Thesis for the Degree of Master of Fisheries Science

An Economic Analysis for Pond Culture Systems of Nile Tilapia (*Oreochromis niloticus*) in Ghana

By

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KOICA-PKNU International Graduate Program of Fisheries Science

Graduate School of Global Fisheries

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February 2014

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가나 나일틸라피아의 연못양식시스템에 대한 경제적 분석에 관한 연구

Advisor: Prof. Heedong Pyo

By

Diana Sakyibea Obuobi

A thesis submitted in partial fulfilment of the requirements for the degree of

Master of Fisheries Science

In KOICA-PKNU International Graduate Program of Fisheries Science

Graduate School of Global Fisheries

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February 21, 2014

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Abstract

Aquaculture is very promising in Ghana particularly Nile tilapia (*Oreochromis niloticus*) culture. Little information is known about the cost of Nile tilapia production. The various culture systems in producing Nile tilapia (*Oreochromis niloticus*) with or without African catfish (*Clarias gariepinus*) predation in ponds were used in order to obtain the economic viability as well as assist in financial planning for fish farmers in Ghana. Three scenarios were used in this study namely, mixed sex with or without African catfish predation and all male (Hand sexed) were the three Scenarios that were evaluated in this study. An ideal pond size of 600m² was used for all the three systems and three fingerlings per meter squared were used as stocking rate. Complete compound feed was used throughout the production cycle for all the above listed scenarios. A twenty year project plan was made for all the three systems. The production cycle was one year, of which harvesting was to be done. All male tilapia production proved superior to polyculture and mixed sex without predation. It has a Net Present Value (NPV) of US$12,399.49 as polyculture and mixed sex culture without predation has NPV's of US$11,042.41 and US$1,358.13 respectively at the discount rate of 10%. Internal Rate of Return (IRR) for all male tilapia culture was 37%and Benefit Cost Ratio (BCR) of 1.43.34% IRR for polyculture and BCR of 1.44.17% IRR for mixed sex culture without predation with a BCR of 1.06 also at 10% discount rate.

Sensitivity analysis is also calculated to know the most sensitive of all the parameters. For this reason, +10% (1.1) is added to all the parameters and -10% (0.9) is also added to the parameters. In all, cost is the most sensitive in all the parameters. Revenue is the least sensitive for mixed sex without predation and all male tilapia production but discount rate is the least sensitive in polyculture. The De Graaf model is used to calculate at a given point in time, the number of fish that will be in the pond. To achieve this, natural mortality and predator mortality is calculated each month in order to know the number of fish that will remain in the pond in every month. Mixed sex without predation has the largest number of fish at harvest time as three fourth of the biomass at harvest was made of recruits. The predator density reduced with time as the African catfish are known to be highly carnivorousand voracious predators.On the other hand, there was a slight increase of the all male tilapia culture due to human error as the male selection was manually done. The study recommends that farmers should practice all male tilapia production as fish gain uniform and big size, it yields high returns and harvesting can be done in a short time. In addition to that, the government together with the Fisheries Ministry should organise more trainings on the manual selection of the male tilapia in order to avoid the few incorporation of females into the supposed all males' tilapia production system resulting in the recruits.

CHAPTER 1 INTRODUCTION

Fisheries constitute an important sector in the national economic development contributing 3% of the national GDP and 5% of the Agricultural GDP in Ghana. It provides livelihood options in rural areas of developing world as it creates employment and income for many Ghanaians and other countries. With a per capita consumption of about 25 kg per annum, fish is a preferred source of animal protein in Ghana. Fish is expected to contribute 60% of animal protein intake of Ghanaians.About 75% of the total domestic production of fish is consumed locally. The fishing industry in Ghana is based on resources from the marine and inland (freshwater) sectors, coastal lagoons and aquaculture.

