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The economic evaluation of aquaculture as a climate change adaptation option in fisher communities of Zimbabwe

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By

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Abstract

Due to climate change, fisher households who depend on fishing for their livelihood are faced with a number of challenges that include low productivity. There is now an acknowledgement internationally that fishers cannot depend on hunting fish when all other food producing sectors have adapted. How economic and feasible is it for fishers to consider aquaculture in the face of climate change? This dissertation investigates the economic viability of aquaculture as a climate change adaptation option in rural fisher communities of Zimbabwe. The southern lowveld district of Mwenezi was used as a case study in the economic evaluation of pond culture and cage culture as a climate change adaptation strategy from a baseline position. Data was obtained from secondary sources which include the private sector involved in aquaculture, civil society organisations and the fishers practising aquaculture in both Mwenezi and another district, Kariba.

The cost benefit analysis method of economic evaluation was used to assess the economic viability of pond and cage culture forms of aquaculture. The net present value, internal rate of return and benefit cost ratio were used as the decision criteria. Two scenarios were considered depending on the type of funding for the initial investment - scenario one was built on donor funding support while scenario two relied on a bank loan with interest for financing. A sensitivity analysis was also performed to determine the extent to which different factors affect the economic viability of both pond and cage culture.

Both pond and cage culture were found to be economically viable as climate change adaptation options in fisher communities of Zimbabwe. Cage culture was found to have a higher net present value under both scenarios when compared to pond culture. However, under scenario two, pond culture was found to have a higher internal rate of return and benefit cost ratio. The inconsistencies were due to the variations in the scale of upfront investments between pond and cage culture where the latter requires a higher initial investment. Key factors that affect the viability of aquaculture as an adaptation strategy in Zimbabwe include the market price of fish, the cost of fish feeds and the price of fingerlings. While these factors are primarily economic, there are other factors which may affect the viability such as the increasing frequency of natural disasters.

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Glossary of Terms

AQZ	Aquaculture Zimbabwe
BCR	Benefit Cost Ratio
CBA	Cost Benefit Analysis
CEA	Cost Effective Analysis
DCF	Discounted Cash Flow
DFID	Department for International Development
EC	European Commission
EEA	European Economic Area
EJ	Expert Judgement
FAO	Food and Agriculture Organisation
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
IFAD	International Fund for Agricultural Development
IPCC	Intergovernmental Panel on Climate Change
IRR	Internal Rate of Return
MCA	Multi Criteria Analysis
NGO	Non-Governmental Organisation
NPV	Net Present Value
OECD	Organisation for Economic Co-operation and Development
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention for Climate Change
WV	World Vision
ZNPWM	Zimbabwe National Parks and Wildlife Management

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1. Chapter one: Introduction

1.1. Background to the study

Climate change is a phenomenon that is rapidly adding to the expanding list of stressors that are challenging humanity's ability to attain economic, social and ecological objectives which together define sustainability (Yohe et al., 2007). Moreover, it poses an ever-increasing danger particularly to communities which depend on natural resources for social and economic wellbeing. The impacts of climate change depend on the exposure level of the livelihood systems, the degree of sensitivity to the impacts, and the adaptive capacity of the groups involved (World Fish Centre, 2009), but are more severe in developing countries such as Zimbabwe, which are resource constrained.

Fishing communities, located along major rivers, man-made dams and lakes in Zimbabwe have a heightened sensitivity to climate change and a low adaptive capacity. Fishers living in these communities mostly practice artisanal fishing which is dependent on the productivity of the ecosystem. There is not much that fishers can do to immediately influence the productivity of rivers, dams and lakes which form the bedrock of their livelihoods. As a result, they are faced with declining catches, catches of only smaller fish which do not fetch good money on the markets and increasing costs of fishing, all of which are climate change induced (Brummet, Lazard & Moehl, 2008; Aquaculture Zimbabwe, 2015). Furthermore, Aquaculture Zimbabwe (AQZ), a local non-governmental organisation (NGO) working for the development of fisheries and aquaculture in low lying areas of the country, noted in 2015 that the fishers are not able to practice other typical livelihood activities such as cropping and livestock because the areas where they live are arid and infested with livestock diseases such as tsetse fly (Bourn, Grant, Shaw & Toor, 2005; Alsan, 2014). Unlike in other communities in Zimbabwe which can practice the tripartite livelihood activities of fishing, cropping and livestock rearing, the fishers only have one. Fishing, therefore, becomes a key livelihood strategy that supports many households and care needs to be taken to ensure the sustainability of the fishers' way of life. The World Bank (2005) reported that the number of fishers has grown by 400% since 1950 and it was likely that more vulnerable and poor people were going to resort to fishing as the negative impacts of climate change on agriculture and other economic sectors worsen.

To counteract the impact of climate change on the livelihoods of poor and vulnerable rural people, mitigation and adaption measures are necessary. Across the world, many organisations and governments recognise the urgency of this need and have been implementing various steps to ensure that the adaptive capacity of resource-constrained poor communities is enhanced through various resilience building activities. In Zimbabwe, the government and some aid agencies have principally been focusing their attention on broad adaptation strategies that not only help communities to adapt but also to attain development to build resilient and sustainable livelihoods. However, more effort is needed in developing and implementing sector specific adaptation strategies, such as in the fisheries sector.

1.2. Problem statement

For their household economic wellbeing, fishers are known to depend on fish, a natural resource whose distribution and productivity is influenced by climate dynamics (Allison et al., 2005). The impacts of climate change on fisheries in Africa was found to be linked to reduced productivity in lakes (O'Reilly, Alin, Plisnier, Cohen & McKee 2003). According to Allison, Andrew and Oliver (2007), climate change affects the productivity and distribution of fish resources through changes in growth rates and mortality rates. The changes experienced in fisheries can also be attributed to changing levels of rainfall and unpredictable rain patterns and increasing intensity of mid-season dry spells (Barange & Perry, 2009). Moreover, there is often localised extinction of certain species and emergence of others resulting in the need for investment in new fishing gear and the need to look for new markets (Aquaculture Zimbabwe, 2015). This is especially true in some areas such as Manyuchi in the Mwenezi district of southern Zimbabwe. Badjeck, Allison, Halls and Dulvy (2010) noted that fisheries the world over are also declining sharply due to overfishing. Furthermore, most fishing takes place in zones being threatened by pollution and the mismanagement of resources and habitats through poor resource governance systems (Badjeck et al., 2010). The fisher communities are thus faced with decreasing productivity of fisheries and the downward spiral in yields as well as their variability. The continued decrease and variability in yields directly results in reduced profitability for the fishers while also facing increasing costs to adapt to changes in the environment with dire consequences in meeting essential household costs such as health and education. As mentioned, developing nations, including Zimbabwe, appear to be highly vulnerable to climate change effects on fisheries as they have limited capacity to adapt and cope with these impacts (Agrawala & Fankhauser, 2008).

Over the years, fisher communities have been adapting to climate change in different ways, which include increasing fishing effort through investing in new technologies when productivity falls, diversifying livelihood portfolios in the face of increased variability of fish yields, exiting from fisheries or migrating when faced with reduced profitability among other activities International Fund for Agricultural Development (IFAD, 2014). However, for the poor and often marginalised communities, most of the adaptation options are out of reach due to limited access to resources.

Research on fisheries has focused principally on investigating the vulnerability and adaptive capacity of this sector, as well as the dependent communities, to climate change (Sadovy, 2005; McClanahan et al., 2008; Allison et al., 2009). As a result, the limited adaptive capacity and the rapidly increasing vulnerability of fishing communities are well-documented (Drinkwater, 2005; Lehodey et al., 2006; Brander, 2007). However, very little research has been done on the economic viability of specific adaptation options, with particular focus on fisher communities. Within the context of overexploited fishing grounds, resource constraints and high vulnerability, decision makers require meaningful information and the analysis thereof to guide investment initiatives to establish or strengthen climate change adaptation options so as to make the most of scarce resources (Allison et al., 2009). Kumar, Shyamasundar and Nambi (2010) proposed that an interrogation of various economic scenarios is vital when assessing the vulnerability of fisheries to climate change primarily because there is a close connection between adaptive capacity and the availability of financial resources. Against the backdrop of the dwindling supply of fish in lakes and dams, there is need for more information and analysis that can efficiently guide investments in climate change adaptation in the sector (Mullon, Freon & Cury, 2005; Newton, Cote, Pilling, Jennings & Dulvy, 2007). This research thus attempts to contribute towards information needs of development organisations and governments in the analysis and prioritisation of investments in adaptation options of fishing communities with specific attention on Zimbabwe where the livelihoods of fishers are threatened by the impacts of climate change.

What can possibly be the most realistic and economically viable climate change adaptation option in fisher communities? Instead of relying on hunting wild fish, is there no alternative for the fishers such that their catches can become more guaranteed and not open to the natural distribution of fish? Fish farming, or aquaculture, appears to be an immediate and easy answer.

However, one key question that has to be answered is: **is aquaculture a viable climate change adaptation option in inland fishing communities?** Therefore there is need to undertake an in-depth economic evaluation of aquaculture in Zimbabwe, assessing its economic viability when employed as an adaptation strategy among small-scale poor rural fishers. Zimbabwe is a landlocked country hence fisheries refer to inland activities with fishers plying their trade in rivers, dams and man-made lakes. Economic viability is taken to mean that aquaculture will be economically feasible and financially profitable such that fishers can supplement (diversify) or replace their dependence solely on fisheries (Lee & Yoo, 2014). This feasibility analysis is important particularly because there are not many agricultural activities which can be done in the low lying, arid and drought prone areas of Zimbabwe where most of the fishing communities are found.

1.3. Research objectives

This research focuses on the economic evaluation of aquaculture as a climate change adaptation option in fishing communities of Zimbabwe to contribute towards the local adaptation literature, with a specific focus on the analysis of the costs and benefits of aquaculture in traditional fishing communities. The main objective of the research is thus to assess the economic viability of aquaculture as a climate change adaptation option in fishing communities of Zimbabwe.

The research objectives include the following:

- Determine the economic viability of climate change adaptation option for fisher communities in Zimbabwe when supported by donors (financial or training)
- Determine the economic viability of climate change adaptation option for fisher communities in Zimbabwe without donor support (financial or training)
- Establish the more preferable aquaculture option for fisher communities in Zimbabwe
- Identify the key factors that influence the economic viability of aquaculture in Zimbabwe

The key research questions to attain the main objective are:

- Is aquaculture an economically viable climate change adaptation option for fisher communities in Zimbabwe when supported by donors (financial and training)?

- Is aquaculture an economically viable climate change adaptation option for fisher communities in Zimbabwe without donor support (financial or training)?
- Is pond or cage culture the more preferable aquaculture option for fisher communities in Zimbabwe?
- What are the key factors that influence the economic viability of aquaculture in Zimbabwe?

1.4. Justification for the study

With the help of decision makers, vulnerable communities need to implement accelerated adaptation measures to cope with the additional burdens arising from climate change. This is especially important in the context of the fisheries sector given the dependence of fishers on natural ecosystems with all its sensitivities to climate change variability (Osbahr, Twyman, Adger & Thomas, 2010).

Despite aquaculture being a feasible and highly flexible source of fish in Africa (Brummet et al., 2008), inland fisheries are often left in the periphery of climate change adaptation prioritisation. Success in aquaculture can increase the amount of fish available for human consumption both at local and international levels. If well-linked to markets, it can create business opportunities beyond simply fish production but can also create employment, facilitate infrastructure development and ultimately contribute to economic growth (Brummet et al., 2008). Ovie and Belal (2010), as quoted in IFAD (2014), noted that small scale aquaculture, among other interventions, is already being used as a viable adaptive strategy to climate change impacts by fishers living around Lake Chad Basin where severe droughts are causing a reduction in the size of the lake.

Although aquaculture can work well as an alternative source of fish for the fishers, its adoption as an option for adapting to climate change has been limited across the world. Despite the fact that aquaculture itself, like all sources of livelihoods, must also adapt to climate change, its use for this purpose in fishing communities has been partially limited by the need for external investments mostly from aid agencies and local governments (Klein & Mohner, 2009). These institutions require information on the viability, efficiency and effectiveness of aquaculture interventions because investments in climate change adaptation compete with other priorities in the broader development finance discourse. Thus, the economic evaluation of adaptation strategies can provide decision makers with important evidence for evaluating and exploring alternative uses of scarce resources, as well as when and how to make adaptation investments that are effective and efficient (World Bank, 2010). According to Heltberg, Siegel and Jorgensen (2009), there is a need to have realistic estimates of the costs and benefits involved in climate change adaptation strategies in order to inform and influence decision making at the policy level. To date no adaptation options in the fisheries communities in Zimbabwe have been subject to in-depth and rigorous economic evaluation to weigh these trades-offs.

Fishing communities no doubt form one of the most vulnerable groups within our society to climate change. Climate change is causing significant challenges to the productivity of fisheries and directly impacts on the resilience of the dependent livelihoods into the foreseeable future within an ever-increasing intensity. Livelihood resilience to the impacts of climate change is needed and it will take concerted efforts in committing time and resources to build meaningful adaptive capacity. Adaptive capacity or strategies can take various forms ranging from processes to actions all with the intention of improving mechanisms for coping with the changing conditions within the environment (Smit & Wandel, 2006). This study will explore the possibility of building the adaptive capacity of fishers to the impacts of climate change on their livelihoods through engaging in aquaculture to reduce the variability of their yield and their income. Establishing whether such aquaculture will be economically viable is therefore of paramount importance.

The remainder of this study is laid out as follows: chapter 2 provides a review of the literature pertaining to the state of fisheries, impacts of climate change on fisheries and how aquaculture can be used as a climate change adaptation option in fisher communities. In chapter 3, the methodology followed in this study is outlined. The assumptions underpinning the analysis along with the results and analysis are presented in chapter 4. The conclusions and recommendations for future research are discussed in chapter 5.

2. Chapter two: Literature review

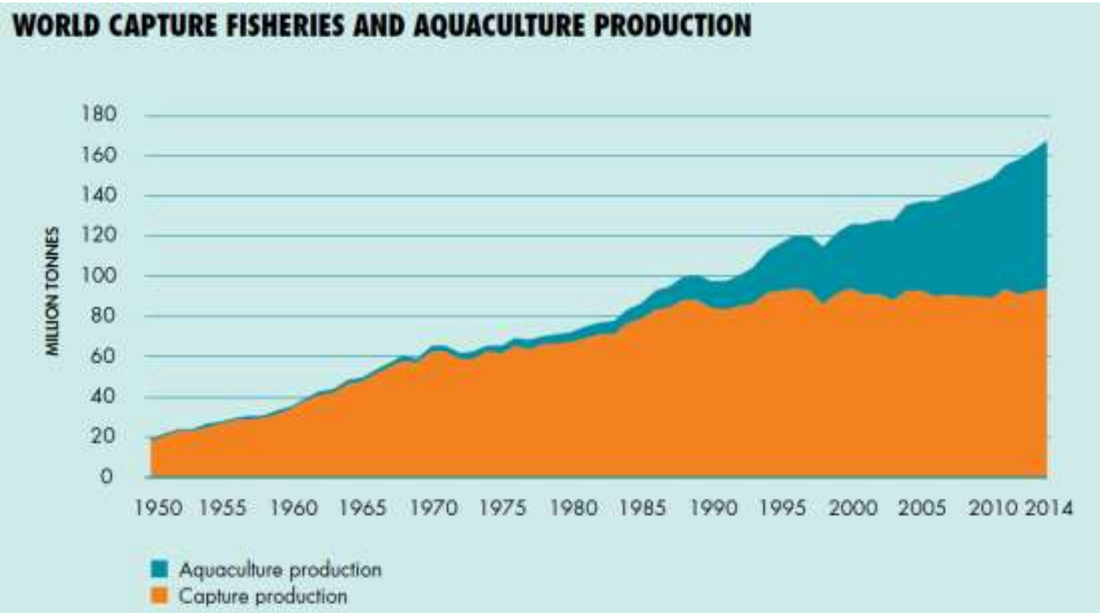
2.1. Introduction

This chapter reviews the trends in the smallholder fisheries subsector and how it has been affected by climate variability. It also focuses on the status of the Zimbabwean fisher communities and how they have been influenced by climate change. In addition, the chapter explores possible adaptation measures to counter the impacts of climate change including aquaculture and its economic benefits.

2.2. Fisheries and their importance in the economy

Fisheries are a critical contributor to society – from both a humanitarian and an economic perspective. They provide a substantial quantity of food, with the supply of fish at a global level having grown at an average annual rate of 3.2% from 1961 to 2013 (Food and Agriculture Organization [FAO], 2016a). As Figure 1 shows, the growth in the production of fish has been particularly pronounced in the past 25 years, with total fisheries production having increased from approximately 100 million tonnes in 1990 to more than 170 million tonnes in 2014. This food helps to reduce hunger and promotes health as fish is a nutrient-dense food; this is particularly important for poorer communities such as those in Sub-Saharan Africa (SSA) (Mohammed & Uraguchi, 2013).

