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Economic and social aspects of aquaculture in Upper Zambezi watershed, Zambia

BACHELOR'S THESIS

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Declaration

I hereby declare that I have done this thesis entitled Economic and social aspects of aquaculture in Upper Zambezi watershed, Zambia independently, all texts in this thesis are original, and all the sources have been quoted and acknowledged by means of complete references and according to Citation rules of the FTA.

In Prague 16.4.2024

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Šimon Šimeček

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Abstract

Aquaculture is an important industry in Zambia, contributing to economic development, food security and employment in the country. Recently, there has been a significant increase in aquaculture production, although its full potential is still far from being used. The Zambian government is therefore trying to make the industry a more viable business to expand its production. With the help of government and donor programs that have sustained large-scale aquaculture systems, Zambia has seen market-driven capital expenditures that have enabled remarkable increases in production. Investment in intensive cage and pond aquaculture, mostly non-native species of tilapia, which now account for most of the annual production, characterizes the emerging commercial industry. This work focuses on the Western Zambia region where aquaculture has potential due to the Zambezi River water resources. The thesis is focused on the comparison of the price return of the construction of natural and dam liner ponds and shows the time period of their price return. The thesis focuses on farmers' earnings in case of sales to neighbours, resellers, restaurants or by selling dried fish. The thesis calculates the total costs of building a natural and dam liner pond.

Key words: adoption, cost-benefit, integrated farming, productivity, ponds, Zambia

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List of the abbreviations used in the thesis

EPA	eicosapentaenoic
DHA	docosahexaenoic acids
GDP	gross domestic product
LDC	Least Developed Countries
MT	mega tons
ZMW	Zambian Kwacha
CBA	Cost benefit analysis

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1. Introduction

Zambia is a country located in the southern part of the African continent. The country is classified as one of the Least Developed Countries (LDCs) by the United Nations. Western Province is one of the poorest provinces in Zambia due to difficult geographical and climatic conditions and the effects of long-term neglect of investment and economic isolation. It is very far from the capital and due to the great remoteness of some areas and poor infrastructure, industry is very limited. Fishing is considered one of the fundamental pillars of food security and self-sufficiency. It takes place mainly naturally on the Zambezi River; however the river is currently overfished, and some species of fish are declining very quickly. The Zambian government, through the Ministry of Agriculture and Livestock, implements an annual fishing ban from December 1 to February 28 each year to allow fish to reproduce and to replenish fish stocks, as this is the peak of their breeding season. The most popular and certainly the most farmed fish in Zambia is tilapia. The Nile tilapia has distinct, regular and vertical stripes that run from the head to the tail fin. It lives up to nine years. The dorsal fin is entire and extends from head to tail, with 15–18 hard and 11–13 soft rays. Males are bluish pink, sometimes with a dark throat, belly and anal fins. Females are usually brownish, silvery white with about 10 thin vertical stripes. It has cycloid scales and a homocercal caudal fin. Tilapia is omnivorous. Its main diet is phytoplankton and benthic algae, but it also eats mosquito larvae, making it a tool in the fight against malaria in Africa. Tilapia is one of the most widespread and important fish in tropical freshwater aquaculture. The main advantages of Tilapia are its relatively low production costs, resistance, fast growth, easy breeding and meat quality. Fishermen sometimes use illegal means such as homemade explosives, mosquito nets, and traditional fish poisons to kill and catch as many fish as possible during the fish ban. These methods can devastate aquatic ecosystems, causing harm to both targeted and unintended species. It often results in overfishing, damaging the balance of the ecosystem and threatening the livelihoods of fishermen who follow the regulations. Since farmers are not allowed to fish from December to February under the threat of a severe fine, the winter season is the perfect opportunity for farmers to set up their own ponds in which to grow fish.

Therefore, Integrated Farming I, II and III projects have been implemented by Mendel University in Brno (MENDELU) and their partners within the Czech Development

Cooperation. The aim of these projects has been to increase the efficiency and productivity of farms and household income of small and medium farmers through the introduction and development of an integrated approach to farming in the Western Province of Zambia, thereby contributing to improving the standard of living of the local population. Since 2018, projects have supported integrated agriculture in the Western Province of Zambia, including the development of aquaculture. Aquaculture production in the Western Province was introduced within the projects also in cooperation with and the technical project support of the Czech private company Holistic Solutions s.r.o., when 4 sustainable ponds in four project districts (Mongu, Limulunga, Senanga and Nalolo) were successfully built or rehabilitated for selected project farmers. The Czech University of Life Sciences also cooperates with Holistic Solutions on the construction of ponds, so it is a very important partner.

2. Literature review

2.1. Importance and evaluation of the role of aquaculture for society

Aquaculture is currently the fastest growing animal food production sector. Aquaculture is the practice of growing aquatic organisms such as fish, crustaceans, molluscs and aquatic plants under controlled conditions. Aquaculture has become one of the most productive industries globally over the past 50 years, as evidenced by the increasing global demand for seafood and the pressures resulting from limited availability of resources and space (Chatzivasileiou et al. 2024). Aquaculture is important for the development of food security. With the ever-growing world population, the demand for sources of protein and important vitamins is increasing. Aquaculture provides a significant portion of the world's seafood supply and offers a reliable and specific way to produce high-quality protein for human consumption (Osmundsen et al. 2020). Aquaculture is one of the fastest growing food production sectors in the world. Over the years, it has been refined, expanded and strengthened in almost all parts of the world. As the number of people on the planet grows, so does the demand for aquatic food products (Subasinghe et al. 2009). Aquaculture also plays an essential role in economic development through contribution to the national economy by creating jobs, especially in rural and coastal areas where employment opportunities may be limited. It promotes economic growth through trade, investment, and the development of supporting industries such as feed production, equipment manufacturing, and transportation. It has been proven that even when a small number of fish is consumed, they often form a nutritionally indispensable part of the diet of many people in developing countries (Fiorella 2023). Fish is a vital source of protein and micronutrients and improves protein quality in a predominantly plant and starch-based diet by providing essential amino acids that are very important for humans. In some coastal and island countries, fish provides more than half of animal protein. It is a particularly important part of the diet of the poor because it is often the most accessible form of animal protein. Fish are very rich in iron, zinc, magnesium, phosphorus, calcium, vitamin A and vitamin C, and marine fish are a good source of iodine, which is essential for the proper functioning of the human body. These vitamins are also found in fruits and vegetables, but in much smaller amounts. Fish also contains fatty acids that are essential for brain development and are especially important for the nutrition of infants, children and pregnant women. Eating fatty acids during pregnancy reduces the risk of low birth weight and mortality. In addition, some other amino acids found in fish and especially taurine may play an important role in the beneficial effects of fish protein, especially in fatty fish including sardines, for example by reducing complications of type 2 diabetes and reducing glucose, insulin and insulin resistance (Khalili Tilami & Sampels, 2018). The nutritional benefits of eating fish are also particularly important for living humans with HIV/AIDS. Vitamins contained in fish increase the effectiveness of antiretroviral drugs and reduce susceptibility to secondary diseases. Unlike traditional fishing, which can deplete wild fish populations and dramatically damage marine ecosystems, aquaculture allows for sustainable seafood production. By growing aquatic organisms in a farmer-controlled environment, aquaculture reduces pressure on wild fish populations and helps preserve biodiversity (Finegold 2009).

The aquaculture industry is vast and complex, with more than 650 species of fish, molluscs, aquatic plants and algae species cultivated in 2020 in a variety of marine, brackish and freshwater systems and widely traded. Aquaculture development is directly linked to four key policy areas: public investment in infrastructure and research and development; policies to support aquaculture value chains; regulatory policies that ensure environmental protection and social protection; and trade policies. Many state policies have historically shaped the geographic distribution of aquaculture growth, as well as the types of species, technologies, management practices, and infrastructure adopted in different locations (Naylor et al. 2023). Innovation is the driver of increased aquaculture productivity and lower input prices for producers and consumers.

A study from the Food and Agriculture Organization of the United Nations (FAO) states that the combined production of fisheries and aquaculture worldwide reached 177.8 million tonnes in 2020. Fish and other marine creatures are essential to the world's food security and nutrition, supporting tens of millions of people worldwide and contributing more than 80% of the total since 1990. But attempts to prevent overfishing and protect marine life have been at conflict with the rising worldwide demand; as a result, during the past three decades, aquaculture's importance has grown significantly while fisheries harvests have been mostly unchanged. Compared to 13 percent in 1990 and 26 percent in 2000, fish, crustaceans, and molluscs were farmed for 49% of the world's supply in 2020.

While species such as carp, salmon, oysters, and shrimp are frequently cultivated in aquaculture, the majority of anchovies, pollock, tuna, herring, and cod are still caught in the wild. The FAO reports that 89 percent of the world's aqua animal production was utilized for human consumption, with the remaining 11 percent mostly going toward the manufacture of fishmeal and fish oil. China was, by far, the world's largest producer of fish and other marine creatures in 2020. As all of Asia accounted for 84% of the approximately 60 million employments in fisheries and aquaculture globally, the nation accounted for 15% of global capture and 57% of aquaculture production ("Chart: Aquaculture Accounts for Half of the World's Fish Supply | Statista" 2017).

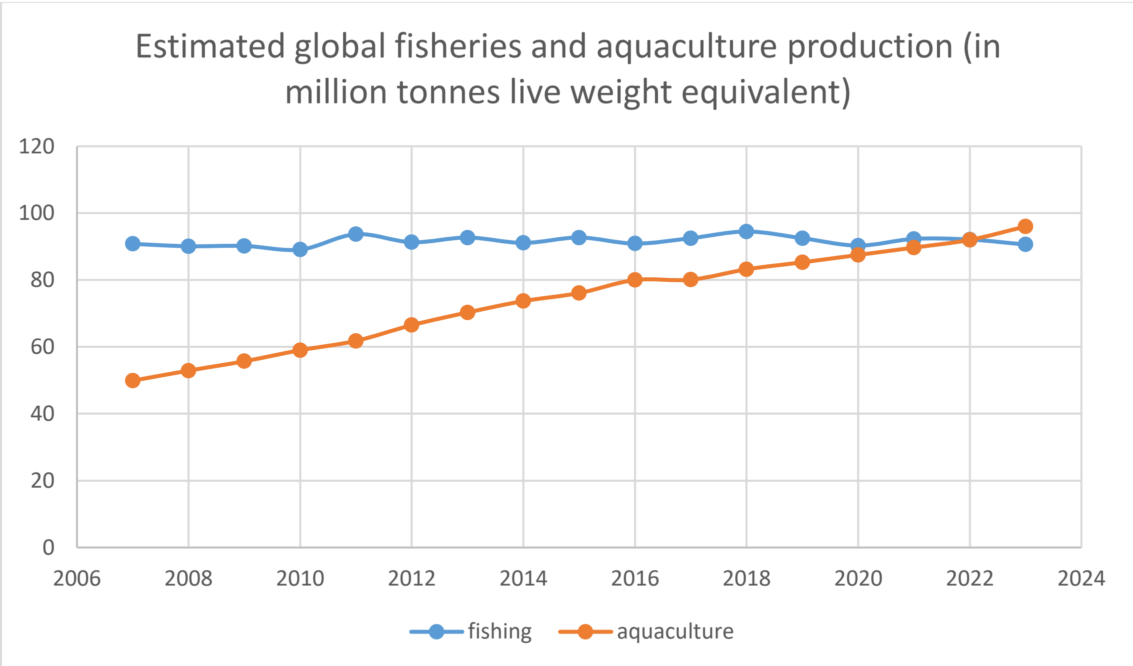

Figure 1. Estimated global fisheries and aquaculture production (Statista 2023)

