JIMMA UNIVERSITY

SCHOOL OF GRADUATE STUDIES

COLLEGE OF NATURAL SCIENCES

DEPARTMENT OF BIOLOGY

Assessment of the Status of Pond Aquaculture Development in Jimma Zone, Southwest Ethiopia: The Case of Kersa and Seka-Chokorsa Districts

By: - Debele Jaleta

Main advisor: - Mulugeta Wakjira (PhD)

Co- advisor: - Tokuma Negisho(PhD)

A Thesis Submitted to Department of Biology, College of Natural Sciences, Jimma University in Partial Fulfillment of the Requirements for the Award of the Degree of Master of Sciences in Biology (Aquaculture and Fisheries Management)

June, 2024

Jimma, Ethiopia

Approval sheet

1. Adviser name	signature	date
____	___________	_______
2. Co-adviser name	signature	date
____	__________	________
3. Examiner name	signature	date
____	____________	__________

Abstract

Fisheries and aquaculture are crucial in the fight against hunger and poverty. Pond aquaculture has the potential to contribute to food security. In Ethiopia aquaculture is a potential alternative source of animal protein and food security. The activities of pond aquaculture development in Jimma zone including the present study areas is not scientifically assessed and documented. Therefore, this study was designed to assess the status of pond aquaculture development in Kersa and Seka-Chokorsa districts of Jimma zone. Data was collected from ten Kebeles of the two purposively selected aquaculture potential districts. Descriptive statistics were used for data analysis. The findings revealed the presence of a total of 124 fish ponds in the two districts, which were predominantly earthen ponds (99.2%). Of these 74.2% were functional and 25.8% were non-functional. All the fish ponds are rectangular in shape with a size of range $80m^2$ to $200m^2$ and most of the fishponds sizes were $150m^2$ with mean depth of 0.92m. The water sources for the ponds include stream (92.7%), and ground water (7.3%). The dominant fish species are Nile Tilapia in monoculture system (97.6%) and tilapia-catfish polyculture system (2.4%).The fingerlings for stocking the ponds were obtained from Sebata and Batu research centers assisted by livestock and fishery sector development program organization in technical and budget support (91.1%) and neighbor fishponds (8.9%). The stocking rate is high and stunting fish growth is low. The most common fish feeds used by all farmers included chicken manure, cow manure and other food roughage like injera and the feeding frequency is occasional. Most of the fish ponds are not clean; there are ponds that are full of grass, frog, submerged plants and foreign materials due to poor management. The mean values of the physicochemical characteristics water of the ponds were of $22.09\pm1.15C^0$ (Water Temperature), 5.23 ± 1.15 mg/l (DO), 7.08 ± 0.33 (pH), $89.96.16\pm26.77$ µs/cm (EC) and 59.10 ± 17.49 mg/l (TDS). The study also found that many respondents had not harvested any fish due to stunting fish growth, and some had sold fingerlings. About 30.6% of the aquaculture owners earned an average income of 1158.28 ETB per pond/year from fish sold and the average revenues gained from selling fingerlings were 712.50 ETB in all years. Series problems observed in study areas were overstocking, lack of fish gears, lack of fish feed and stunting fish growth. The study highlighted the major opportunities including suitability of environmental conditions such as availability of year-round water supply, suitability of soil for pond construction, natural resource availability, and availability of Jimma University for technology and knowledge transfer.

Keywords: Aquaculture, Fish pond, pond management, Seka choqorsa, Kersa, water quality

Acknowledgments

Firstly, I would like to acknowledge God who gave me the strength and patience throughout the work, and being with me. Then, I would like to express my deepest gratitude to my advisors Dr. Mulugeta Wakjira and Dr. Tokuma Negisho for their guidance, constructive comments, valuable suggestions, advices and support without any tedious for better preparation of this research. I would like to thank Jimma University, College of Natural Sciences and Department of Biology for giving the big chance to learn master of degree in aquaculture and fisheries management and I would like to thank the staff members of Biology department of Jimma university for the assistance in their areas of knowledge which enabled me to complete this research work.

Table of Contents

Approval sheet i

Abstract ii

Acknowledgments iii

List of Figures vi

List of Tables vii

Acronyms/Abbreviations viii

1. Introduction 1

1.1 Background of study 1

1.2 Statement of the problem 2

1.3 Research Questions 3

1.4 Objectives 3

1.4.1 General Objective 3

1.4.2 Specific Objectives 3

1.5 Significance of the Study 4

2. Review of Related Literature 5

2.1 Over View of Aquaculture 5

2.3 Aquaculture potential in Ethiopia 6

2.3 Status of Aquaculture in Ethiopia 7

2.4 Site selection and Pond construction Site selection 8

2.4.1Water 8

2.4.2 Soil 9

2.4.3 Climate 9

2.4.4 Topography 9

2.4.5 Location 10

2.5 Socio-economic impacts of the aquaculture ponds 10

2.5.1 Importance of Aquaculture in Food Security 10

2.5.2 Contribution of Aquaculture in Nutrition 11

2.5.3 Contribution of aquaculture to national economy 12

3. Materials and Methods 14

3.1 Description of Study Area 14
3.2 Sampling and Data Collection 14
3.3 Pond Dimensions and Water Quality Parameters 15
3.3.2 pH 15
3.3.3 Conductivity 15
3.3.4 Dissolved Oxygen (DO) 15
3.4 Data Analysis Techniques 15
4. Results 16
4.1 Demographic Characteristics of the Respondents 16
4.2 Pond Characteristics 17
4.3 Pond Management and Current Status of Aquaculture ponds 18
4.4 Water Quality Parameter of the Study Area 21
4.5 Socio-Economic Benefits from Aquaculture ponds 21
4.6 Challenges of Developing Aquaculture Ponds 22
4.7 Opportunities to Develop a Fishpond Farm in the Study Area 23
5. Discussion 24
5.1 Demographic Characteristics of the Respondents 24
5.2 Pond Characteristics 24
5.3 Pond Management and Current Status of Aquaculture ponds 26
5.4 Water Quality Parameter of the Study Area 26
5.5 Socio-economic Benefits from Aquaculture ponds 29
5.6 Challenges of Developing Aquaculture Ponds 29
5.7 Opportunities to Develop a Fishpond in the Study Area 31
6. Conclusions and Recommendations 32
6.1 Conclusions 32
6.2 Recommendations 33
7. References 34
8. Appendixes 40

List of Figures

Figure 1: Good and bad soil 9
Figure 2: study area map 14
Figure 3: Current condition of pond related with fence 20
Figure 4: Clean and no clean ponds.. 20
Figure 5: functional and discontinued ponds... 21

List of Tables

Table 1: Study districts and their respective Kebeles 14
Table 2: Characteristics of the respondents 16
Table 3: Characteristics (size, depth, ponds seal, shape, ownership and constructed year) (N = 124) 17
Table 4: different attributes of the ponds (N = 124) 18
Table 5: Pond Management and Current Status of Aquaculture ponds 19
Table 6: water quality parameter 21
Table: 7 Challenges of aquaculture ponds 23
Table 8: Amount of fish harvested and total earning 22

Acronyms/Abbreviations

ASF	Animal source food
BOD	Biological Dissolved oxygen
DO	Dissolved oxygen
EC	Electrical conductivity
ETB	Ethiopian birr
FAO	Food agricultural organization
FGD	Focus group discussion
GERD	Gilgel gibe Ethiopian renaissance dam
GIS	Geographical information system
NGO	Non-government organization
PH	Power of hydrogen
TDS	Total dissolved substance
UN	United nation
WHO	World health organization

1. Introduction

1.1 Background of study

Aquaculture production around the world has been growing at a very significant rate over the past 20 years (FAO, 2018). It is one of the industries that produces food the quickest and provides the majority of the fish protein for many developing nations (Golden *et al.*,2017; FAO, 2018). At the moment, aquaculture accounts for more than 47% of the world's fish production (FAO 2018). Less than 2% of the world's fish is produced in Africa. Few fish species dominate the production, with Nile tilapia accounting for nearly half (43.6%) of the total, followed by catfish (11.9%) and common carp (10.5%) (AFD, 2017).

Although Ethiopia is rich in diverse fish resources, water and environmental resources, it is found at the bottom of the aquaculture producers list (Erkie *et al.*, 2020). A study by Gordon *et al*. (2007) has estimated aggregated demand growth for fish in Ethiopia to be 44% over last ten years. Abegaz *et al*. (2012), indicated that the national per capita fish consumption is about 0.21 kg/person/year. However, in fish producing areas of Ethiopia this figure changes and is estimated about 8.5 kg/person/year (Erkie *et al.*, 2020). Although Ethiopia has huge fresh water and fish resources, conducive climatic conditions, huge labor and unsatisfied local demand for fish, aquaculture development in the country is lagging behind compared to other agricultural activities (Zewdie, 2016). In the country, the demand for fish grows exponentially every year, while the supply from the capture fisheries has consistently lagged behind the growth rate of demand for fish (Rothuis *et al.,* 2012). Thus, the current increasing market demand for fish in Ethiopia can be met only when the capture fishery is supplemented by the culture fishery (Ashagrie *et al.,* 2008; Berihun and Goraw, 2010). Therefore, aquaculture adoption is clearly necessary to bridge such gaps (Olaoye *et al.,* 2014).

Aquaculture serves as a best alternative for over-exploited natural aquatic resources (Agbebi, 2011). It can reduce the pressure on the natural ecosystem and maintain ecological balance (Kassahun, 2012). Thus, aquaculture is carried out not only for increasing the availability of fish for food, but also to conserve the natural stock and thereby protect the biodiversity (Dereje *et al.*, 2015). Disappointingly, given favorable physical and hydrographic conditions (such as suitable geographic relief, good rainfall, and sufficient freshwater availability), aquaculture production is still negligible in Ethiopia. In addition, it remains more potential than in actual practice (Sileshi, 2015) despite the fact that the country's environmental and socio-economic conditions support its development (FAO, 2014).

The fast growing population in Ethiopia demands development of aquaculture as an alternative source of animal protein and food security (subsistence consumption). Erkie *et al., (*2020) indicated the availability of conducive environmental and climatic conditions suggesting the possibility for pond aquaculture development in the country. Moreover, a GIS-based modelling conducted by FAO Sub-regional office for Eastern Africa indicated the availability of about 99.4 million hectares of land constituting moderate to highly suitable conditions for development of Nile tilapia pond culture (Rothuis *et al.*, 2012). Most of these high potential zones for Nile tilapiapond culture lie in the western and south western parts of the country (Erkie *et al.,* 2020).

