteria for evaluating the aquaculture potential of species relate to a number of

characteristics such as growth rate, yield and market value (Mwanjia et al., 2011). In the main, aquaculture species on which to concentrate as economic sources of protein would be those species which are fairly popular as food, low on the food chain, hardy, easy to culture and fast growing. Among the local species found in the country, species known as having a good breeding potential are *Oreochromis niloticus, Sarotherodon galilaeus, Heterotis niloticu*s and *Clarias* species (Gordon et al., 2007; Kundu et al., 2010). Similarly, tilapia, common carp and Clarias species are among the different most important species for aquaculture in Sub Saharan Africa (Mwanja et al., 2011). In Ethiopia Nile tilapia, *Oreochromis niloticus, Clarias gariepinus* and Carp species are most common.

Potential of fish feed

Fish feeds play a role in fish viability and profitability, which account for at least 40 to 60% for cost of production (Gabriel et al., 2007). Although there are rooms for enhancing aquaculture production in Africa through improvements in the overall production system, in genetics and general farm management principles, the desired growth of aquaculture which is necessary in order to meet the increasing demand for fish is only achievable through cost effective and high quality fish feed (Hirpo, 2017). Conventional feed resources are cheaper sources of protein to meet fish's requirement and, hence, reduces cost of animal production in developing countries. Therefore, the search for inexpensive and better alternative sources of protein, which might be unsuitable for human consumption, the most underlined (FAO, 2016).

In the spotlight of this, in Ethiopia, a number of agricultural processing byproducts not utilized for human consumption, but high potential feeds for small scale aquaculture are available. It is acceptable that the transformation of locally available byproducts low in protein into high quality fish protein can be a major contribution to improving the protein supply for local human population (FAO, 2016; Vadacchino et al., 2011). Several agricultural and agro industrial byproducts available in Ethiopia have been evaluated for their production potential in poultry and livestock feed (Asfaw, 2008). However, only some information is available which cover the suitability of this resource for fish feed (Craig and Helfrich. 2012). Hence, the presence of agriculture is an important indicator of aquaculture potential in the country, because, it is a source of byproducts for fish feed or fertilizer. For small scale fish farming, agricultural byproducts can contribute to higher yields than would be possible from the natural production of the pond. For commercial fish farming, use of byproducts from agriculturally produced industrial food processing can reduce feed costs by allowing replacement of part of the formulated feeds (Tesfaye and Wolff, 2014).

Fish consumption trends

It is revealed that fish contain high biological value nutrients for human health. In Ethiopia, fish consumption trends are limited, nonetheless of the strong livestock rearing and meat consumption. In Ethiopia, the overall per capita fish intake is very low (0.216 kg per year) compared to that in Africa (FAO, 2016). However, consumption is greatly biased towards quite limited geographical areas and also weighted towards fasting days (Wednesdays and Fridays) and fasting periods (55 days in March/April, 15 days in August, as well as other periods which may be less widely observed) (FAO, 2003). Increasing scarcity (apparently reflecting both rising demand and supply constraints) has resulted in increseing real prices for fish, so there is an increasing tendency for fish to be a luxury product consumed by higher income groups (FAO, 2016; FAO, 2009).

Marketing system of fish in Ethiopia

Most Ethiopians prefer beef to fish though it is much more expensive and hence not easily obtained (Adugna, 2007). Fish marketing in Ethiopia is also influenced by many factors, most of which are common to many under developed countries (FAO, 2016; Hirpo, 2017).

Substantial potential of fish marketing system exists in Ethiopia and there is a demand for fishes. However, absence of fish trading tradition, inefficient marketing network, poor transportation and preservation facilities affects fish marketing system in Ethiopia. In addition to the above challenges, selectivity of people to some species have also been found to harm the marketing situation of fish. Fish price is determined by fish demand and supply condition in the country, which has increased from time to time. The same findings have indicated that the price of whole fish per kilo of almost doubled within 5 years of time for instance in Lake Tana. And selling price of filleted fish has increased almost by three fold. But now a kilo of whole and filleted fish ranged from 15 to 20 Birr and 65 to 85 Birr, respectively including in *RVA* and even more than this in Addis Ababa (Asfaw, 2008; Daw et al., 2012).