Figure 1 Capture fisheries and aquaculture production



(Source: FAO, 2016a, p. 3)

In addition to the important contribution of fisheries to food security, they also create substantial employment and thus aid in supporting the livelihoods and income generation of millions (Barange & Perry, 2009; Shelton, 2014). According to the FAO (2016b), employment in the fisheries sector has grown faster than the world's population in recent years. Mohammed and Uraguchi (2013) noted that up to 43.5 million people work in the fisheries sector, most of whom live in developing countries. For example, in Africa's inland fisheries, over two million people are employed (de Graaf & Garabaldi, 2014). Barange and Perry (2009) estimated that the fisheries sector supports up to 200 million livelihoods when also accounting for men and women who work in backward and forward integrated industries supplying inputs and processing, marketing and distribution. Such levels of employment creation are possible because fish is one of the most traded and exported food commodities particularly in developing countries (Daw, Adger, Brown & Badjeck, 2009; Shelton, 2014). Further to this, the sale of fish from domestic fisheries internationally also contributes to economic growth through providing foreign currency which can possibly service international debt, pay for food imports and fund operations of national governments (Mohammed and Uraguchi, 2013).

Global capture fisheries demonstrate variations in terms of scale, technology used, markets, and nature and type of fishers. However, despite this diversity, fisheries are usually classified as either marine fisheries, referring to large-scale ocean-based activities, or inland fisheries, which are generally small scale in rivers, reservoirs or lakes (Allison, Andrew & Oliver, 2007). Moreover, the term fisheries includes both traditional capture fisheries, usually simply referred to as just fisheries and aquaculture, which involves fish farming (Allison et al., 2007). As is evident in figure 1, global fish supplies from capture fisheries has stagnated since the 1980s while that from aquaculture has grown immensely in the past 25 years. In fact, by 2014, total capture fisheries' contribution to global aquatic food for human consumption was only 55% compared to more than 80% in 1990 with aquaculture now contributing 45% compared to less than 20% (FAO, 2016a). Moreover, aquaculture is officially the world's fastest growing agro food sector; having sustained an average growth of over 8.8% per annum in a little more than three decades (Toufique & Belton, 2014).

In developing countries, particularly those in SSA, most fisheries are inland (Mohammed & Uraguchi, 2013). Daw et al. (2009) noted that fisheries in developing countries are predominantly located in rural and remote areas, which are characterised by limited to non-availability of any other economic activities. In these rural and remote areas, inland fisheries are dominated by fishers operating informally in a relatively disorganised system (WorldFish Centre, 2010b). However, the informal sector forms an important bedrock of most African economies, and thus represents a critical engine of growth (Daw et al., 2009). However, Daw et al. (2009) note that inland fishers are often marginalised and their contribution to food security and economic growth is often underestimated.

Like all other sectors, fisheries have been affected by climate change. Climate change "refers to any change in the climate over time, whether due to natural variability or as a result of human activity" (Intergovernmental Panel on Climate Change [IPCC], 2007, p. 871). Fishers who have access to limited geographical areas to fish and few livelihood alternatives are extremely vulnerable to climate change (Grafton, 2010). Daw et al. (2009, p. 118) noted that climate change will be "experienced as an increased frequency of extreme events" in fisheries. The unpredictability of the systems may possibly endanger the wellbeing of fisheries' dependent communities. It is therefore important to understand how fisheries are currently being impacted and how they are adapting to the existing changes and variations in the climate and what other adaptation options can be pursued to sustain and grow fisheries so that they can continue to contribute both socially and economically.

2.3. Climate Change and Its Impact on Fisheries

Although there is some disagreement regarding the status of fisheries across the globe, there is consensus on the fact that marine and inland aquatic species and habitats are at risk from both human pressures and climate changes. On one hand Shelton (2014) noted that there is rampant overexploitation of fishery resources and pollution as well as changes in fish habitats which are all human driven. In addition, IFAD (2014) also lamented the existence of discrimination in accessing resources and poor regulation in the sector as well as some of the decisions made by governing authorities which result in competition from other land water dependent sectors such as agriculture. On the other hand the speed and intensity of climate change is outpacing the ability of aquatic systems to adapt (IFAD, 2014). Climate change is therefore an additional burden to an already overstretched system, affecting both socio economic and ecological systems (Allison et al., 2007; Barange & Perry, 2009; Brander, 2007; Daw et al., 2009; Roy, 2012; Williams & Rota, 2010).

The impacts of climate change on fisheries are mainly driven by the on-going warming and related physical changes in the environment such as the accelerating frequency and intensity of extreme weather events (Cochrane, De Young, Soto & Bahri, 2009). Such changes are taking place at a time when there are other numerous social and economic pressures on natural resources. The table below summarises some of these impacts of climate change on inland fisheries.

Table 1: Impacts of climate change on inland fisheries

Type of changes	Climatic variable	Impacts	Potential outcomes for fisheries
Fish stocks	Higher water temperatures	Altered timing of spawning, migrations and/or peak abundance Increased invasive species, diseases and algal blooms	Changes in timing and levels of productivity across freshwater systems
Ecosystems	Reduced water flows and increased droughts	Changes in lake water levels Changes in dry water flows in rivers	Reduced lake and river productivity
Infrastructure and fishing operations	Increased frequency of storms	Increased risk of accidents during fishing Damage to aquaculture installations (fish cages and ponds)	Reduced viability of fishing and aquaculture as a livelihood option for the poor
Inland fishing operations and livelihoods	Changing levels of precipitation	Where rainfall decreases, reduced opportunities for farming, fishing and aquaculture as part of rural livelihood systems	Increased risks to agriculture, greater reliance on non-farm income, reduced diversity of rural livelihoods
	More droughts or floods	Damage to productive assets (fish cages and ponds, weirs and homes)	Increased vulnerability of riparian and floodplain households and communities
	Less predictable wet/dry seasons	Decreased ability to plan seasonal livelihood activities	

Adapted from Allison et al. (2009, p.177)

2.3.1. Fish stocks and ecosystems

The impacts of climate change in SSA fisher communities varies across countries; however, one exception is the impact on the availability of fish which affects all countries, with stocks expected to fluctuate significantly from one season to the next (Brander, 2010). The impacts of climate change on fish stocks can be categorised as either physical or biological change where physical changes include temperature rise or changes in water salinity and acidity while biological changes include fish stock production and distribution (Mohammed & Uraguchi, 2013). Changes in factors such as water temperature can have significant ecological effects on water ecosystems within which the fish thrive (Barange & Perry, 2009; Brander, 2010). If the water temperatures rise above the maximum tolerable threshold of species, their physiological processes will be affected. For example, a temperature rise may result in alterations to the traditional fish spawning times, increasing the outbreak of diseases and triggering algal blooms. As a result, fishers are likely to experience changes in timing and productivity of freshwater sources as well as increased variability in catches (Daw et al., 2009).

Badjeck et al. (2010) noted that the declining fish availability as well as variability in harvests already being experienced is mostly attributable to the changing climate at different societal levels. At the global level climate change impacts on the ecosystems will require fishers to adjust the measures necessary for capture fisheries to remain sustainable as it will affect fish habitats (Barange & Perry, 2009). The adjustments fishers need to take may include fishing practices and processing facilities.

2.3.2. Infrastructure and fishing operations

Allison et al. (2007) noted that climate change can possibly damage physical infrastructure such as landing sites for fishers, fish processing centres and communication infrastructures linking fishers to the markets. Post-harvest handling infrastructure is particularly important for inland fisheries as they often act as rural economic centres. Disruptions to both operations and infrastructure will disconnect these rural economic centres with the outside economy thereby cutting them off from markets for both fish and inputs needed in fishing operations. Aquaculture installations such as fish ponds and cages may also be damaged hence they need to be constructed with the extreme events in mind. Ultimately there can be a reduction in the viability of capture fisheries and aquaculture as important livelihood sources for the poor in remote areas as a result of the effects of climate change on infrastructure and operations (Allison et al. 2005).

2.3.3. Inland fishing operations and livelihoods

Livelihood diversification is a reliable mechanism to transfer risk and reduce the impact of shocks. Climate change reduces options for diversification and this will negatively affect livelihoods for fisher communities (Barange & Perry, 2009). In remote areas where options for adaptation are limited, fishers often integrate their fishing operations forward by seeking to engage with the markets and provide fish beyond the usual landing sites. However, extreme events may render such efforts difficult.

Where rainfall decreases, reduced opportunities for farming, fishing and aquaculture as part of rural livelihood systems may result in greater fisher household reliance on non-farm income. However, reduced livelihood options will push fishers to change occupations and increase social pressures. An example of this scenario is when water shortages, due to reduced precipitation, may create competition for water resources thereby affecting inland fisheries production which in turn creates resource-use conflicts among fishers and other societal groups.

Inland fisheries can be significantly affected by droughts and floods (Allison, Perry, Renn, Brown & Poulain, 2013). Climate change also impacts negatively on household food and income security. For example, Southern Africa has been experiencing increased frequency of droughts which is leading to receding lake levels and river flows thereby affecting all livelihoods which have a fisheries component (Barange & Perry, 2009; Badjeck et al., 2010). Faced with this, fishers are likely to deploy varying coping strategies that include relocation to places deemed to have better fishing opportunities. Badjack et al. (2010) noted that such coping strategies are likely to result in resource access conflicts and challenges for authorities to establish vital government institutions such as schools and hospitals.

Climate change impacts men and women differently in the fisher communities. Most men are active in fish production (the actual artisanal fishing) while women take part in post-harvesting activities such as fish trading as well as salting and drying fish not sold (IFAD, 2014). De Graaf and Garabaldi (2014) estimated that of the women active in the fisheries sector in Africa, for example, 91.5% are working in post-harvest handling processes. Access to water for fishing is as important to men as access to markets is for women where they can profitably dispose fish. Disruptions to fishing activities driven by either droughts or floods therefore has particular gender implications as women would also be directly affected.

Fluctuations in fish stocks due to the less predictable seasons increases the vulnerability of fisher communities that heavily depend on fish for their livelihoods. Such dependence is often associated with vulnerability and lack of adaptive capacity because, as highlighted by Bene (2003), people may be poor because they are fishers surviving on poor returns from overexploited fisheries which is an open access resource with no barriers to entry. As a result, people generally engage in small-scale fishing, which is a livelihood of last resort, because they are poor (Bene, 2003). This poverty among fishers is likely to be exacerbated by fluctuations in fish stocks caused by climate change.

Shocks such as droughts and economic crises, which impact negatively on other economic sectors, often displace people through unemployment and push them into fisheries. Fishing, by its nature, is an easily accessible productive activity which can potentially offer immediate returns. Such displacements put immense pressure on fishing communities as they compete for fishing rights and access with new entrants.

2.4. Climate change adaptation and mitigation

As part of dealing with climate change, mitigation and adaptation efforts are often undertaken. Mitigation mainly deals with reducing greenhouse gas emissions while adaptation entails devising mechanisms to cope with climate change at a local level (de Bruin, 2011). In the case of fisheries, adaptation is more important because the greenhouse gas contributions of fisheries and the related supply chain are small when compared to other sectors (Barange & Perry, 2009). Yet, fisheries are prone to the negative effects of adaptations in other sectors such as when irrigation systems are installed, dams for hydropower constructed and fertilisers and other chemicals are used (De Silva and Soto, 2009). While it is notable that poor resource-constrained communities that are dependent on fish have always adapted, projections of climate change and likely adaptation measures to be taken will have detrimental effects on the livelihoods of fishers leaving their traditional coping mechanisms largely inadequate (Adger et al., 2007; Daw, Adger, Brown & Badjeck, 2009).

The IPCC (2007, p.869) defines adaptation to climate change as "the adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities". Such adjustments take place through well thought out investments in initiatives that tackle potential damages of climate change while making the most of new or emerging opportunities (Adger et al., 2007). In essence, adaptation measures work by increasing the involved groups' adaptive capacity while decreasing its sensitivity to climate change, in the process lowering the group's vulnerability to the locally felt climate change impacts (Mastrandrea, Heller, Root & Schneider, 2010). Therefore, adaptation to climate change can involve both building adaptive capacity of the vulnerable populations aimed at increasing their ability to adapt to changes and also converting that capacity into action. For example, in fisheries, adaptation to climate change may involve adjusting the frequency and scale of fishing to sustainable levels by changing the technology used (Shelton, 2014).

There are apparent vulnerabilities to climate change in both natural systems, such as wetlands and lakes, and human systems such as agriculture and settlements (McCarthy, Canziani, Leary, Dokken & White, 2001). Different forms of adaptation can be undertaken and Fankhauser, Smith and Tol (1999) distinguished between four different forms of adaptation namely: reactive, proactive/ anticipatory, autonomous, and planned adaptation. On one hand McCarthy et al. (2001) noted that adaptation in natural systems is reactive, when initial impacts have already manifested, while in human systems it is primarily anticipatory, that is, taking place before the apparent manifest of the impacts. On the other hand, autonomous adaptation is unplanned and therefore consists of spontaneous reaction to the changing environment while planned adaptation is deliberate and proactive in nature (Shelton, 2014; Watkiss, 2015). Of these, anticipatory adaptation has been identified as the best response mechanism to the changing climate for a number of reasons; key among them being its cost effectiveness when compared to the often unpredictable reactive adaptation. Shelton (2014) further went on to articulate a 'no regrets' approach to climate change adaptation which builds general resilience without substantial dependence on projections of specific climate change impacts. However, within these broad groups of adaptation measures, a challenge that decision makers often encounter is the identification of the optimum measures. It is only through well thought out assessments of adaptation options and mechanisms that decision makers are able to make evidence-based decisions about feasible measures to promote and adopt (de Bruin, 2011).

A few studies have examined the costs of climate change adaptation in developing countries. The World Bank (2009), for example, estimated that by 2050, climate change adaptation would cost developing countries between $75 and $100 billion a year. Watkiss, Downing and Dyszynski (2010) derived the adaptation costs for Africa using an integrated assessment model and found that they would likely total between 1.5% and 3% of GDP annually. According to Adger (2006) most research on climate change focuses on its impacts, the vulnerability of people, livelihoods and entire communities to climate change and the adaptation constraints that they face. However, there is very little focus on weighing up the benefits and costs of the various adaptation options and initiatives that are available, especially in each country. This is confirmed by Adger, Agrawala and Mirza (2007) and Agrawala and Fankhauser (2008). This shortage of research is particularly pronounced in the fisheries sector where aggregate assessments have been conducted but few practical assessments of adaptation options in specific countries have been undertaken. In fact, Adger et al. (2007), in an assessment of adaptation practices, options and constraints and capacity, found that many adaptations can be implemented at low cost benefiting resource constrained communities, but comprehensive estimates of adaptation costs and benefits are currently lacking.

2.5. Climate change adaptation options in fisheries

Allison et al. (2007) documented that resource-dependent communities, particularly in the developing world, have adapted to climate variability throughout history. However, adaptation measures that were traditionally used are unlikely to be sufficient in the face of rapid effects of climate change as well as human-induced problems such as overfishing. Many fishers are being pushed beyond the limits of their experience in coping with the impacts of climate change (Coulthard, 2009). While Daw et al. (2009) noted that adaptation varies according to location and context, Coulthard (2009) emphasised that generally all adaptation in the fisheries sector either entails maintaining a fishery-based livelihood or exiting. Daw et al. (2009) further explained that in maintaining fishery based livelihoods, fishers can consider intensifying fisheries by increasing fishing effort, capacity and diversifying the targeted species. Nonetheless, Coulthard (2009) noted that in between sustaining and exiting from a fishery-based livelihood there is diversification of livelihoods. These three alternatives are considered below.

2.5.1. Maintaining a fishery-based livelihood

Many fishers across the globe have various mechanisms to cope with lean fishing seasons which negatively affect their incomes. Shelton (2014) notes that some fishers in resource poor communities are proactively reducing destructive fishing practices such as fishing with poisons and explosives. Development agencies are also playing their part by helping communities enhance their adaptive capacities. IFAD (2014) documented that numerous adaptation options have been implemented successfully in fisheries throughout the world; among these is integrated aquaculture and agriculture systems. For example, Caritas Bangladesh is helping coastal communities that have traditionally relied on fishing to cope with climate change impacts by establishing fish ponds. The ponds are not only being used for aquaculture but are used for irrigation and the dykes form part of vegetable gardens (Shelton, 2014). The project assisted the fishers by supplying fingerlings for mullet and tilapia fish species. Shelton (2014) also noted that Caritas Bangladesh's project improved nutritional uptake and smoothed incomes and food availability for fishers who faced increased variability in their livelihood as a result of climate change.

Gurung et al. (2010) also gave an example in Nepal where farmers who were displaced in the construction of the Kulekhani reservoir, turned to cage culture in the dam. Although government policy makers had not included cage culture a part of their resettlement plans from the onset, the government ended up providing bighead and silver cap fingerlings for cage culture. As a result, up to 81% of the farmers displaced adopted cage culture.

In communities surrounding Lake Malawi, various development agencies have helped the fishers deal with post-harvest losses by introducing fish smoking kilns (Jamu, 2011). In addition to reducing post-harvest losses, the smoking kilns also resulted in a huge reduction in deforestation which helped in improving water quality and therefore habitat for fish (Jamu, 2011). These developments were particularly important for the fishers whom Allison et al. (2007) described as heavily dependent on fisheries and fish trading. Another good example is that of Alaska in North America where the fishers' livelihoods are increasingly under pressure from the negative impacts of climate change. The fishers are diversifying their livelihoods from traditional fishing activities to aquaculture with some very positive results being recorded (Johnson, 2012).