Although different agents in Jimma zone (Kersa, Seka-Chokorsa, Omonada and others) Districts have constructed a number of aquaculture ponds. There is no updated information or documentations on their performance. In addition, the successes or bottlenecks of the currently pond aquaculture development have not been well articulated. This study has therefore aimed to assess the status of pond aquaculture development in Jimma zone, southwest Ethiopia: the caseof Kersa and Seka-Chokorsa districts.

1.2 Statement of the problem

Aquaculture is one of the fastest-growing animal food production sectors worldwide and is the main source of animal protein in many countries. The availability of conducive environmental and climatic conditions suggesting the possibility for pond aquaculture development in the country. To transform the rate of aquaculture development in Ethiopia, the country needs a multi-sectorial approach and well-coordinated collaborative efforts from all different stakeholders. Once raising fish is decided, one should make sure that land is suitable for fishpondconstruction. It is important to look for the factors affecting site selection for pond construction including water, soil, climate, topography and location. In Oromia region one of the well-knownin pond aquaculture development is Jimma zone. Reportedly many pond aquacultures were constructed in Jimma zone including Kersa and Seka-Chokorsa districts. However, activities of pond aquaculture development in the Zone and the extent of development as well as the related issues have not been scientifically assessed and documented. Quantitative assessment of the spatial ponds in the zone is of utmost importance for appraisal of the development activities, to identify challenges and opportunities, and plan for the necessary intervention actions to ensure sustainability of the ponds and the attached socio-economic values.In addition water quality condition of the ponds related to temperature, DO, EC and pH, and current conditions of the ponds of the study areas have not been assessed and documented. Therefore, the study aimed to assess the status of pond aquaculture development in Kersa and Seka- Chokorsa districts Jimma zone southwest Ethiopia.

1.3 Research Questions

1. When and how were the ponds built and who built them (i.e. farmer or other bodies?
2. How many ponds are owned privately and by cooperatives respectively?
3. What are the categories of the ponds based on their size?
4. How suitable are the pond location in terms of topography, sustainable availability of water source, and soli type?
5. How suitable are the ponds for the cultured fish species in terms of basic water quality parameter?
6. What fish species was stocked in to the ponds and when was first stocked?
7. What are the fish stocking rates of each pond?
8. What are the source or supply of fish feed and fingerlings to fish farmers?
9. What are the current management and physical condition of the fish ponds?
10. What are the socio-economic significance of the fish ponds on the livelihood of the pond owners?
11. What are the opportunities and challenges of developing fish pond in the study area?

1.4 Objectives

1.4.1 General Objective

The general objective of this study was to assess the status of pond aquaculture development in Kersa and Seka-Chokorsa districts Jimma zone, southwest Ethiopia

1.4.2 Specific Objectives

- ✓ To ascertain the construction dates of the ponds and identify their ownership status (private or cooperative).

- ✓ To identify the categories of ponds based on their size.
- ✓ To determine suitability of the pond location in terms of topography, sustainable availabilityof water source, soil type and basic water quality parameter.
- ✓ To identify the type of fish stocked, fish stocking rate, source of fish feed and fingerlings tofish farmers.
- ✓ To evaluate the current management and physical condition of the fish ponds.
- ✓ To assess the socio-economic significance, the opportunities and challenges of developingfish pond in the study area.

1.5 Significance of the Study

The fast growing population in Ethiopia demands development of aquaculture as an alternative source of animal protein and food security. Therefore a major future task is to increase participation of producers and relevant public authorities in the allocation and management of aquatic resources and land uses. In light of this, the proposed study has the following significance.

1. It provides baseline information about the current condition of aquaculture ponds in the study area.
2. It provides information about socio-economic impacts of the aquaculture ponds in the area.
3. It highlights opportunities and challenges of developing pond aquaculture in the study area.

2. Review of Related Literature

2.1 Over View of Aquaculture

Aquaculture is defined by the UN's food and agriculture organization (FAO) as the farming of aquatic organisms including fish, molluscs, crustaceans and aquatic plants'. Farming implies some sort of intervention in the rearing process to enhance production, such as regular stocking, feeding, protection from predators and it can also include encouraging of accessible market chain. This farming can be ran by individual or corporate ownership for planning of stock being cultivated, sites selection, development and operation of aquaculture systems, providing of facilities and practices, the production and transporting of the products (FAO,1996).

Aquaculture is one of the oldest food production activities in the history of mankind (FAO, 2002). It is the fastest growing food producing sector in the world (FAO, 2006; AFD, COM and GIZ, 2017). Even though Global aquaculture production grows faster than other major food production sectors, it no longer enjoys the high annual growth rates of the 1980s and 1990s (11.3 and 10.0 percent, excluding aquatic plants). Average annual growth declined to 5.8 percent during the period 2000–2016, although double-digit growth still occurred in a small number of individual countries, particularly in Africa (FAO, 2018). It is probably one of the most promising answers by providing additional food and employment for the rising world population if it will amplify. FAO (2005) reported that out of the total tonnes of fish consumed in the world every year, almost half is produced in a controlled environment, whereas the remaining half is harvested from the wild (Lakew *et al.*, 2016). Aquaculture can serve as one of the best alternatives for the over-exploited natural aquatic resources, i.e. aquaculture can help to reduce pressure and maintain the ecological balance of the natural ecosystem (Lakew *et al.*, 2016).

Aquaculture is developing, expanding and intensifying in almost all regions of the world, except in Sub-Saharan Africa, as the global population demand for aquatic food products is expected to increase (FAO, 2012). As the report of World Bank (2013) fish consumption in Sub-Saharan Africa is decline during the 2010–30 periods. But, due to rapid population growth, which is estimated at 2.3 percent annually during the 2010–30 periods, the total fish food consumption demand would grow substantially by 30 percent between 2010 and 2030. World Bank report (2013) indicated that in-line with rapid population growth, capture fish production is to increase from an average of 5,422 thousand tons in 2007–09 to 5,472 thousand tons in 2030. Moreover, aquaculture is projected to increase from 231 thousand tons to 464 thousand tons during the same period in Sub-Saharan African. The region fish imports in 2030 are projected to be 11 times higher than the level in 2000. With this prospect, the region‘s dependency on fish importsis expected to rise from 14 percent in 2000 to 34 percent in 2030.

2.2 Aquaculture potential in Ethiopia

A potential aquaculture production exists in Ethiopia, but it is not yet fully realized. Aquaculture in Ethiopia is still in its infancy despite favorable physical conditions available inthe country and fish species documented. The high central plateau above 2,500 m (11 percent of total area) has potential for all year round farming of cold water species. Likewise, the surrounding and central highlands present temperature characteristics favorable for the breeding of a large number of species, from cold water to warm water fish (Natea *et al.*, 2017). In addition Ethiopia is endowed with 12 drainage basins (8 river basin, 1 lake basin and 3 dry basins) with a mean annual flow (runoff) estimated at 122 billion cubic meter and a total length estimated at 8065 km. Similarly, the country has also many lakes and reservoirs, small water bodies and floodplain areas covering a total surface area of about 13,637 km2 (Gashaw and Wolff, 2014). The reservoirs under construction such as Gilgel-gibe III and Grand Ethiopian renaissance dam (GERD) will undoubtedly increase the total inland water by over fifteen percent at the end of their completion (Lakew *et al*., 2016; Meko *et al*., 2017).

In the same way Ethiopia has very diverse agro-ecological zones offering a favorable potential for developing fish culture both in terms of land/water and in its climatic system. The GIS analysis was carried out based on physical, socioeconomic, climatic and infrastructure suitability indicators, as well as the biology of the selected fish species. According to (Rothuis *et al*., 2012), Sub regional Eastern Africa is highly suitable for Nile tilapia pond culture. Nevertheless this is equivalent only to about 1% of the countries surface area, it has been indicated to be sufficient enough to produce significant amount of fish in pond aquaculture (Wakjira *et al*., 2013). On the other hand as the report of Habte silassie (2012) shows the country has nearly 200 freshwater fish species in its lakes and rivers. However candidate species for aquaculture development in Ethiopia include mainly only Nile tilapia (*Oreochromis niloticus*) and few the African catfish (*Clarias gariepinus*) (Yalew *et al*., 2015).

In spite of some ecological problems reported by conservationists, there have been success stories which resulted in a significant increase in supply of fish for the local communities and markets of major cities. As the evidence from Lakes like: Fincha, Hashenge, Koka, Batu, Gilgal gibe I, Bishoftu, Abaya and others the fish production were inadequate (FAO, 2005; Asaminew, 2012). Nevertheless, the fish productions from these water bodies are supporting the livelihoodof poor farmers living around water bodies in providing inexpensive, but high quality protein and promoting income generation. Generally aquaculture in Ethiopia remains more potential than in actual practice, despite the fact that the country's environmental and socio-economic conditions support its development (Natea *et al*., 2017; Asmare, 2017).

2.3 Status of Aquaculture in Ethiopia

Ethiopia is endowed with considerable amounts of freshwater systems including lakes, reservoirs, rivers, ponds and wetlands that support development of aquaculture sector. The freshwater system sustain considerable amount of fisheries that have significant nutritional and economic values. However, the capture fisheries are unregulated and poorly managed leading to resource overexploitation, degradation of biological diversity and reduction in fish supplies and income (MOA, 2011; Natea *et al*., 2017). Despite having favorable physical and hydrographic conditions (suitable geographic relief, rich soil quality, good mean annual rainfall, and sufficient freshwater availability), the aquaculture production is negligible in Ethiopia. Even though the country has high potential and wide environmental condition for aquaculture farming; it was existing as small-scale, subsistence oriented and only to a certain degree commercial. It is estimated that there are subsistence fish in Ethiopia with various pond sizes (Abera, 2017).

The consumption and demand for fish as a cheap source of protein is increasing in Ethiopia. But the fish supply in most cases comes from the major lakes and rivers in the country. While capture fisheries based on species that are presently exploited seem to have reached their natural limits (MoA, 2011; Asaminew, 2012). As a result of high population growth in the country, there is high competition to be engaged in fisheries activities around the lakes area. Thus, as the experience of different countries in the world shows, if aquaculture is developed in a sustainable way, it can be the best alternative to tackle these kinds of problems. According to FAO estimates, per capita fish consumption in Ethiopia at 2009 was estimated to 0.2 kg, which places the country in the lower end of fish consumers amongst African countries (where the average is 9.4 kg). National estimates for 2012 indicate a higher yearly per capita consumption of 0.34 kg**.** This national average does not reflect regional differences in consumption. In areas surrounding lakes and rivers, yearly consumption can reach 21 kg per capita (John & Rios, 2013). Domestic supply is fulfilled entirely by capture fisheries and fishery resources are assessed as underexploited overall. Fisheries contribute to food security in Ethiopia at a very low level. In 2009, FAO estimated that fishery products account for 1 percent of animal protein intake, were below the African average (19.1 percent). Ethiopia is a country where animal protein from fish is the lowest in Africa. The per capita protein supply from fish has shown an inconsistent performance, reaching 0.1 grams in 2009 (Breuil & Grima, 2014; FAO, 2014).