Shimada (2013) reported that the production cost for fish/kilo varies depending on season of the fish availability around fishing areas. In seasons like July to September and February to May production reaches above the mean. Peak production occurs between July and September, mainly in the month of August and the cost of production during this season drops. Hence individual fishers as well as cooperatives fetch large benefit in this season (EIDP, 2013). However, in the other seasons the amount of produce dropped below the mean to the extent that no fish is caught in some months of a year. During these period fishers, mainly commercial ones, lose money and stop fishing.

EFFORTS MADE FOR FISHERY SECTORS IN ETHIOPIA

Institutional or management arrangements

In Ethiopia, Ministry of Agriculture (MoA) is responsible for

the development and management of fisheries while the universities and research centers conducting research in response to the sector's needs, and thus, remarkable technologies were generated for the sustainable utilization of fishery resources (Shimada, 2013). According to Alemayehu (2017), 78% of the small scale animal farming dwellers from those of integrating the pond fish culture with vegetables production and poultry become effective and benefited through the concerted efforts made by both the farmers themselves and Ziway Research Center. In some areas of the country, nursery sites were established and hatchery process started; different locally available agro processing byproducts important for fish culture were identified (Hirpo, 2017). The effect of stocking density and supplementary feeding on growth performance and fish yield (FAO, 2016) as well as effect of feed and water quality on growth performance in cage culture fish production (Shimada, 2013); effect of feeding frequency on growth performance and survival of fish in cage culture system (Wang et al., 2018) were identified; and evaluation of Aquaponics are under way at Ziway and Debre Birhan fishery research center Addis Ababa University is an encouraging job. In addition, different fishery technologies are scaled up to the farmers (Kundu et al., 2010; Golubtsov and Habteselassie, 2010).

Fisheries policies

According to the constitution of the Federal Democratic Republic of Ethiopia (Proc. 1/1995), land and water belongs to the state and the people (FDRE, 2010), meaning all the water and associated resources cannot be privately owned. The Agricultural and Rural Development Policy and Strategy document (November 2009) is important as it emphasizes the need for management, conservation and sustainable utilization of natural resources. In line with this document, the federal fisheries proclamation was ratified by Parliament on 4th February 2009 and the proclamation is referred to as the ''Fisheries Development and Utilization Proclamation No. 315/2003'' (FDRE, 2010). The same report documented that the latest legal document specific to the fisheries sector, has the following objectives: "conserve the biodiversity of fish and its environment as well as prevent and control overexploitation of the resources, increase the supply of safe and good quality fish and ensure a sustainable contribution of the fish toward food security, and expand the development of aquaculture''. According to Tesfaye and Wolff (2014), it comprises four parts and twenty-one articles describing the legal procedures and rules to be followed to achieve these objectives. It is intended that the regional states use this document as the broad framework and adapt it to their own regional context. However, so far only in two states (Amhara and Southern region) the document was adapted and ratified by their respective regional council but the others are expected yet to do the same. However, similar to the National Fisheries Development and Utilization Proclamation, the regional proclamation emphasizes ''command and control'' by fisheries inspectors without mentioning the by now worldwide common practices of co-management (Gordon et al., 2007), which allows for the active involvement of the resource users in the resource management and policy debates. It thus seems that the proclamation may need some revisiting and the rules (directives) and guidelines should be formulated accordingly.

The other policy document directly related to the fishery is the fish quality standards. The code of conduct Article II (FAO, 2016) states that member states should adopt appropriate measures to ensure the right of consumers to safe, wholesome and unadulterated fish and fishery products. Thus, the Ethiopian Quality and Standard Authority endorsed 21 fish quality standards, although its implementation requires ratification of the fish products quality control regulations (MoA, 2010). The national level fisheries resource development and utilization regulations and guidelines, and the quality control regulations were submitted to the Council of Ministries for official endorsement (MoA, 2010; Gordon et al., 2007).