2.5.2. Livelihoods diversification

Livelihood diversification is a very important attribute for ensuring sustainability across the developing world, particularly in rural areas. Allison and Ellis (2001) noted that risk of livelihood collapse can be managed through diversity, spreading risk across a number of options. Agrawal and Perrin (2007) examined adaptation strategies in livelihood systems that are dependent on natural resources and noted that all of them involved pooling and sharing risks through mobility and diversification. Mobility also includes venturing into other sectors apart from fishing. Diversification is particularly important in fisheries because of the high levels of risk involved and seasonal fluctuations in catches (Shelton, 2014). It is related to the category of actions that fishers can take to sustain a fisheries-based livelihood.

2.5.3. Exiting fisheries

Coulthard (2009) notes that exiting fisheries is a necessary and permanent long-term adaptation which can potentially lead to massive regeneration of fishery resources for future generations. It essentially entails finding alternative sources of livelihoods that are not linked to fisheries. UNDP (2011), as cited in Shelton (2014), noted that fishers in Mozambique's coastal zone have been receiving finance options from a UNDP's Global Environmental Programme to assist them in transitioning from fisheries to alternative livelihoods. The fishers received training in developing bankable business plans and forming associations as part of the support.

Allison and Ellis (2001), however, cautioned that exiting fisheries may not yield any benefits as it may result in a mere substitution of one insecure livelihood with another and encouraged fishers to find alternative livelihood sources as they may potentially raise the opportunity income of fishing. A key recommendation from Allison and Ellis (2001) is that adaptation may be of benefit to fishers if they are assisted in finding their own pathways out of their circumstances through building on their capital and capabilities.

2.6. Aquaculture

Aquaculture is defined by the FAO (2005) as the farming of aquatic organisms including fish. Farming involves protecting and feeding fish as well as creating conditions that enhance the growth rates of species. Fish farming has long been proposed as a means of enhancing food, nutrition and income security in the developing world, with a number of governments and international development agencies investing in its development (Toufique & Belton, 2014). Some of the factors that make aquaculture appealing are its high degree of elasticity and resilience with potential to be adaptable to different environments and investment levels from small to large commercial scales (Brummet et al., 2008). As early as 1998, Chikafumbwa, Katambalika and Brumet (1998) documented that in Malawi, aquaculture was being practiced in temporary water reservoirs to produce fish. In Lake Kariba, large commercial-scale aquaculture is being practiced by Lake Harvest which has markets in the region and Europe. Moreover, as highlighted in Section 2.1, aquaculture now contributes 45% to global aquatic food for human consumption and is the fastest growing agro food sector.

2.6.1. Economic benefits of aquaculture

Empirical evidence shows that aquaculture has the potential to substantially improve the livelihoods of vulnerable and marginalised rural fisher communities (Husken & Holvet, 2010; Barman & Little, 2011; Pant, Shrestha & Bhujel., 2014). Pant, Shrestha and Bhujel (2014), in a study of a programme which promoted aquaculture among poor communities in Bangladesh, found that there was a significant increase in the incomes, savings and regular consumption of fish among beneficiary households. Roy (2012) noted that aquaculture plays an important role in supporting the livelihoods of many in India. Ahmed and Lorica (2002) highlighted the ability of aquaculture to improve productivity and increase incomes in traditional agricultural farms of Asian countries such as China, Indonesia and Thailand among others.

The benefits of aquaculture accrue not only to the fisher households (the 'direct' benefits) but also the community (the 'indirect' benefits). As shown in Figure 2, these indirect benefits arise through increased access to fish and lower priced fish in the market as well as through employment creation on the fish farms and the greater supply chain. It is thus evident that aquaculture is typically allied to a reduction in rural poverty and pro poor (Ahmed & Lorica, 2002; Toufique & Belton, 2014). Aquaculture is therefore not only promoting rural development through smallholder fish production systems but is also leading to economic development with commercial enterprises earning vital foreign currency and generating employment (Brummet & Williams, 2000). Brummet et al. (2008) felt that aquaculture can be applied to other African countries with similar benefits being realised although they felt that more people may benefit from small-scale aquaculture than commercial operations. However, Toufique & Belton (2014) also acknowledge that aquaculture alone may not be sufficient to meet future demand for fish and reduce. Rather, viable capture fisheries can effectively complement aquaculture activities.

Figure 2: Economic benefits of aquaculture

	Direct	Indirect
Consumption	Increased consumption of fish from own fish production	Increased availability of fish in markets Increased accessibility of fish due to reduced prices
Income	Increased incomes from entry into aquaculture or increased returns from existing production	Employment on fish farms Employment in up and downstream value chains Consumption linkages in the rural non-farm economy

This figure summarises the economic benefits of aquaculture along two planes – direct versus indirect and income versus consumption. The benefits can accrue directly when community members benefit through fish production, household consumption and disposing of excess produce in the local market. The community may also benefit indirectly when they purchase locally produced fish at reasonable prices, obtain employment in the local fish value chain or earn income which they can use for other purposes.

(Source: Toufique & Belton, 2014, p. 611.)

Aquaculture is often accused of wasting a lot of water thereby causing water resource access conflict among different user groups, particularly in the face of reduced precipitation. Admittedly, fish need water throughout the production process, however, when compared with other food production processes, aquaculture uses negligible water quantities and this water is often reusable for other food production purposes. Moreover, it also ensures that food production becomes independent of the seasonality of rains (Brummet et al. 2008).

2.6.2. Aquaculture and climate change

Although aquaculture is also affected by climate change, the impacts are different from fisheries because farmers can exercise more control over fish production in aquaculture than in fisheries (Williams & Rota, 2010; IFAD, 2014). De Silva and Soto (2009) noted that the links between fisheries and the ecosystems in which they thrive are more intricate than those in other agricultural activities since the productivity of a fishery is directly linked to how the ecosystem performs. Humans can only control fisheries' productivity through adjusting fishing effort (Brander, 2007). However, in aquaculture, human actions can alter the fish production environment, for example through feeding fish, and other environmental conditions such as water flows and quality; thereby minimising dependence on ecosystem services (IFAD, 2014). It should also be noted that aquaculture is not meant to completely substitute capture fisheries but rather to complement.

Within fisher communities there is vast potential to expand aquaculture, even in the face of climate change, through targeting species that have environmental tolerances (de Silva & Soto, 2009). Prior to implementing these systems, it is necessary to undertake assessments to identify commercially viable aquaculture species that can thrive in high temperature, low quality, freshwater and survive common diseases. A fish species which is well known to possess these characteristics is the oreochromis tilapia (popularly known as the Nile tilapia). They are omnivores and thus consume a wide variety of organic matter meaning that they can feed on a wide range of foods. Moreover, tilapia are a highly adaptable species that can be farmed even in poor water conditions with higher temperature ranges, they grow fast and breed easily (Brugere, 2015). There are three commercial species of oreochromis namely; the Nile, mossambicus and blue tilapia (Nandlal & Pickering, 2004). Of the three, the Nile tilapia is the most popular farmed specie which also grows fastest and is often the biggest (Nandlal & Pickering, 2004; Brummet et al., 2008).

Ensuring aquaculture is sustainable entails consideration of economic, sociological and ecological factors which thus necessitates balancing the need for aquaculture development on one hand and conservation of natural resources on the other (Yohe et al., 2007). Market-led development will stimulate the development of infrastructure, influence policy development, open employment opportunities, improve livelihoods and promote efficient and beneficial utilisation of natural resources as well as maintenance of ecosystems. Of the three pillars of sustainability in aquaculture highlighted above, planned prioritisation of economic issues has the potential to stimulate autonomous consideration of sociological and ecological issues as smallholder fish farmers seek to satisfy market demand and thus build sustainable livelihoods[1] (Yohe et al., 2007).

2.7. Fisheries and adaptation alternatives in Zimbabwe

2.7.1. The current landscape for fisher communities

There are a few studies which have investigated the situation of fisher communities in SSA, particularly in Mozambique, Malawi and Zambia given the prevailing changes in the climate. Although many of the common vulnerabilities and adaptation strategies have been documented, the situation in Zimbabwe is rather unique. The fisher communities' plight in Zimbabwe has been worsened by a decade long economic meltdown which took place in a hyperinflationary environment from 1999 to 2009. Following the introduction of the multicurrency regime in 2009, where currencies from other countries were accepted in place of the Zimbabwean dollar, the economy sluggishly recovered before starting to experience crippling liquidity challenges. In such an economic environment, some of the key fisher adaptation strategies that have worked well elsewhere, such as making investments in upgrading fishing technologies or changing fishing gear to target other fish species, have been constrained. The situation has significantly reduced the number of coping strategies for fish dependent households in fisher communities.

Furthermore, fishing communities throughout the country are located in remote and typically arid low lying areas which are prone to droughts. These areas have geophysical factors that do not facilitate the adoption of a tripartite approach to livelihood activity, which as mentioned in chapter one, involves engaging in cropping, livestock rearing and fishing. Such factors, combined with gender inequalities among resource constrained rural fishers, deepens their vulnerability, especially among women. In addition, the government has established wildlife sanctuaries around large dams and along major rivers where most of the fisher communities are located. As a result, fishers often live in fishing camps since they are not allowed to set up permanent structures in game reserves. Since fishing camps are located inside these animal sanctuaries, cropping and livestock rearing is impossible. Diversification of livelihoods in

[1] A livelihood is sustainable when it has the ability to withstand and recover from shocks such as droughts and floods in such a manner that it even enhances its current and future capabilities without undermining the natural resource base (Chambers and Conway, 1992).

fisher communities along the lines seen elsewhere on the continent, particularly in Malawi and Zambia, has therefore not been possible.

Over the years, the government's capacity to institute strong regulation and curb incidences of unlicensed fishing has been weakened due to a lack of resources, resulting in the sector being open to exploitation. The situation has been worsened with the rapid decrease in demand for farm labour when the government's land reform programme replaced large commercial farms with mostly smallholder plots which exacerbated rural unemployment. Some of these affected people have resorted to fishing in the numerous water bodies dotted across the country and this has increased the challenges and threats to livelihoods that the fisher communities face over and above those attributed to the changing climate.

As documented in section 2.4, Allison et al. (2007) noted that that resource-dependent communities, particularly in the developing world, have adapted to climate variability throughout history. There is evidence of such natural adaptation in Zimbabwe. For example, it has been observed that in the southern Lowveld, communities surrounding Manyuchi dam have been investing in new low cost fishing gear and developing new skills required to catch river sardines which are now abundant in the dam. However, while such natural learning and skills development is critical, more strategic input to facilitate adaptation within the fisher communities is typically required and this is no different in Zimbabwe. Due to the rapidly increasing pressure on fish and water resources at a time when the Zimbabwean government has no capacity to provide technical expertise and extend support to ensure responsible fishing practices, donor agencies such as the European Commission and non-governmental organisations such as AQZ, World Vision and Basilwizi Trust are intervening to provide the technical expertise necessary to ensure responsible and sustainable fisheries. However, despite the presence of donor agencies and NGOs in the fisher communities, their contribution needs to be complemented by fully capacitated government institutions that provide effective regulation of the sector.

2.7.2. The state of aquaculture

One approach that the NGOs (along with government) have realised will go a long way towards protecting and strengthening the livelihoods of fisher communities from these multiple stressors including climate change is rural aquaculture. The key advantage of this adaptation option is that the fishers will have sole water access rights and land property rights which are easily enforceable through the local and traditional or informal legal systems (Gono, Muzondiwa, Chihanga & Manhondo, 2015). Moreover, in adapting mainstream agriculture to climate change, the government and donor agencies have steadily invested in multipurpose water storage facilities such as dams, overnight water storage ponds and irrigation systems to cope with the increasingly variable rains and reduce inconsistencies in water supply for agricultural use. These facilities have indirectly created many opportunities for engaging in aquaculture particularly in the drier parts of the country.

The opportunities for aquaculture development as a climate change adaptation option in fisher communities in Zimbabwe are, however, currently not being fully exploited, partially because of the lack of a sector specific policy framework and because of limited knowledge about the economic viability of aquaculture when undertaken on a small-scale. Although the development of a policy framework is at an advanced stage, with the financial backing of the European Commission, the economic potential of the sector, particularly for the smaller players, remains largely unaddressed. Zimbabwe is home to Africa's largest private investment in aquaculture (Lake Harvest Aquaculture), which provides many lessons on investing successfully in the sector. Despite this, smallholder aquaculture development has not been embraced as much as in neighbouring countries like Zambia. Noticing the opportunities available, donors have sought to make the sector friendlier to smallholder players by identifying and dealing with structural bottlenecks in the fish value chain so as to open it up and facilitate broad based development, which is inclusive of fisher households. For example, through funding from the United Kingdom's Department for International Development (DFID), the sector now has private players producing fish feed (AquaFeeds Pvt Ltd) and Lake Harvest Aquaculture has been encouraged to join in providing quality fish seed (fingerlings). Research, however, is needed to complement the private sector and donor agencies' efforts by providing technical and economic feasibility studies for investments in aquaculture in Zimbabwe. Such economic evaluations of aquaculture will be of use to banks, individual investors, community-based organisations and government departments and are thus critical to the assessment of aquaculture as a viable adaptation mechanism for fisher communities.

3. Chapter three: Methodology

3.1. The research area

3.1.1. *Mwenezi district*

The district of Mwenezi in southern Zimbabwe was targeted for this research as the primary area of study (as shown in the map in Figure 3), while another district in northern Zimbabwe, Kariba, was used as a means to gather additional information. These districts were selected due to their features and characteristics which typically exemplify the situation of fishers in their communities in Zimbabwe, as is explained further below.

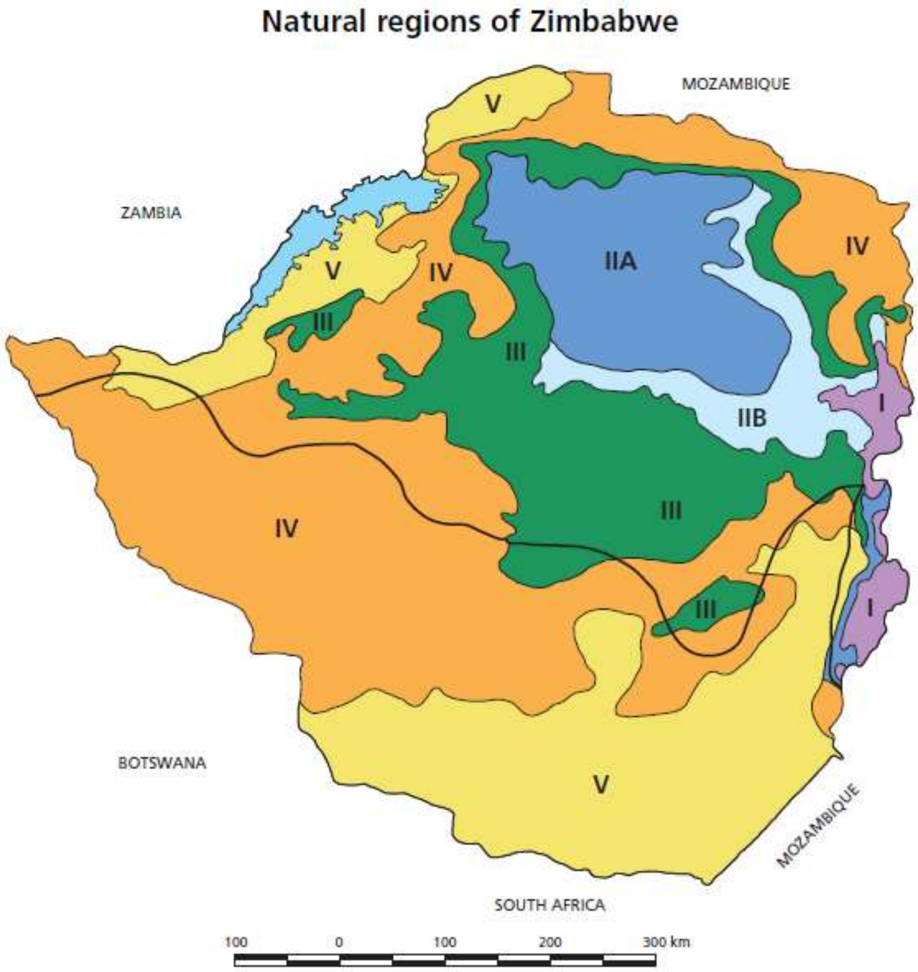
Figure 3: Mwenezi district

(Source: Mujaju and Nybom, 2011, p.5824)

As Figure 4 shows, Zimbabwe is divided into five agro ecological regions. These subdivisions are based on several factors which include rainfall patterns, quality and type of soil as well as the flora and fauna found in an area (FAO, 2006). Generally, the quality of the land resource in terms of the nature and type of productive use declines from natural region one to five (Moyo, 2000). Natural regions four and five are located in low lying areas, popularly referred to as the Lowveld, which is found in the southern and northern parts of the country as indicated on the map. Thus both the Mwenezi and Kariba districts lie in the Lowveld, with similar climatic conditions, although the former is in the south of the country (as shown in the map in Figure 3) and the latter is in the north. These regions receive less than 650 millimetres of rain per year and are characterised by erratic rains, frequent droughts and lengthy dry mid-season spells and are therefore often considered unsuitable for dryland crop production (FAO, 2006). Despite the challenging environment, Moyo (2000) noted that occasionally, drought tolerant crops, which include sorghum and pearl millet, as well as cattle production and wildlife, can thrive under such conditions. However, according to the FAO (2006), the yields of households in regions four and five are perennially extremely low with very high risk of crop failure. Rearing livestock is also difficult due to the presence of wild predator animals such as lions and tsetse fly (Alsan, 2014).