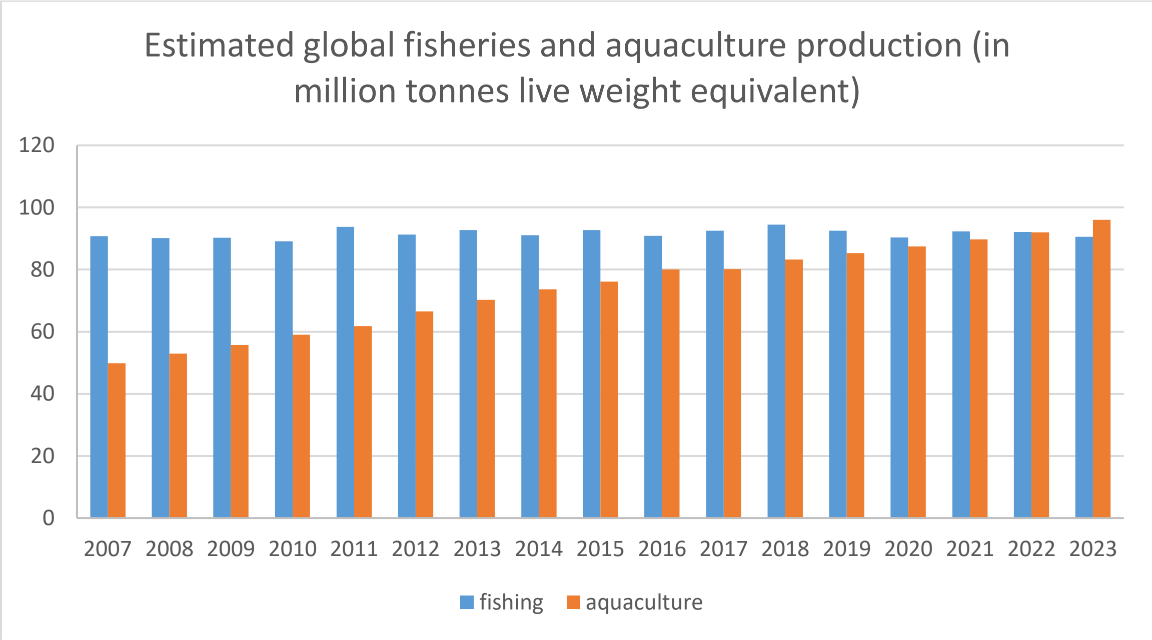

Figure 2. Estimated global fisheries and aquaculture production (Statista 2023)

2.2. Aquaculture economics

There are areas in Zambia where foraging can be a little more difficult. Aquaculture can be one solution in providing the basic needs of the rural poor. This can produce a source of protein for poor people living in rural areas at an affordable price. Aquaculture also helps create limited employment opportunities for poor people in rural areas and provide major support for local economic development. Aquaculture can help the efficient use of fish resources and their efficient distribution (Jolly & Clonts, 2020). Aquaculture economics specializes in the financial aspects of aquaculture operations, including production costs, yields, profitability, and economic sustainability. It is a field that involves various costs, including those related to feed, equipment, energy, water, land and infrastructure (Pillay 1997).

Profitability analysis involves evaluating the overall performance of aquaculture operations by comparing revenue to production costs. Basically, the main goal of any aquaculture farm is to maximize profit using available resources, technology and production methods (Saha et al. 2022). Therefore, fish farmers work with inputs and outputs in such a rational way to maximize their profit. One way to increase profitability is to increase fish production per unit of pond area (Shawon et al. 2018). A significant proportion of aquaculture farmers try to follow intensive or semi-intensive farming systems to increase productivity. Commercial intensive or semi-intensive aquaculture production is directly related to several factors such as feed, labour and water treatment equipment (Ferdous et al. 2011). This directly highlights the fact that fish feed accounts for more than 70 % of the total cost (Belton et al. 2011). However, feed quality has decreased in recent years due to contamination (Pietsch 2020). However, on the other hand, the demand for feed ingredients has increased as aquaculture production has increased rapidly due to the use of commercial feeds (Rana et al. 2009).

Aquaculture development creates new jobs, alleviates poverty, and helps rural development. Economic impact assessments analyse aquaculture's contributions to employment, income distribution, gross domestic product (GDP), trade balance and overall economic growth. These assessments provide policy makers, investors and stakeholders with valuable insights into the socio-economic benefits and challenges of aquaculture development. Aquaculture economics also includes the analysis of policies, limits, regulations, and government interventions that affect the economic environment for aquaculture investment and development (Kadowaki & Kitadai 2017). Aquaculture is increasingly recognized as a source of household income, especially cash income for subsistence and semi-subsistence households in rural agricultural settings, although it is not necessarily the main source of income. Compared to crop farming, the use of domestic labour in aquaculture and animal husbandry is relatively low, but the use of aquaculture for household labour and employment can still be significant. The introduction of modern technologies (multiple cropping, irrigation, seeds and fertilizers) caused a higher demand for labour, including higher wages, increased demand for hired labour, and increased migration of people. The impact of aquaculture on employment, wage rates and labour markets has been very little researched so far. Most documented studies on labour absorption in aquaculture refer only to its use for pond operation and management, measured either in physical units or in monetary value (Ahmed & Lorica 2002).

2.3. Aquaculture development in the world

In 2016, aquaculture production reached 80.1 million metric tons globally. This is an increase from 603,000 metric tons in 1950 and 2.5 million metric tons in 1970 (FAO 2018). In 2013, aquaculture even surpassed fisheries as a source of food for human consumption. Aquaculture is primarily a sector of developing and highly populated countries for several reasons. In 2016, 94.4 % of production took place in developing countries, the largest share in Asia (89.4 %). The dominant producer is China (61.5 %), followed by Indonesia and India (Anderson et al. 2019). China is one of the world's largest producers of farmed seafood and has a very long history of aquaculture dating back thousands of years. The country farms a wide variety of species, including fish, shellfish and algae, and leads the world's aquaculture industry in terms of production volume and technological innovation (Leung & Cai 2005).

For example, Norway is a leader in salmon farming and is known for its high-quality aquaculture practices. The country has developed advanced salmon farming techniques, including open net systems in its fjords. Norwegian aquaculture companies are also involved in research and sustainability initiatives (Bjørkan & Eilertsen 2020). Norway has been a world player in farmed salmon farming since the introduction of production technology in the late 1960s. Since then, Norwegian salmon production has increased from 600 tons in 1974 to about 1,300,000 tons today. From the beginning, aquaculture in Norway has experienced considerable popularity. Salmon production accounts for about 90%, rainbow trout 7-8% and cod 2%. In addition, Arctic char, halibut, and turbot are also produced (American 2012). Salmon farming is today one of the most important industries in rural Norway, with an annual landing value of approximately NOK 60 billion (€6.5 billion). In the beginning, farmers used net cages in the fjords, nowadays large production facilities are used (Maroni 2017). However, there are costs and benefits associated with the production of salmon for economic purposes. About 6,000 jobs are created in this industry. Aquaculture is estimated to contribute between 0.5-1% per year to Norway's GDP. Salmon production has doubled tenfold since 1992 and has doubled since 2005. In 2015, Norway produced 53% of the world's production of Atlantic salmon, while Chilean production accounted for 25% of the world market (Olaussen 2018).

Chile is a leading producer of farmed salmon and trout with a well-established aquaculture industry concentrated in the southern and cooler regions of the country (Salazar et al. 2018). Chile is one of the main producers of farmed salmon (Buschmann et al. 2009) Salmon is a global commodity in Chile and other countries and, as an oily fish, contains a rich source of the health-promoting long-chain omega-3 fatty acids eicosapentaenoic (EPA) and docosahexaenoic (DHA) acids. Salmon represents an important item for the aquaculture sector and its further development (Sprague et al. 2016). From a zero share of world production in the early 1980s, production began to increase in the late 1980s and by 1992 had overtaken both the United Kingdom and Canada, making Chile the second largest producer of farmed salmon in the world. In 2000, Chile's share of world production was about 20%. Chile's salmon aquaculture industry is centred around Puerto Montt and the island of Chiloe, located approximately 1,000 km south of the capital, Santiago de Chile. Thanks to the rugged coastline, these areas offer sheltered spots with ideal water temperature and salinity. Due to the low population density, the water is of very high quality. Thanks to the constant flow, the water does not freeze and thus represents stable favourable climatic conditions for salmon production for most of the year (Bjørndal & Aarland 1999).

Vietnam is one of the leading aquaculture producers in Asia, specializing in freshwater species such as catfish, shrimp, and tilapia (Phuong & Oanh 2010). Vietnam's aquaculture industry has experienced rapid growth, supported by suitable climatic conditions, abundant water resources and a strong focus on export markets. Aquaculture has been practiced in Vietnam for a long time (Nhu et al. 2010). There are three main stages in the development of the aquaculture industry: the initial period from the early 1960‘s to the Vietnam War in 1975, the second from 1975 to the introduction of another policy in 1986, and the third from 1986 to the present. In the initial period, aquaculture was primarily fish farming in ponds in freshwater areas. After 1975, the aquaculture sector was supported because of the creation of new jobs. As of 2005, Vietnam is the fourth major producer of aquaculture in the Asian region and in the world after China, India and Indonesia. Aquaculture yield to total world aquaculture production increased from 3.23% in 2005 to 5.04% in 2018. Vietnam's aquaculture has developed both inland and marine and coastal areas. The country ranks fourth in inland and eighth in marine aquaculture. Marine and coastal aquaculture is known for raising marine shrimp (Bich Xuan et al. 2021). The inland one is characterized by the breeding of striped catfish. Vietnam is the third largest producer of shrimp in the world. Since 2014, Vietnam exports the largest amount of seafood after China and Norway. Most of the Vietnam’s aquaculture production occurs at the small, or familial scale. Of the 2.4 million households that are involved in aquaculture, 75 % of them have farms that are less than 2 hectares in area and 90 % are less than 3 hectares. The small-scale nature of Vietnam’s aquaculture sector makes it particularly vulnerable to the unpredictable and changing weather patterns brought on by climate change. Aquaculture farmers in Vietnam are especially vulnerable to change. Sea cage farms are located offshore where they are exposed to storms, while shrimp farms are often located in low lying areas that are impacted by rising sea levels (Nn et al. 2021).