There are also other more general policy documents and legislations related to environment and water resources, animal and animal product quality and marketing. The Environmental Impacts Assessment Proclamation (No. 299/2002) was issued to assess possible impacts of projects on the environment prior to their approval and implementations; Animal, Animal Products and By-products Marketing Development Authority Establishment Proclamation (Nos. 117/1998 and 198/2000) and Animal Diseases Prevention and Control Proclamation (No. 267/ 2002) are also related to fisheries (BOMOSA, 2009). However, the implementation of the policies seems to be still at very low level as some of the Rift Valley lakes already show declining trends in catches due to overfishing, while others still seem to be underfished and many of the water bodies have not even started to develop any fishery.

The national standards

The national standards set out for which fishery management plans and fishery regulations must be consistent. Under 2006 amendments, 3 new national standards were added to the previous fishery conservation and management measures that may include:

- prevent overfishing on a continuing basis, the optimum yield.
- based upon the best scientific information available.
- be managed an individual stock as a unit throughout its range, and interrelated stocks of fish shall be managed as a unit or in close coordination.
- avoid discriminate between residents of different states. If it becomes necessary to allocate/assign fishing privileges among various fishermen, such allocation

shall be (a) fair and equitable to all such fishermen; (b) reasonably calculated to promote conservation; and (c) carryout in a manner no particular individual, corporation, or other entity acquires an excessive share of privileges.

- consider efficiency in resources utilization where practicable; except no such measure shall have economic allocation as its sole purpose.
- consider and allow for variations, and contingencies in, fisheries, fishery resources and catches.
- minimize costs and avoid unnecessary duplication where practicable.
- consistent with conservation requirements of this Act (including prevention of overfishing and rebuilding of overfished stocks), importance of fishery resources to fishing communities to: (a) provide for sustained communities participation and (b) minimize adverse economic impacts on such communities.
- minimize by catch and the mortality of such by catch.
- promote the safety of human life at sea.

Fisheries management practices

FAO (2012) defined fisheries management as ‘‘the integrated process of information gathering, analysis, planning, decision-making, allocation of resources, and formulation and enforcement of fishery regulations by which the fishery management authority controls the present and future fishing activities, in order to ensure the continued productivity of the living resources’’, which implies to regulate the exploitation of the biomass to the level that the resource remains sustained. With a similar concept the MoA has been trying to manage the fisheries resources and on the basis of the National Fisheries Development and Utilization Proclamation No. 315/2003, different management measures have been implemented to regulate the fisheries.

According to Hussien (2010), management measures like prohibition of destructive gears such as poisonous and explosive gears of any type are fully in place; mesh regulation including both twine and mesh size, and dimension of the net need to be standardized and adjusted to the needs and requirements of individual fish species; some area and seasonal closure have been implemented and reserve (park) area have been declared. According to Wang et al. (2018), area and seasonal closure refers to a protection of those parts of the lake where the target species are known to breed, whereas a reserve area is permanently closed for fishing. However, the latter was only possible where a national park and a fishery share the same lake and thus, the portion of the lake claimed by the park is restricted from fishing and serves as a reserve area for the fishery itself. An example could be Nech Sar National Park, which also includes parts of the lakes Chamo and Abaya. Lake Ziway was also closed for fishing in the years 1986 and 1987 (Hussien et al., 2011).

Moreover, fishery experts at the district level also tried to monitor the type of fishing gear and mesh size that the fishermen deployed and took some measures. Hussien (2010) reported that beach seines have been banned in some lakes as has the use of monofilament nets. However, the Monitoring, Control and Surveillance (MCS) system are often constrained by limited capacity in terms of qualified personnel, availability of budget and logistics for field work, which somehow affects regular data collection.