In general, aquaculture in Ethiopia is at a very low level of development due to lack of extension support and training, shortage of expertise, lack of fingerlings, lack of funding, little research and institutional capacity. Nowadays there are certain trials to increase fish production and to integrate aquatic farming with terrestrial farming at different parts of the country by the Sebeta Fisheries and Aquatic Life Research Center, Batu Fishery Research Center and Bahirdar Fisheries and other Aquatic Life Research Center for the farmers. Moreover the started trials on the artificial propagation of fingerlings at these centers must be supported and supplemented by necessary inputs. To boom and assure this practice the farmers should be trained by the expertise come from those institutions before the start of fish farming (Natea, 2019).

2.4 Site selection in Pond construction

Once you have decided to raise fish, you should make sure your land is suitable for building a fishpond. It is important to look important factors such as water, soil, topography, climate and location (USAID, 2019).

2.4.1Water

A year-round source of water must be available for the fish pond. However, this does not mean that water should run into the pond continually. Enough water needs to fill the pond in pond construction. The available of water for the pond throughout the dry season must be considered in pond construction. Springs, streams, and groundwater are good water sources for a fishpond. However, the water should be free from chemicals that are sprayed on crops. Using tap water that contains chemicals such as chlorine can kill fish and other aquatic organisms. Rainwater and runoff are also good water sources for fishponds. However, ponds that rely on rainwater alone often dry up during the dry season. In these ponds, you must harvest the fish before the water level drops too low. Then, when the rains begin to fill the pond, you can restock the pond and start again (USAID, 2019).

2.4.2 Soil

Soil containing clay is the best type for fishponds because it holds water well. Sandy soil is not good for fishponds. Using the top layer of soil is not recommended in checking soil type. The sample should be taken from the bottom of the whole and at least one meter down into the soil (USAID, 2019). Squeeze a handful of moist soil into a ball and throwing the ball about 50 cm up into the air is a procedure that can use in checking good soil type. In these procedure if the ball holds together, it probably has enough clay to support a fishpond and if the ball falls apart in your hand, this means the soil is not good for building ponds.

Figure 1: Good and bad soil

2.4.3 Climate

Pond water temperature is very important when raising fish. The climate and elevation affect the water temperature. Tilapia grow best in warm water (25-30°C), which is usually found at low elevations. Tilapia can live in cooler water at higher elevations, but they grow and reproduce more slowly. Try to find the warmest area you can for building fishponds and keep the area free from trees and shrubs, which shade the water and lower its temperature. Tilapia thrives in open, sunny locations where the water temperature remains warm (USAID, 2019).

2.4.4 Topography

Gently sloping land is ideal for fish farming. Ponds can also be built in flat or hilly areas, but construction and management are more difficult in these locations. Areas to avoid for fishponds are flat or swampy low areas, which cannot be drained, steep areas where building would be difficult and areas that flood such as valleys and gullies. These conditions can present problems all the way through the process, during construction, maintenance and harvesting (USAID, 2019).

2.4.5 Location

A good location for your fishpond is very important for success. It should be near your house so it is easy for you to feed and check on the fish. Keeping the pond close to home will help you protect your fish from thieves and predators (USAID, 2019).

2.5 Socio-economic impacts of the aquaculture ponds

Aquaculture ponds such as small-scale fisheries are the backbone of socio-economic well-being in coastal communities throughout the world. Particularly in the tropics where the majority of countries with heavily fish dependent populations are situated. The importance of fisheries, especially small-scale fisheries, as a source of nutrition, employment and income for many of the world‘s coastal and rural poor can hardly be overestimated (Golden *et al*., 2016).

2.5.1 Importance of Aquaculture in Food Security

Aquaculture have often traditionally been components of local food systems, in that the benefits of the fishery, both in terms of finances and food, often remain local and the consumer and the producer are closely connected (Olson *et al.,* 2014). The ability to benefit from fish on anindividual basis, however, is often related to people‘s position within these food systems and to the degree of control they have over them. Aquaculture will often fish or glean locally, share and exchange fish informally and/or use local markets. Aquaculture activities have been developed and adapted based on local knowledge to reflect local realities, including aspects such as location, seasonality, edible parts, and methods of collection, preparation and preservation.Within certain environments, fishing can be an almost universal activity. For example Garaway et al. (2013) found that in Lao PDR, more than 90 per cent of aquatic animals consumed were collected by households themselves. These informal mechanisms and low barriers to entry can enhance access by, and availability to, poorer people, enabling them to produce their own food. Fish obtained by a household‘s own fishing efforts can play a critical role, making the difference between food security and food shortages, and between sufficient or lacking nutrition. This includes fishing and gleaning by women that is often overlooked in national statistics and policies. This includes fishing and gleaning by women that is often overlooked in national statistics and policies (Béné & Heck, 2005).

Tilley *et al.* (2020) reported that many activities related to small-scale fisheries, including fishing, gear manufacture and processing, are not full-time occupations and people who fish may belong to households with diversified and stretched livelihoods (e.g. Winkels, 2011). Aquacultures are also often able to react to the availability of particular fish, often due to the seasonality of abundance of certain species. This is an important aspect of Aquaculture that they can adjust their fishing approaches and target fish based on seasonality, local abundance and local demands, employing a wide range of fishing gears. This degree of flexibility requires a high degree of local ecological and environmental knowledge, but also requires a certain degree of freedom in terms of the fisher access to different resources, in different areas and during different times in order to benefit (Arthur, 2020).

2.5.2 Contribution of Aquaculture in Nutrition

Aquaculture including fish is an animal-source food (ASF), rich in micronutrients, essential fatty acids, and animal protein, which can help support cognitive development, alleviate stunting, improve maternal and childhood health outcomes, strengthen the immune system, and reduce cardiovascular disease. Thilsted *et al.*, (2016) Fish provide 17% of animal protein and 7% of total protein consumed globally (FAO, 2020). ASF (including fish) consumption is associated with reduced childhood stunting due to higher concentrations and bioavailability of key micronutrients compared to plant-source foods (Headey *et al.,* 2018). Additionally, fish high in essential fatty acids can reduce risks for cardiovascular disease, with 1.4 million cardiovascular- related deaths worldwide in 2010 attributable to diets low in fish-source omega-3 fatty acids (Lim *et al.*, 2012). Thus, fish nutrients can alleviate conditions related to under nutrition as well as non-communicable disease risk. In many contexts, fish is more affordable than other ASFs such as red meat (Funge-Smith & Bennett, 2019), making it more accessible to the poor, although prices for some species are driven up by global demand. Nine countries all from the Global South—obtain at least half of their animal protein from fish. 3 as a wild food, fish is often available to landless people who cannot produce crops and serves as a safety net for people during economic and climate-driven shocks and geopolitical conflicts affecting land based food production (Funge-Smith & Bennett, 2019). In some regions, aquaculture prices have fallen over time, demonstrating that farming fish has the potential to serve as a pro-poor food production system (Edwards *et al.*, 2019). Besides being affordable and accessible, fish production systems often provide crucial nutrients with less detrimental environmental impact than other ASFs (Hilborn *et al*. 2018).

2.5.3 Contribution of aquaculture to national economy

Aquaculture such as fisheries can make significant contributions to national economies through the generation of foreign exchange derived from international trade. International trade in fish and fishery products has grown rapidly over the last twenty years. Export values have risen from US$ 15 billion in 1980 to US$ 56 billion in 2001. In the same period developing countries 'share of total exports has risen from 40 percent to 50 percent, with net receipts (i.e. deducting their imports from the total value of their exports) from fish trade by developing countries increasing from less than US$ 4 billion to almost US$ 18 billion. Aquacultures including small-scale fisheries are playing an increasingly important role in the fish exports of many developing countries (FAO, 2005).

Wealth generated by individuals, households or small enterprises can make significant contributions to local economies through income and employment multiplier effects. This is especially the case in fisheries because of the –cash crop‖ nature of the harvest. Fish may be one of the few products in some rural economies that can generate cash to spur and stimulate demand, because other food products may be more generally bartered or consumed within the household. As well as the direct impacts related to sales, and to income and employment effects on the producers themselves, which result from changes in the demand or production of fish products, there are indirect impacts upstream and downstream of the production activity that occur through the commodity/supply chain.

Upstream activities are those activities supplying inputs to the fishing operation. Typical inputs for small-scale capture fisheries include: investment costs in vessels, engines and gear; operational costs of fuel, ice, food, bait; labour costs; financial services; and maintenance costs. Downstream activities are those following the harvesting of product, which themselves require inputs. Some examples of the inputs required are: investment in design, construction and equipping, processing and marketing facilities; labour; transport of fish from landing sites and to markets; financial services; variable costs such as ice, knives, wood for smoking, salt for drying, packaging materials and fish boxes; and maintenance costs. Induced impacts are also brought out in the form of sales, income and employment effects from the changed levels of income and expenditure throughout the local economy as a result of direct and indirect. Taking the upstream and downstream indirect activities together, and considering the induced impacts, one can easily imagine how small-scale fishing activities can become the main driver of poverty reduction, particularly in rural locations, with a web of businesses and individuals generating sales, income and employment as a result of the multiplier effects of fishing activity (FAO, 2005).

3. Materials and Methods

3.1 Description of Study Area

The study was conducted in selected kebeles of Kersa and Seka Chokarsa, Jimma zone, Oromia regional state, south west Ethiopia. These two district were selected, based on the presence of pond aquaculture practices and their potentials, seven kebeles from Kersa and eleven kebeles from Seka-Chokorsa were purposively selected for the study (**Table 1**).