Another Asian country, India, is characterised by a long tradition of aquaculture, especially in freshwater farming of species such as carp and shrimp (Jayanthi et al. 2018).The country is a major global producer of farmed shrimp, with aquaculture playing a significant role in rural livelihoods and economic development in the country's coastal regions. India has seen a huge increase in fish production over the last sixty years (Jayasankar 2018). In India, annual fisheries and aquaculture production increased from 0.75 million tonnes in 1950 to 9.6 million tons in 2014. Globally, the country is now second only to China in aquaculture and annual production. India produces more than one-third of the world's fish production. Almost all this amount is consumed domestically, except for shrimp and freshwater shrimp, which are often exported (Katiha et al. 2005). India mainly imports shrimp to the Netherlands. Freshwater aquaculture has grown over the past thirty years from 0.37 million tons in 1980 to 4.03 million tons in 2010. The national average annual consumption of fish and fish products in 2010 was 2.85 kg/inhabitant (De Jong 2017).

In Indonesia, Aquaculture has been practiced since the fifteenth century. Since then, the nation has significantly increased its share of aquaculture output for both home and foreign markets. These days, Indonesia's economy greatly benefits from capture fisheries and aquaculture, which provide jobs in rural regions, produce food security through primary production, and bring in substantial amounts of export revenue. Although Indonesian aquaculture is expanding quickly and is seen to have significant potential for growth, capture fisheries are thought to be completely or virtually fully utilized. With projected 2014 production from capture fisheries and aquaculture, including aquatic plants, of 6.5 and 14.4 million tons, respectively, Indonesia is the world's second-largest fish producer behind China. The fisheries industry contributes significantly to Indonesia's economy via generating revenue, diversifying sources of livelihood, providing animal proteins, and earning foreign cash. In 2012, the sector earned US$ 4.2 billion from seafood exports, contributed 3.1% to the country's overall gross domestic product (GDP) and 21.0% to the GDP of agriculture, and supplied 54.8% of the country's animal protein needs. It also generated an estimated 6.4 million direct employment for Indonesians. In Indonesia, the amount of fish consumed annually per person increased from 21.0 kilogram in 2003 to 33.9 kg in 2012. Over the past 50 years, Indonesia's fish supply has increased steadily, rising from 0.8 million tons in 1960 to 10.7 million tons in 2014. Although fish landings have levelled down over the past ten years, most of these fish still originate from wild catch fisheries in both inland and coastal areas. In consequence, aquaculture has emerged as the primary force driving Indonesia's increased fish supply in recent times. The aquaculture industry has grown at a pace of around 7.7% year since 1960. As a result, the proportion of farmed fish in overall fish output increased from 10.6% in 1960 to 40.2% in 2014. With more than 17,000 islands and 81,000 kilometres of coastline, Indonesia is likewise seen to have enormous potential for growing aquaculture. For instance, the Indonesian government claims that an extra 26 million hectares of land are available for the establishment of aquaculture (Tran et al. 2017).

The Food and Agriculture Organization of the United Nations (FAO) estimates that fish production reached over 178 million tons worldwide in 2021 ("Top 10 Fish Producing Countries in the World – Geeks for Geeks" 2021). In terms of fish output, Asia continues to lead the way, followed by Africa and Latin America. The top ten aquaculture producers are shown below:

Table 1. shows top 10 fish producers (Geeks for Geeks 2019)

Rank	Country	Fish production in 2021
1	China	67.8 million tonnes
2	Indonesia	16.7 million tonnes
3	India	10.9 million tonnes
4	Vietnam	6.4 million tonnes
5	Bangladesh	6.3 million tonnes
6	Norway	4.9 million tonnes
7	Chile	4.4 million tonnes
8	Japan	3.1 million tonnes
9	United States	2.8 million tonnes
10	Egypt	2.7 million tonnes

2.4. Aquaculture in Africa

Aquaculture began to be introduced to Africa in the early 20th century, primarily to meet the needs of colonial fisheries. In the 1920s, tilapia began to be produced in stagnant ponds in Kenya (Food & Organization of the United Nations 2020). Aquaculture was later introduced by colonial governments in Africa between the 1940s and 1950s to improve nutrition in rural areas, supplement income, diversify to reduce the risk of crop failure, and create jobs in less developed parts of the country. As a result, governments in many countries built many fish hatcheries in the 1950s, with approximately 300,000 active production ponds across Africa by the end of 1950 (Adeleke et al. 2020). Aquaculture in Africa is an emerging industry with significant potential for growth and development. Several countries across the continent are making great strides in aquaculture, learning to take advantage of their natural resources, favourable climate conditions, and increasing demand for seafood (Avadí et al. 2022). Although tilapia was cultivated in Egypt as early as 2500 years ago, there is rather less tradition of fish culture in most African countries, despite Africa's natural wealth of high potential aquatic genetic resources and the abundance of water in several parts of the continent (Trottet et al. 2022).

This situation is now slowly changing, thanks to a combination of increasing demand for food and other goods from limited natural resources and the efforts of farmers, researchers, national governments and development aid agencies. Although still small, African aquaculture production has entered a steady phase of expansion. A third of the total production is tilapia, especially Nile tilapia (*Oreochromis niloticus*). Almost half of the total reported production from African aquaculture came from Egypt (Brummett & Williams, 2000).

Egypt is one of the leading countries in aquaculture production in Africa (Mehanna 2022). The country has a long history of aquaculture dating back to ancient times with the farming of Nile tilapia. Egypt uses the basin of one of the longest rivers in the world, the Nile, for the production and breeding of fish. Currently, Egypt is now the largest aquaculture producer in Africa (representing 71% of the continent's production) and a major global aquaculture power (Pauly & Zeller 2017). Egypt is the third largest producer of tilapia in the world (after China and Indonesia), with tilapia aquaculture directly essential to the national economy and food security, as all Egyptian production is marketed locally (Rossignoli et al. 2023). Today, Egypt's aquaculture industry is diversified, producing a variety of species including tilapia, mullet, carp and catfish. The government has invested in infrastructure, research, and technology to support the higher development of the sector (Hinrichsen et al. 2022).

Nigeria is considered an attractive and growing market for aquaculture. Nigeria has a rapidly growing aquaculture industry driven by increasing demand for fish protein and declining wild fish stocks. The development of aquaculture is the increasing accumulation of wealth, the limited import of currency and the increasing demand for protein (Ogunji & Wuertz 2023). Annual per capita fish consumption in Nigeria is 11.2 kg. In 2018, the country had a total stock of 2.1 million metric tons of fish. Of this, a total of 291,000 tonnes from aquaculture (98% catfish and 2% tilapia); 866,000 t from small-scale fisheries; 940,000 t from imports and 11,600 t from sea catch (Monty Simus et al. 2022). Aquaculture production in the country is based mainly on catfish farming, but tilapia, carp and other species are also grown. The demand for fish in Nigeria is increasing due to extremely rapid population growth (Oboh 2022). Aquaculture in Nigeria started to develop at Panyam Fish Farm, Jos in 1951 as a government enterprise. It has now spread to all parts of the federation as a private sector managed enterprise covering all aquatic environments and utilizing a range of aquatic species (Kaleem et al. 2021).The country has great natural resources to support the development of aquaculture. Inland, there are 14 million hectares of freshwater reserves and 1.7 million hectares of available land for aquaculture development. Cultivated species include, among others, Clarias, Tilapia, Carp and Heterotis. Shrimp farming is also taking place, but so far on a small scale (Adewumi 2015). Aquaculture in Nigeria is currently largely urban driven. The Nigerian government has implemented policies to promote the development of aquaculture and has invested significant sums in training programs for fish farmers (“Aquaculture Development in Nigeria and FAO’s Role - ProQuest” 2020).

The Kenyan aquaculture sector is broadly categorized into freshwater aquaculture and mariculture. Whereas freshwater aquaculture has recorded significant progress over the last decade, the mariculture sector has yet to be fully exploited. The Kenyan aquaculture industry has seen slow growth for decades until recently, when the government-funded Economic Stimulus Program increased fish farming nationwide (Munguti et al. 2014).Warmwater aquaculture is widely practiced in Kenya and is dominated by Nile tilapia (*Oreochromis niloticus*), which accounts for 75 % of total production. It is followed by African catfish (*Clarias gariepinus*) with 18%. Aquaculture started in Kenya in the 1920s and had an upward trend until 2014 when it peaked at 24,096 MT. However, production has declined drastically over the past 3 years, with 14,952 metric tons (MT) reported in 2016. Most farmers use a semi-intensive cultivation system based on earthen ponds. In the past, farmers tried to cultivate some native fish, such as African carp (*Labeo victorianus).* However, cultivation of this native species has not met expectations, and therefore Nile tilapia is mainly cultivated (Opiyo et al. 2018). The country's aquaculture industry faces many challenges and obstacles, such as limited access to quality feed, rapid fox population growth, insufficient infrastructure and inconsistent political support. Tilapia is the most commonly farmed fish in the country. There are about 7,477 small ponds in the country, from which several tons of fish are caught annually. This number will increase in the future, but aquaculture in Kenya faces several challenges (Rothuis et al. 2011).Here it is possible to mention the low support of aquaculture through many institutions which include government, research institutions, universities and non-governmental organizations. In addition, there is a lack of certified quality seed, weak research programs, ineffective training programs for farmers and workers, low government funding for activities and low private sector investment, and finally, poor record keeping by farmers and ineffective statistical data collection (Mbugua & Mwangi 2008).

Located at the very south of the black continent, South Africa has a somewhat smaller but growing aquaculture industry focusing on species such as abalone, trout and tilapia. The country's aquaculture sector benefits from well-established infrastructure, research institutions and supportive policies. The South African government has identified aquaculture as a priority area f or agricultural development and has introduced initiatives to encourage investment and innovation in the sector (Déla et al. 2013). In 2014, the total production in aquaculture was 4,314 tons and the number of employees was 7,168. In South Africa, aquaculture was first introduced in the 1950s. Tilapia dominates the number of farmed fish. In the 1970s, the South African government sought to exploit the growing potential of aquaculture and invested large sums in its support. The government has tried to support research and build aquaculture hatcheries for indigenous fish species. However, most hatcheries are now in a dysfunctional state (Amosu et al. 2013). The country's government launched Operation Phakisa several years ago in effort to increase aquaculture production. Despite all these efforts, tilapia culture in South Africa has not yet achieved the expected results and the project has been less successful (Moyo & Rapatsa 2021).