From working in the area, it has been observed that most households in Mwenezi district, particularly in the areas surrounding Manyuchi dam, have at least one member who is a fisher plying his or her trade in Manyuchi dam. Manyuchi dam and other smaller reservoirs and perennial rivers, have come under increasing strain due to climate change. For example, some smaller rivers and dams are drying out due to the recent spike in the intensity and frequency of droughts in the area. Overfishing has also been prevalent in Manyuchi dam with fishers now spending more time only to catch less fish than has been the case before. Finding ways to cope with the impacts of climate change has never been so important to protect the livelihoods of the fishers in this area than it is now.

Figure 4: Agro ecological zones in Zimbabwe



(Source: FAO, 2006, p. 6)

3.1.2 Aquaculture in the Mwenezi District

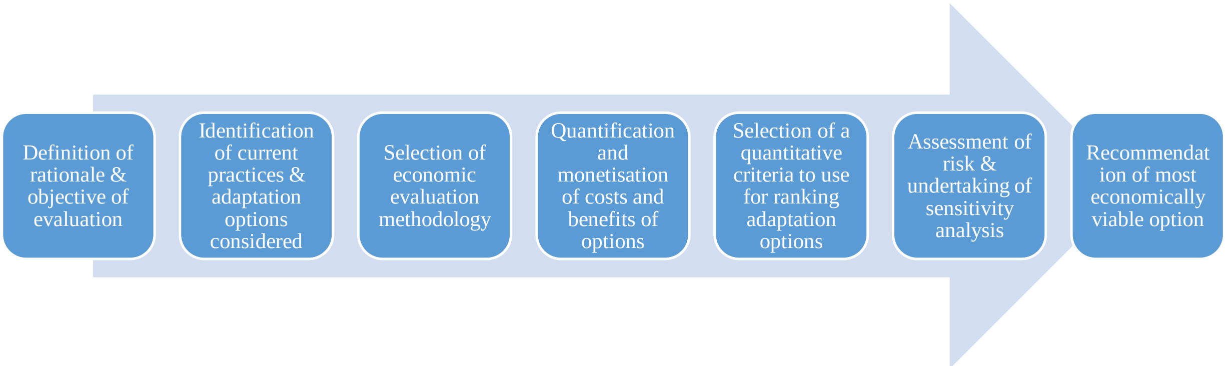
AQZ is a local NGO established in 2007 to support the sustainable development of aquaculture and fisheries in Zimbabwe and in so doing, to fight poverty and diversify livelihoods. It is the biggest NGO working in the sector in Zimbabwe and has established a number of pro poor fish production systems in both fisher and non-fisher communities in the rural areas of the country. Using aquaculture as a livelihood diversification strategy, AQZ works in the agro-ecological regions four and five, among other areas, where many commonly practiced agricultural activities typically have limited success. Specifically, the organisation aims to increase rural food security, livelihood options and incomes of poor smallholder fishers and farmers through integrating aquaculture to existing livelihood systems. AQZ is already working with fisher communities looking at ways of diversifying their livelihood off capture fisheries in Lake Kariba amongst others. It is therefore also providing support to fish cage culture projects.

Through the aid of AQZ and its donors, the communities in Mwenezi are incrementally turning to aquaculture using water from perennial dams and are also considering cage culture in Manyuchi dam. The Nile talapia has been used extensively in existing aquaculture projects in Zimbabwe (Aquaculture Zimbabwe, 2015).

3.2. Research Design

This research was undertaken in a manner closely following the well-established steps often used in the economic evaluation of climate change adaptation options as recommended by the UNDP (2009). Although there are slight variations to the economic evaluation process used in the literature, seven steps were implemented in this economic evaluation, as shown in the flowchart below. These steps follow the guidelines established by Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ, 2013) and UNDP (2009). The flow chart below shows the economic evaluation process followed in this research, with the details thereof discussed in the following sub-sections.

Figure 5: The process for evaluating the adaptation options



(Source: GIZ 2013)

3.2.1. Step 1 – Definition of the rationale and objective of undertaking the evaluation

As explained in chapter one, the primary objective of this study is to determine the economic viability of aquaculture as a climate change adaptation option in fishing communities of Zimbabwe through a focus on the Mwenezi district.

3.2.2. Step 2 – Identification of the baseline scenario and the adaptation options

The baseline scenario should reflect the current practices of the fisher households without aquaculture. It becomes a point of comparison for the analysis of the proposed aquaculture adaptation options. Information about the current artisanal fishing in Manyuchi dam was obtained from the fishers who shared their estimated catches, prices at which they sell fish and the estimated monthly costs. This was achieved with the assistance of AQZ.

In Zimbabwe, two forms of aquaculture can be implemented - cage and pond culture. According to Miller (2009), a fish cage is a mechanism to restrain fish in one place within a flowing or stagnant body of water. This characteristic of cage culture makes it suitable for use in many types of water resources such as lakes, dams and rivers (Masser, 1988). In contrast, in a pond fish are farmed under controlled conditions in stagnant water which has been enclosed for the purposes of retaining water (Welcomme, 1975). Fish ponds can be made of concrete or simply earthen (Baluyut, 1989). Both forms of aquaculture represent a feasible means of diversifying the livelihoods of fishers because they entail a greater level of human control which is not possible in wild capture fisheries (Brander, 2007).

A case of pond culture in Mwenezi district will be assessed using information available from aquaculture activities currently being practiced in the region. Although only pond culture systems are used in southern Zimbabwe, small scale cage culture is being practised in other provinces. Thus to examine the feasibility of cage aquaculture in Mwenezi's Manyuchi dam, information was gathered from a smallholder cage culture in Lake Kariba. The Kariba district was selected because it also forms part of the Lowveld and therefore lies in region five which has similar agro-ecological characteristics as the Mwenezi district.

In a brief history of the development of aquaculture in Africa, Brummet et al. (2008) noted that the sector initially received a lot of funding from colonial governments in the 1960s since they recognised it as a viable means of food production. However, Brummet et al. (2008) also noted that following independence, newly elected governments did not prioritise aquaculture, which only received a new lease of life starting in the late 70s when international donor agencies took over. In Zimbabwe donor funding for the development of aquaculture has continued and currently European Commission and USAID among others have funding for aquaculture (Gumbo, 2015; US Embassy in Zimbabwe, n.d). Individuals receiving grants for aquaculture from donors also receive mentorship and technical training and support from NGOs such as AQZ and Basilwizi Trust. The government, through pro-agriculture banks such as Agribank has also been availing loans to support agro based initiatives. However, these loans do not come with any form of support. The government expects such individuals accessing loans from the bank to look for information and organize their own mentorship and technical support.

Data on the benefits and costs involved in pond culture was obtained from a site in Mwenezi while the information pertaining to cage culture was obtained from a site in Lake Kariba. Additional data on recommended fish feed regimes, the availability of fingerlings and general costs involved in aquaculture was obtained from private companies that produce these key aquaculture inputs. The producers include AquaFeeds, who provide fish feed, and Lake Harvest, who provide fish fingerlings. These key inputs are available through an extensive distribution network of ProFeeds farmers' shops. The input producers supply all the fish farmers in Zimbabwe, hence both the cage and pond culture sites use the same feed. However, although commercial feeds are available, farm-based supplements are often used in pond culture.

Technical aquaculture extension information was obtained from four senior technical field staff members from AQZ who work closely with the fishers and fish farmers. It was considered prudent to access information about aquaculture via the same channels as the aquaculture farmers. Data from the producers was therefore obtained using key informant interviews and document review methods. The information about inputs and technical support was then validated through interacting with the fishers who are practising pond culture in Mwenezi as well as those practising cage culture in Lake Kariba. The actual sites selected were recommended by AQZ with various records accessed in liaison with AQZ

3.2.3. Step 3 – Selection of an economic evaluation methodology

After successful identification of adaptation options, what follows is the appraisal in terms of their economic viability (McCarthy et al., 2001). The main methods include: cost benefit analysis (CBA), expert judgement (EJ), multi criteria analysis (MCA) and cost effectiveness analysis (CEA) (De Young et al., 2012; GIZ, 2013).

CBA is preferred in situations where both the benefits and costs can be expressed in monetary terms United Nations Framework Convention on Climate Change (UNFCCC, 2012). In contrast, MCA is appropriate when it is not possible to quantify and attach monetary values to costs and benefits (GIZ, 2013). CEA is suitable for situations where the costs can be expressed in monetary terms but not the benefits (Niang-Diop & Bosch, 2011). It is effectively a hybrid of CBA and MCA and is most suitable for confirming a decision which has already been reached through the MCA or CBA approaches. EJ is often used at a later stage in policy decision making United Nations Development Programme (UNDP, 2009).

In line with the UNDP's (2009) recommendation that the selection of the economic evaluation method should be based on factors such as the availability of data and resources as well as the objectives, CBA emerged as the best economic evaluation method for the purposes of this study. Moreover, CBA has also been touted as the most preferred method for assessing climate change adaptation options (UNFCCC, 2002, 2012; Chadburn, Ocharan, Kenst, & Venton, 2010; Chambwera & Stage, 2010; Hallegatte, Lecocq & de Prerthuis 2011).

CBA entails the quantitative evaluation of the adaptation options, where the economic costs and benefits of each option are assessed to estimate the net benefits (Pearce et al., 2006). When there are net benefits then the adaptation option is said to be economically viable. However, if the estimated costs are perceived to be more than the benefits then the adaptation option is deemed to be unfeasible.

3.2.4. Step 4 – Quantification and monetisation of costs and benefits of the options

Following the selection of CBA as the preferred economic evaluation method, the costs and benefits of the adaptation options were quantified based on assumptions which were made around fish production parameters for both cage and pond culture. These assumptions are discussed in chapter four. It is important to note that some of the benefits and costs cannot be quantified such as social and environmental benefits. Chadburn et al. (2010) noted that monetary and non-monetary benefits may be difficult to identify and this forms the core downside of CBA. As the World Bank (2010) noted, there is little consensus on valuing non-monetary costs and benefits, such as externalities, especially in environments where there are many prevailing uncertainties, taxation and subsidies induced distortions and poorly or non-existent capital markets among other concerns. Following a similar study by Nkomo and Gomez (2006) of commercial fishing in Gambia and South Africa, only costs and benefits that could be quantified and easily expressed in monetary terms were included. The benefits are the revenues from the sale of fish produced through aquaculture while the costs represent the stream of expenditures associated with producing this fish in any year, the opportunity costs associated with diversifying from traditional fishing activities and the initial investment (Lunduka, 2013).

3.2.5. Step 5 – Selection of a quantitative criteria to use for ranking adaptation options

The discounted cash flow (DCF) method of investment appraisal was used in this research as it is known to provide an objective evaluation of projects taking into account the time value of money and risk (van Horne & Wachowicz, 2008). As such, in adopting this approach it is necessary to specify a discount rate and select an appropriate time horizon over which to evaluate the alternatives.

3.2.5.1 Timeline for the projection of costs and benefits

In 1996, the European Commission highlighted that the projection of costs and benefits in an economic evaluation of climate change should be for a period long enough to allow for understanding of the likely medium- to long-term impacts of climate change. As a result, the European Commission (1996) established guidelines which specified that most infrastructure projects should have a time horizon of not less than 20 years while for productive investments a timeline of 10 years should be used. Just a little over a decade later, the European Commission (2008) noted that the time horizon over which the benefits and costs of climate change should be projected should generally be in line with the economic life of the main assets being used in the project. The UNFCCC (2012) policy docket concurs with this recommendation. Hence when assessing adaptation options with long lives, the useful life of the assets should be considered because it is the shorter time frame when compared with the lifespan of the project. According to the Commonwealth of Australia (2006), adopting a shorter time frame is preferable as it reduces uncertainty in extrapolated data. Furthermore, the process of discounting reduces the significance of distant costs and benefits when compared to the present and hence negates the impact of considering very long periods of time in economic evaluations. Taking into consideration these recommendations and the knowledge of culture schemes, a timeline of 10 years was considered appropriate for this research. Mmopelwa, Raletsatsi & Mosepele (2005) used a 10-year period in a CBA of commercial fishing in Shakawe Botswana.

3.2.5.2 Discount rate

Selecting an appropriate discount rate is very critical in investment analysis as it has a huge impact on perceived economic viability. In the context of the evaluation of climate change adaptation mechanisms, it is necessary to ascertain whether to apply a social discount rate (SDR) or a market-determined rate (Wise & Capon, 2016). In making a choice between these two alternatives, Wise and Capon (2016) also noted that generally, the choice depends on whether the benefits are primarily private or public. In the context of climate change adaptation, they thus argued that the SDR is preferable to a market-determined rate because the benefits are more public than private.

Campos, Serebrisky and Suarez-Aleman (2015) found that a number of international development agencies recommend the use of a single and constant SDR for evaluation of investment projects and provided examples of the World Bank, Inter American Bank and the Asian Development Bank which use a rate in the range of 10% to 12%. However, upon further analysis, Campos et al. (2015) observed that for projects in developed countries lower discount rates are typically used ranging between 3 to 7% while for projects in developing countries higher discount rates, between 8 and 15%, are employed. The OECD (2015) highlights that market interest rates typically fall within the range of 6% to 20% with developed countries on the lower side while developing countries on the higher side and thus the magnitude and trends in SDRs are similar to market-determined rates.

In a study estimating and comparing costs and benefits of specific adaptation projects in South Africa and Gambia, Nkomo and Gomez (2006) used a discount rate of 9% for a period of 60 years in Gambia and 6% for a 30-year period in South Africa. Mmopelwa et al. (2005) applied a discount rate of 10% in their CBA of commercial fishing activities in Botswana. In the Pacific region, Buncle, Daigneault, Holland, Fink, Hook and Manley (2013) noted that a recent CBA for natural resources management used a discount rate in the range of 7 to 10%. Furthermore, in a recent feasibility study of milkfish aquaculture in the Solomon Islands by Sulu, Vuto, Schwarz, Chang and Basco (2016) a discount rate of 8% over a 20-year period was. In line with the trends in the developing countries this study used a discount rate of 12% which is within the range of interest rates stipulated by the RBZ (2016).

3.2.5.3 Quantitative criteria

The primary quantitative criteria of the DCF approach include the net present value (NPV), internal rate of return (IRR) and the benefit-cost ratio (BCR). The NPV is the difference between the present value of future benefits and costs associated with the adaptation option (Lunduka, 2013). The adaptation option will be accepted if the NPV is positive i.e. the present value of cash inflows exceeds the present value of cash outflows. When comparing alternatives, the higher the NPV, the more economically viable the adaptation option (Chadburn et al., 2010).

The IRR is the discount rate at which the present value of the future net cash flows from an investment project are identical to the project's initial cash outflow i.e. the NPV is zero (Van Horne & Wachowicz, 2008). The IRR gives a task to a decision maker to make a judgement on whether this rate is acceptable or not. However, typically the acceptable criteria used with the IRR method is to compare the IRR to the discount rate (which reflects the required rate of return), with projects which have an IRR exceeding the specified discount rate accepted (Van Horne & Wachowicz, 2008; GIZ, 2013). According to van Horne and Wachowicz (2008) the BCR of a project is the ratio of the present value of future net cash flows to the initial cash outflow project costs. The BCR indicates the level of benefit accruing for every dollar of cost (Chadburn et al., 2010). A ratio greater than one indicates that the project is financially viable. The higher the BCR, the more economically viable the project (Lunduka, 2013).

The three DCF techniques work together providing supplementary information to each other thereby enriching the quality of decisions made on the choice of adaptation options taken. In cases where one adaptation option is considered, NPV, IRR and BCR techniques would provide the same accept/ reject decision (Van Horne & Wachowicz, 2008). The two adaptation options examined in this study; cage and pond culture, can be viewed as mutually exclusive meaning that the selection of one project results in the rejection of the other; both cannot be implemented. When multiple projects which are mutually exclusive are considered then the three techniques may yield different answers[2] because of differences in the upfront project costs of the adaption options and/or the timing of cash flows and/ or variance in the project length (although the latter is not applicable to this study) (GIZ, 2013; Lunduka, 2013). In such circumstances, NPV is preferred because it provides an absolute measure of value creation rather than IRR or the BCR which are relative measures and thus ensures that the optimal scale of investment is achieved (Commonwealth of Australia, 2006; van Horne & Wachowicz, 2008). Other similar studies that have sought to evaluate adaptation options that have used the DCF method have made use of both NPV and BCR (Chadburn et al., 2010; Lunduka, 2013).

[2] This is not true in the evaluation of independent projects as more than one project can be selected (van Horne and Wachowicz, 2008).