Table 1: Study districts and their respective Kebeles

S/N	District	Kebele
1	Kersa	Ankaso, Marawa, Girma, Kitinbile, Xiqur Abollo and Omo tuchoo
2	Seka-Chokorsa	Shashamane, Sakala genefo, Gura ulauke, Alaga, Tunjo, Qacama, Dabo yaya, Ula qoce, Seka 02, Mexi and Gibe boso

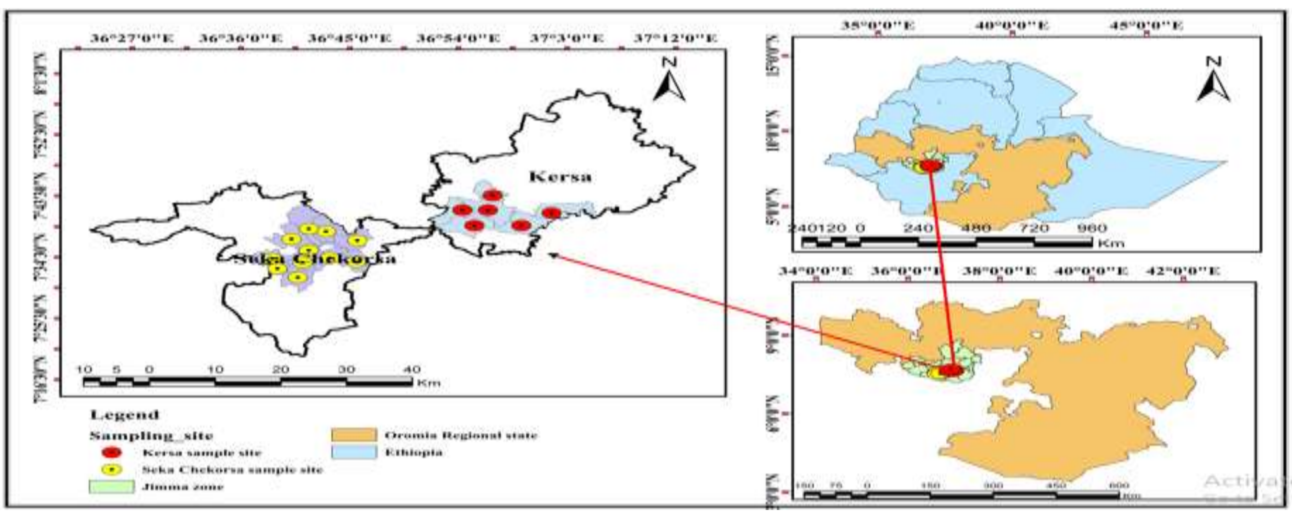

Figure 2: study area map

3.2 Sampling and Data Collection

The selected districts and all kebeles with ponds were purposely chosen to collect data related to pond aquaculture development. In this regard, the main criteria used for site and respondent selection are the existence of pond aquaculture practices. In the districts, the number of aquaculture ponds was not substantial and thus almost all aquaculture ponds were surveyed. Data was collected thoroughly from all pond owners using a questionnaire (**Appendix 1&2**), direct observation (**Appendix 3&4**) and key informant interviews to collect data from key informants including fishery experts (**Appendix 5**). The questionnaires were designed to solicit information about the status of pond aquaculture development.

3.3 Pond Dimensions and Water Quality Parameters

Various pond dimensions such as pond length, width and depth were measured. Additionally, the physico- chemical water quality parameters (e.g. dissolved oxygen, water temperature, pH, electric conductivity and turbidity) were measured in-situ using a multimeter probe (**Appendix 6**).

3.3.1 Temperature (°C)

The temperature was measured using a thermometer**.** The thermometer probe was immersed in the pond water and left for at least 30 seconds to stabilize before taking the reading.

3.3.2 pH

A pH meter was used to measure pH. The meter probe was immersed into the water to10 cm depth let to stabilize, read and recorded.

3.3.3 Conductivity

The conductivity was measured using a conductivity meter type with temperature compensation to 25°C. The conductivity probe was then immersed in water to a depth of 10 cm. It was then allowed to stabilize and the readings were read and recorded in µS/cm-1.

3.3.4 Dissolved Oxygen (DO)

Dissolved oxygen was measured with an Oxygen meter. The DO probe was immersed in the water to 10cm depth, while stirring the water, the readings were let to be stable and the dissolved oxygen read in mg/l.

3.4 Data Analysis Techniques

Descriptive statistics such as mean, percentage, and standard deviation were computed on different characteristics of fish ponds and status of pond aquaculture development. On the other hand, qualitative method of data analysis was used to narrate and supplement the quantitative data.

4. Results

4.1 Demographic Characteristics of the Respondents

The demographic characteristics of the respondents are summarized in **Table 2**. The study found that most (83.8 %) ponds were owned by men. The few women owning fishponds were mainly widows, divorced or unmarried. The majority (94.6 %) of the respondents were between 21 and 50 years old with a primary school education. Furthermore, some (26.1 %) of the pond owners had less than 5 years of experience in fish farming.

Table 2: Characteristics of the respondents

Variables		**Frequency**	%
Gender	Male	77	83.8
	Female	14	15.2
Age group (yrs)	Below 20	-	-
	21- 35	37	40.2
	36-50	50	54.4
	Above 51	5	5.4
Marital status	Married	80	87.0
	Single	4	4.3
	Widowed	5	5.4
	Divorced	3	3.3
Education level	None	6	6.5
	1-8	70	76.1
	9-12	9	9.8
	Higher education	7	7.6
Fishing experience (years)	1-5	24	26.1
	6-10	56	60.9
	11-15	12	13
	Above 16	-	-

4.2 Pond Characteristics

In both districts all the aquaculture ponds were constructed from 2015 to 2023. Out of 124 ponds, 59 ponds were built by Jimma University, 33 ponds by farmers and 32 ponds were built by NGO (livestock and fishery sector development organization). Of the surveyed aquaculture ponds, 95 ponds were privately owned, 28 ponds owned by cooperative and one pond was under government (technic school) ownership. The ponds were stocked with fish during the same years of their construction. All ponds showed were rectangular in shape with the size ranging from 80 m^2 to a maximum of 200 m^2. The ponds had an average size of 131.3 m^2 with a mean depth of 0.92 m. Most of the constructed ponds and its dikes were earthen ponds. But one constructed ponds and its dike is concrete pond. Most of the ponds and their dikes were earthen pond (99.2%) and some the pond was concrete (0.8). The study also found that most of the water sources for the aquaculture ponds come from the streams (92.7%) and the remaining water source is from the ground water (7.3%) **(Table 3)**.

Table 3: Characteristics (size, depth, ponds seal, shape, ownership and constructed year) (N = 124)

Characteristic	Description	Seka-chokorsa		Kersa	
		Freq.	Perc.	Freq.	Perc.
	Below 100.0 m	26	36.1	15	28.9
Size of the ponds	From 1.0 m to 2.0 m	46	63.9	37	71.1
	Above 2.0 m	-	-	-	-
	From 0.7 m to 0.9 m	43	59.7	30	57.7
Depth of the ponds	1 m	26	36.1	32	44.3
	Above 1 m	3	4.2	-	-
	Earthen	71	98.6	52	100
Bottom seal of the pond	Concrete	1	1.4	-	-
	Geo-membrane	-	-	-	-
	Rectangular	72	100	52	100
Shape of the ponds	Square	-	-	-	-
	Circle	-	-	-	-
	Stream	67	93.1	48	92.3
Source of water	Ground water	5	6.9	4	7.7
	Spring	-	-	-	-
Year of fish pond constructed	Below 2015	-	-	-	-
and stocking year	From 2015-2020	43	59.7	35	67.3
	From 2021- 2023	29	40.3	17	32.7
	Private	71	98.6	24	46.2
Ponds Ownership	Cooperative	-	-	28	53.8
	Government	1	1.4	-	-

Based on the agro ecology of the area, all of the ponds were stocked by Nile Tilapia and some ponds were stocked with both Nile Tilapia and catfish. The main sources of fingerlings (113 aquaculture ponds) were from different research center (Sebeta fishery research center and Batu fishery research center) and the remaining sources of fingerlings (11 aquaculture ponds) were from neighbor pond owned farmers. Out of 124 aquaculture ponds 32 ponds are not functional and the remaining aquaculture ponds (92) were functional and about 62.0 percent of stocking rate is high, 32.6 percent, 5.4 percent is medium and low respectively. The most common fish feeds used by all farmers included Chicken manure, cow manure and other food roughage and the feeding frequency is occasional **(table 4).**

Table 4: Different attributes of the ponds (N = 124)

Attributes	Description	Seka-chokorsa		Kersa	
		Freq.	Perc.	Freq.	Perc.
Species farmed	Tilapia	72	100	49	94.2
	Catfish	-	-	-	-
	Tilapia- catfish combination	-	-	3	5.8
Source of fingerlings	Research center	66	91.7	47	90.4
	Other farmer	6	8.3	5	9.6
	Wild	-	-	-	-
Stocking rate	High	35	62.5	22	61.1
	Medium	18	32.1	12	33.3
	Low	3	5.4	2	5.6
Fish feed	Cow manure	12	21.4	18	50
	Chicken manure	15	26.8	10	27.8
	Other	29	51.8	8	22.2
Feeding frequency	Once a day	-	-	-	-
	Once a week	-	-	-	-
	Occasionally	56	100	36	100

4.3 Pond Management and Current Status of Aquaculture ponds

Regarding pond management and current status of aquaculture ponds the obtained data indicate most of the farmers do not regularly monitor the overall performance of their ponds. The pond management practice and current status of surveyed aquaculture ponds are not identical. But the statuses of majority of assessed aquaculture ponds are have similarity.

Table 5: Pond Management and Current Status of Aquaculture ponds

Type of observation	Level of fish pond management	Seka-chokorsa		Kersa	
		Freq.	Perc.	Freq.	Perc.
It has a fence	Strong	2	2.8	-	-
	Medium	14	19.4	10	19.2
	Weak	36	50	30	57.7
	None	20	27.8	12	23.1
Condition of pond surrounding	Clean	4	5.6	-	-
	Low clean	55	76.4	40	76.9
	Not clean	13	18.0	12	23.1
Presence of Tree and unwanted thing surround of pond	Highly present	21	29.2	15	28.8
	Present	45	62.5	37	71.2
	None	6	8.3	-	0
Pond functioning	Yes	47	65.3	45	86.5
	No	25	34.7	7	13.5
Water holding capacity of soil pond constructed	Very good	54	75.0	40	76.9
	Good	18	25.0	12	23.1
	Low	-	-	-	-
Elevation /topography of the pond location to allow water flow following gravity	Highly suitable	5	6.9	5	9.6
	Very suitable	64	88.9	44	84.6
	Moderate suitable	3	4.2	3	5.8

A majority of the ponds were under individual ownership, a mode which is reported to work better than when ponds are under group ownership. In group fishpond ownership, there is a passive kind of management, misunderstandings between group members and consecutive pond abandonments. Of the surveyed aquaculture ponds only 2 pond (1.6 %) have strong fence. whereas, 24 pond (19.4%), 66 pond (52.4%), 32 pond (25.8%) have medium, weak, and haven't fence respectively **(table 5).**

Figure 3: Sample of current condition of pond related with fence

Some of (3.2%) surveyed aquaculture ponds are clean. From 124 ponds 25 are completely no clean and about 95 ponds are low clean. Many trees and unwanted thing are presented surround most of surveyed aquaculture ponds. There are ponds that are full of grass, frog, submerging plants and unwanted materials due to poor management.