Table 2. shows top 10 aquaculture producers in Africa (FAO 2021)

Country/area	Aquaculture production of all species (tonnes) in 2020	Annual growth since 2000 (%)
Egypt	1 591 896	8.02
Nigeria	261 711	12,30
Uganda	123 897	28,52
Tanzania	108 568	3,84
Ghana	64 010	13,60
Zambia	45 670	12,62
Tunisia	23 486	14,55
Kenya	20 831	20,36
Zimbabwe	15 425	10,35
Madagaskar	13 550	2,68

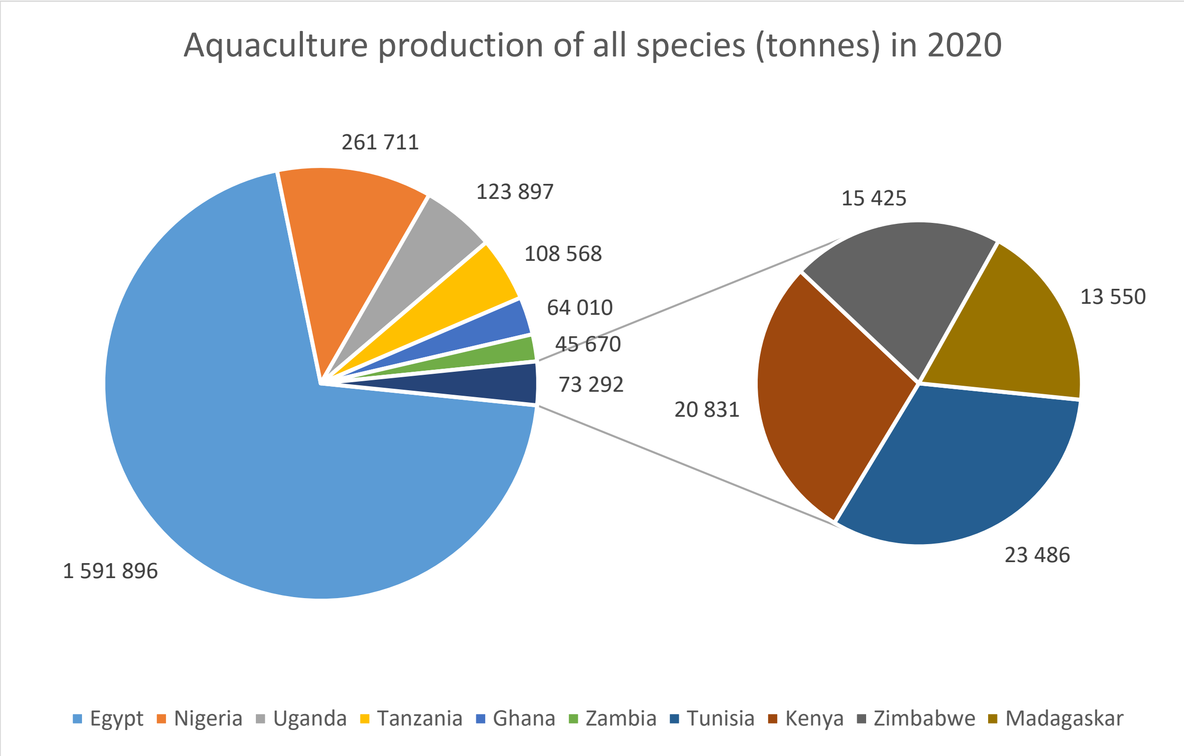

Figure 3. African top aquaculture producers in 2020 (FAO 2021)

2.5. Aquaculture in Zambia

The history of aquaculture in Zambia dates back more than fifty years, with the government in the 1960‘s experimenting with fish farming and establishing aquaculture research stations. In the 1970‘s, the newly formed Department of Fisheries took an active role in implementing small-scale aquaculture development programs in rural areas under the banner of food security and establishing government hatcheries and training programs. about basic pond management. Some donors such as the United States Development Program (UNDP), United States Agency for International Development (USAID), Norwegian Agency for Development Cooperation (NORAD) etc. have seen an opportunity in the development and support of the rural aquaculture sector. It has mostly created and sustained the small farmer sector through models called project models (Kaminski et al. 2018).

Aquaculture in Zambia is still in the early stages of development compared to other countries with more established aquaculture industries. However, there is growing willingness and investment in aquaculture to improve food security, generate income and support economic development in rural areas. Aquaculture in Zambia has continued to develop in recent years and has experienced rapid growth, including a five-fold increase in 10 years. It is expected to play a significant role in food and nutritional security (Namonje-Kapembwa & Samboko 2020). With fisheries likely to stagnate or even decline in the coming years due to the use of unsustainable fishing practices and with the desire to reduce fish imports into the country, aquaculture production is currently becoming more important to supply the Zambian population with fish for consumption (Avadí et al. 2022). Production in 2022 was 45,647 tonnes of fish. In 2016, annual per capita fish intake was 14.5 kg, which is below the world average of 19.2 kg/year, but above the sub-Saharan African average of 8.9 kg/year ("Aquaculture growth potential in Zambia WAPI factsheet to facilitate evidence-based policy making and sector management in aquaculture" 2022). The country's government annually issues a ban on fishing from December to February, so it is best for fishermen to sell during these months. Even if the price of fish drops slightly from March to May, the price of fish is still the highest during this period. Farmers are not advised to sell fish from June to November due to a significant drop in the price of fish.

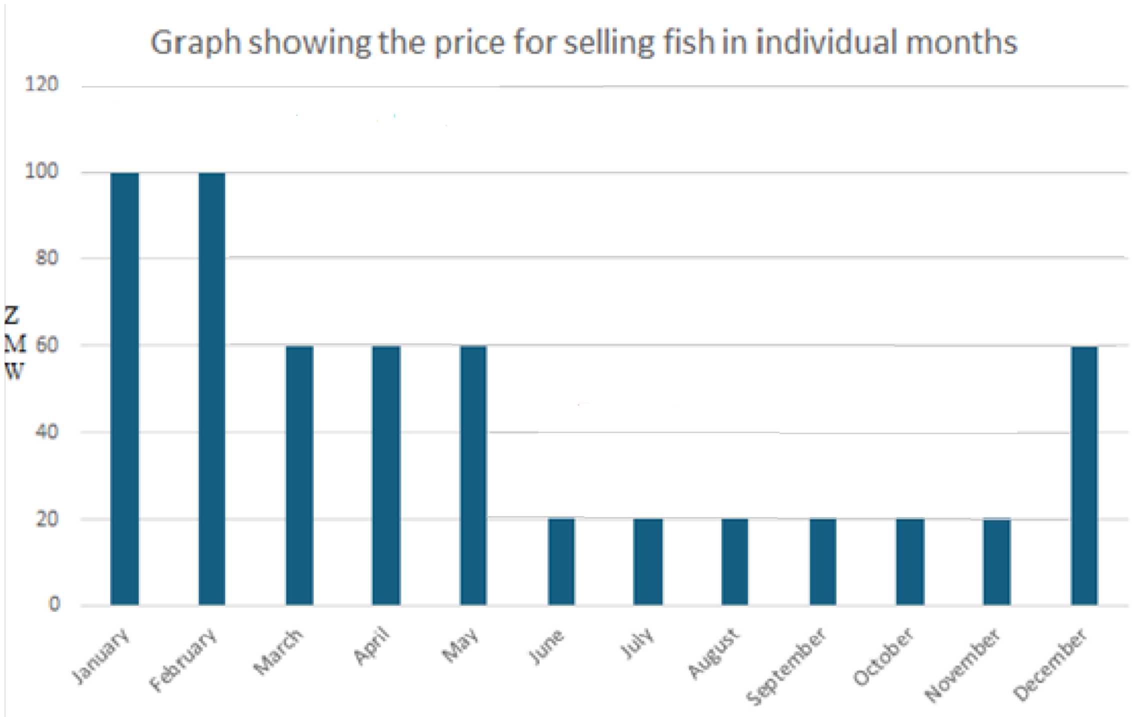

Figure 4. showing the prices of fish selling (Holistic Solutions 2022)

Zambia is now one of the top ten aquaculture producers in Africa. The most produced fish in Zambia is Nile tilapia, accounting for about 60% of the total production. A total of 12,019 aquaculture workers were reported in 2016, an increase to nearly 36,000 in 2019. The increase in aquaculture production is attributed to the rapid growth of the large commercial sector, particularly the cage culture industry and large fish farms in Zambia's lakes (Zhang 2023).

It is envisaged that Zambia's aquaculture industry can act as an engine of economic growth and poverty reduction in the National Development Plan's Vision 2030. However, the biggest challenge is that the country has failed to realize its full potential over the resources and several potential indigenous fish species suitable for farming. Zambia has also established strong trade links with fish markets in its neighbours such as the Democratic Republic of the Congo, Botswana, Angola, Namibia, Tanzania and Zimbabwe (Genschick et al. 2018). These markets allow for reciprocal trade, but Zambia lacks a national fisheries and aquaculture development policy to guide the development trajectory of this value chain in the country. The industry is governed by many broad policies, such as the National Fisheries and Livestock Policies and Implementation Plan, which have a major impact on both how the policies are put into practice and the financial resources allocated to fish producers and animals.

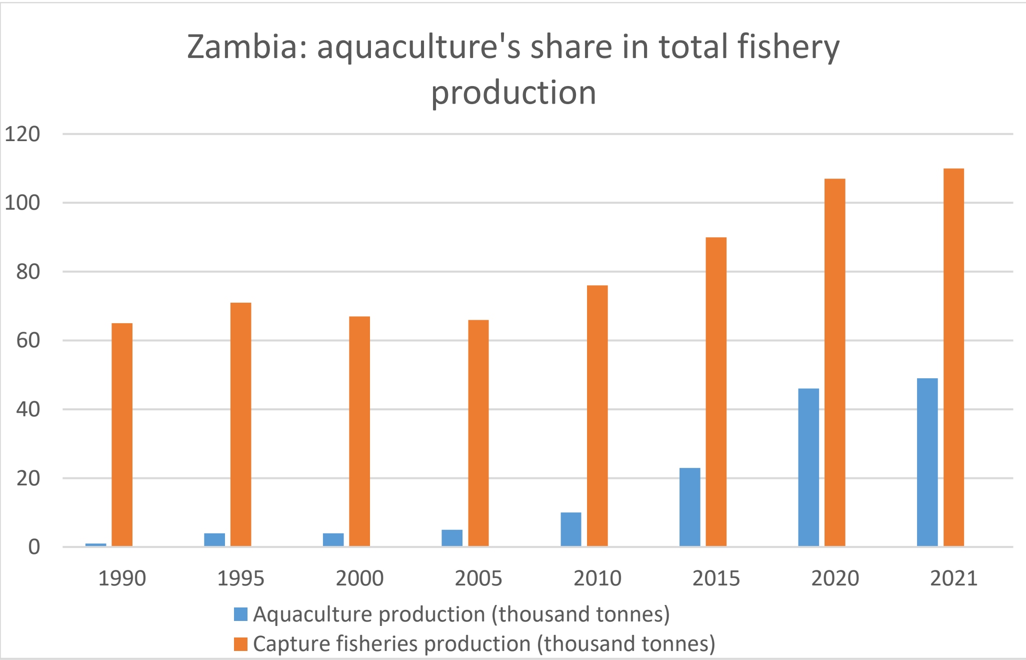

Figure 5. show Zambian aquaculture share in total production (FAO 2021)

Two types of ponds are built in Zambia, natural and dam liner ponds. These ponds must be built near water, preferably a river, so that the ponds have a constant source of water. The ideal pond size is 10 × 20 meters or 10 × 30 meters. The optimal depth is 0.5 meters on one side and 1.5 meters on the other. A natural pond can only be built where groundwater is available and close to the surface. Building a natural pond requires tools like shovels, spades and picks. Gloves and goggles should be used to protect workers when digging to avoid injury (Hasimuna et al. 2023).