Gordon et al. (2007) also pointed out that there are capacity constraints relating to data collection on Lake Tana. Fishery associations and cooperatives are also involved in the management process. However, they often lack sufficient capital (including access to credit) to purchase fishing gears (Gordon et al., 2007) and have also no saving culture which makes them weak organizations and very sensitive to changes in product availability and market price fluctuations. They are forced to use low cost fishing materials like papyrus reeds to make canoes, which limit the fishers to go further offshore, and in some cases make the fisher use spears and other traditional gears, which have adverse effect on fish populations. Despite use of all these regulatory measures, some lakes already show clear signs of overexploitation (Tesfaye and Wolff, 2014). This could imply that the management methods that are implemented are either inappropriate or lack efficient enforcement. Generally, this traditional centralized or topdown management approach has failed in many parts of the world and a new more flexible and participatory approach, called co-management is becoming popular and successful case studies and detailed explanations could be found. It allows sharing the responsibility of the government and the resource users in decision making processes and implementation of management strategies, and increases sense of ownership and equity.

Investment in the sector

An estimated 90% of fishers and fish farmers globally, are classified as small scale (Asfaw, 2008; Gordon et al., 2007). In additional more than 100 million people are estimated to be employed in other fisheries associated occupations, particularly in processing and trading, bringing the total estimated to directly or indirectly employed in small scale fisheries and aquaculture to be about 138 million in 2002 (Kundu et al., 2010). Those facing fisheries in natural habitat which include: overfishing, obnoxious and unconventional fishing practice such as use of chemical poison (ichytotoxic) plants and use of unregulated mesh sizes (FAO, 2016).

Some investors have started to show interest to develop aquaculture in Ethiopia and there are now 4 private enterprises that are licensed for the same. These are: (i) EthioFisheries PLC that built a fish processing plant in Arbaminch, near Lake Abaya, (ii) Victoria Viezzt CarloTalaric PLC initiate fish farms along the shores of Lake Chamo, (iii) MIDGE 2000PLC Cage Culture and (iv) Ashraf Industrial Group Cage Culture, both planning to

operate on Lake/Tana. There are also two crocodile farms in Arba Minch, one governmental and one private that raise crocodiles especially for crocodile skin export (FEDR, 2010; Kundu et al., 2010).

Fish welfare

Researchers concerned about animal welfare generally presume that animals are capable of suffering or discomfort (Hickley et al., 2008). In order to consider the welfare of an organism, it must be conscious of at least some basic emotion. Thus, fish welfare should only be of concern if fish are not only aware but also conscious. That is, the fish must have the ability to subjectively experience pain, coldness, comfort, discomfort and to consciously differentiate perceived internal states as 'good/bad', 'pleasant or unpleasant', etc. Such ability, termed sentience, is a necessary attribute for concerns about animal welfare (Tigabu, 2010). The same report indicated that fish are capable of suffering and we approach this by considering the controversial issue of whether they experience physical damage as pain. The three main indicators of humane slaughter are that excitement, pain and suffering in pre slaughter handling is minimized animal become insensible to pain within >1sec of any aversive stunning or slaughter procedure application that persists until the animal death (Hickley et al., 2008). These features are a legal requirement for animal slaughter in UK, being a part of Animals Welfare (Vadacchino et al., 2011).

CONSTRAINTS ON FISHERIES DEVELOPMENT IN ETHIOPIA

Major challenges on freshwater fisheries

In Ethiopia, fisheries sector is still undeveloped and traditional for several technical and nontechnical attributes, among which limited production awareness and skills, overfishing, fishing tradition and climate change and most people low fish consumption habit is frequently quoted (Craig and Helfrich, 2012). Traditionally, small scale (artisanal) fisheries are used to characterize those mainly none mechanized, low level of production due to constraints faced fishermen (Hirpo, 2017). In Ethiopia, the rate of environmental degradation, mainly due to deforestation, erosion by water and wind, and grasslands overgrazing by cattle, siltation and exotic toxic weeds infestation of the most lakes, and illegal fishing practices (FAO, 2016), consequently, a decreased in fish fauna biodiversity in the different drainage basins and Rift Valley Lakes (Wang et al., 2018).