Figure 4: Clean and non-clean ponds

As it indicated above, out of the surveyed fish ponds 74.2% of them were functional and from these aquaculture ponds there are low functional ponds. Whereas about 25.8% of the ponds are became totally nonfunctional and discontinued. Due to the soil type of most of aquaculture ponds in study areas are clay soil, the water holding capacity of ponds are very good (75.8%) and good (24.2%). About 87.1% of topography of the pond location is very suitable. In addition 8.1% and 4.8 % of topography of the pond location is highly suitable and moderate suitable respectively (table 4).

Figure 5: Functional and discontinued ponds

4.4 Water Quality Parameter of the Study Area

Different water quality parameter like pH, temperature, dissolved oxygen and electrical conductivity was assessed in study area. The Results of this study indicated that the maximum average pH in aquaculture water pond ranged from 6.5 to 7.5. The concentration of TDS ranged from 27 mg/L to 148 mg/L while the concentration of electric conductivity ranged from 43 µS/cm to 255 µS/cm. The temperature and total dissolved oxygen of assessed aquaculture ponds are 19.2 ^{0}C to 24.5 ^{0}C and 3.02 m to 7.45 respectively. The minimum and maximum results of aquaculture ponds salinity are 0.01 and 0.8 respectively (**Table 6**).

Table 6: water quality parameter

Water quality parameter	Seka-Chokorsa				Kersa			
	Min.	Max.	Mean	Std. Dev.	Min.	Max.	Mean	Std. Dev.
Temp. ^{0}C	19.5	24.50	22.08	1.12	19	24	22.2	1.23
DO mg/l	3.06	7.75	5.22	1.15	3.02	7.54	5.13	1.10
EC µS/cm	43.00	255.00	85.32	26.76	69	115	82.06	8.61
TDS mg/L	27.00	148.00	57.09	17.48	41	63	55.82	2.41
pH	6.50	7.9	7.3	0.33	6.6	7.5	7.2	0.31
Salinity	0.01	0.07	0.02	0.11	0.01	0.02	0.014	0.012

4.5 Socio-Economic Benefits from Aquaculture ponds

Most Pond fish farmers in the study area did not keep any written records of costs and returns of fish culture. However, it is assumed that they possess a sharp memory and can estimate everything in concentration with their farm business. The result from **(Table 7)** indicates only 30.6% and 51.6 of the pond owners try to harvest fish for sale and home consumption respectively. During the focus group discussion (FGD), in related to data collected from questioner, the farmers reported that the average revenues gained from selling fingerlings were 712.50 ETB, and the average fish consumed was 9.8 kg/year/pond (valued at 980 ETB). However the average amount of fish sold was 4.31 kg/year/pond and total earned in ETB/ year are 1158.28 **(Table 7).**

Table 7: Amount of fish harvested and total earning

		Parameter					
Study area		Amount harvest in kg/ year/pond	Amount consumed at home/kg/	Amount sold in kg/year	Total earned in ETB/ year/pond	Amount of fingerlings sold	Income from sale of fingerlings ETB/ year/p
Seka-Chokarsa	N	30	30	8	8	3	3
	Min.	3.00	3.00	2.00	300.00	100	300.00
	Max.	20.00	15.00	8.00	1500.00	200	600.00
	Mean	11.90	8.50	4.5	560.00	150	412.00
	Std. dev.	4.50	3.21	1.99	321.81	65.37	186.12
Kersa	N	34	34	30	30	5	5
	Min.	3.50	4.50	3.00	350.00	100	400.00
	Max.	22.00	20.00	10.00	2100.00	300	900.00
	Mean	12.10	9.40	4.2	1350.00	250	705.58
	Std. dev.	4.60	4.01	2.23	495.12	75.37	218.65

4.6 Challenges of Developing Aquaculture Ponds

A serious problem observed in many aquaculture ponds is identical due to its geographical location. From the results the site selection, inlet and out let, fingerlings transfer problem, data recording problem at the districts are not a series problem. A series problem observed in study areas are overstocked fish problem, lack of fishing gears, lack fish feed, stunting fish growth, low farmer and experts interest and data recording problems of pond owners (**Table 8**).

Table: 8 Challenges of developing aquaculture ponds

problems for aquaculture ponds	Extent of the problems											
	Seka-Chokorsa						Kersa					
	Very high		High		Low		Very high		High		Low	
	Freq	%	Freq.	%	Freq.	%	Freq.	%	Freq.	%	Freq.	%
Site selection problem	-	-	-	-	72	100	-	-	-	-	52	100
Overstocked fish problem	25	44.6	27	48.2	4	7.1	15	41.7	16	44.4	5	13.9
Fingerlings transfer problem	-	-	-	-	72	100	-	-	-	-	52	100
Lack of fishing gears	31	43.1	41	56.9	-	-	20	38.5	32	61.5	-	-
Lack fish feed	52	72.2	20	27.8	-	-	32	61.5	20	38.5	-	-
Stunting fish growth	47	65.3	25	34.7	-	-	40	76.9	12	23.1	-	-
Farmer and experts interest problems	26	36.1	37	51.4	9	12.5	20	38.5	30	57.7	2	3.8
Data recording problems	14	19.4	38	52.8	20	27.8	10	19.2	35	67.3	7	13.5
Data recording problem at district	-	-	20	27.8	52	72.2	-	-	16	30.8	36	69.2

4.7 Opportunities to Develop a Fishpond Farm in the Study Area

The data obtained from interviews in addition to physical observation indicates that there are many opportunities to enhance the development of aquaculture ponds in the study area. The major opportunities include suitability of environmental conditions such as availability of year-round water supply, suitability of soil for pond construction, availability of fingerlings, natural resource availability, and availability of Jimma University for technology and knowledge transfer, existence of natural water resources, such as rivers, stream and ground water. In addition, with a growing population and increasing incomes, the rising demand for fish protein and fish pond aquaculture can help meet this demand and contribute to food security is part of the country's strategy.

5. Discussion

5.1 Demographic Characteristics of the Respondents

The subjects of the study were pond owners and woreda experts who work in the study area. The data collection methods used was questionnaire, interview and observation in this study. The questionnaires were distributed to the respondents and all the distributed copies of the questionnaires were filled in and returned back on time.

In this study, most of (83.8 %) ponds are owned by men. This is in line with cultural settings in many aspects in study area where traditionally assets are under men ownership. The few women owning fish ponds were mainly widows, divorced or unmarried. However, this does not mean that women do not contribute to fish farming in this area. Women had great contribution to fish farming practices especially supporting males. The majority (94.6 %) of the respondents were between 21 and 50 years old with a primary school education. This indicates that there is enough work force but with low formal education level. Furthermore, some of (26.1 %) of the pond owners had less than 5 years of experience in fish farming, which can be a reason for the fairly low fish yield. However, this implies that there is an opportunity to improve aquaculture production as experience increases with time, considering that the majority of famers were within the working age class and also motivated to continue with fish farming.

5.2 Pond Characteristics

This study was conducted two woreda namely kersa and Sekka chokorsa in Jimma zone and 124 ponds was surveyed. All the aquaculture ponds were constructed from 2015 to 2023. Out of 124 ponds, 59 ponds were built by Jimma University, 33 aquaculture ponds were built by farmer and the others ponds 32 ponds were built by NGO (livestock and fishery sector development organization). Of the surveyed aquaculture ponds, 95 ponds were privately owned, 28 ponds owned by cooperative and one pond was under government (technic school) ownership. The ponds were stocked with fish during the same years of their construction.

All ponds were showed rectangular in shape. According to Erkie *et al.*, (2020), all pond shapes can produce fish, but the rectangular ponds are more suitable compared to the circulars. This is mainly due to the fact that rectangular ponds can be easily fertilized within a short period of time. In addition, large surface area of the pond (rectangular) water can easily be exposed to sunlight and this facilitates the photosynthesis process. The size of rectangular fish ponds ranges from a minimum of $80m^2$ to a maximum of $200m^2$. In addition, the average size of the pond was about $131.3m^2$ with a mean depth of 0.92m. However, there was a statistically significant mean difference in pond size and depth between all the ponds. Specifically, the average size of the ponds in Sekka chokorsa is about $150.1m^2$ with an average depth of 0.92 m. Due to similar in physical and hydrographic conditions across the study area, the bottom of the ponds were similar. For instance, most of the constructed ponds and its dikes were earthen ponds. But one constructed ponds and its dike is concrete pond. In this regard, most of the constructed aquaculture ponds in the study area are earthen pond (99.2%) and concrete (0.8%). This result reveals that earthen ponds are more common in the study area than any other type of ponds. A study by Erkie *et al.*, (2020) recommended earthen ponds as a means to ensure maximum utilization of pond resources and increasing production. Similarly, Erkie *et al.*, (2020) asserted that earthen ponds are more common due to their high level of zooplankton and phytoplankton productivity. The collected filled data indicates most of the water sources for the aquaculture ponds come from the streams (92.7%) and the remaining water source is from the ground water (7.3%). The aquaculture ponds were recharged from ground and stream water due to ground and stream water is available year-round.

Based on the agro ecology of the area, all of the ponds were stocked by Tilapia and some ponds were stocked both Tilapia-catfish combination. In the mid- highland or temperate area of the region, Tilapia is the main fish species preferred and recommended for aquaculture. The main sources of fingerlings (113 aquaculture ponds) were from different research center and the remaining sources of fingerlings (11 aquaculture ponds) were from farmers. Out of 124 aquaculture ponds 32 ponds are not functional and the remaining aquaculture ponds (92) are functional and about 62.0 percent of stocking rate is high, 32.6 percent, 5.4 percent is medium and low respectively. The most common fish feeds used by all farmers included Chicken manure, cow manure and other food roughage and the feeding frequency is occasional. Even though some farmers add fish feeds to their ponds in a seldom ways, there are many farmers who do not totally feed their fishes due to lack of awareness. Surprisingly, these farmers also perceived as fish will grow as long as they are in pond water. They do not even realize that best performance would be obtained if the fishes have a balanced diet.