Despite this shortcoming of the IRR and BCR, all three methods were used so as to understand how the project performs when its returns are compared with the required rate under the IRR method but care was given when comparing the two options under this method.

3.2.6. Step 6 – Assessment of risk and undertaking of sensitivity analysis

Sensitivity analyses focus on investigating the effects of changes in key variables such as revenues, costs or the discount rate on the NPV, IRR and BCR of the adaptation options. A 'what if' analysis is performed focusing on key variables and comparing the outputs to the base scenarios (Van Horne & Wachowicz, 2008). The Department of Environmental Management and Tourism (DEAT, 2004) noted that sensitivity analyses aim to test the robustness of the CBA outputs, especially the underlying assumptions. It is therefore an approach to measuring risk and uncertainty (Engle, 2010). The World Bank (2010) recommends that the evaluation of climate change adaptation process incorporate sensitivity analysis as a way to rigorously test the climate change adaptation options' sensitivity to the estimates outlined in the parameters.

Sensitivity analysis should be run on all parameters for which values are not known or are highly variable (Angle, 2010). In most cases, three scenarios are considered; optimistic, most likely and pessimistic, especially if the benefits are seen to be sensitive to certain variables. The exercise is undertaken so as to identify key variables which may influence the adaptation options' cost and benefit flows and therefore need close monitoring depending on the severity of their impacts as well as identifying possible mitigation strategies (Iloiu & Csiminga, 2009). Knowing the sensitivity of an adaptation option to certain key variable helps decision makers in estimating whether it is worth instituting further investigations before the final investment decision is made (Van Horne & Wachowicz, 2008). Sensitivity analysis thus helps in guiding risk management in the adoption of climate change adaptation options and providing recommendations to ensure the project creates value when implemented.

3.2.7. Step 7 – Recommendation of the most economically viable option

UNFCCC (2012) noted that the final step of CBA is to make recommendations. The results from the NPV, BCR, and IRR computations as well as the sensitivity analysis will be used to determine whether aquaculture is feasible as an adaptation option in Zimbabwe taking into consideration the funding options and the two forms of culturing.

4. Chapter four: Data analysis and Results

4.1. Introduction

Chapter four presents the key assumptions and financial models that were used in evaluating the two adaptation options - pond and cage culture – under the two financing scenarios. Thereafter the results from the DCF techniques including the NPV, IRR and BCR used to evaluate the adaptation options as well as the sensitivity analysis undertaken are presented and discussed.

4.2. The Baseline Model

The key assumptions for artisanal fisheries include the following:

- *Capital investment*: According to (Elago, 2012, p.7) artisanal fisheries use a wide range of gears and crafts such as gillnets, traps and hand lines operated from dugout canoes while others use relatively modern planked boats with or without outboard motors. For the purposes of this analysis, fishers are assumed to use peddlers which are not fitted with outboard motors.
- *Informal sector*: Artisanal fishers do not follow formal accounting procedures hence their records are not organised or observable.
- *Seasonal variation in fishing activities*: Fishing activities and hence catches are more intense during summer (August to March) than in winter (April to July). The year considered here starts in January and ends in December.
- *Fish sales*: Fish selling transactions are cash-based with no credit or barter exchanges. Fish is sold at the landing site while fresh and whole.
- *Permits/licences*: Fishers need permits to access the lake for fishing purposes. The permits are renewed once a year at the Zimbabwe National Parks and Wildlife Management (ZNPWM), with the fees paid at the end of each year.
- *Household fish consumption:* There are no records showing the fish quantities taken home for household consumption. The allocation of fish catches for household consumption is insignificant and hardly ever quantified hence for practicality reasons these were added back to the total catches which are sold.

Table 2: Summary of model inputs – parameters of artisanal fishing

Fishing parameter	Unit	Value
Fishing trips per annum	Number	156.00
Average catches per fishing trip	Kg	15.00
Average fish price	$/kg	1.50
Fish permit per month	$	10.00
Boat maintenance per month	$	6.67
Gear repairs and maintenance per month	$	2.50
Ice per month	$	10.00
Bait per month	$	2.00
Food and other provisions per month	$	20.00
Labour costs - proportion of fish allocation	%	0.40
Labour costs per fishing trip	$	9.00

The artisanal fishing model inputs are explained in the following subsections and documented in the table thereafter under the categories of total annual revenue, fixed and variable costs.

4.2.1. *Total annual revenue*

The variables which make up the total annual revenue were determined by the fisheries statistics which fishers compile and send to the ZNPWM and supplemented from direct discussions with the fishers. A fishing day usually start at about 3pm in the afternoon and ends in the morning before 9am. Fishers, on average, go on a fishing trip for 3 days in a week and thus in a year fishers make an average of 156 fishing trips (3 trips/week x 52 weeks). The average price of fish is determined by the market forces of demand and supply. Mhlanga and Mhlanga (2013) noted that the price of fresh fish (tilapia) can be as low as USD2 compared, for example, to beef which is consistently above USD5. Recently the price has remained stable at USD3 even when supply has been constrained because of the droughts and demand has been on the increase (Reuters, April 2016). The fishers typically sell at the landing sites for much less than the going price in the market. On average the landing site price is USD1.50 per kg which can be viewed as a wholesale price. However, on the market fish costs USD3 per kg. It is more appropriate to use the price on the landing site and not the one in the market because the fishers typically sell their produce at the landing site to fish traders who then take the fish to the markets.

The fishers estimated that on average they catch 15kg of fish per fishing trip which is equivalent to 45kg per week (3 fishing trips x 15kg of fish per trip) which equates to 2.34 tonnes of fish per annum (15kg of fish per trip x 156 trips per year). Attempts at verifying the annual total catch per fisher of 2.34 tonnes per year was difficult due to non-availability of such data on fisheries across the country.

4.2.2. Fixed costs

Fixed costs are incurred regardless of the amount of fishing undertaken by the fishers. For the artisanal fishers one of the major costs is the mandatory fishing permit fees which they pay as part of securing access to the waters. The fishing permit fees are similar for all fishers and are paid in accordance to the requirements of the Parks and Wildlife Act. The actual amount is gazetted by the department annually with the current amount pegged at USD10 per month or USD120 (USD10/month x 12 months) per fisher. However, individual fisher's investments in boats, manpower and fishing gear varies depending on capacity and preferences. The costs of maintaining the boats therefore vary significantly although they average USD80 per annum. The average cost involved in fishing gear repairs, maintenance and in some instances replacement add up to USD300 per annum.

4.2.3. Variable costs

These are costs that are directly related to the fishing activities. However, the information obtained from the fishers was not on a "per unit" basis but rather a monthly cost. This information was then adjusted to account for the number of fishing trips the fishers undertake per year to obtain an annual estimate of each of the costs. Fishers calculated the costs of food and other provisions such as bait, ice, communication (credit for mobile phones) and other consumables over a period of one month and not necessarily per fishing trip. There are many overlaps between individual trips as they are often short.

Ice is often used during the summer for keeping fish fresh while still fishing. In some instances it is also used when there is need to store fish for customers who have placed orders. On average the fishers estimate that ice costs them about USD15 per month. Summer stretches for 8 months therefore costs per annum add up to USD120 (USD15 x 8 months). Bait is only used during days when it is not possible to go on fishing trips and is thus not used frequently. At most this bait will cost USD2 per month resulting in an annual average of USD24. Food and other provisions needed during fishing trips often cost the fishers about USD20 per month and add up to USD240 annually.

The labour costs were estimated following the commonly used practice where each permit is granted to one artisanal fisher who in turn can employ two people who assist him/her. The permit holder normally determines the payment arrangement for the other two workers. No one gets a regular payment or salary but a share of catches allowing 60% for the owner and 20% apiece for the workers. The workers are then free to dispose of the fish whichever way they want. Therefore the labour costs per fishing trip is USD9 (average fish catches per day 15kg x average price of fish USD1.50 x proportion allocated to labour 0.4).

The values for each of the components described above are detailed in the table below.

Table 3: Model inputs for artisanal fisheries

Item	Variable	Amounts (USD)
Sales		
Average catch per fishing day	A	15
Average price of fish per kilogramme	B	1.50
Average number of fishing days per year	C	156
Total annual revenue	D	3510
Fixed costs	*E*	
Boat repairs and maintenance	F	80
Fishing gear repairs and replacement	G	200
Fishing license	I	120
Total fixed costs	J	400
Variable costs	*K*	
Ice	L	160
Baits	M	24
Food & provisions	N	120
Labour costs	P	1404
Total variable costs	Q	1708
Total costs	R	2108
Annual profit	S	1402

Considering the fisher's income per annum as documented on table 3 above, the income per fishing trip were allocated to a per trip profit value by dividing by the total number of trips a fisher is assumed to do each year (156 trips).

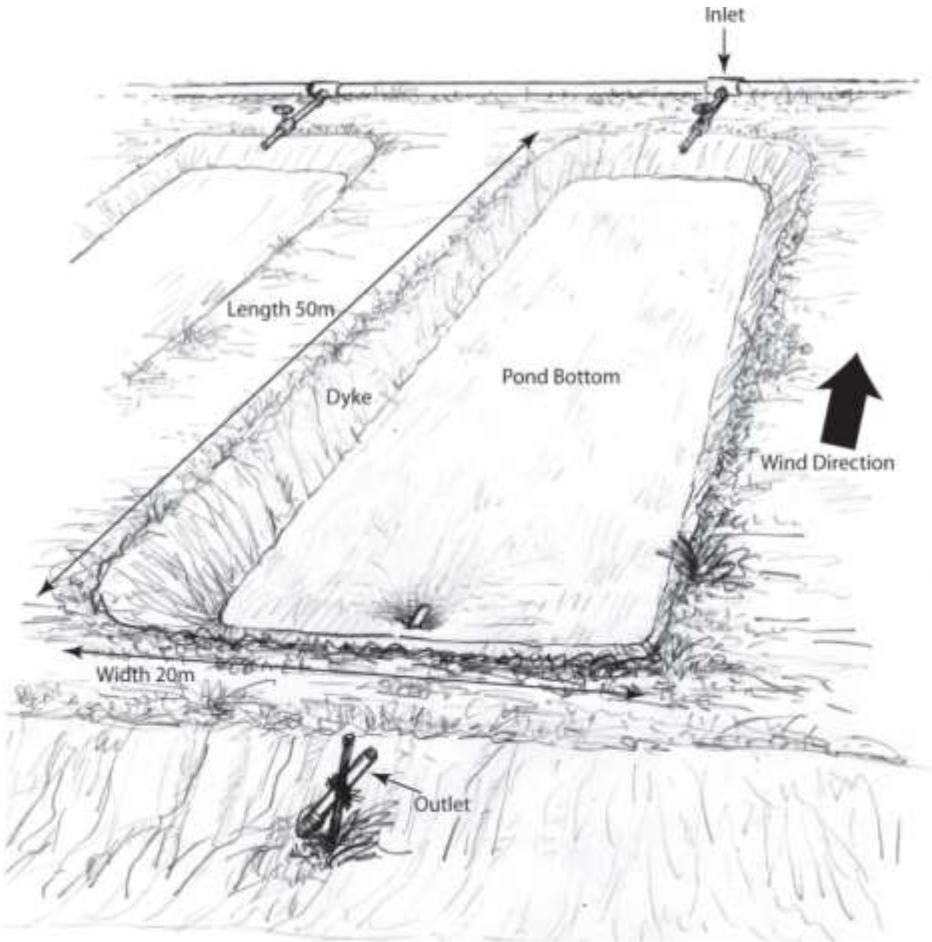
4.3. Assumptions and inputs to the aquaculture adaptation models

4.3.1. Identification and quantification of key economic costs and benefits

Although the uptake of aquaculture is in its infancy across Zimbabwe, there has been a phenomenal increase in demand for information on how to get started. The data used in this CBA was gathered from the three prominent private sector players that are actively promoting small scale aquaculture; AquaFeeds, Lake Harvest and Profeeds. In addition, further practical experiences of AQZ were also used in formulating some assumptions. The key assumptions for the aquaculture models are as follows:

- *Capital investment*: The fishers are able to construct fish ponds and cages using locally sourced materials.
- *Informal sector*: The fishers produce and sell fish in quantities below the taxable threshold and are therefore not subject to taxation.
- *Seasonal variations*: The fishers have 2 production cycles which are 22 weeks long within each year. The first cycle typically begins in January and the fish will be ready for the market by mid-May while the second cycle typically begins in July and ends by mid-December.
- *Fish harvesting*: The fishers undertake partial harvesting of fish starting at the onset of winter (April). The harvesting coincides with a seasonal decline in fish on the market from capture fisheries. This creates demand which is important for the fish farmers as they will be able to sustain a sale price of USD3/kg. Another harvest in December coincides with the festive season when demand for fish and fish products will be high.
- *Fish sales*: The fish is sold fresh, whole and ungutted soon after harvesting. Fish is sold by weight in kilograms. All fish sales transactions are on a cash basis with no credit or barter exchange.
- *Household fish consumption*: The fishers will take some fish from their produce for household consumption. However such quantities are not significant therefore are not considered as part of sales.
- *Fish culture:* The tilapia fish is cultured in fish ponds and floating cages. At a minimum the cages and ponds are designed to accommodate a single cohort of fingerlings. In the fish pond, semi-intensive culture will be practiced where fish are given supplementary feeds over and above the naturally occurring food in the pond as a result of water fertilisation (Nandlal & Pickering, 2004). In such a system, Nandlal and Pickering (2004) recommend a stocking density ranging from 3 to 8 fingerlings/m^2. AQZ has recommended a stocking density of 2.5 fingerlings/m^2 in Mwenezi district and have had successful results (Chitagu, 2015). While there are many types of fish ponds that can be used in aquaculture, earthen ponds like the one illustrated below (Figure 5) are easy to contract on a limited budget. Soil quality is of importance to ensure that water is not unnecessarily lost through seeping. Good compaction of the ground and dykes during construction often improves the quality of earthen ponds.

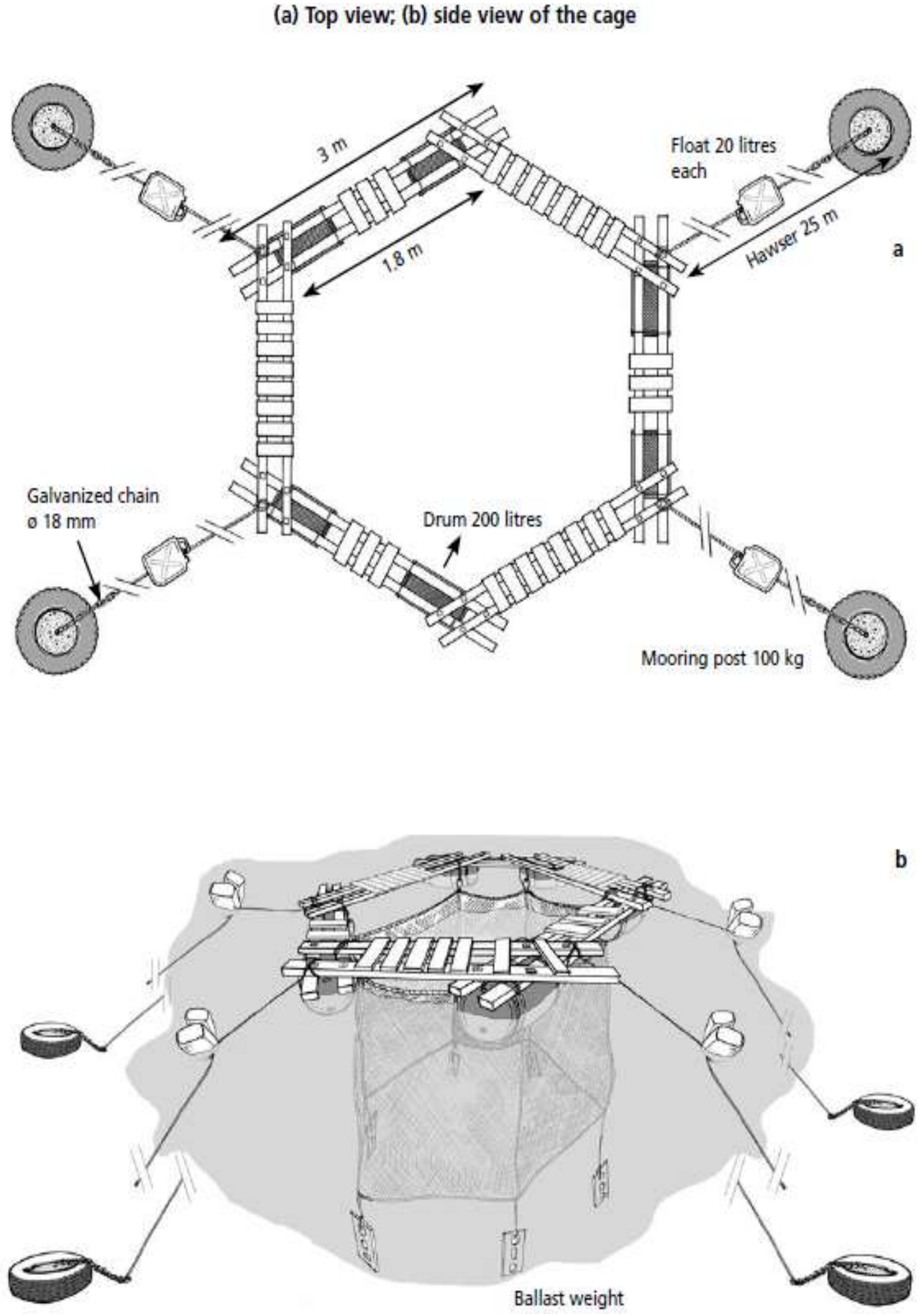
Figure 6: Typical earthen fish pond



Adopted from Nandlal and Pickering (2004, p. 20)

In cage culture, cages are used with the suspended net anchored on the bottom as shown in Figure 6 below. The actual cages used in Lake Kariba are rectangular and therefore different from the hexagonal ones used for illustration. Floaters are used to ensure the frame of the cage remains on top while the net is completely submerged and secured firmly on the bottom of the water body. Cages make it possible to intensify fish production through increasing the stocking density from those possible in fish ponds without compromising the rate of fish growth and survival. Piccolotti and Lovatelli (2013) recommend a stocking density of 30kg of fish/m^3. According to Blow and Leonard (2007a), Lake Harvest in Lake Kariba has a stocking density of 80 fingerlings per m^3 and a harvest density of up to 45kg of fish/m^3. In the communities AQZ has been promoting a stocking density of 40 fingerlings which allows for the semi-intensive nature of fish production that is more feasible at community level where technical expertise is still low. The cages have a carrying capacity of 1000 fingerlings with a volume of 25m^3 (4m x 2.5m x 2.5m) at this stocking density.