Environmental degradation: this increases in subsistence agricultural growth, deforestation, municipal and industrial effluents and human encroachment on the shoreline has given rise to historically unprecedented nutrient loadings into lake. Degradation and depletion have the most immediate impact on rural poverty, food insecurity, malnutrition and under nutrition are closely linked to environment degradation, as poverty depletes natural resource, which in turn aggravates suffering of the rural poor (Adewumi et al., 2012). When people's survival is at stake, they are forced to farm marginal lands, to reduce fallow periods, to cut vital forests in their search for arable land or fuel, to overstock fragile rangelands and to overfish rivers, lakes and coastal waters (Asfaw, 2008; FAO, 2003). Nevertheless, the fishing sector of the economy has various problems. Among others, mismanagement of the resource, inappropriate policies and institution, inadequate technical and material backup to the sector and market are most underlined (Hussien et al., 2011). Moreover, lakes are threatened by catchment's deforestation, shore damage, water pollution, siltation and eutrophication and overfishing. There has also been increased extent of irrigation schemes and mechanization in recent years (EIDP, 2013). Constraints and vulnerability of fisheries communities are mainly due to resource depletion, increasing competition on open access resources, inequitable resources use, natural disasters like storms and overreliance on one type of asset and lack of options (Wang et al., 2018). Moreover, lack of government support, remote locations and poor services, low literacy and innumeracy and weak organization capacity are other factors that expose fishing communities to poverty. Increased number of fishermen and fishing gears, which cause resources scarcity, thus, limits the livelihood (Hussien, 2010).

FUTURE STRATEGIES OF FISHERIES AND AQUA-CULTURE DEVELOPMENT IN ETHIOPIA

Fisheries and aquaculture Inputs and materials

Fish seeds

Governments needs to establish and strengthen model seed production centers until the private sector takes over, encourage youths' cooperatives and hatcheries to produce quality seed; set up proper seed distribution centers and channels; perform supervision and monitoring activities and build capacity and skills of youths on identified gaps of seed production and distribution through appropriate training; and maintain quality brood stocks of selected culture organisms corresponding to identified production systems. Similarly, private sector should also produce and distribute quality and traceable fish seeds; maintain all data concerned with production, distribution and sales of fish seeds; and adopt latest technologies on hatchery management and seed production.

Fish feeds

Government must develop guidelines on quality fish feed

production and storage; Facilitate the establishment of modern feed processing and formulating industry and building the private sector skills for preparing species specific fish feeds and their storage. Private sector must aware Government strategy regarding different production systems within aquaculture zones; produce and distribute quality feed at fair price to fish farmers; and publicize information on feed availability, quality, efficiency and price. Finally, monitor and get feedback and keep performance records.

Capital investment

Government should: ensure lending financing institutions understand the aquaculture advantages and profitability; set up a developmental fund for aquaculture activities; evaluate the technical merits of investment proposals submitted to lending institutions for funding; advise fish farmers on where and how to access financial assistance; interact with the funding institutions to negotiate preferential interest rates for aquaculture development; and encourage farmers to prepare feasible aquaculture business plans.

Private sector should: build a capacity to organize business plans and management skills; develop strong and acceptable feasibility reports with all prerequisites for developing a business proposal; and lending institutions should finance viable aquaculture businesses.

Fishing gears and other aquaculture equipment

Government should: Initiate and support the establishment of local fishing gears manufacturers; monitor fishing gear standards; educate farmers to use nets for handling different stage of fish; and demonstrate the advantage and use of other aquaculture equipment in fishponds.

Private sector should: Produce standard fishing gear materials and fishing gears; upgrade skill and knowledge of making and mending of fishing gears; and demonstrate the operation and maintenance of gears and other aquaculture equipment for durability.