Similar to Erkie et al. (2020) among the fish feeders, they frequently used cow manure as a fish feed but the way they apply was not efficient. These farmers put a sack with a full of cow dung at a side in the pond for lots of months without replacing and refreshing the water. This might produce fish pathogens, bad smell, and reduced water quality, diminishing phytoplankton and zooplankton abundance and depleted oxygen as well. In one or the other way, all these problems can directly affect the growth of fish at the pond.

5.3 Pond Management and Current Status of Aquaculture ponds

Fish feed types that farmers frequently used are cow manure, chicken manure, residuals from human feed and non-marketable residue of horticulture crops similar to (Erkie *et al.,* 2020). However, our study also found that most of the pond owners feed their fishes irregularly. In addition, most of the farmers do not regularly monitor the overall performance of their ponds. Because of these, farmers do not know whether there is market sized fish in their ponds or not. A majority of the ponds were under individual ownership, a mode which is reported to work better than when ponds are under group ownership. In group fishpond ownership, there is a passive kind of management, misunderstandings between group members and consecutive pond abandonments. On the other hand, some ponds are not exposed to direct sunlight due to the shades of trees and their branches around the ponds. In addition, there are ponds that are full of grass, frog, submerging plants and unwanted materials due to poor management. As it indicated above, out of the surveyed fish ponds only 74.2% of them were functional and from this aquaculture ponds most of the ponds are low functional. Whereas about 25.8% of the ponds are became totally nonfunctional and discontinued. According to collected data from the stockholders, poor fish consumption habits and weak pond management are the two contributing factors to the failure of aquaculture in the area. Based on the level of input used, feeding frequency and type and the degree of management, the current aquaculture practice of the study area inclined towards extensive type. Such extensive type aquaculture practices are known for their poor pond management.

5.4 Water Quality Parameter of the Study Area

Different water quality parameter like pH, temperature, dissolved oxygen and electrical conductivity was assessed in study area. The pH result indicates that the study area has a favorable pH range for growing a wide variety of fish species as the optimum pH range for aquaculture is 6.5

to 9 (Boyd et al., 2016). A study done by APHA (2017) obtained results of pH which, ranged from 7.45 - 8.9 that are in the agreement with this study. Fish thrive best in a pH range of 7.0 to 8.5 outside of this range fish get stressed and at low pH may lead to fish mortality FAO (2015). The pH affects the metabolism and other physiological processes of aquatic organisms as its great variation can cause lowering production levels, cause stress, poor growth and susceptibility to diseases and even death. During the day if the phytoplankton absorbs too much CO_2, can cause pH increase of fish pond up to the values above 8.5. The signs of sub optimal pH include increased mucus on the fish grill, poor growth, fin fray and unusual swimming behavior. In fish culture, the pH level should not be less than 4 and not more than 9 (Ekubo et al., 2011).

The solubility of gases and the water density can be affected by TDS. When the amount of TDS increases the water density become increase and the solubility of the gases become decrease. The concentration of DO varies between 3.02 mg/l and 7.45 mg/l **(Table 6).** Different fish species have different DO requirements, and it changes with the activities and sizes of the fishes. For instance, the optimum DO requirement for Catfish is 3 mg/l, but it falls below 1 mg/l for Tilapia fish (Leonard and Mahenge, 2022). Fishes grow best when the concentration of DO is above 5 mg/l, and as the level of DO falls below 5 mg/l, the fishes start compensating for the reduced DO status through a series of physiological and behavioral changes, and < 1 mg/l level can be lethal (Leonard *et al.*, 2022). According to Leonard *et al.,* (2022) aquaculture ponds should have a minimum of 3mg/l. The results were comparable to the study done by Kiran (2010), who recorded DO ranging between 2.0 mg/l and 8.6 mg/l in a study done in fish ponds of Bhadra Karnataka. It is also comparable with study by Milkah (2020) done in aquaculture ponds in Gatundu, Central Kenya where a mean range of 3.2 to 10.0 mg/l was recorded and Keremah *et al.,* (2014) who recorded mean range of 2.8 to 6.6 mg/l.

The variation in DO may be caused due to variation in weather conditions of the days of sampling and ambient conditions and the time of sampling (Kitur, 2009). During the day, there is a distinct diurnal fluctuation of oxygen, with lowest concentrations just after dawn, and increasing during daylight hours because of the photosynthetic production of oxygen to maximum in late afternoon and decreases again during the night (Makori *et al.,* 2017). Cloud cover also affects DO; it is high around midday when photosynthesis is high resulting in accumulation of DO in water. When cloud cover is below 10%, DO is low since ponds are shallow with a maximum depth of 1.5m which favor organic matter decomposition. The variation in dissolved oxygen is also caused by variation in weather conditions of the days and ambient conditions and the time of sampling (Kitur, 2009). DO in water is depleted by processes including respiration from fish, microbial life, and plants, and the degrading of organic matter by microorganisms (biological oxygen demand or BOD) also affects oxygen in aquaculture ponds.

The temperatures measured during the study period showed variations, the temperature ranged from 19.0 ^{0}C to 24.5 ^{0}C **(Table 6).** The lowest temperature of aquaculture pond was 19.0 ^{0}C and the highest was 24.5 ^{0}C. The temperature difference in water bodies is influenced by variation in weather conditions during sampling and ambient conditions, which ranged from clear sky to cloud, cover (Kitur, 2009). Suspended particles also increase the temperature of surface water by absorbing heat from sunlight (Milkah, 2020). According to Milkah (2020), the acceptable ranges for optimal growth for warm water fish is 20 to 28 ^{0}C, the water temperature recorded in all the ponds during the study period were within the range except some ponds **(Table 6).** The results were also comparable to studies by Laibu (2010), who recorded a mean range of 18 to 29 ^{0}C in a study done on fish pond in Abothuguchi Central, Meru Country.

The values of conductivity recorded were varied in the various ponds. Concentration of electric conductivity was ranged from 43 µS/cm^{-1} to 255 43 µS/cm^{-1}. Variations in conductivity in water are influenced by amount and levels of dissolved particles in inflowing water and residence time in water body. The total dissolved solid load is determined by type of soil at the catchment, human activities and the nature of geological drainage (Kitur, 2009). Dams and reservoirs receiving large quantities of surface run-off have higher conductivity like in case of a study done by Tessema *et al.*, (2014). The World Health Organization (WHO) limit for conductivity is 700 µS/cm (WHO, 2003) for drinking and potable water. The results were close to studies done by Keremah *et al.,* (2014) in Bayelsa State, Nigeria where a range of 117.3 ± 91.01 to 378.4+130.20 µS/cm was recorded.

Salinity concentration ranged from 0.01 to 0.8 across all sampling points. The causes of elevated concentration of salinity in fish pond could be due to the type of water used for aquaculture which contained elevated concentration of dissolved ions or salts. The elevated dissolved ions are accelerated from anthropogenic activities including agricultural activities, poor solid and liquid wastes management and nature of geological rocks to where the source of water is allocated (Leonard *et al.,* 2022). Some types of fish are more sensitive to salt concentration, thus, the more the salt water contents; the more the effects to the fish growth and osmoregulation, when the salinity is very high, fish begin to loose water to the environment (Leonard *et al.,* 2022). A drastic salinity change by more than 5 ppt at each time of water exchange is not recommended as it alters their population densities and other phytoplankton fauna hence instability of the ecosystem. The suggested range of salinity in fish culture is less than 2% but it varies among fish species (Leonard *et al.*, 2022).

5.5 Socio-economic Benefits from Aquaculture ponds

Most Pond fish farmers in the study area did not keep any written records of costs and returns of fish culture. However, it is assumed that they possess a sharp memory and can estimate everything in concentration with their farm business. The result from **table 8** indicates only 30.6% and 51.6 of the pond owners try to harvest fish for sale and home consumption respectively. During the focus group discussion (FGD), in related to data collected from questioner, the farmers reported that the average revenues gained from selling fingerlings were 712.50 ETB, and the average fish consumed was 9.8 kg/year/pond (valued at 980 ETB). However the average amount of fish sold in 4.31 kg/year/pond and total earned in ETB/ year are 1158.28 **(Table 8).**

Given these multiple benefits, the pond owners try to harvest fish for home consumption and market. However, due to stunted fish growth and poor managements of fish ponds farmers start harvesting after three to four years of stocking. Such stunting fish growth probably came from fish reproduction in the ponds due to mixed-sex stocking. This over population through reproduction increases the competition for feed and space. Thus, most of the aquaculture pond seems as a multiplication pond than production. In desperation, farmers (25.8%) decided to discontinue their pond management practices once they had harvested their fish. The reason for this discouragement arises from farmers' financial comparison between the costs incurred from pond construction to harvest and its actual returns. On the other hand, only 6.5 % of the aquaculture pond owners sold fish fingerlings as a seed for other aquaculture users and mostly aspired by government. These (6.5%) fish farmers sold mean of 250 fingerlings and generated a mean of ETB 712.5. This return might not be simple, but there is no private fingerling buyer in uninterrupted way. This finding is also in consistent with the finding of (Erkie *et al..*, 2019).

5.6 Challenges of Developing Aquaculture Ponds

A serious problem observed in many aquaculture ponds is identical due to its geographical location. From the results the site selection, inlet and out let, fingerlings transfer problem, data recording problem at the districts are not serious problems. Serious problems observed in study areas were overstocking, lack of fishing gears, lack fish feed, stunting fish growth, low farmer and experts' interest and data recording problems by pond owners (**Table 7**).

The results of the study indicate that 34.7% and 70.2 % of aquaculture ponds are facing with a very high problem of fish over population and stunted fish growth respectively. These problems are caused due to the poor management of ponds and feeding practice of aquaculture ponds. On the other hand, fishing net is among the determinant factors for aquaculture development in the study area. As we can see from **table 7,** 41.1% and 58.9 % of the pond fish farmers categorized fishing net as a very high and high problem respectively. Most of farmers have adopted aquaculture ponds without having fishing net. Therefore, if farmers want to harvest fish for home consumption or market, they have two options: the first option is catching their fish by using old mosquito net locally called agobar and other clothes. The second option, which is practiced by most pond owners, is not to harvest until they get their own fishing net or until the water drained out or dried. This finding is also in consistent with the finding of (Erkie *et al.,* 2020).