Aquaculture plays an important role in the development of many national economies and a key role in the social-economic resilience of the rural areas, potentially offering valuable and skill-based employment opportunities, and in some cases stabilizing the economic base of otherwise fragile communities (Edwards, 1999; Haylor and Bland, 2001; Muir, 1999). In 2011, annual production of tilapia and catfish in Ghana were 19,092.563MT of which 8% was from ponds, 85% from cages and others (dugouts, reservoir and dams) 7%. Egypt, South Africa, Nigeria and Morocco contributed 42% out of a total of 7.5 million MT that's 5.6% of the world population. This is the total fish production in Africa in the year 2002. The other 50 African countries contributed 58%. Protein is an essential component in human body and it's mainly obtained through animal sources of livestock, wildlife and fish. The livestock and wildlife have failed to meet the animal protein need of many Africans. The fish production sector is very important not only as an animal protein source to ensure food security but also improve employment and income for poverty elimination in developing countries. The average daily protein intake of Africans is very low. This then leads to malnutritional diseases, mostly among young people. Malnutrition has been recognized as a major factor affecting health, socio-economic development and well being of the people in developing countries. It causes child morbidity and mortality. Maternal health, high proportion of low birth-weight babies and poor outcome of pregnanciesare all causes of malnutrition. FAO 1977 has declared that 38% of children under the age of six years in developing countries suffer from moderate to severe under malnutrition. In Africa, Egypt, Nigeria, Madagascar and Ghana contributed 90% of the continental total aquaculture production in the year 2002.To bridge this gap, there's the need to intensify fish farming which is the only alternative to solving the menace. In Ghana, fish farmers are faced with many challenges which include, high cost of complete compound feed, inadequate resources for the continues monitoring of all farmers across the country, inadequate and less quality fingerlings among others.Tilapia and African catfish have been the two main species cultivated by fish farmers in Ghana.One major problem of tilapia farming has been the early reproduction of the female tilapia causing overpopulation in the pond. This results in many problems such as harvesting fish of smaller sizes even if production period takes one or more years. Many Ghanaians prefer tilapia of big sizes and so it becomes a problem selling those fishes. There have been other ways of controlling the menace. These include incorporating of catfish in the same pond of the mixed sex tilapia in other to control the population.

Other method can also be the culture of only male tilapia so that there will be no reproduction and these two methods have yielded positive for farmers but little information is known about the economic analysis of Tilapia farming. This therefore resulted in the need for this study. The De Graaf Model is used to assess the pond with time. This includes the predators relation at each time, the natural mortality rate, number of recruits produced in each month as well as the number of fish in the ponds at a particular time. This helps to know the stock assessment of each of the ponds.

The objectives of this study are**:** Firstly, to estimate and compare the economic evaluation of mixed sex tilapia (*Oreochromis niloticus*) with or without catfish (*Clarias gariepinus*) predation and all male/ hand sexed tilapia culture. Secondly, to estimate the stock assessment for the mixed sex tilapia with or without predation and the all male hand sexed production. Finally, to estimate the cost of the three tilapia farming methods.

CHAPTER 2 FISH PRODUCTION IN GHANA

2.1 Marine Fisheries

The fishing industry consists of marine fisheries, freshwater fisheries and lagoon fisheries. Marine fisheries account for over 80% of the fish consumed in Ghana as shown in Table 1.The marine fishing industry in Ghana consists of three main sectors namely: small scale (or artisanal), semi-industrial (inshore) and industrial sectors.The artisanal (wooden canoes) sub-sector is the most important in terms of fish outputs in the marine sector and contributes about 60–70% of the marine fish output. The semi-industrial (inshore) fleet consists of locally built wooden vessels of 8-37m in length with in-board engines of 400HP. Industrial vessels are large, steel-hulled foreign built trawlers, shrimpers, tuna pole and line vessels and purse seiners. Over 300 different species of commercially important fish, 25 species of crustaceans and 3 turtle species are caught from marine sources in Ghana.Small pelagic species of the families Clupeidae (Sardinellas), Scombridae (chub-mackerels) and Engrulidae (anchovies) together with large pelagic species of the family Thumidae (tunas) also exist. The main commercial tuna species which occur in Ghanaian waters are the Yellowfin

(*Thunus albacares)*, Skipjack (*Katsuwonus pelamis*) and Bigeye (*Thunus obesus*). Export of fish from Ghana comprises of frozen fish, tuna, dried or smoked fish and cuttlefish, and they are usually exported to European Union countries.

2.2 Freshwater/ Inland Fisheries

Total inland fishery production in Ghana is dominated by Lake Volta fishery which contributes about 90% of the landings. The Lake Volta is rich in fish and about 140 species of fish could be identified e.g Tilapia spp., *Chrysichthys* spp., *Synodontis* spp., *Labeo* spp. Etc. The Volta Lake covers an area of 8,480km and a length of 410km (Fig. 1).