Figure 7: Typical fish cage



Adopted from Piccolotti and Locatelli (2013, p. 25)

- *Labour:* Family labour is generally used by small scale tilapia farmers while the use of hired labour is very rare due to limited funds (El – Sayed, 2013). AQZ has promoted the use of family and community labour in aquaculture. Emphasis has been on local capacity building to reduce dependence (technical and economic) on external support. Nonetheless, once in a while there is need to get professional assistance.

4.3.2. Key model inputs

4.3.2.1. Fish fingerlings

Lake Harvest produces high quality fingerlings which are being sold across the country through the ProFeeds distribution network at a cost of $50 per 500 as shown in Figure 8. At double the price a fish farmer can obtain two packets each with 500 fingerlings to obtain 1000 which is the number AquaFeeds is working with on its guidance notes and infomercials to farmers. This message is then publicised in rural and remote corners of Zimbabwe by AQZ which has well established networks.

As the fingerlings being sold through the ProFeeds distribution network are sourced from the reputable and biggest aquaculture farm in Africa, they are of high quality and as such, very low mortality rates have been recorded during production. From AQZ's experience providing farmer aquaculture extension support in the field, farmers are able to attain survival rates of approximately 90% in pond culture and 95% in cage culture from a starting weight of 5 – 15g to a weight of approximately 400g at harvesting. Such high rates are also possible when adhering to feeding regimes which come with all the guidance notes from AquaFeeds.

Figure 8: Advert for fish fingerlings

(Source: Profeeds, n.d)

4.3.2.2 Fish feed

AquaFeeds provides a breakdown of the feed requirements for 1000 fish. Assuming that all conditions are favourable, the growth rates of the tilapia have been factored into the calculations detailed in the poster below. At the point of buying fish feed, farmers are informed of the feeding frequency and anticipated length of production cycle. This helps them to know when to change the feed type as the fish grows. Although there are numerous farm-based fish feeds which they can use to supplement, the commercial feeds now available are adequate for a fish farmer to attain market size of fish within the expected timeline.

Figure 9: Tilapia fish feeds advert

(Source: Profeeds, n.d)

Figure 10: An example of a fish feeding regime

Feeding Regime

Example Feeding 1000 fish

Product	Size	Feed until end of	Feed Required	Fish Size	Cost of Feed	Feeds per Day
Starter 1	small crumble	week 6	1 kg	<1g	$ 1	8
Starter 2	medium crumble	week 9	5 kg	1-5g	$ 7	6
Starter 3	large crumble	week 12	10 kg	5-15g	$ 15	4
Juvenile 1	small pellet	week 16	40 kg	15-50g	$ 42	3
Juvenile 2	medium pellet	week 20	80 kg	50-100g	$ 82	3
Grower	large pellet	week 30	320 kg	100-300g	$ 304	3
Harvest	large pellet	week 34	160 kg	300-400g	$ 136	3

Expectd Total Cost of Feed $ 587
Expected Total Harvest 400kg

collections and payments:
Profeeds Pvt Ltd
82 Woolwich Road
Willowvale
Harare

Oct-14

made in partnership with PROfeeds

(Source: Profeeds, n.d)

Table 4: Summary of the model inputs – parameters of fish production

Fish Production Parameter	Unit	Pond Culture	Cage Culture
Weight at stocking	G	15	15
Weight at harvesting - target weight	Kg	0.4	0.4
Total fish / cohort / year	number	1000	1000
Survival rate	%	0.9	0.95
Stocking density	Pond- fish/m^2 &cage – fish/m^3	2.5	40
Number of ponds/cages	number	1	1
Pond/Cage size	m2/m3	400	25
Total fish stocked in pond/cage	number	1000	1000
Cost / 1000 fingerlings / year	$/cohort	100	100
Number of cohorts stocked / production cycle	number	2	2
Production cycle	weeks	22	22
Total fish weight at harvest	Kg	360	380
Total feed for 1000 fish / production cycle	Kg	600	600
Total feed for 1000 fish / production cycle	$	564	564
Fish selling price	$/kg	3	3
Labour	$/production cycle	20	30
Security	$/production cycle	30	30
Repairs & maintenance	$/production cycle	20	50
Aquaculture permit	$/production cycle	0	20
Fertiliser	$/production cycle	7	0

4.4. Financial estimates for the aquaculture models

As with the artisanal fishing model inputs explained in the preceding section, the model for the aquaculture adaptation options are explained in the following subsections.

4.4.1. Total annual revenue

A total of 1000 fingerlings are stocked at the onset of a production cycle in 1 fish pond and another 1000 fingerlings in a cage. For the fish pond, there will be a 90% survival rate at the end of the 22 week production cycle. Therefore a total of 900 whole fish (1000 fingerlings x 90% survival rate) will grow to 400g weighing a total of 360kg (900 fish x 400g per fish). The market price for fish stands at USD3 and as such the total sales for the production cycle is USD1080 (360kg of fish x USD3/kg). Fish sales from aquaculture coincides with low catches in winter and high demand during the December holidays hence market price can be used and not land site price of $1.50. The total revenue per year will be USD2160. The fish cage will yield higher revenue of USD2280 per year due to the higher survival rate of 95%, with all other values identical to the pond culture (950 whole fish weighing a total of 380kg sold at a price of USD3/kg twice per annum).

4.4.2. Fixed costs

Communities mostly rely on family labour. However, sometimes hired labour is required for assessing fish production parameters for enhanced fish culture management. Parameters which need constant monitoring include water temperature, amount of dissolved oxygen in the water, levels of acidity and salinity of the water among others (Nandlal & Pickering, 2004). Hired labour is used for sampling fish to estimate fish growth rates and food conversion ratios. In that regard, it becomes a fixed cost for covering the required professional fees. For such costs, fishers make a provision of USD20 per production cycle and therefore the annual cost will be USD40.

The continued security of fish ponds and cages is a critical part of fish production in an environment where there is a constant threat of thievery and vandalism. Much of the security requirements are met using family labour. However, such efforts are often complemented by hired labour. In addition, resources are required to maintain security systems and structures.

USD15 is set aside per production cycle for security of ponds while USD30 is set aside for cages (USD30 and USD60 respectively per annum). It is necessary to maintain the dykes of the fish ponds and protect them from soil erosion through stone pitching and grassing. The water inlet and outlet systems also need constant maintenance to avoid flooding and damage to the dykes. A modest figure of USD20 is set aside for repairs and maintenance per production cycle. For cage culture the submerged fish nets must be protected from predators such as crocodiles through constant monitoring of the predator net which forms an outer shell protecting the net holding the fish. Maintenance of nets often warrants the hiring of divers and procurement of materials to use such as threads. Communities set aside a total of USD50 per production cycle translating to USD100 per year.

Blow and Leonard (2007b) bemoaned the absence of a clear legal framework for the aquaculture sector as is the case for the fisheries sector. It is therefore not surprising that the annually produced schedule of fees for various permits to do with fisheries are completely silent on aquaculture. There are no permits required to move fish from the Profeeds shops to the fish ponds and cages.

4.4.3. Variable costs

Profeeds provide a feeding regime which assumes that the fish farmer starts with fish fry weighing an average of less than 1g. However, in this case fishers are accessing the fingerlings from Lake Harvest through the Profeeds shops. These fingerlings are sold with an average body weight of 15g and thus according to the feeding regime provided by Profeeds, the fingerlings will be around week 12 on the complete production cycle of 34 weeks from an average body. Effectively, the fishers are culturing fish for a period of 22 weeks to reach the market size since the first 12 weeks are carefully managed by Lake Harvest. This is shown in the table below. As such, the total cost of feed required per production cycle will be a summation of the specified costs corresponding to the quantities of feed required at different stages of the production cycle totalling USD564. Lake Harvest packs fish fingerlings in bags of 500 and costing USD50 and therefore fishers need USD100 to purchase 1000 fingerlings.

The purpose of adding fertiliser to tilapia grown in ponds is to stimulate the growth of food organisms which can be eaten by fish in addition to supplementary and commercial feeds. According to Nandlal and Pickering (2004), urea should be applied into the fish pond at a rate of $6g/m^2$ and is applied whenever the pond water is not very green, that is, when the Secchi disc remains visible for depths greater than 30cm. In addition to commercial fertiliser fishers complement with organic fertilisers such as chicken manure. A 50kg bag of fertiliser costs typically retails for USD35 in Zimbabwe. No fertilisation is required for cage culture. The model inputs are detailed in the table below. The details of the depreciation and interest expenses (which vary across the years) are explained and detailed in the following sub-sections.

Table 5: *Fish feed requirements in a production cycle*

Product	**Size**	**Feed until end of (weeks)**	**Weeks for culturing**	**Feed (kg) Required**	**Fish size (g)**	**Cost of feed (USD)**	**Feeds per day**
*Starter 1**	*small crumble*	*6*		*1*	*< 1g*	*1*	*8*
*Starter 2**	*medium crumble*	*9*		*5*	*1 - 5g*	*7*	*6*
Starter 3	*large crumble*	*12*		*10*	*5 - 15g*	*15*	*4*
Juvenile 1	small pellet	16	4	40	15 - 50g	42	3
Juvenile 2	medium pellet	20	8	80	50 - 100g	82	3
Grower	large pellet	30	18	320	100 - 300g	304	3
Harvest	large pellet	34	22	160	300 - 400g	136	3
Total for the farmer*				600	0	564	

(Source: Profeeds,n.d)

*Starters 1, 2 and 3 are excluded from the computation as it is used by Lake Harvest.

Table 6: *Model inputs for pond and cage culture*

Item	**Variable**	**Amount (USD)**	
		Cage	***Pond***
Sales			
Average quantity of fish harvested	A	360	380
Average price of fish per kilogramme	B	3	3
Total annual revenue	C		
Fixed costs			
Pond/cage repairs and maintenance	D	20	50
Harvesting gear repairs and replacement	E	10	10
Aquaculture permit/license	F	-	-
Security for facilities	G	30	60
Other fixed costs	H	-	-
Total fixed costs	I	**60**	**120**
Variable costs			
Fingerlings	J	100	100
Fish feed	K	564	564
Fertilisers	L		35
Labour costs	M	20	30
Other variable costs	N		
*Depreciation			
*Interest			
Total variable costs	O	**684**	**729**
Total costs	P	744	849
Annual profit	Q		

4.4.4. Initial investment and related cash flows

4.3.4.1 Scenario 1 - Grant from AQZ

AQZ provides grants to fishers, who are targeted primarily because they will be the most vulnerable and poor members in fisher communities, initiate either pond or cage culture, covering the upfront investments and the costs needed for the first complete production cycle while fishers provide all the labour required. Such grants are often provided through development and donor agencies such as the European Commission. Thereafter the fishers will take over using their own resources. That is, during the second production cycle of the first year, all normal costs are incurred. Fishers are not expected to repay the grant but to carry on with fish production with technical support from AQZ and the government extension office. The fisher will be expected to attend training workshops, be available during technical and mentorship visits by experts from AQZ. The details of the upfront investment provided by AQZ are discussed below.

Fish ponds in resource poor fisher communities are hand constructed using basic hand tools such as shovels, hoes, picks, mattocks and wheelbarrows. These tools often become handy during continual maintenance of the ponds. Technical guidance in terms of site selection, pond design and water reticulation is guided by AQZ and local government extension officers. AQZ provides all the tools and equipment required as part of the donor grant which the fishers receive. The fishers' biggest contribution is the labour required to dig and haul soil forming pond dykes. AQZ estimates the cost of tools and equipment needed at about USD100 per pond.

More expertise are required in cage construction than fish ponds. The choice of cage model is important as it affects the economic factors which have to be considered such as the cost and availability of materials to be used, simplicity during construction, stocking volume required and ongoing maintenance. Key materials to be used include steel bars for the frame, improvised containers which act as floaters, predator and fish nets among other consumables. The fishers contribute labour while AQZ provides the technical expertise. The major cost driver is the materials that are needed and these have been estimated at USD75 per cage and these are bought through AQZ from the donor grant it manages.

Both pond and cage culture require shade for safe keeping of fish feeds, tools and equipment used for fish production. Such a facility is also important during day to day management for feed preparation, used as office and for production and or safe keeping of ice (Piccolotti & Lovatelli, 2013). It is from the shade that fishers weigh and sell their fish. The shade is also constructed from the donor grant through AQZ. The materials needed include steel poles, cement and corrugated iron sheets. AQZ estimates the total materials costs at about USD60.

Cage culture requires the use of boats for accessing the cages from the shore where a shade is built. The boats will be used when feeding fish and also during fish harvesting transporting the fish from the cages to the shore. The boats used are locally made non-motorised vessels that are made by the fishers. AQZ estimate the cost for materials needed to be about USD50 per boat. Finally, important small equipment such as weighing scales, packaging materials and other fittings necessary in the fish shade to meet minimum hygienic requirements are estimated at about USD30. The details of all of these upfront costs are shown in the table below.

Table 7: Initial investment for aquaculture

Capital Component	Pond Culture	Cage Culture
Cage preparation & mounting		75.00
Pond construction (building)	100.00	
Facilities (building)	60.00	60.00
Boats	-	50.00
Other equipment & fittings	30.00	30.00
Total Initial Capital	**190.00**	**215.00**

Although the total investments described in the preceding section are covered by AQZ, the fisher, as the owner of these assets, should include depreciation in their income statement. Depreciation is a non-cash expense which represents a systematic allocation of the total value or cost of a capital asset over a period of time for financial reporting purposes (Van Horne & Wachowicz, 2008). The straight-line method was used for this purpose.

Poccolotti and Lovatelli (2013) noted that generally, the life span of cages is shorter than that of ponds. Nonetheless, AQZ estimate that with good maintenance, the cages' lifespan can exceed 10 years after about 20 fish production cycles while that of ponds can significantly exceed 10 years. Consequently, for the purposes of this research the timeline considered is 10 years. The computation of depreciation over a 10 year period is shown below. However, other equipment and fittings are assumed to have a useful life of 5 years and the computation of depreciation is aligned to that time period.

Depreciation was not, however, included in the cash flow analysis as it is a non-cash expense and the cash flow implications of this expense in terms of a tax shield do not arise for the fishers as their income levels are assumed to fall below the taxable threshold level.

Table 8: Computation of depreciation

Capital Component	Straight line method				
	Pond Culture	**Cage Culture**	**Useful life**	**Depreciation - Pond Culture**	**Depreciation - Cage Culture**
Cage preparation & mounting		75.00	10	-	7.50
Pond construction (building)	100.00		10	10.00	-
Facilities (building)	60.00	60.00	10	6.00	6.00
Boats	-	50.00	10	-	5.00
Other equipment & fittings	30.00	30.00	5	6.00	6.00
Total Initial investment required	190.00	215.00			
Depreciation (years 1 to 5)				**22.00**	**24.50**
Depreciation (years 6 to 10)				**16.00**	**18.50**

4.3.4.2 Scenario 2 - Borrowing the funds for the initial investment

Although AQZ currently supports aquaculture among fishers in the Mwenezi district in Zimbabwe by providing them with the equipment and facilities required to initiate pond or cage culture, the organisation has limited resources and thus cannot extend such financial support to all those who may wish to diversify their livelihoods. The training and support services are also limited due to financial constraints and accessibility. As such, it becomes imperative that a second scenario be considered for analysis purposes under the assumption that the fishers have to borrow funds to get the operations started.