Lack of fish feed is another serious problems in the study area. Due to this problem some farmers add fish feeds to their ponds occasionally. But there are many farmers who do not totally feed their fishes due to lack of awareness. Surprisingly, most farmers have incorrect view as fish will grow as long as they are in pond water. They do not even realize that best performance would be obtained if the fishes have a balanced diet. From the fish feeders, cow manure is the frequently used fish feed. But way the add fish feeds to their ponds was not efficient. In one or the other way, all these problems can directly affect the growth of fish at the pond.

During data collection, extensive discussions were held with aquaculture pond owners. From the discussion a market problem and rewards from aquaculture ponds are a series problem. The problem is that strong market linkage for those aquaculture owners who do not consume fish is not available. This finding is also consistent with the finding of Akpabio and Inyang, (2007). These authors reported that most of aquaculture ponds are located in rural area, whereas the customers with adequate purchasing power are around the urban areas. In addition, poor roads, poor electricity and lack of vehicles with refrigerated compartments, are the problems for effective marketing of fishes from aquaculture. Thus, farmers become discouraged to continue in such a manner. In addition absence of immediate benefits from pond fish farming is a problem observed in study areas. Therefore, it poses a great discouragement for aquaculture pond and for aquaculture development in study areas. This finding is also in consistent with the finding of (Erkie *et al..,* 2020).

5.7 Opportunities to Develop a Fishpond in the Study Area

The data obtained from interviews in addition to physical observation indicates that there are many opportunities to enhance the development of aquaculture ponds in the study area. The major opportunities include suitability of environmental conditions such as availability of year-round water supply, suitability of soil for pond construction, availability of fingerlings, natural resource availability, and availability of Jimma University for technology and knowledge transfer, existence of natural water resources, such as rivers, stream and ground water.

The existence of year-round source of water can be a big factor that determines the success of the fish pond farm practice. In addition, there is an opportunity to integrate aquaculture ponds with other agricultural activities such as vegetables, honey production, and chickens that can enhance fish pond practice of study area. Due to Jimma University can serve a local community to transfer technology and knowledge, the availability Jimma University nearest to the study areas is one of big opportunity to develop fish pond farm. Also, the geographic characteristics of all districts, which are full of the natural resources needed for aquaculture development, favor suitable conditions to establish small-scale fish farm development. Overall, the selection of topography for fish pond aquaculture should be based on the availability of water and soil suitability.

6. Conclusions and Recommendations

6.1 Conclusions

The current research involves assessment of the status of pond aquaculture development in Jimma zone, southwest Ethiopia: The Case of Kersa and Seka-Chokorsa districts. In this study various parameter like Pond Characteristics, Pond Management and Current Status of Aquaculture ponds, water quality parameter, Challenges of aquaculture ponds, Benefits from Aquaculture ponds and opportunity to develop aquaculture ponds were examined to assess the current status of fish ponds.

From the results all fish ponds were constructed from 2007 to 2015. Totally, 124 fish ponds were constructed in the study area. Of the surveyed aquaculture ponds 95 ponds are private, 28 ponds are Cooperative and 1pond is government ownership. Out of 124 fish ponds 92 fish ponds are functional and 32 fish ponds are non-functional. The finding revealed a total of 124 fish pond in the study area, predominantly earthen (99.2%) and concrete (0.8%). All the fish ponds are rectangular and the average size of fish pond is about $131.3m^2$ with a mean depth of 0.92m. The majority of water source is from stream (92.7%), and ground water (7.3%). Nile Tilapia (97.6%) and mixed tilapia-catfish (2.4%) are dominated fish species stocked. About (91.1%) and (8.9%) stocked Fingerlings were from research centers and neighbor fishponds respectively. Most of fish ponds stocking rate are high and Stunting fish growth is low. The most common fish feeds used by all farmers included Chicken manure, cow manure and other food roughage and the feeding frequency is occasional. Majority of the fish ponds are not clean; there are ponds that are full of grass, frog, submerging plants and unwanted materials due to poor management. The result of physicochemical characteristics of water includes mean values of $22.09\pm1.15C^0$ (Water Temperature), 5.23 ± 1.15 (DO in mg/l, 7.08 ± 0.33 (pH), 89.96.16±26.77 (EC in µs/cm) and 59.10 ± 17.49 (TDS in mg/l).The study indicated that many respondents had not harvested any fish, and some had sold fingerlings. 30.6% of the aquaculture owners earned an average of 1158.28 ETB per fish pond and the average revenues gained from selling fingerlings were 712.50 ETB. The study highlighted the major opportunities include suitability of environmental conditions such as availability of year-round water supply, suitability of soil for pond construction, availability of fingerlings, natural resource availability, and availability of Jimma University for technology and knowledge transfer.

6.2 Recommendations

In general, most of the constructed fish ponds are not functional and the most of them are on the way to discontinue. Based on these findings, here are some recommendations for fish farmers and other stockholders:

- Build capacities of fish ponds famers through training on pond management due to the study areas have high opportunities for fishpond aquaculture practice.
- Promoting a multipurpose extension by integrating aquaculture development with other forms of agricultural practices.
- Proper promotion and marketing of harvested fish to attract farmers and guarantee its future sustainability.
- Supplying of equipment used to caching fish by the stockholders for farmers is important.
- Intensive follow up and endeavor for pond management are vital to minimize problems of the ponds.

7. References

Ekubo, A. A, & Abowei, (2011). Review of some water quality management principles in culture fisheries, *Research Journal of Applied Sciences, Engineering and Technology, 3*:1342-1357

Abbas, I. I., & Ukoje, J. A. (2009). Rural water utilization: Factors affecting aquaculture in Owo local government area of Ondo State, Nigeria. *Journal of Geography and Regional Planning*, 2(8), 190–197.

Agbebi, F. O. (2011). Impact of Fish Farming on Poverty Alleviation in EkitiState. *International Journal of Science and Nature*, 2(3), 456–460.

Abera, L.(2017). Fisheries production system scenario in Ethiopia. *Int. J of Fisheries and Aquatic Studies*. 5(1): 79-84.

Agence Française de Développement (AFD)., European Commission (COM) and Gesellschaft für Internationale Zusammenarbeit (GIZ). (2017). Opportunities and challenges for aquaculture in developing countries. Joint Report.

Akalu, T., Enyew, A., & Bancy, M. (2010). Impact of water harvesting ponds on household incomes and rural livelihoods in Minjar Shenkora district of Ethiopia. ecohydrology {&} hydrobiology, 10(2–4), 315– 322. https://doi.org/10.2478/v10104-011-0016-5

Akpabio, I. A., & Inyang, E. B. (2007). Major constraints affecting aquaculture development in Akwa Ibom State, Nigeria. *African Journal of Aquatic Science*, 32(1), 45–50. https://doi.org/10.2989/AJAS.2007.32.1.7.144

APHA. Standard methods for the Examination of water and wastewater, 23rd edn (2017), *American public health association*, Washington DC

Arthur, R. I. (2020). Small-scale fisheries management and the problem of open access. Marine Policy, 115, 103867

Asaminew, K. (2012). Utilization of locally available feedstuffs for small-scale aquaculture production in Ethiopia. Doctoral Dissertation at University of Natural resources and Applied life Sciences, Vienna, Austria.

Ashagrie, G., Abebe, G., & Seyoum, M. (2008). Effect of stocking density on the growth performance and yield of Nile tilapia [Oreochromis niloticus (L., 1758)] in a cage culture system in Lake Kuriftu, Aquaculture Research, 39, 1450–1460. https://doi.org/10.1111/j.1365- 2109.2008.02021.x.

Asmare, E. (2017). Financial Viability of Hatchery Rearing of *Oreochromis niloticus* at Dera District, Amhara Region, Ethiopia. *J Fish Aqua Development*.

Béné, C., & Heck, S. (2005). Fish and food security in Africa. NAGA, WorldFish Center Quarterly, 28(3–4), 8–13

Berihun, T., & Goraw, G. (2010). Integrating aquaculture with traditional farming system: socioeconomic assessment in the Amhara Region, Ethiopia. Ecohydrology {&} Hydrobiology, 10(2–4), 223–230 https://doi.org/DOI: 10.2478/v10104-011-0010-y.

Boyd C.E., Tucker, C.S., Somiridhivej, B. 2016. Alkalinity and hardness: critical but elusive concepts in aquaculture. *Journal of World Aquaculture Society*, 47(1): 6-41. https://doi.org/10.1111/jwas.12241

Breuil, Chr. and Grima, D. (2014). Baseline Report Ethiopia. Smart Fish Programme of the Indian Ocean Commission, Fisheries Management FAO component, Ebene, Mauritius. 24 pp.

Dereje, D., Prabha, L. D., Sreenivasa, V., & Abebe, G. (2015). The growth performance of Nile Tilapia in earthen ponds located at different altitudes of Toke Kutaye Woreda, Ethiopia. *International Journal of Aquaculture*, 5(34), 1–7.

Edwards, P., W. Zhang, B. Belton, and D.C. Little. 2019. Misunderstandings, myths and mantras in aquaculture: Its contribution to world food supplies has been systematically over reported. Marine Policy 106: 103547

Erkie Asmare, Brehan Mohamed, and Haimanot Mulugeta (2020). Assessment of Integrated Aquaculture Intervention System in Amhara Region, Ethiopia. *Ethiopian Journal of Economics Vol. XXVIII No 2,*

FAO, Rome, Italy FAO. (2006). State of world aquaculture 2006. FAO Fisheries Technical Paper 500, Rome, Italy.

FAO. (1996). *Aquaculture production statistics* 1984-94. FAO fisheries Circular, No 815, Revision.

FAO. (2002). Global Aquaculture Production. Fishery Statistical Collections. FAO Fisheries and Aquaculture Department, Rome

FAO. (2005). Ethiopia information on fisheries management (from IFMC) water report no. 29, FAO, Rome, Italy.

FAO. (2014). Fishery and Aquaculture Country Profiles: The Federal Democratic Republic of Ethiopia. FAO Fisheries and Aquaculture Department. Rome.

FAO. 2020. State of the world fisheries and aquaculture: Sustainability in action. Rome: FAO

FAO.(2014). Fishery and Aquaculture Country Profiles: The Federal Democratic Republic of Ethiopia. FAO Fisheries and Aquaculture Department. Rome.

FAO.(2018). The State of World Fisheries and Aquaculture. Meeting the sustainable development goals. Rome.