Research and extension/outreach services

The government is required to duly support universities. They are to provide quality technical assistances through efficient outreach program, demonstrate and disseminate aquaculture technologies, and information networks in order to enhance outreach activities to development agents and end users; it needs to train and equip aquaculture service providers; strengthen the FTC and youths to allow for ease of information delivery and sharing of best practices; facilitate communication channels amongst different aquaculture stakeholders; facilitate farmer internships including farmer to farmer contact to enhance learning; and maintain all activities and reports relating to outreach programs.

Fishery or aquaculture professional organizations should: Act as forum for information exchange among stakeholders; rationalize the marketing and purchasing of inputs, as well as to exert social control on service suppliers; defend the collective interests and lobby for appropriate intervention of the public sector; and establish relations with the research institutions and other stakeholders.

Private sector should: Collect all baseline information for setting up outreach programs and inform the details to the government; obtain all appropriate extension material from concerned government agencies and other organizations involved in aquaculture; and inform the government the constraints that they experience and solution sought.

Research

Government should: consider research on aquaculture as one areas of the priority in agricultural development; allocate adequate budget to aquaculture oriented research activities; identify area of research gap; support the farmer participatory research directed at different production systems; ensure that research is responsive to the needs of fish farmers; provide and support aquaculture research facilities; conduct research on aquaculture technology packages; upgrade status of research to a fully-fledged institute; demonstrate aquaculture research outputs to users; and develop infrastructure facilities for aquaculture research.

Private sector should: Collaborate with government and establish modern facilities to conduct advanced research; adopt research results.

Training, education and capacity building

Government should: Promote the higher educational institutions on aquaculture at all levels including the curricula development; develop and support continuing training plans for aquaculture technicians, farm managers and researchers and assist in linking candidates with local, regional and international agencies providing training, education and distance learning options; allocate experts in a rational manner; and provide appropriate hands on training to all existing fisheries personnel in aquaculture.

Private sector should: Provide feedback and advice on training, including the efficiency of training and required

training needs; and facilitate practical training opportunities on their farms.

Culture based fisheries

Government should: Ensure that conflicts arising out of the multipurpose use and management of water bodies and water harvesting facilities are amicably resolved; commonages the fisheries of water bodies with participation of the private sector and fish farmers.

Private sector should: Actively participate in the conservation and management of water bodies; manage the fisheries, the water resource and other activities relating to their businesses having in mind the interest of all the other users; aware of carrying capacity of the resource of sustainable development; and protect water bodies from pollution/degradation while practicing cage farming in natural water bodies.

Fish health and management

Government should: Monitor and control fish health on fish farms and water bodies; educate fish farmers on fish health and fish health management; certify the quality and safety of fish imports and exports; make the surveillance of fish disease in natural and cultural systems; regular monitoring of water quality both in source water and in cultural systems; identify bacterial, protozoan and metazoan parasite infestations; find out other fish disorders like abnormality, nutritional disorders, pollution induced changes and other physiological disorders in cultivable fish; take appropriate prophylaxis and other curative measures; establish and strengthen Fish Health Laboratory in Ethiopia with international support; supervise for fish cases registry from natural and culture systems; establish contacts with FAO and World Fish Center to develop and promote fish health programs; develop farmers capacity to identify diseases in its early developmental stage; train farmers on methods of disease control in culture systems; and develop quarantine methods to import seeds to assess their health.

Private sector should: manage, prevent and control spread of diseases within and outside the farms; report diseases outbreaks on the farms to the appropriate authorities; familiar with the knowledge of water quality parameters; and familiar with the common parasite and disease of cultivable fishers with their control.

Gender issues

Government should: Promote gender equality and empower women on aquaculture; develop a strategy to incorporate more women in aquaculture practice, processing and marketing of aquaculture products; take into account the specific gender issues in the education, training and extension of aquaculture capability development programs; elaborate indicators of reference in the effective implementation of gender issues in aquaculture sector; encourage community based aquaculture and village group concept to develop aquaculture with women groups involvement; and develop capacity building for women group to undertake viable aquaculture methods.

Private sector should: Develop capacity building for women group to undertake viable aquaculture methods to ensure gender equality; know the details and provide on the involvement of men and women in aquaculture activities; and know the funds allocated for addressing the gender issues.