Figure 6. Natural pond built in Western Province as part of the Integrated Farming II project (Holistic Solutions 2022)

A low area with a high groundwater level is suitable for a dam liner pond, but the groundwater level should not extend into the pond but should be lower than the lowest part of the bottom of the pond. For the construction of a dam pond, it is necessary to procure a high-quality dam lining (500 microns) and a pump. The pond needs a source of water, so it is advisable to install a water supply system. Basic tools must be available to build a dam pond, without which the pond cannot be built. The most important thing is the film, which prevents water absorption. Excavation tools such as shovels, spades and hoes are another essential item.

Figure 7. Built dam liner pond in Western Province as part of the Integrated Farming II project (Holistic Solutions 2022)

3. Aims of the thesis

The bachelor's thesis focuses on analysis economic performance of proposed aquaculture technology in Upper Zambezi watershed, in western province of Zambia.

Specifically, the thesis will compare traditional technique of pond construction with the proposed improved pond construction. Firstly, initial costs and operational costs are collected and compared to understand the investment challenges of both technologies. Secondly, overall benefits from harvesting fish and additional products will be also compared with special regard to price fluctuations on the local markets (incl. fish ban). Finally, overall profitability of both technologies will be presented and quantified indicators compared and discussed.

4. Methodology

4.1. Study sites

Pond surveys and analysis were conducted in western Zambia, specifically the Upper Zambezi Watershed. This part of Zambia can be described as a rural area located about 600 km west of the Zambian capital Lusaka. The inhabitants here live a traditional way of life, and a large part of the households make a living from agriculture and aquaculture. This area of Zambia is one of the poorest, but it is full of potential for the future. Tilapia farming is among the most widespread in this area.

Figure 8. Show location of western province in Zambia (Holistic Solutions 2022)

4.2. Data collection

Data were collected in cooperation with Czech company Holistic Solutions. Data on materials were obtained from the markets and data on sold fish from the market and interviews with fish sellers and consumers. On the base of these interviews, the items needed for the construction of ponds were summed up. After preparing the construction site, it is possible to build a pond and its water management structures. Dams are the most important part of the pond, because they keep the necessary volume of water retained and form the pond itself; their design and construction is particularly important. Every pond dam should have three basic characteristics. The pond should be able to withstand the water pressure resulting from the depth of water in the pond. It must be impermeable, water seepage through the dam is limited to a minimum. The height is important so that the water in the pond never overflows over the top of the pond, which would quickly destroy the dam. Part of the clay is brought to the top of the pond and it is possible to put seeds on top. After digging the ideal size, the bottom of the natural pond is clogged with clay. A foil is placed on the bottom of the Dam liner pond. A dam liner pond requires the installation of piping and other items such as liners and a pump. The ponds are filled with water and after a certain period, fish are planted there, which are caught after reaching a suitable size. It is necessary to constantly check the quality and pH of the water in order to avoid high mortality of fish ("Fish Pond Construction" 2021).

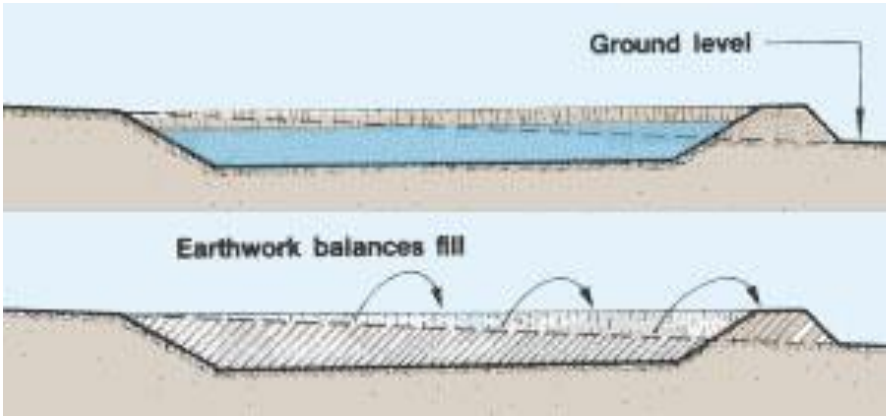

Figure 9. Show process of pond construction (Holistic Solutions 2022)

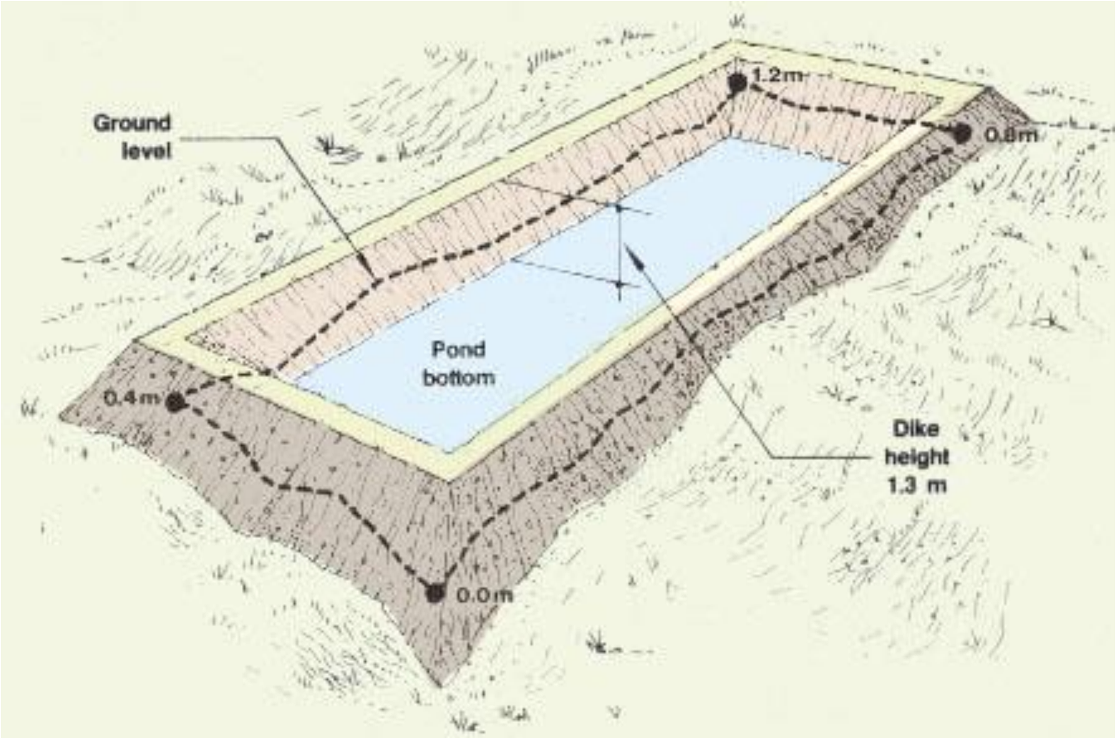

Figure 10. show ideal depth of both types of ponds (Holistic Solutions 2022)

Table 3. provides an overview of the initial costs of a typical natural pond in a given area

Quantity	Item	Price per unit	Total
4	Drainage pipes 110 mm	350	1,400
2	Poly pipe by 110m	1,700	3,400
2	Shovels and spades	500	1,000
		Total	5,800

Table 4. shows fixed costs used to build natural ponds

Quantity	Item	Price per unit	Total
2	Local diggers, 5 days	1,000	10,000
2	Expert joiner/labour	1,500	3,000
		Total	13,000

	Total cost of building a natural pond		18,800 ZMW

Table 5. shows the fixed materials

Quantity	Item	Price per unit	Total
2	Dam liner 350 m^2	15,000	30,000
1	Installation kit + glue	5,000	5,000
2	Softwire (5kg)	250	500
3	Timber 100 By 50m	120	360
4	Drainage pipes 110m	350	1,400
2	Connectors for pipe	180	360
2	Poly pipe by 100m	1,700	3,400
		Total	41,020 ZMW

Table 6. shows variable materials

Quantity	Description	Unit Price	Total
2	Expert joiner/labour	1,500 ZMW	3,000
2	Local diggers, 5 days	1,000 ZMW	10,000
1	Hilux fuel	9,000 ZMW	9,000
2	Shovels and spades	500 ZMW	1,000
1	Petrol 1 year	3,500 ZMW	3,500
1	Water pump	10,000 ZMW	10,000
1	Saw blades + holders	450 ZMW	450
1	Genset service	1,500 ZMW	1,500
		Total	38,450

	Total cost of building		79,470 ZMW

4.3. Data analysis

The traditional method of smoking fish in a drying oven was excluded from the economic assessment due to the high purchase price and little interest from farmers (Leon et al. 2002). The price of ponds is calculated as the sum of the costs of the construction material used, including labour costs. A cost-benefit analysis (CBA) was used to document the profitability of aquaculture in the target area. Data and results were calculated using mathematical equations. The first shows revenue from sales in Zambian Kwacha. The second shows the internal rate of return and the third calculates the payback period of the pond construction.

NPV (Eq. 1) and IRR (Eq. 2) were defined via the following equations:

$$\mathrm{NPV} = -\mathrm{C}_0 + \sum_{t=1}^{n} \frac{B_t - C_t}{(1+i)^t} \text{ (thousands ZMW)} \quad (1)$$

$$0 = \mathrm{NPV} = -\mathrm{C}_0 + \sum_{t=1}^{n} \frac{B_t - C_t}{(1+i)^t} [\%] \quad (2)$$

where B_t is the benefit in each year, C_t is the annual cost in each year; i is the interest (discount) rate, t is the number from 1, 2, 3, ..., n, where n is the number of years, i.e. the life of the pond, which should reach decades.

The equation for calculating PBP (Eq. 3) uses inflation and interest rates to estimate the time it takes for a return on investment in both natural and dam liner ponds:

$$\text{PBP} = \frac{\ln\left(1 - \frac{C_0}{B_t - C_t}(d - f)\right)}{\ln\left(\frac{1+f}{1+d}\right)} [\text{years}] \tag{3}$$

where C_o is the initial investment, B_t is the benefit in each year, C_t is the annual costs in each year, d is the real interest rate, and f represents the inflation rate.

5. Results

5.1. Comparison of construction of natural with dam liner pond

This chapter of the bachelor thesis will focus on the results, comparing the initial costs for two types of ponds (natural and dam liner).