FAO. (2015). Achieving Blue Growth through implementation of the Code of Conduct for Responsible Fisheries. Policy Brief. Rome

Funge-Smith, S., and A. Bennett. 2019. A fresh look at inland fisheries and their role in food security and livelihoods. Fish and Fisheries 20: 1176–1195

Gadisa Natea (2019). Aquaculture potential, status, constraints and future prospects in Ethiopia: a review. *Int. J. Adv. Res. 7(1), 336-343.*

Garaway, C. J., Photitay, C., Roger, K., Khamsivilay, L., & Halwaert, M. (2013). Biodiversity and nutrition in rice-based ecosystems; the case of Lao PDR. Human Ecology, 41, 547–562

Gashaw, T. and Wolff, M. (2014). The state of inland fisheries in Ethiopia: a synopsis with updated estimates of portential yield. Ecohydrology and Hydrobiology. 14:200-219.

Golden, C. D., Allison, E. H., Cheung, W. W., Dey, M. M., Halpern, B. S., McCauley, D. J., et al. (2016). Nutrition: fall in fish catch threatens human health. Nature 534, 317–320.

Gordon, A., Sewmehon, D., & Melaku, T. (2007). Marketing systems for fish from Lake Tana, Ethiopia: Opportunities for marketing and livelihoods. Nairobi, Kenya.

Habtesilassie, R. (2012). Fishes of Ethiopia: annotated checklist with pictorial identification guide. p.250. Office for Development Cooperation of Austrian Embassy, Addis Ababa, Ethiopia.

Headey, D., K. Hirvonen, and J. Hoddinott. 2018. Animal sourced foods and child stunting. American Journal of Agricultural Economics 100: 1302–1319

Hilborn, R., J. Banobi, S.J. Hall, T. Pucylowski, and T.E. Walsworth. 2018. The environmental cost of animal source foods. Frontiers in Ecology and the Environment 16: 329–335

Hussein, A., Alayu, Y., & Ermias, M. (2012). Fish Resource Survey in Benishangul-Gumuz Regional State based on Fish Resource Survey in Benishangul-Gumuz Regional State. The Fourth Annual Conference of the Ethiopian Fisheries and Aquatic Sciences Association (EFASA); ‒The Role of Aquatic Resources for Food Security in Ethiopia,‖

219–245. Adiss Ababa: EFASA.

Hussein, A., Alayu, Y., & Ermias, M. (2012). Fish Resource Survey in Benishangul-Gumuz Regional State based on Fish Resource Survey in Benishangul-Gumuz Regional State. The Fourth Annual Conference of the Ethiopian Fisheries and Aquatic Sciences Association (EFASA); ―The Role of Aquatic Resources for Food Security in Ethiopia,‖ 219–245. Adiss Ababa: EFASA.

Kassahun, A. (2012). Utilization of locally available feedstuffs for small-scale aquaculture production in Ethiopia. Natural Resources and Applied Life Sciences.

Keremah R.I., Davies O.A. and Abezi I.D. (2014) Physico-Chemical Analysis of Fish Pond Water in Freshwater Areas of Bayelsa State, Nigeria. *Greener Journal of Biological Sciences Vol. 4 (2).* Ph.D. Thesis, Kenyatta University, Nairobi, Kenya.

Laibu. P.K (2010). *Determination of bacterial composition, heavy metal contamination physico-chemical parameters of fish pond water in Abothuguchi Central, Meru county, Kenya.* Nairobi.

Lakew, A., Tadesse, Z. and Dagne, A. (2016). Technologies Suitable for Aquaculture Development in Ethiopia. Ethiopia Fish and fisheries Association.

Lim, S.S., et al. 2016. Sustaining healthy diets: The role of capture fisheries and aquaculture for improving nutrition in the post-2015 era. Food Policy 61: 126–131

L.S. Leonard a and A. Mahenge, (2022). Assessment of Water Quality from Privately Owned Fish Ponds Used for Aquaculture in Dar es Salaam, Tanzania Appl. J. Envir. Eng. Sci. 8 N°1, 20-33

Makori, A.J., Aboum, P.O., Kapiyo R., Anyona, D.N. and Dida, G.O. (2017). Effects of water physico-chemical parameters on tilapia (*Oreochromis niloticus*) growth in earthen ponds in Teso North Sub-County, Busia County, Kenya. *Fisheries and aquatic Science Journal*.

Meko, T., Kebede. A., Hussein, A. and Tamiru, Y. (2017). Review on Opportunities and Constraints of Fishery in Ethiopia. *Fish Sci* .1(1):1-8.

Ministry of Agriculture (MoA). (2011). Annual report.

Milkah Gathoni Mbuthia, (2020). Assessment of water quality in aquaculture ponds in tigoni, kiambu county, kenya. MSc thesis, Kenyatta University, Nairobi, Kenya

Natea, G., Wakjira, M., Negisho, T. and Endebu, M. (2017). Spawning response of African catfish (*Clarias gariepinus* (Burchell 1822), Claridae: Teleost) exposed to different piscine pituitary and synthetic hormone. *Inte. J of Fisheries and Aquatic Studies*. 5(2): 264-269.

Olaoye, O. J., Adegbite, D. A., Oluwala-, E. O., Vaughan, I. O., Odebiyi, C. O., & Adediji, A. P. (2014). Comparative Evaluation of Economic Benefits of Earthen Fish Ponds and Concrete Tanks in Aquaculture Enterprises in Oyo State, Nigeria. Croatian *Journal of Fisheries*, 72, 107–117. https://doi.org/http://dx.doi.org/10.14798/72.3.708.

Olson, J., Clay, P. M., & Pinto da Silva, P. (2014). Putting the seafood in sustainable food systems. Marine Policy, 43, 104–111

Rothuis, A., van Duijn, A. P., Eshete, D., Kamstra, A., van der Pij, W., Rurangwa, E., & Stokkers, R. (2012). Business opportunities for aquaculture in Ethiopia Summary. Den Haag.

Sileshi, A. (2015). Rethinking fisheries and aquaculture development in Ethiopia: systemic and innovative approach to addressing industry challenges. In M. Seyoum (ed.), Sustainable Fish Production, Societal Welfare and Development Goals of Ethiopia (pp. 49–59). Arba Minch: The Ethiopian Fisheries and Aquatic Sciences Association.

Tessema, P., Mohammed, D., Birhanu, and Negu, M. (2014*). Assessment of Physicochemical Water Quality of Bira Dam, Bati Wereda, Amhara Region, Ethiopia. Aquaculture Research and Development.* Accessed on 02 November, 2015, from http://www.omicsoonline.org/.

Tilley, A., Burgos, A., Duarte, A., dos Reis Lopes, J., Eriksson, H., & Mills, D. (2020). Contribution of women‘s fisheries substantial, but overlooked, in Timor-Leste. Ambio, 50, 113–124

Wakjira, M., Tolemariam, T., Kim, J. D. and Kim, K. R. (2013). Aquaculture Development in Ethiopia: Review on Potential and Strategy. *J of Agricultural, Life and Environmental Sciences.* 25(3):20-25.

Winkels, A. (2011). Stretched livelihoods–The social and economic connections between the Red River Delta and the central highlands. Upland transformations: Opening boundaries in Vietnam. Singapore: National

World Bank. (2013). Agriculture and Environmental Services Discussion Paper. FISH TO 2030 Prospects for Fisheries and Aquaculture. world bank report number 83177- glb public disclosure authorized.

Yalew, A., Dejen, E. and Spliethoff, P. (2015). Business Opportunities Report Aquaculture #10 in the series written for the "Ethiopian Netherlands business event. Rijswijk, The Netherlands.

Zewdie, T. (2016). Welcoming Speech: Proceedings of the Eighth Annual Conference and Workshop of EFASA,12-13 Feb. 2016. Debre-Birhan, Ethiopia

8. Appendixes

Appendix1: Opportunity and challenges of aquaculture ponds questionnaire

Opportunity and challenges of aquaculture ponds	Extent of the problem			
	Very high	high	low	No problem
Site selection and outlet problem				
Overstocked fish population				
Fingerlings transfer problem				
Lack of fishing gears				
Lack of fish feed				
Stunting fish growth				
Low farmer‘s and expert‘s interest				
Data recording problem at farmer level				
Data recording problem at district level				

Appendix 2: socio economic Profit farmer get from fish farming per year

Amount of fish harvested and total earning	Fish in number/year	Fish in Kg/year	value (ETB/year)
Amount harvested			
Amount consumed at home			
Amount of fish sold			
Amount of fingerlings sold			
Total earned in for one farmer per year			

Appendix 3: Types, shape and some other parameter of fish pond

Attribute	Types and states of fish pond			
Shape of the ponds	Rectangular	Square	Circular	Triangular
Water source for the pond	Stream	Diverted from rivers	Ground	Irrigation

Bottom seal of the pond	Earthen	Geo-membrane	Concrete	
Dike (wall) of the pond	Earthen	Geo-membrane	Concrete	
Inlet and outlet of the pond	Very good	Good	bad	None
Depth of pond	1.2m	1m	0.9m	0.8m and blow
Area of a pond	$\geq$200m^2	200m^2 to 100m^2	100m^2	<100m^2
Water holding capacity of soil pond constructed	Very good	Good	low	Poor
Elevation /topography of the pond location to allow water flow following gravity	Highly suitable	Very suitable	Moderately suitable	unsuitable

Appendix 4: Direct observations of the current condition of the fish ponds

Type of observation	Level of fish pond			
It has a fence	Strong	Medium	Weak	None
Condition of pond surrounding	Clean	Low clean	No clean	
Presence of Tree and unwanted thing surround of pond	Highly presence	Presence	none	
Pond functioning	Yes	No		

Appendix 5: key informant interview (KII)

S/N	Types of questions			
1	When were the ponds built?			
2	Who built the ponds?	farmer	Gov.	NGO
3	What types of fish stocked?	Tilappia	catfish	other
4	What is the fish stocking rate?	High	medium	low
5	When the ponds were first stocked?			
6	How many ponds are owned privately?			
7	How ponds are owned cooperatively?			
8	Source of fingerlings			
9	Source of fish feed	Local	Commercial	
10	What are the current condition of ponds and associated challenges			

Appendix 6: Measurement of the fish pond dimension and water quality

Parameter	units
DO in the water	**In mg/l**
Water pH	**In ppt (%)**
Water Temperate	**^{0}c**
Electric conductivity of water	**Cm/s**
Total Dissolved substance	**Mg/l**