Access industries and fish farmers to land/ aquaculture zones

Government should: Identify potential areas of aquaculture; facilitate farmers and investors in suitable site selection for aquaculture; guarantee aquaculture investors' rights to land and their investment; and technologies developed: GIS and remote sensing to identify and select suitable sites for aquaculture.

Legal and regulatory framework

Government should establish clear and secure user rights to land and water for aquaculture investment; Involve private sector and other stakeholders in policy and development of regulations; regulate quality and production of feed and seed; develop a system to ensure that all sectors are aware of the regulations; effectively implement the regulation; develop environmental protection rules and regulations for aquaculture activities; give legal backing to the collection, analysis and publication of reliable and up to date statistics; and regulate the introduction of indigenous and exotics and the movement of aquaculture species.

Private sector should adhere to relevant regulations, and control measures; follow procedures and regulations in the development of aquaculture practices; respect regulations on the introduction, importation and movement of aquaculture species; seek permit before establishing aquaculture farms; conduct environmental impact assessment for aquaculture enterprises; self regulate to ensure a safe to consume product is provided to all consumers; participate in the formulation of policies, strategies, regulations and development programs; and provide completed and accurate data for monitoring by the Government.

Improved marketing

Government needs to provide basic marketing infrastructure such as roads, electricity, potable water and communication facilities; provide information on fish wholesale and retail prices from main domestic markets; provide and make technical and economic information on preservation and other postharvest processes, technologies and techniques available to producers and consumers; increase fish consumption by promoting new food fish recipes; develop marketing channels that are accessible to fish producers; protect local producers against unfair foreign competition provided that the protective measures conform to international agreements; promote marketing of fish by increasing clients' acceptability of aquaculture products through fish quality assurance; and assist fish farmers to increase incomes through value addition to their products.

Public private partnerships

Government should assign clear roles to identifiable public and private institutions in the development of aquaculture; encourage private sector to produce inputs such as seed, feed and fishing gears; limit its involvement in aquaculture development to monitoring, evaluation and creation of enabling environment for the private sector to operate; Government and private sector should also develop strong institutional arrangements in support of aquaculture development.

Monitoring and evaluation of aquaculture industry

Government should control quality inputs (feed, seed, drugs, chemicals) and products through certification; enforce compliance with appropriate international codes such as the FAO Code of Conduct for Responsible Fisheries (CCRF); control introduction and export of aquatic organisms; establish a data collection, analysis and publication system for an effective evaluation of all aspects of the sector; and ensure that Environmental Impact Assessment (EIA) studies are properly conducted before an aquaculture establishment is set up.

Private sector should comply with the regulations on the responsible conduct of aquaculture and on their obligations towards the conservation of the environment; obtain a permit before establishing an aquaculture establishment; regularly provide reliable and up to date statistics on their operations; and comply with the quality standards set by Government for aquaculture inputs and products.

Policy issues

Government should encourage the private sector to participate in aquaculture policy formulation; incorporate aquaculture production into water harvesting, irrigation agriculture and hydroelectric power generation schemes. Increase and sustain the aquaculture contribution to food security and poverty alleviation; coordinate federal and regional state policies on issues related to aquaculture; promote aquaculture development in accordance with the NEPAD Action Plan and the MDG; participate in the work of relevant international organizations such as FAO, its CIFAA, the ANAF and the World Fish Centre; provide incentives for investors to undertake aquaculture business; put aquaculture to the priorities rank of the government policy as stated in the PASDEP and RDS; and encourage the integration of aquaculture with other farms. The priorities amongst them include:

a. education and training for specialists in fisheries and aquaculture such as lecturers, researchers instructors, and extensionists;
b. studying to identify suitability of potential areas considered as good for aqua according to different techniques;
c. undertake sensitization programs to create awareness to different stakeholders in the country including the local people, communities, investors, NGOs and donors;
d. formulate aqua technical packages fitted to various physical, social, environmental, cultural and socio economic concerns, and
e. undertake pilot projects in agroecological zones having best potential in aquaculture.