Table 7. Pond installation cost (Holistic Solutions 2022)

Item	Unit of measure	Price per unit	Natural pond		Dam liner pond	
			Quantity	Costs per unit	Quantity	Costs per unit
Building material						
Drainage pipes 110 mm	m	350	4	1 400	4	1 400
Poly pipe by 110m	m	1 700	2	3 400	2	3 400
Shovels and spades	number	500	2	1 000	2	1 000
Installation material						
Dam liner 350 m	m	15 000	0	0	2	30 000
Installation kit + glue	number	5 000	0	0	1	5 000
Softwire (5kg)	kg	250	0	0	2	500
Timber 100 By 50m	m	120	0	0	3	360
Connectors for pipe	number	180	0	0	2	360
Hilux fuel	m	9 000	0	0	1	9 000
Petrol 1 year	m	3 500	0	0	1	3 500
Water pump	number	10 000	0	0	1	10 000
Saw blades + holders	number	450	0	0	1	450
Genset servise	number	1 500	0	0	1	1 500
Labour						
Expert joiner/labour	man-days	1 500	2	3 000	2	3 000
Local diggers, 5 days	man-days	500	20	10 000	20	10 000
Total investment costs				18 800		79 470

Table 8. Pond annual operational (Holistic Solutions 2022)

benefits

Item	Price per kg (ZMW)	Natural pond		Dam liner pond	
		Fish catch (kg)	Value (ZMW)	Fish catch (kg)	Value (ZMW)
Tilapia	40,00	250,0	10 000,0	210,0	8 400,0
Catfish	50,00	180,0	9 000,0	170,0	8 500,0
Ducks	60,00	50,0	3 000,0	60,0	3 600,0
Frogs	100,00	20,0	2 000,0	15,0	1 500,0
Clarias	80,00	30,0	2 400,0	20,0	1 600,0
Goose	50,00	50,0	2 500,0	45,0	2 250,0
Total annual benefits			28 900,0		25 850,0

Table 3 Pond annual operational costs

Item	Price per unit (ZMW)	Natural pond		Dam liner pond	
		Unit used	Value (ZMW)	Fish catch (kg)	Value (ZMW)
Labour (man-days)	10,0	5,0	50,0	20,0	200,0
Dung value used (kg)	8,0	200,0	1 600,0	350,0	2 800,0
Water (m^3)	60,0	0,0	0,0	50,0	3 000,0
Fish feed (kg)	90,0	300,0	500,0	300,0	500,0
Fishing net	1 700,0	1,0	1 700,0	2,0	3 400,0
Vats for catching fish	100,0	10,0	1 000,0	10,0	1 000,0
Maintenance (2% of installation costs)			97,0		200,0
Total annual costs			4 947,0		11 100,0

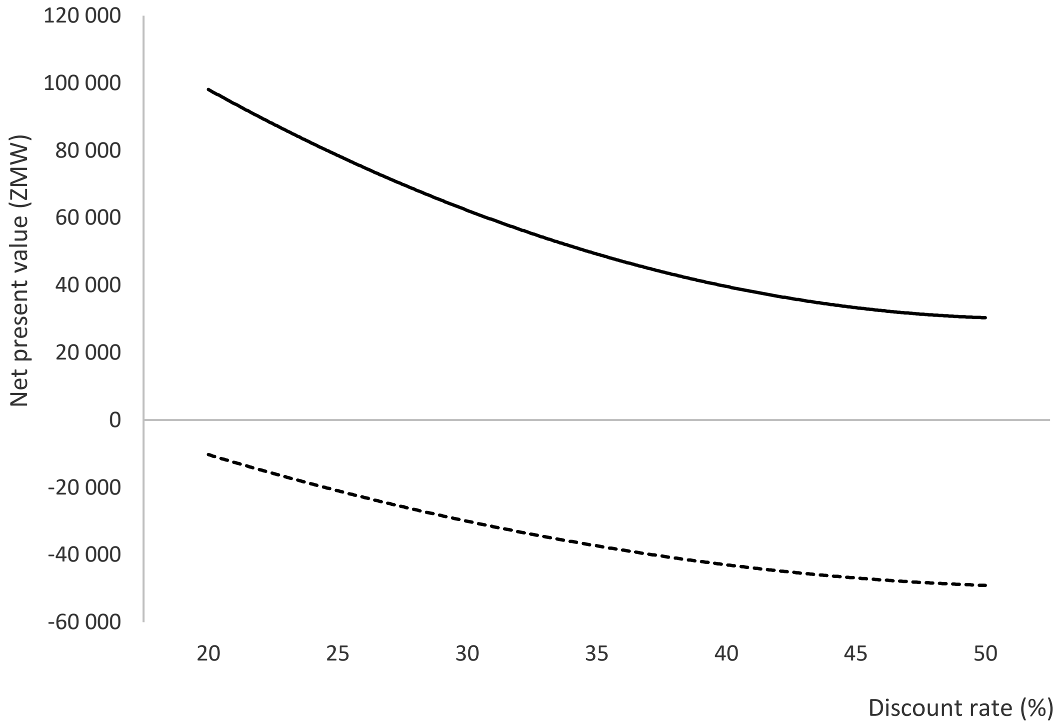

Figure 11. Net present value of natural and dam liner ponds in discount rate. The solid line represents the values for the natural pond and the dashed line for the dam liner pond

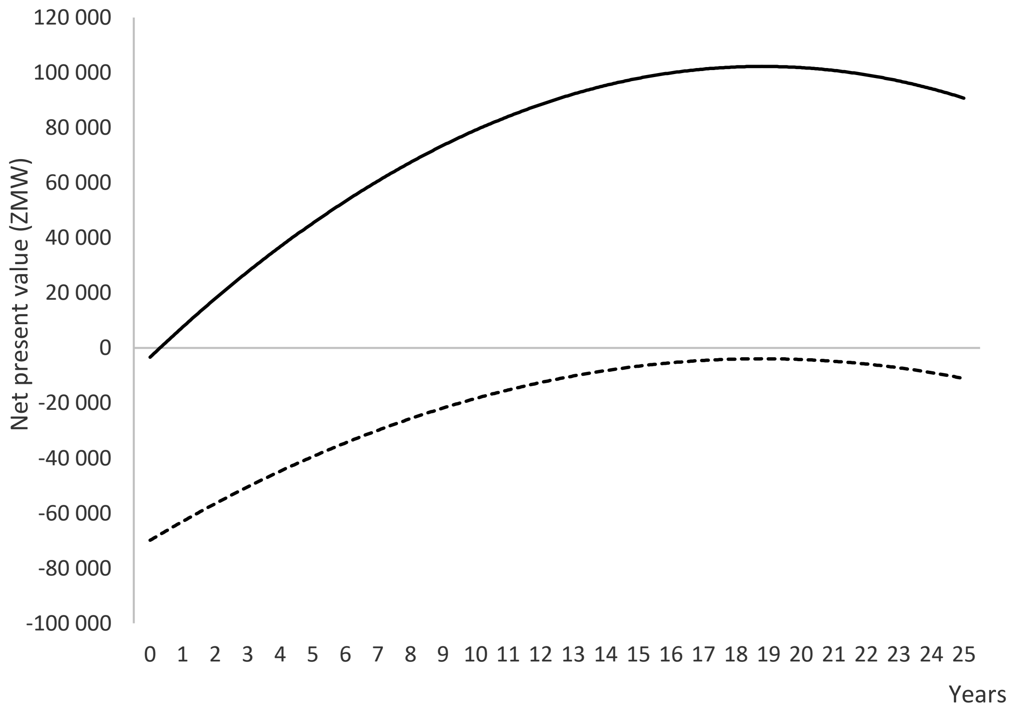

Figure 12. Net present value of natural and dam liner ponds in years

5.2. Fish production and sales of Tilapia

The required size of Tilapia for sale is 60 cm and weight up to 4.3 kg, but sometimes it can weigh up to 5 kg. Selling fish can provide farmers with a relatively good income. Of course, farmers can sell fish to neighbours, but the selling price is the lowest compared to other options. The selling price is expected to be a maximum of 18 ZMW/kg. The advantage of this method is low cost of transport.

Another option is to sell fish in the nearest town. However, in this case it is necessary to think about the provision of refrigerated transport, boxes and transport costs. But even so, the purchase price at markets in larger cities is up to 100% higher than when fish are sold to neighbours. The selling price is around 40 ZMW/kg. The prices of fish in the market are not constant. It depends on the season. The most expensive for 1 kg of fish is 50-60 ZMW. The cheapest is around 15 ZMW.

Figure 13. Fresh Tilapia fish (Fox 2022)

Farmers can also sell their fish to restaurants where they can receive up to 73 ZMW/kg. It is necessary to demonstrate sales skills and deliver the fish in the desired and excellent quality and in a suitable cooler that will keep the fish fresh.

Of course, farmers can earn an even higher amount of money in various ways. For example, they can dry or smoke fish. However, the construction of a smokehouse is very expensive for farmers, so they use this sales option very little. For that reason, this variant will not be considered in the document. Return price for dried fish is 165 ZMW/kg. However, there are additional costs associated with this method for the farmer, as they would have to build a smokehouse or hire someone to take care of the process for them. For this reason, many farmers prefer to sell fish to fish markets or restaurants. The average yield per year is approximately 200 kilograms of fish. The fish are expected to reach their marketable length of 20 cm within 6 months. The estimated price of one fish of 20 cm in length is 20 ZMW. It is also essential to consider some fish losses. The usual success rate is around 75 %, which means that 750 baby fish survive. 750 × 20 ZMW = 15,000 ZMW. Fish are harvested once a year.

Figure 14. Catfish (Goldfish 2020)

As for the selling fish, selling fish to neighbours is the least profitable. The selling price of fish to neighbours is around 18 ZMW/kg. Annual production is approximately 200 kg. 18 × 200 = 3600 ZMW. The selling price of fish to the nearest town is 40 ZMW/kg. 40 × 200 = 8,000 ZMW per year. Farmers can sell fish to restaurants for as little as 73 ZMW/kg. 73 × 200 = 14,600 ZMW per year. However, selling to restaurants is an ideal case that cannot always be repeated. Tilapia can also be dried, but in this case the selling price is 165 ZMW/kg. Dried fish has high costs for fish processing, drying, packaging and labour intensity, which must be considered. 200 × 165 = 33,000 / 3 = 11,000 ZMW/kg.