In October 2015, the RBZ agreed with the Bankers Association of Zimbabwe to the interest rate guidelines shown in the table below, with all banking institutions required to comply with these lending rates. Due to the underdeveloped aquaculture sector in the country, particularly for small to medium size farms, the interest rates are likely to be on the high end from non-agriculture focused banks. Moreover, small scale fishers are likely to be in the category of 'borrowers with high credit risk' which attracts interest rates between 12% and 18%. However, if fishers can access agri-business loans from the Agribank of Zimbabwe, which primarily focuses on promoting agricultural development in the country, they can negotiate for a minimum rate of 12% per annum. This is possible due to the presence of underserviced market for fish and fish products throughout the country. In applying its lending criteria, Agribank emphasises the ability to recover funds lent out hence the presence of a market provides an assurance that the fishers will be able to timely service the loans in line with the loan agreement (Agribank, n.d.). An interest rate of 12% will be in line with the observed interest rates in the market (Nyarota, Nakunyada, Mupunga & Kupeta, 2015). This rate was used to compute the interest expense value in the income statement assuming that the loan and interest are repaid in equal annual instalments as shown in tables 9 and 10 and that the loan is obtained for a ten-year period matching the estimated lifespan of the assets and equipment. However, following the recommendation of the Commonwealth of Australia (2006) interest expense was not accounted for in the computation of the cash flows because it is tacitly included in the discounting process through the discount rate.

Table 9: RBZ interest rate guidelines

Category	**Lending rates**
Lending to productive sectors	
Prime borrowers with low credit risk	6% - 10% p.a.
Borrowers with moderate credit risk	10% - 12% p.a.
Borrowers with high credit risk	12% - 18% p.a.
Housing	
Housing finance	8% - 16% p.a.
Consumptive	
Consumptive lending	10% - 18% p.a.
Default rate	3 – 8% above the interest rate charged to the borrower

Adopted from the RBZ (2015, p49)

Table 10: Computation of interest expense - Pond culture

Interest @ 12% p.a.	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**
Opening Balance	190	179.17	167.05	153.47	138.25	121.22	102.14	80.77	56.83	30.02
Interest expense	22.80	21.50	20.05	18.42	16.59	14.55	12.26	9.69	6.82	3.60
Principal Repayment	10.83	12.13	13.58	15.21	17.04	19.08	21.37	23.94	26.81	30.02
Closing Balance	179.17	167.05	153.47	138.25	121.22	102.14	80.77	56.83	30.02	0.00

Table 11: Computation of interest expense - Cage culture

Interest @ 12% p.a.	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**
Opening Balance	215	202.75	189.03	173.66	156.45	137.17	115.58	91.39	64.31	33.97
Interest expense	25.80	24.33	22.68	20.84	18.77	16.46	13.87	10.97	7.72	4.08
Principal Repayment	12.25	13.72	15.37	17.21	19.28	21.59	24.18	27.08	30.33	33.97
Closing Balance	202.75	189.03	173.66	156.45	137.17	115.58	91.39	64.31	33.97	0.00

4.5. Income statements for the aquaculture options

The income statements for the pond and cage culture under scenario one, where the grant from AQZ is obtained are shown in tables 12 and 13. while those from scenario two, where the fishers have to borrow the funds, are shown in tables 14 and 15.

Table 12: Scenario one income projection - pond culture

Item	Year									
	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
Revenue										
Sales	2,160.00	2,160.00	2,160.00	2,160.00	2,160.00	2,160.00	2,160.00	2,160.00	2,160.00	2,160.00
Production based costs										
Fingerlings	100.00	200.00	200.00	200.00	200.00	200.00	200.00	200.00	200.00	200.00
Feed costs	564.00	1,128.00	1,128.00	1,128.00	1,128.00	1,128.00	1,128.00	1,128.00	1,128.00	1,128.00
Hired labour	20.00	40.00	40.00	40.00	40.00	40.00	40.00	40.00	40.00	40.00
Security	30.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00
Repairs & maintenance	20.00	40.00	40.00	40.00	40.00	40.00	40.00	40.00	40.00	40.00
Fertiliser	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00
Total production based costs	748.00	1,482.00	1,482.00	1,482.00	1,482.00	1,482.00	1,482.00	1,482.00	1,482.00	1,482.00
EBITDA	1,412.00	678.00	678.00	678.00	678.00	678.00	678.00	678.00	678.00	678.00
Depreciation	22.00	22.00	22.00	22.00	22.00	16.00	16.00	16.00	16.00	16.00
EBT	1,390.00	656.00	656.00	656.00	656.00	662.00	662.00	662.00	662.00	662.00
Net Income	1,390.00	656.00	656.00	656.00	656.00	662.00	662.00	662.00	662.00	662.00
Cash flows	**1,412.00**	**678.00**	**678.00**	**678.00**	**678.00**	**678.00**	**678.00**	**678.00**	**678.00**	**678.00**

Note: This table shows a 10-year income projection for pond culture under scenario one where the fisher obtains a grant from AQZ for initial set up.

Table 13: Scenario one income projection - cage culture

Item	Year									
	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
Revenue										
Sales	2,280.00	2,280.00	2,280.00	2,280.00	2,280.00	2,280.00	2,280.00	2,280.00	2,280.00	2,280.00
Production based costs										
Fingerlings	100.00	200.00	200.00	200.00	200.00	200.00	200.00	200.00	200.00	200.00
Feed costs	564.00	1,128.00	1,128.00	1,128.00	1,128.00	1,128.00	1,128.00	1,128.00	1,128.00	1,128.00
Hired labour	30.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00
Security	30.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00
Repairs & maintenance	50.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Aquaculture permits	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00
Total production based costs	794.00	1,568.00	1,568.00	1,568.00	1,568.00	1,568.00	1,568.00	1,568.00	1,568.00	1,568.00
EBITDA	1,486.00	712.00	712.00	712.00	712.00	712.00	712.00	712.00	712.00	712.00
Depreciation	24.50	24.50	24.50	24.50	24.50	18.50	18.50	18.50	18.50	18.50
EBT	1,461.50	687.50	687.50	687.50	687.50	693.50	693.50	693.50	693.50	693.50
Net Income	1,461.50	687.50	687.50	687.50	687.50	693.50	693.50	693.50	693.50	693.50
Cash flows	**1,486.00**	**712.00**	**712.00**	**712.00**	**712.00**	**712.00**	**712.00**	**712.00**	**712.00**	**712.00**

Note: This table shows a 10-year income projection for cage culture under scenario one where the fisher obtains a grant from AQZ for the initial set-up.

Table 14: Scenario two income projection – pond culture

Item	Year									
	2017	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**
Revenue										
Sales	2,160.00	2,160.00	2,160.00	2,160.00	2,160.00	2,160.00	2,160.00	2,160.00	2,160.00	2,160.00
Production based costs										
Fingerlings	200.00	200.00	200.00	200.00	200.00	200.00	200.00	200.00	200.00	200.00
Feed costs	1,128.00	1,128.00	1,128.00	1,128.00	1,128.00	1,128.00	1,128.00	1,128.00	1,128.00	1,128.00
Hired labour	40.00	40.00	40.00	40.00	40.00	40.00	40.00	40.00	40.00	40.00
Security	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00
Repairs & maintenance	40.00	40.00	40.00	40.00	40.00	40.00	40.00	40.00	40.00	40.00
Fertiliser	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00
Total production based costs	1,482.00	1,482.00	1,482.00	1,482.00	1,482.00	1,482.00	1,482.00	1,482.00	1,482.00	1,482.00
EBITDA	678.00	678.00	678.00	678.00	678.00	678.00	678.00	678.00	678.00	678.00
Depreciation	22.00	22.00	22.00	22.00	22.00	16.00	16.00	16.00	16.00	16.00
Interest	22.80	21.50	20.05	18.42	16.59	14.55	12.26	9.69	6.82	3.60
EBT	633.20	634.50	635.95	637.58	639.41	647.45	649.74	652.31	655.18	658.40
Net Income	633.20	634.50	635.95	637.58	639.41	647.45	649.74	652.31	655.18	658.40
Net Cash flows	**655.20**	**656.50**	**657.95**	**659.58**	**661.41**	**663.45**	**665.74**	**668.31**	**671.18**	**674.40**

Table 14 shows a 10-year income projection for pond culture under scenario two where the fisher borrows funds from a financial institution for initial set-up.

Table 15: Scenario two income projection- cage culture

Item	Year									
	2017	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**
Revenue										
Sales	2,280.00	2,280.00	2,280.00	2,280.00	2,280.00	2,280.00	2,280.00	2,280.00	2,280.00	2,280.00
Production based costs										
Fingerlings	200.00	200.00	200.00	200.00	200.00	200.00	200.00	200.00	200.00	200.00
Feed costs	1,128.00	1,128.00	1,128.00	1,128.00	1,128.00	1,128.00	1,128.00	1,128.00	1,128.00	1,128.00
Hired labour	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00
Security	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00
Repairs & maintenance	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Aquaculture permits	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00
Total production based costs	1,568.00	1,568.00	1,568.00	1,568.00	1,568.00	1,568.00	1,568.00	1,568.00	1,568.00	1,568.00
EBITDA	712.00	712.00	712.00	712.00	712.00	712.00	712.00	712.00	712.00	712.00
Depreciation	24.50	24.50	24.50	24.50	24.50	18.50	18.50	18.50	18.50	18.50
Interest	25.80	24.33	22.68	20.84	18.77	16.46	13.87	10.97	7.72	4.08
EBT	661.70	663.17	664.82	666.66	668.73	677.04	679.63	682.53	685.78	689.42
Net Income	661.70	663.17	664.82	666.66	668.73	677.04	679.63	682.53	685.78	689.42
Cash flows	**686.20**	**687.67**	**689.32**	**691.16**	**693.23**	**695.54**	**698.13**	**701.03**	**704.28**	**707.92**

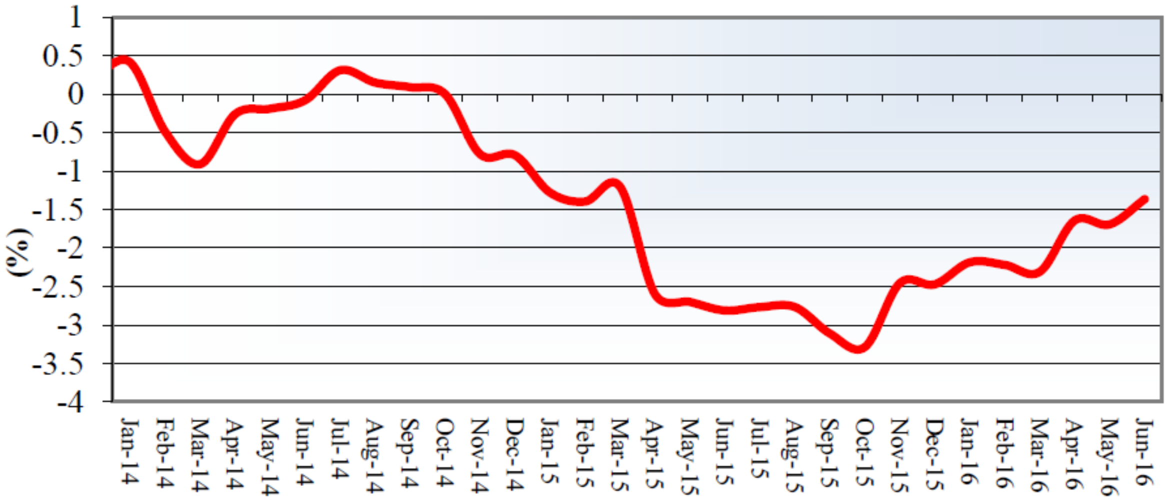
Note: This table 15 shows a 10-year income projection for cage culture under scenario two where the fisher borrows funds from a financial institution for initial set-up

4.6. Cash flow statements

To compute the cash flows from the values detailed in the income statement, it was assumed that all cash flows occur at the end of each year, except for the initial cash outflow which occurs immediately (at time zero). Moreover, both cage and pond culture are assumed to generate cash flows for the entire duration of the 10-year horizon.

Inflation in Zimbabwe has remained low, well below annual levels of 5% in 2009 and for 2016 it has consistently been in the negative territory as shown in Figure 11 below. Although inflation has been in the negative for some time, interest rates have largely remained quite high. Nyarota et al. (2015) explained that the high cost of credit has been driven by the expensive credit lines that banks have been accessing offshore at about 10% per annum due to the perceived high risk country profile. Zimbabwe has been accumulating external payment arrears further increasing its risk. At 10% per annum, offshore loans are way above the 365 day London Interbank Offered Rate (LIBOR) of 1.07% per annum thereby effectively making the cost of capital in Zimbabwe very expensive when compared with international developments (Nyarota et al., 2015). The inflation outlook is expected to remain broadly subdued due to persistently low aggregate demand in the economy which will put more downward pressure on prices in the economy (RBZ, 2016). Therefore the forecasted cash flows will not be inflation-adjusted.

Figure 11: Annual inflation profile for Zimbabwe (January 2014 - June 2016)



(Source: RBZ, 2016, p. 23

4.6.1. Opportunity cost of venturing into aquaculture

Within the CBA framework, it is imperative to compare the aquaculture options to the baseline. In this regard, the fishers are not giving up traditional fishing to embark solely into aquaculture but rather are encouraged to use aquaculture to diversify their livelihoods. By doing this, they will have to forego some of their traditional fishing trips and the lost income associated with this can be viewed as an opportunity cost. An opportunity cost refers to the value of what would be earned from using an identified resource for one purpose instead of the other (Engle, 2010). Specifically, it refers to the economic value of the next best option that must be given up (Engle, 2010; Harrison, 2010).

As explained previously, learning is an important condition associated with the grant provided by AQZ. Hence the fisher will be expected to attend technical training and other related activities, especially during the first full year of starting an aquaculture project. Hence from the usual 3 fishing trips per week, the fishers will forgo 2 fishing trips during the first year and thereafter only 1 fishing trip per week. Therefore, during the first year, fishers will forgo a total of 44 fishing trips per production cycle (2 trips x 22 weeks) and 88 trips in a year. Under scenario two, even though the fisher has not accessed a grant, he is still going to devote his time and labour towards establishing the aquaculture project. However, he may be able to retain more flexibility than under scenario one. As a result, the fisher will forgo only a single trip per week or 44 per annum spanning the two production cycles. The product of the profit from each fishing trip (as shown in table 2) and the total number of fishing trips forgone was used as the opportunity cost of engaging in aquaculture alongside traditional fishing instead of only traditional fishing.

4.6.2. **Scenario one**

The cash flows for the pond and cage culture under scenario one are shown in the following two tables.

Table 16: Scenario one cash flow projection – pond culture

Item	-	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
Cash flows from operating activities		1,412.00	678.00	678.00	678.00	678.00	678.00	678.00	678.00	678.00	678.00
Opportunity cost - reduced number of fishing trips		812.15	406.38	406.38	406.38	406.38	406.38	406.38	406.38	406.38	406.38
Net cash flows from operating activities		**599.85**	**271.62**	**271.62**	**271.62**	**271.62**	**271.62**	**271.62**	**271.62**	**271.62**	**271.62**
Discount rate	0.12										
NPV	**$1,827.78**										

Note: This table shows a 10-year cash flow projection for pond culture under scenario one where the fisher obtains a grant from AQZ for initial set-up.

Table 17: Scenario one cash flow projection – cage culture

Item	-	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
Cash flows from operating activities		1,486.00	712.00	712.00	712.00	712.00	712.00	712.00	712.00	712.00	712.00
Opportunity cost - reduced number of fishing trips		812.15	406.38	406.38	406.38	406.38	406.38	406.38	406.38	406.38	406.38
Net cash flows from operating activities		**673.85**	**305.62**	**305.62**	**305.62**	**305.62**	**305.62**	**305.62**	**305.62**	**305.62**	**305.62**
Discount Rate	0.12										
NPV	**$2,055.60**										

Note: This table 17 shows a 10-year cash flow projection for cage culture under scenario one where the fisher obtains a grant from AQZ for initial set-up.

4.6.3. Scenario two

The cash flows for the pond and cage culture under scenario two are shown in tables 18 and 19. Consistent with the explanations provided in the preceding chapter, these cash flows were discounted at 12% and the three CAB criteria – NPV, IRR and BCR were computed.

Table 18: Scenario two cash flow projection – pond culture

Item	-	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
Cash flows from operating activities		655.20	656.50	657.95	659.58	661.41	663.45	665.74	668.31	671.18	674.40
Opportunity cost - reduced number of fishing trips		406.38	406.38	406.38	406.38	406.38	406.38	406.38	406.38	406.38	406.38
Net cash flows from operating activities		**248.82**	**250.12**	**251.57**	**253.20**	**255.03**	**257.07**	**259.36**	**261.93**	**264.80**	**268.02**
Initial investment	-190.00										
Total cash flow	**-190.00**	**248.82**	**250.12**	**251.57**	**253.20**	**255.03**	**257.07**	**259.36**	**261.93**	**264.80**	**268.02**
Discount rate	0.12										
NPV	**$1,251.38**										
IRR	**131.50%**										
BCR	**7.59**										

Note: This table shows a 10-year cash flow projection for pond culture under scenario two where the fisher borrows funds from a financial institution for initial set-up.