CONCLUSIONS AND RECOMMENDATIONS

In this review, observed studies to estimate Ethiopia's fish harvest potential were reexamined and estimates informed based on the most recent enumeration of different types of water bodies and their surface areas. The estimate of 94,500t/y$\pm$5.2% distributed as 73,100t/y$\pm$3.3% for lentic (lakes, reservoirs and small water bodies) and of about 21,400t/y$\pm$11.9% for the lotic ecosystems (riverine fishery) is higher by about 83% than previous estimates due to larger number of water bodies considered including newly constructed reservoirs for irrigation development and hydropower generation.

In Ethiopia, the fishery exclusively comes from inland water bodies and is mainly both artisanal and subsistence. Despite the existence of high fish diversity, only few fish species are targeted and constitute the bulk of the commercial catches. The current production is still far below the estimated potential yield, which suggests scope for further expansion of the fishery. However, some of the fished lakes already show signs of overfishing of the commercial target species, while others exhibit increasing catch levels, or conditions of rather stable catches. Fisheries assessment thus needs to be done for each important water body separately to estimate the actual level of fishing and to optimize management measures for

the sustainable use of the water bodies' resources. For this purpose, Maximum Sustainable Yield and Maximum Economic Yield levels need to be calculated for the target resources in the different water bodies. It is suggested here to prioritize research on economically important case study areas in different water body types (lakes, reservoirs, rivers) in order to provide baseline information for more meaningful extrapolations to other water bodies of similar characteristic and to understand the forces that drive the dynamics of the fisheries in these areas. While a sustainable and economically optimized use of the presently harvested resources needs to be the primary goal for research, there are also unexploited potential resources such as freshwater shrimps and crabs, commercially important microalgae and ornamental fish, whose commercial potential needs to be assessed for the country.

While the potential for further fisheries development and other uses of the inland waters of Ethiopia appears large, the subsector has as yet been unable to realize its full potential due to several limitations: (1) there is a lack of awareness and scientific information with regard to the state of the fishery in the different areas of the country and monitoring, control and surveillance systems are not efficient; (2) fishermen are poorly organized, lack access to credit facilities and rely on simple fishing technologies; (3) the market system is ineffective and product prices are strongly determined by FPME and few traders; (4) environmental degradation of water bodies (eutrophication, contamination) continues at a fast rate and invasive aquatic weeds make boating and fishing almost impossible in some water bodies. An important further problem is high post-harvest loss (about 40%) and a lack of stringent sanitary and phytosanitary standards and product quality.

The management in place follows the traditional command and control (top-down) approach rather than the recent widely accepted co-management approach. For a further efficient development of the fishing sector and for management and enforcement of rules to become more efficient, a participatory approach appears promising through which relevant stakeholders should be involved in development process and in the elaboration of fisheries policies. Generally, Ethiopia as a least developed country, should consider its fishery as an important intervention area to curb malnutrition and enhance food security in terms of caloric intake, protein and fat availability as well as providing for a wide range of essential vitamins and minerals. The sector moreover provides substantial employ-ment and an alternative source of income for many poor people, thereby improving the livelihoods of the society.

To this ended, either the government/fishing communities or both should follow strict production and management options. The updated, comprehensive assessment of resources supported by sound policy guidelines development; geared restriction like mesh size regulation, catch limits, closed season or area is most common regulatory measure used by local fishery officer; fishing instrument including gears and boats used in most water bodies are developed through experience and practical. In addition to the scenarios aforementioned, to sustain and utilize the aquatic ecosystems and to promote fisheries in Ethiopia, the following should be taken into consideration.

- clear scientific and timely National strategies of priority,
- successful implementation, must take cognizance of environmental and socio-economic conditions,
- partners and donor agents in Ethiopia/Africa, took initiative to prepare Aqua Development Strategy,
- the policy strategies and or approaches described in this paper needs to be followed.

CONFLICT OF INTERESTS

The authors declare that they have no conflict of interest.

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