Sources:https://www.cia.gov/library/publications/theworldfactbook/graphics/maps/larg

Fig. 1 The map of Ghana, showing the various boarder countries and the Volta Lake

Table 1 Total fish production of wild catch and aquaculture in Ghana

(Unit: 000MT)

Year	2005	2006	2007	2008	2009	2010	2011
Marine	322.8	323.6	291	343	326	305	300
Inland	81.6	81.3	81.5	81	75.8	74	73
Aquaculture	1.15	1.67	3.26	5.6	7.2	10.2	19.6
Total	405.55	406.57	375.76	436.6	409	389.2	392.6

Sources:Ministry of Food and Agriculture (Fisheries Commission/Ghana)

2.2.1 Lagoon Fisheries

There are more than 50 lagoons of various sizes located in the coastal area of Ghana. Lagoons provide an important source of protein and other resources for the communities that live around them. The most important of Ghana's lagoons is the Keta lagoon with a potential yield of 4,000 tonnes per annum. Most important commercial lagoon species in Ghana are tilapias, grey mullets, crabs, shrimps and oysters

2.2.2 Aquaculture

Fish farming started in 1953 when fish ponds were built by the former Department of Fisheries in the northern part of the country to serve as hatcheries to support the culture-based reservoir fishery development program. After gaining independence in 1957, the national government adopted a policy to develop fish ponds within all irrigation schemes in the country.State-owned irrigation facilities were to be developed, as far as it was technically possible under a policy of converting 5 percent of the scheme into fish farms. Fish farming is new to Ghanaians, but there is growing interest in it and its practice is becoming widespread in the country especially in the Ashanti, Brong Ahafo, Central, Eastern, Volta and Western Regions.The aquaculture sub-sector comprises largely small-scale subsistence farmers who practice extensive aquaculture in earthen ponds.Currently, fish are cultured semi-intensively in earthen ponds either as monoculture of tilapia or polyculture of tilapia and catfish. Cage culture in ponds has recently been introduced and is being practiced on one commercial fish farm. Pen culture with tilapia, recently introduced in the Keta lagoon, has been very successful.

Shrimp/prawn farming has not caught on in Ghana even though research has shown that there is a great potential for commercial farming of the local shrimp species, *Penaeus notialis* and *P. kerathurus.*

The sector therefore lacks the organization to take up the challenges of providing inputs such as fish seed and feed as viable commercial activities.

Main systems of production have been ponds, dugouts and reservoirs with pens and cages becoming production systems after 2000. Currently there are 4,852 fish farmers in Ghana. Operational ponds are 4,560.Total surface area of the operational ponds is 680.41ha. Total production in 2011 was 19,092.563 MT. Most commonly cultured fish by farmers has been tilapias *(Oreochromis niloticus*) and African Catfish (*Clarias gariepinus)*

2.3 Fish Exports

Fish is the most important non-traditional export commodity and export earnings in the country. From fish and fishery products on an average account for approximately 60 million US Dollars annually. In 2002, Export earnings form fish and fishery product amounted to nearly US$96 million. The export destination is mainly EU countries.Fish and seafood exports from Ghana are made up of tuna (whole, loins and canned), frozen fish (mostly demersal species), shrimps, lobsters, cuttlefish and dried/smoked fish.

Table 2 The various regions in Ghana with the number of ponds in each region.

Regions	No. of Ponds
Brong Ahafo	1315
Central	527
Western	636
Eastern	285
Ashanti	1138
Greater Accra	260
Upper East	68
Upper West	17
Northern	75
Volta	239
Total	**4560**

Sources: *Fisheries commission – Ghana (2012)*

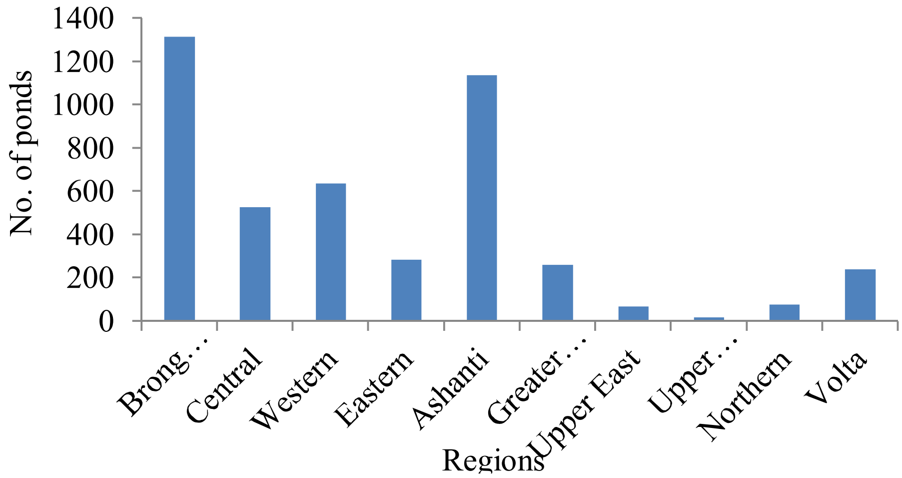

Fig. 2 The various regions and the number of ponds in Ghana (2012).