Figure 15. show dried tilapia fish (Kaminski 2019)

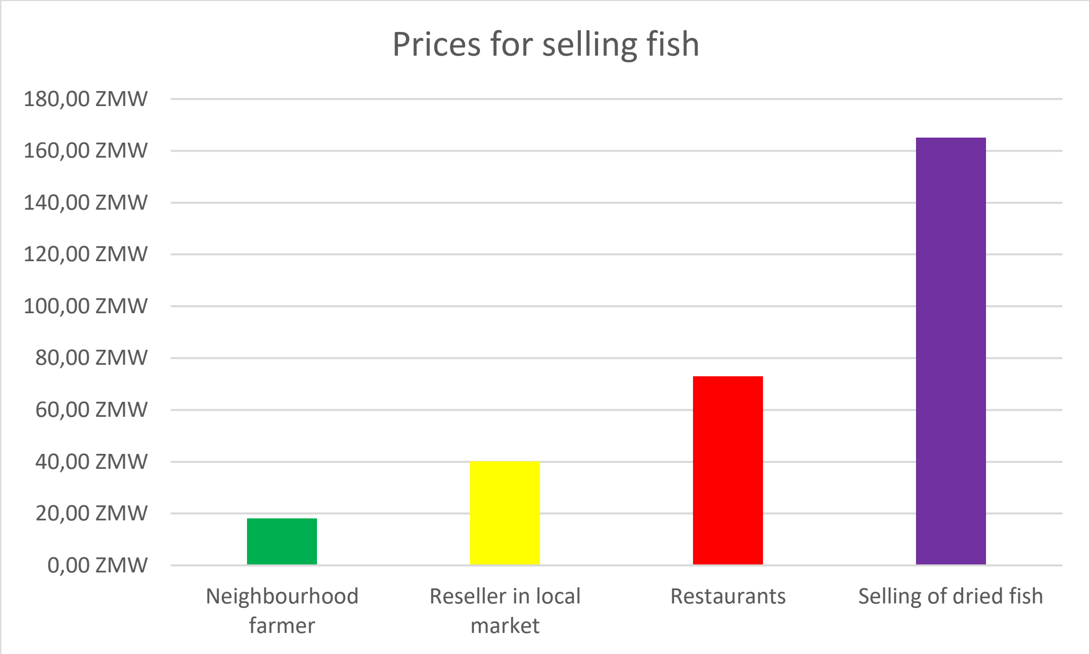

Figure 16. is comparing the selling price of fish (Holistic Solutions 2022)

The table below summarizes the costs, income and return on construction of both types of ponds. The table clearly shows how much farmers earn from selling fish in one year. The price per kg of fish is lowest if the farmers sell the fish to their neighbours. Furthermore, the table shows the return on time for the construction of a natural pond and a pond with foil. Subsequently, the total price for the construction of the pond is considered in the lower part of the table.

Table 9. shows earnings from fish sale in one year

	Natural pond	**Dam liner pond**
Earnings from the sale of fish to neighbours (in one year)	3,600 ZMW	3,600 ZMW
Earnings from the sale of fish to resellers (in one year)	8,000 ZMW	8,000 ZMW

Earnings from the sale of fish to restaurants (in one year)	14,600 ZMW	14,600 ZMW
Earnings from the sale of dried fish (in one year)	11,000 ZMW	11,000 ZMW

Table 10. shows return of investments

	Natural pond	**Dam liner pond**
Return of investment in case of selling fish to neighbours	5 years, 4 months	22 years
Return of investment in case of selling fish to resellers	2 years, 5 months	10 years, 1 month
Return of investment in case of selling fish to restaurants	1 year, 4 months	5 years, 6 months
Return of investment in case of selling dried fish	1 year, 9 months	7 years, 4 months

Table 11. shows total price of ponds constructions

	Natural pond	**Dam liner pond**
Total price for the construction of the pond	18,800 ZMW	79,470 ZMW

5.5. Return on investment in both types of ponds

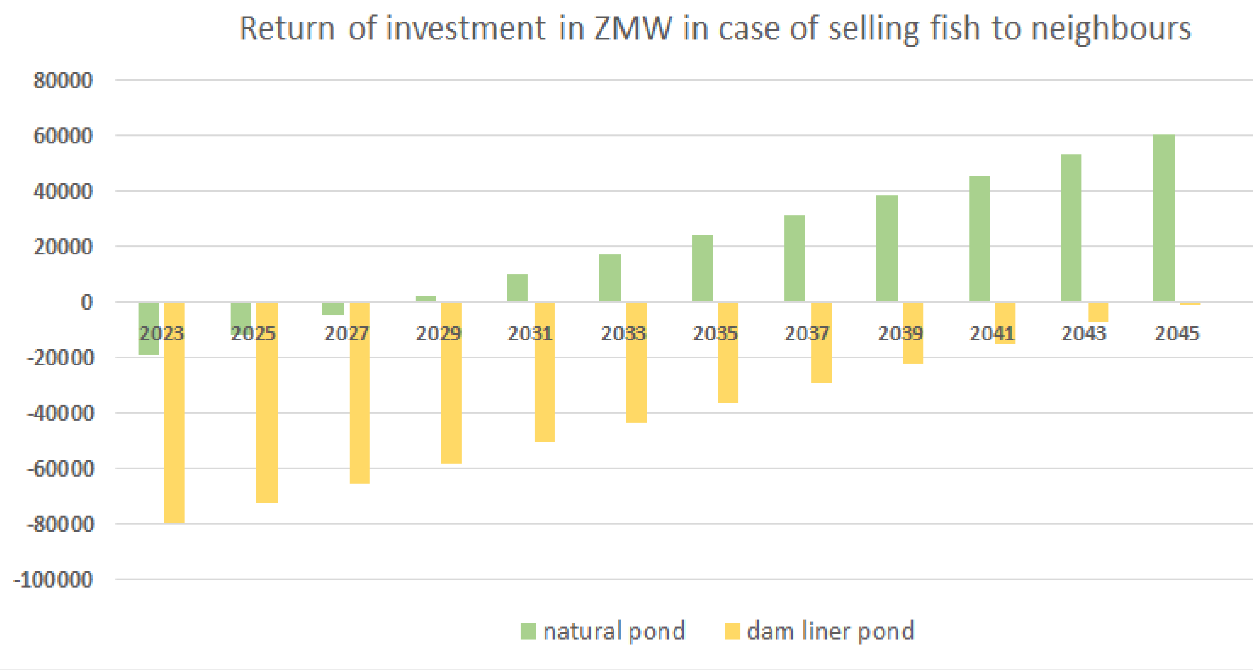

Figure 17. is showing return of investment in case of selling fish to neighbours

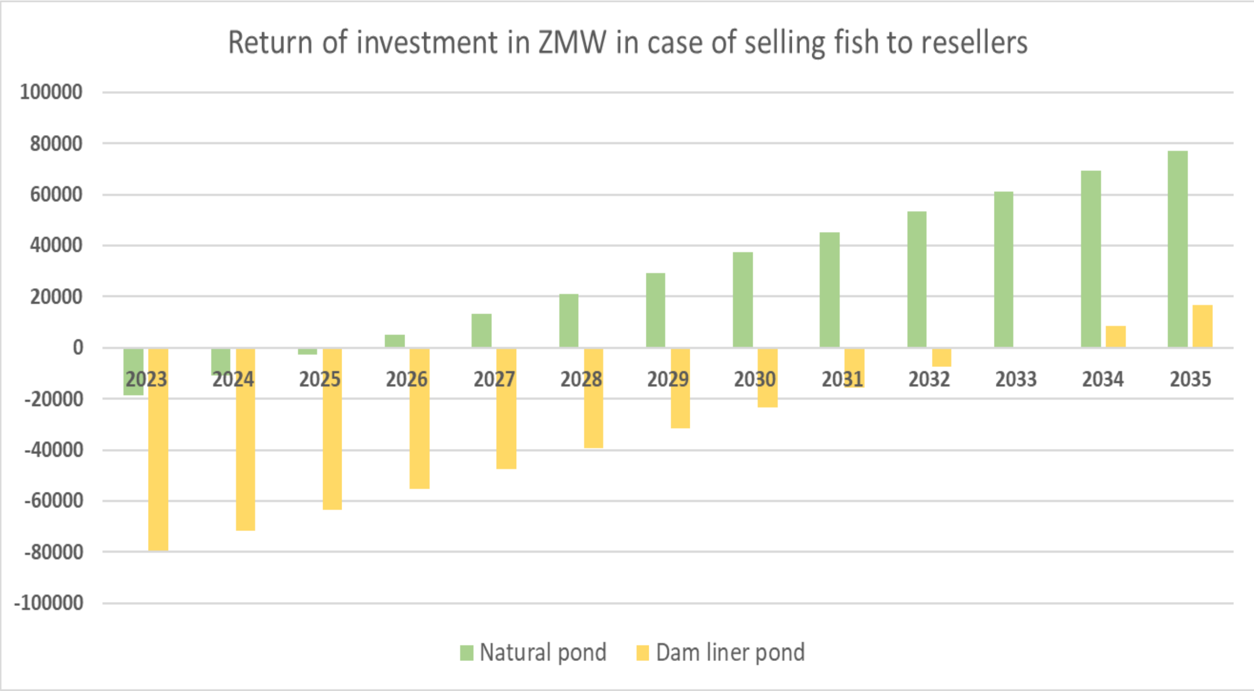

Figure 18. is showing return of investment in case of selling fish to resellers

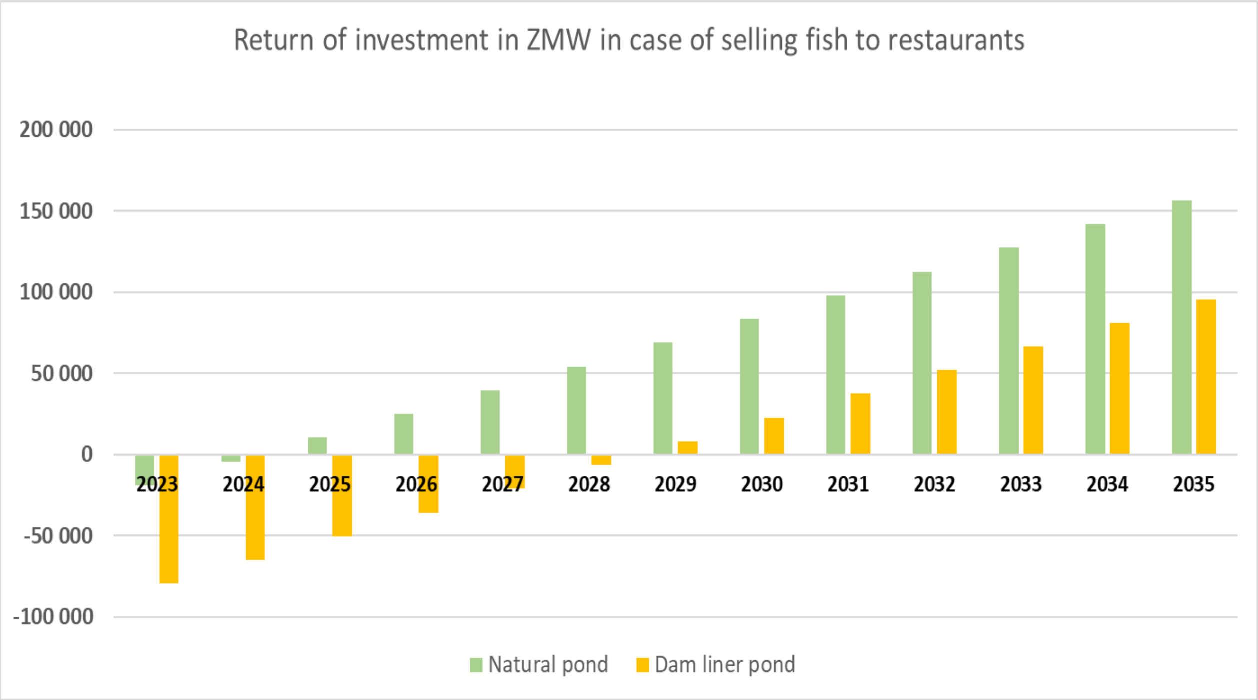

Figure 19. is showing return of investment in case of selling fish to restaurants