Table 19: Scenario two cash flow statement - cage culture

Item	-	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
Cash flows from operating activities		686.20	687.67	689.32	691.16	693.23	695.54	698.13	701.03	704.28	707.92
Opportunity cost - reduced number of fishing trips		406.38	406.38	406.38	406.38	406.38	406.38	406.38	406.38	406.38	406.38
Net cash flows from operating activities		**279.82**	**281.29**	**282.94**	**284.78**	**286.85**	**289.16**	**291.75**	**294.65**	**297.90**	**301.54**
Initial investment	-215.00										
Total cash flow	**-215.00**	**279.82**	**281.29**	**282.94**	**284.78**	**286.85**	**289.16**	**291.75**	**294.65**	**297.90**	**301.54**
Discount Rate	0.12										
NPV	**$1,406.21**										
IRR	**130.69%**										
BCR	**7.54**										

Note: This table shows a 10-year cash flow projection for cage culture under scenario two where the fisher borrows funds from a financial institution for initial set-up.

4.7. Results of the economic evaluation tools

The NPVs for scenario one for the two adaptation options are shown in the table 22 below. The absence of upfront investment costs eliminated the possibility of using IRR and BCR for this scenario. The NPV, BCR and IRR results for scenario two are shown in the table 23 thereafter.

Table 20: Summary of scenario one cash flow projections

Economic evaluation tool	Pond culture	Cage culture
NPV	$1827.78	$2055.60

Table 21: Summary of scenario two cash flow projections

Economic evaluation tool	Pond culture	Cage culture
NPV	$1251.38	$1406.21
IRR	131.5%	130.69%
BCR	7.59	7.54

The absolute NPV values for pond and cage culture under scenario one were $1827.78 and $2055.60 respectively at a discount rate of 12%. Using the same discount rate of 12% for both pond and cage culture, positive NPVs of $1251.38 and $1406.21 respectively were found under scenario two. Comparing pond and cage culture under both scenarios, the NPV values are all positive with the highest being cage culture and scenario one ($2055.60) and the lowest being pond culture are scenario two ($1251.38).

Shongwe, Masuku and Manyatsi (2014) indicated that when comparing climate change adaptation options, the one with the highest NPV is the most efficient and economically viable. While it may hold true that an option with a high NPV may yield higher benefits in absolute terms and should therefore be prioritised when allocating scarce resources, it may not necessarily be true that it yield the highest benefit per dollar spent (GIZ, 2013; Shongwe et al., 2014). A ratio of benefits to costs is needed so as to shed more light.

Considering scenario two, the BCR for pond and cage culture were 7.59 and 7.54 respectively. Both are well above the threshold of 1 which signifies that they can be accepted since benefits exceeds the costs. The higher the adaptation option's BCR when compared to others, the more acceptable it is. The BCR for pond culture is slightly more than that for cage culture. This means that the overall value for money is marginally better in pond culture than it is in cage culture due to the fact that the BCR helps in clarifying the specific benefits that can be obtained per dollar of cost invested.

The IRR for both pond and cage culture under scenario two were substantially larger than the 12% discount rate used at 131.5% and 130.69% respectively. This means both options IRRs are more than the discount rate and this makes them desirable as it exceeds the opportunity costs of capital needed. The higher IRR of the pond culture is consistent with the BCR which also showed this adaptation option to be preferable to the cage culture compared to the NPV where the opposite was true.

Considering scenario one in this research, the NPV for cage culture was found to be 13% more than the one for pond culture. When a grant is provided and the fisher has no upfront investment costs, fishers venturing into cage culture stand to benefit more in absolute terms than those opting for pond culture. However, considering scenario two in this research, the annual net cash flows over the ten-year period increase gradually as the interest payment decreases. The NPV for cage culture is more than that for pond culture by a margin of 12%. However, the IRR for pond culture (131.5%) is higher than for cage culture (130.5%). In addition, the BCR for pond culture (7.59) is more than for cage culture (7.54).

When basing a decision about which adaptation option is preferable on NPV, cage culture will be selected. This is because it maximises the NPV more than pond culture under scenario one. However, if we base the preference decision between pond and cage culture on IRR and BCR under scenario two, then pond culture will be selected. Such a decision will be on the basis of pond culture having a higher IRR and BCR than cage culture. Nonetheless, cage culture will still be ranked on top if the NPV method is solely used as it has a higher value. This creates a conflict which makes decision making difficult under scenario two.

When faced with such a situation, the conflict may be caused by a difference in the scale of investment made. On one hand IRR ignores the scale initial investment made as it expresses the value as a percentage while BCR looks at relative profitability which also ignores the initial investment (Van Horne & Wachowicz, 2008). On the other hand, the NPV method takes into account the initial investment made and its value is expressed in absolute dollar increase in value to the fisher. Hence with respect to the absolute dollar returns, cage culture becomes more preferable to pond culture even though its IRR and BCR are lower than pond culture. Van Horne and Wachowicz (2008) notes that it is the greater scale of initial investment that allows for the greater NPV value that often ensues. It is important to note that the cash flows pattern and the review periods considered were similar except for the initial investment required. Cage culture required on initial investment of $215 compared to $190 for pond culture.

4.8. Sensitivity analysis

In line with the recommendation by Engle (2010) about varying the values of important parameters during a sensitivity analysis, the discount rate, selling price of fish in the market, the price of fish feed were varied to a pessimistic position. The results are summarised in the table below and explained thereafter.

Table 22: Sensitivity analysis

Scenarios	Fish production system	NPV @ base case	% change in NPV after a 10% increase in the fish feed cost	% change in NPV after a 10% decrease in the fish selling price	% change in NPV after a 10% increase in the discount rate
Scenario one	Pond	$1827.78	-32%	-67%	-27%
	Cage	$2055.60	-29%	-63%	-27%
Scenario two	Pond	$1251.38	-51%	-98%	-36%
	Cage	$1406.21	-45%	-92%	-36%

Scenario one: An increase in fish feed costs by 10% leads to a decrease in the NPV by 32% and 29% for pond and cage respectively whereas a decrease in the selling price by 10% leads to a decrease in the selling price by 10% leads to a decrease in the NPV by 67% and 63% for pond and cage respectively. A 10% increase in the discount rate results in a 27% decrease in the NPV for both pond and cage culture systems.

Scenario two: An increase in costs by 10% triggers a decrease in the NPV by 51% and 45% for pond and cage respectively. A 10% decrease in fish selling price leads to a decrease in the NPV by 98% and 92% for pond and cage respectively. A 10% increase in the discount rate results in a 36% decrease in the NPV for both pond and cage culture systems.

Although scenario two yields better NPV values in absolute terms, the levels of sensitivity to changes in the market will render the fishers more vulnerable to changes in the market than would be the case under scenario one. In addition to the advantages of receiving training and mentorship under scenario one, the fishers venturing into aquaculture under scenario one will have more returns than those under scenario two when considering absolute NPV values. Cage culture under scenario one is the most economically viable adaptation option while the least viable is pond culture under scenario two.

Comparing pond and cage culture under both scenarios, it is apparent that cage culture is more economically viable than pond culture as evidenced by the NPV values. The sensitivity of cage culture in the event of an increase in fish feed cost and discount rate remains lesser than that of pond culture. This shows that cage culture is more resilient and stable adaptation option which can withstand shifts in the market more than is the case in pond culture. Market changes often occurs in times of extreme events such as droughts among other phenomenon which are likely to increase as a result of climate change.

When it comes to the price of inputs, both NPV values are sensitive to changes in the price of fish feed under both scenarios. While this is the case for both options, the price of fish feeds will affect pond culture more than it does cage culture. It is currently inevitable for fishers to rely on commercially available fish feeds for both pond and culture due to the limited availability of alternative feeds. Williams and Rota (2013) noted that many rural aquaculture farmers particularly in resource constrained parts of the developing countries invest less inputs into their fish farms thereby only managing to have poor harvest as a result of overly depending on the ecosystem for the wellbeing of their fish. Although the price of feeds are very high and form a substantial percentage of the total production costs per cycle (76% for pond culture and 71% for cage culture), they ensure that the fishers produce market ready fish that can realistically complement their income from fisheries. Any significant changes in the cost of feed will therefore have a considerable impact on the overall costs as well as the net inflows. A favourable situation would be a reduction in the cost of feed which would reduce the costs and increase the NPV values.

However, the feed from Aquafeeds is higher priced per unit of mass as compared to feed from other suppliers but the latter products are not readily available and also not pelletized. Talapia is not a bottom feeder and hence use of feed not pelletized is usually associated with high degree of underutilisation of feed that sinks to the bottom surface of the pond. Complete and extruded good quality pellets are a must for cage culture where feed can easily escape out of the cages and carried by currents.

The net income from both pond and cage culture is very sensitive to the changes in market price for fish. Cage culture is slightly more sensitive than pond culture since a similar change (10%) in the parameter resulted in a higher percentage change. The market price for fresh fish has been stable at around $3 per kilogram over the study period. A decrease in price will be undesirable as the adaptation options are very sensitive.

5. Chapter five: Conclusion and recommendations

Climate change impacts have global ripple effects being felt across different economic sectors. The fisheries and aquaculture sector is no different. What differs is the adaptive capacity of the communities which are dependent on the fish for their livelihoods. Community dependence on fisheries is very risky because the productivity of fisheries depends to a large extent on the ecosystem. Somehow the fisheries sector across the globe has remained stuck in hunting wild fish while the rest of the world has moved on to modern methods of food production (Allison et al., 2010). To think of using aquaculture to help vulnerable fishers adapt to climate change may seem unwise on one end and the easiest thing to do on the other end. This is because, for the most part, the environmental changes due to climate change may have an impact on the extent to which different fish species may grow and or react whether in captivity or in the wild. However, the levels of human control in aquaculture are giving confidence that vulnerable fishers may need not look further than the fish only, that instead of relying on hunting them, they can farm and harvest them. This will not only increase their adaptive capacity but also ensure that they have resilient livelihoods.

The results of this economic analysis confirm that it is indeed economically viable to practice both pond and cage culture in fisher communities of Zimbabwe. Cage culture was found to have a higher NPV under both scenarios when compared to pond culture. However, under scenario two, pond culture was found to have a higher IRR rate and BCR ratio. The inconsistencies were due to the variations in the scale of upfront investments between pond and cage culture where the latter requires a higher initial investment. Key factors that affect the viability of aquaculture as an adaptation strategy in Zimbabwe include the market price of fish, the cost of fish feeds and the price of fingerlings. While these factors are primarily economic, there are other factors which may affect the viability such as the increasing frequency of natural disasters.

The findings of this study are in line with Brummet et al. (2008) who noted that the different forms of aquaculture practiced in Africa are potentially profitable. In a previous study, Brummet and Williams (2000) had argued successfully that aquaculture is a viable proposition for rural development in Africa if done properly. This study has narrowed down aquaculture to specific forms that can be feasible and managed viably at a small scale under a resource constrained environment. The fact that aquaculture in fisher communities of rural Zimbabwe is economically viable is very important to the fishers themselves, aid agencies, the government and the private sector. This research has taken place against the backdrop of increasing demand for fish and fish products across the globe and decreasing fish catches from the wild. Firming demand for fish will result in aquaculture making an important contribution towards climate change adaptation among fishers in their communities and ultimately the economy will also grow.

Development agencies have long invested in different sectors as part of rural development aimed at diversifying livelihoods, supporting communities to cope with the changing climate and to reduce poverty. Investments in the aquaculture sector will result in some of these goals being achieved. Development agencies can promote the wider adoption of economically viable aquaculture systems particularly in low lying areas of Zimbabwe that have access to water. For the fishers, the protection of their livelihood has often been difficult given that fishing is largely open to all. Economically viable aquaculture offers them more control over their livelihoods and therefore stability and security from seasonal fishers over time.

In a little over five years, a tripartite relationship involving the private sector, civil society and the public sector has laid the foundation for the establishment of an aquaculture industry in Zimbabwe. This work has been done with groups of rural fishers who have been existing in the periphery of development and modernity, living away from many urban centres across the country. The private sector is providing essential inputs to aquaculture at reasonable prices and civil society mobilising and providing technical assistance to the fishers all in the enabling environment which the government is creating.

However, if the gains made in aquaculture are to be maintained and strengthened, then certain key factors have to be managed as they have a direct bearing on the economic viability of the industry, particularly pond and cage aquaculture, which can be practised right at the base of the pyramid. These factors include the quality and price of fish feeds made available in the market. Feeds make the biggest proportion of the cost of production for fish and has consequences on the survival rates of fish. Although the survival rate of fish in pond or cage culture also depends to a large extent on the quality of the fingerlings in the first place, having the right feeds in the right form plays a major role in sustaining meaningful fish growth rates. Ultimately, the market price for fish will determine whether it remains worthwhile to continue in aquaculture or not. In the backdrop of these conclusions; the following recommendations are therefore noted.

There is need to ensure that the growth of aquaculture becomes market demand driven. This will give momentum to the adoption of aquaculture in fisher communities and lead fishers to invest more time and effort producing their own fish rather than relying on wild stocks. One way to ensure that the market for fish remains lucrative is to tap into international export markets. The already established close links with the private sector will be key in moving towards this direction as the companies involved may use their international networks and systems to boost their volumes using fish from the fishers.

Since the fish feed is the single biggest production cost for aquaculture, there is need for investment in means and methods of supplementing commercial feeds with farm-based ones. This will drive the production costs downwards and increase the profit margin for the farmers who adopt fish farming as a climate change adaptation option.

5.1. Policy considerations

Financing: Considering the current economic situation in Zimbabwe and the cash inflows for fishers, the starting capital for establishing an aquaculture production system established in this study to be around $190.00 for pond culture and $210.00 for cage culture coupled to initial production costs may be beyond the reach of many rural vulnerable fishers. The government, finance institutions as well as development partners have a major role to play in the development of aquaculture in these threatened areas and their involvement will ease the challenges associated with the lack of finance among the communities.

Funding for aquaculture: Economic viability of aquaculture depends to a large extent on the nature and type of funding available and accessible to fishers. This research had two scenarios which explored two funding streams; donor grants and bank loans. The two possible sources of aquaculture funding has the potential to promote economically viable aquaculture as an adaptation strategy. In addition, donor grants creates opportunities for other fishers to learn important parameters of fish production such as feeding regimes and markets for inputs and possible produce. Such learning is important as it forms part of the basis of decision making on venturing into aquaculture or not. Apart from grants and loans, there is need for trade credit facilities being availed for fishers to cover initial production costs whenever they access a loan for the initial investment. Ultimately, the issue of opportunity costs is also important in shaping decision making about adopting aquaculture as fishers will have to weigh the impacts of venturing into aquaculture on their net bottom line over time.

Opportunity costs: Venturing in aquaculture has some opportunity costs particularly when considering that fishers will have to devote their time and labour which they would have otherwise directed toward their traditional fishing activities. Under scenario one where fishers work with an NGO, the opportunity cost of adopting aquaculture is 50% higher than in scenario two where fishers venture into aquaculture on their own during the first year. Most of the fishers' time will go towards providing labour during set up and attending NGO capacity building activities. However, in scenario two fishers still spend some time engaging markets on their own sourcing financing and inputs and establishing the infrastructure. Nonetheless, they retain a bit more flexibility and are more likely to manage opportunity costs better. Although the opportunity costs calculated herein are higher for fishers that use donor grants, there are many other non-monetary benefits that they obtain such as increased levels of knowledge about aquaculture as a result of training. Fishers venturing into aquaculture on their own may also incur invisible costs as they search for information about fish farming as well as input markets among other things.

Enabling environment for rural aquaculture development: The government needs to consider a policy framework that creates an enabling environment for potential investors to participate in rural aquaculture. Key areas where private investment will make a huge impact in the growth of the sector is in fish feed and seed production as well as research and development that aims at refining practical technical advice to the farmers. The aquaculture support industry needs a policy framework that supports innovation so as to incrementally improve the general quality of aquaculture inputs on the market. Such private sector driven initiatives will increase fish productivity and generate critical mass from small scale fish producers that is needed in servicing growing local and international markets. Existence of a policy framework is also important to development agencies as it creates a platform from which they can advocate and lobby for sustainable and inclusive development of the aquaculture sector in Zimbabwe

5.2. Non-monetary costs and benefits

Adopting aquaculture as an adaptation strategy has some costs and benefits which cannot be quantified in monetary terms. Ideally, attaching market values to such costs and benefits is the recommended practice. However, market values can be identified in an environment where markets are functional and reliable data is available. All the data regarding factors that may distort market values such as taxes and subsidies needs to be available. This has not been the case for this research. Although the study would have been benefited immensely from including non-monetary costs and benefits, the problems of including distorted values are more than would be created by leaving them. The issue of externalities is a challenge which is generally experienced when evaluating adaptation options using CBA. It is methodological weakness that broadly applies to CBA.

5.3. Recommendations for future research

There is need for economic evaluations of adaptation options in not only fisher but also non-fisher rural communities in Zimbabwe. While this study has assessed the feasibility and economic viability of one adaptation option using the CBA approach, there is need to expand the scope of economic evaluations by using other approaches such as the MCA, EJ and CEA. Future studies may also consider the inclusion of non-monetary costs and benefits of adaptation options in their evaluations. Such considerations may also make use of qualitative as opposed to quantitative documentation of the costs and benefits of different adaptation options feasible in Zimbabwe.

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