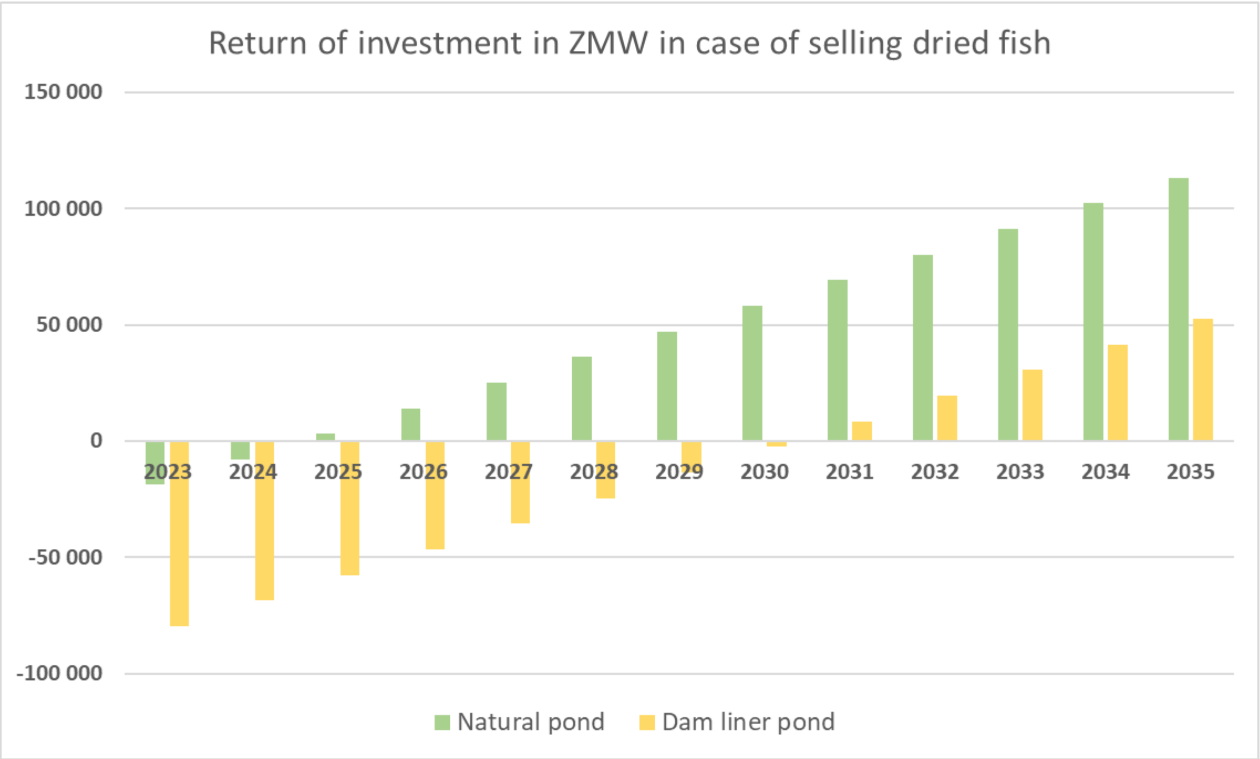

Figure 20. showing return of investment in case of selling dried fish

6. Discussion

6.1. Advantages and disadvantages of both types of ponds

Because constructing a natural pond doesn't require a substantial initial expenditure, the price return is faster. The payback period for the first expenditure is much longer with dam liner ponds. The entire cost of purchasing the ponds will be drastically lowered, maybe down to half of what it was originally intended to cost, should the government pay for the input expenses. The decision to pick a pond may be influenced by the fact that, in comparison to other nations, it might be more difficult to obtain a quality liner in Zambia (Saha 2022). On the other hand, because it helps keep the water clean, foil might be an excellent option if it can be found at a reasonable price. On the other hand, natural ponds could take longer. Because they are less likely to expand and have a simpler ecology to maintain, dam liner ponds require less upkeep than natural ponds. Additionally, the coating provides resistance against wetting. From an environmental perspective, natural ponds, on the other hand, would be a superior option since they can sustain native plants and animals and more closely resemble fish habitats. A natural pool is better than a dam lined pond if the objective is to provide a habitat for native species. The light and black coating can cause a dam liner pond to heat up more quickly, increasing the water's temperature. Natural ponds can better visually fit in with the surrounding environment and tend to seem more natural. If the dam liner is poorly disguised, the black foil makes it easier to see. On the other hand, both kinds of ponds provide quite comparable environments for their fish inhabitants.

6.2. Comparison

This thesis was compared with other studies that dealt with the same topic. This comparative study also looks at pond construction in Zambia. In this study (Namonje-Kapembwa & Samboko 2017), the repayment period of the loan is assumed to be four years with one year for the grace period in the first year of establishment of the pond. The interest rate is 12.5%. The total investment costs and other initial costs are estimated at 24,000 ZMW of which 12,500 ZMW is for the construction of the pond, the establishment of water supply and other fishing equipment. The benchmarking study estimates the profitability and viability of aquaculture production using net present value, benefit-cost ratio as well as internal rate of return. Total prices were determined based on the data collected for this study. There are fixed business costs associated with long-term fish farming operations, such as loan repayments and depreciation. NPV is the most used measure for evaluating the profitability of an investment and shows how much value the investment adds to the business. The results show that the estimated net present values (NPV) with a discount rate of 20%, 15% and 10% and the results show that the NPV is positive. For the purposes of this study, a discount rate of only 15% was used. Using this rate, it was determined that the NPV at the end of 10 years of business operation would be 17,524 ZMW. A positive NPV means that the aquaculture business is feasible and profitable. NPV is sensitive to the choice of discount rate used. At a 20% discount rate, the estimated NPV is 12,829 ZMW compared to 17,524 ZMW and 24,292 ZMW at 15% and 10%, respectively. The decision to accept or reject an investment can be influenced by the discount rate used. The initial costs for this comparative study are lower. This is because the farmers used less machinery during the construction of this pond and the construction costs helped to cover the financing from other sources.

6.3. Recommendations for stakeholders

If aquaculture is to continue to develop in Zambia, small-scale production must increase to keep pace with the current growth of the overall aquaculture industry. There is a group of wealthier farmers who are relatively successful in aquaculture and know methods that are more efficient in aquaculture. However, a large proportion of farmers are poor and rely more on quantity than quality. Therefore, these poorer farmers need to be targeted so that they can increase their production and create wealth. Most of the country's farmers live far from cities, making it more difficult for them to sell fish to urban areas, and they are considered the poorest. The aim should be to include this group of farmers, particularly those in areas such as Western Province where indigenous populations are more reliant on agriculture and natural resources. These farmers need to be supported to modernize their systems and improve their overall performance. It sometimes happens that the poorest farmers are excluded due to their limited capital and purchasing power, which in turn highlights the importance of developing innovative approaches that enable poor farmers to use aquaculture as a means of improving their living standards and improving food and food security. In these breeders, the conditions for raising fish must be assessed so that they are not neglected and are fed regularly and live in suitable conditions.

Greater involvement of women and youth in Zambian aquaculture is also recommended. Aquaculture provides new jobs for women, and aquaculture appears to be more profitable than other agricultural occupations. Even so, there are several obstacles due to which women enter aquaculture less often than men. Among the most common are family disapproval and gender norms, with women employed in the home and taking care of the family. We can also mention limited access to technology and lack of experience. To reduce these barriers for women and for women, gender transformative approaches are needed to create an enabling environment for more women to participate in small-scale aquaculture in Zambia. Such approaches should always include sustainable social change. Relationships within the household should be considered and women's participation in aquaculture should be encouraged. Fish farming is considered a household activity, especially for rural, poor farmers who have adopted aquaculture as part of their livelihood and income. Fish farming is overwhelmingly dominated by older farmers, as younger generations have fewer opportunities to engage in aquaculture. Offering pathways for young people to enter aquaculture could help the sector grow. A critical aspect is likely to be addressing certain cultural and societal norms and beliefs when targeting this group (Kaminski 2019).

6.4. Limitations of the study

The bachelor's thesis is not without limitations. Firstly, data on market prices were collected through participatory methods which could lead to some bias. Particularly monthly selling frequencies could be influenced by illegal fishing and sales that were not captured. Data on investments costs were taken during the period of four years, which could also influence the results of economic calculations.

7. Conclusion

Aquaculture has proven to be a significant source of income for small-scale farmers in Zambia. Studies have been conducted to confirm this fact. The studies were conducted by development, research and government partners. The researchers found that aquaculture is a fast-growing industry in Zambia and appears to be an attractive livelihood strategy for many people. Aquaculture and its direct impacts increase income by selling high-quality products and increasing the availability of nutritious fish products. Aquaculture has a long tradition in Zambia. Smallholder farmers engage in fish farming as part of a diverse livelihood and provide important nutrients for the human body. Although in recent years the commercial sector has created new opportunities for farmers to intensify production through access to high-quality commercial inputs, many small-scale farmers still operate large-scale, relatively low-production systems that are isolated from this commercial development. Many stakeholders in Zambia, including the donor community, the private sector and the government, are currently engaged in understanding how smallholder farmers can improve their position in the value chain and further intensify their systems. Age, gender, wealth and location also affect the status, performance and profitability of different farmers and beyond complexity. The growth of aquaculture in the coming years will depend on the development and application of science and technology in all areas of the industry. Aquaculture production in Zambia has grown significantly in the recent past as it has received a lot of support from both the government and private investors. However, the industry still has great potential for further expansion of aquaculture production. More needs to be done for sustainable development. The rapid increase in aquaculture fish production recorded in recent years is mainly due to the expansion of large-scale farms. Sustainable development of the aquaculture sector in Zambia requires addressing the main challenges faced by smallholder farmers. The study documented fish farming and aquaculture in Zambia. The study showed what is needed to build a natural and dam liner pond. In the study, the total costs for the construction of both types of ponds were calculated, and the internal rate of return, monetary and annual return of the construction were also calculated. The study proved that the construction of a natural pond is financially less expensive than the construction of a dam liner pond.

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