Catfish and tilapia production in the country from 2005-2011 is presented in Table 3 below. It could be realised that tilapia production increased yearly and from 2010 to 2011, it was almost doubled. On the other hand, catfish also increased yearly but from year 2008-2009 there was reduction in production, this was immediately followed by an increase in the year 2010 and then another decrease in 2011. This could be attributed to the inadequate number of hatcheries to produce the needed number and quality fingerlings for production. Increase in the tilapia production could be alsoattributed to the farmers' interest in tilapia culture and preference of the species to many Ghanaians.

Table 3 Annual productions of catfish and Tilapia in Ghana

(Unit: 000MT)

Year	Tilapia	Catfish
2005	1,023.12	130.78
2006	1,433.97	233.5
2007	2,805.34	451.33
2008	5,553.2	960.8
2009	6,292.04	861.65
2010	9,218.32	981.68
2011	18,163.53	929

Sources: *Fisheries commission-Ghana (2012)*

CHAPTER 3 MATERIALS AND METHODS

3.1Review of Previous Studies

A. Stock Assessment Model (De Graaf, 2005)

There are two kinds of simulation models for fish reared in ponds: descriptive-empirical models and explanatory-theoretical models, (de Graaf et al., 2005). Empirical models describe data without explaining the mechanism causing the relationship between data. According to Hopkins and Cruz (1982), in these models, there is no relationship between predator density and efficiency to control juvenile fish recruitment in ponds. Explanatory-theoretical models are based on the knowledge of biological process and flow underlying the production system. While biogenetic models balance the flow of energy, mass, nitrogen, and respiration (Ross and Mac-Kinney, 1989), population dynamic models balance numbers of fish or biomass in the production system (Fischer and Grant, 1994).

These economic simulation models were based on population dynamics as implemented through Tilapia Farming Support Tool (TFST) software (Nefisco 2003) as presented by De Graaf et al. (2005). The main advantages of the population dynamic models include allowing incorporation of prey-predator relationships in the model and modelling based on the individual fish growth dynamics (Sparre and Venema, 1992). The De Graaf et al. (2005) model consists of two modules.

The first module simulates the growth of tilapia (males, females, and recruits).

The second module simulates stocked predators. The model starts with an initial number of male and female tilapia and predators.

During initialization, each individual fish is randomly given a length and the growth parameters K and L are assigned.

The model calculates with steps of 1 day (Δt = 1day). Every day the model calculates the length increment for each individual fish according to the von Bertalanffy growth function: The natural mortality of tilapia and the predator is a function of the length of the fish. The mortality of tilapia caused by the predator is a function of the length of the tilapia and the length of the predator.

When the female tilapias reach their length at first maturity, they generate a number of recruits every day. Growth parameters are assigned to the new born recruits and they follow the same simulation cycle as the parent stock. After each step of1day, the weight of individuals is calculated with length-weight relationship and this is further used to calculate total biomass for the different groups:

Original stocked male tilapia

Original stocked female tilapia

Recruited male tilapia

Recruited female tilapia Predator.

The total weight of stocked tilapia and recruited tilapia is used to calculate the proportion of the fingerlings presented in the system, used for the adjustment of daily growth rate.

The feeding rate was adjusted according to the biomass of Nile tilapia as the African catfish is omnivorous. Each module is based on the principle of length-based fish stock assessment, whereby growth is simulated according to the von Bertalanffy growth function (Somers 1988). The evolution of the number of fish is simulated with an exponential decay function as discussed in Sparre and Venema (1992).

Pond size,

Number of rearing days,

Length of the stocked fingerlings,

Proportion of male fingerlings at stocking, Numbers and lengths of predation and feed levels were the input data set used. The data was used in 3 different experiments under different culture systems in different countries and years. These were followed by calibration and validation by adjusting the value of key parameters on mortality and growth reduction because of the biomass of fingerlings. The impact of four model parameters namely: growth parameter, stocking length of Nile tilapia fingerlings, length at first maturity of Nile tilapia and recruitment on stochastic behaviour of model outputs were investigated using the sensitivity analysis.

The economic analysis conducted are to determine the profitability of mixed-sex tilapia culture with or without catfish predation and hand- sexed all-male tilapia culture in a 600m² ponds. Even though there are different pond sizes owned by farmers, some have smaller ones of 100m²-400m² and others also have bigger ponds above 600m² but the standardized pond size is 600m². Meanwhile, smaller ponds are easily manageable compared to bigger ones. Weight at stocking is based on research recommendation. The cost of land is about US2000 for a hectare of land and can go up or come down depending on the area. Construction of pond is either done manually by pond construction gangs who charge US$1.5 per meter squared or mechanically by operators who charge US$ 400 per day and depending on the operator; he can construct two or more ponds in a day depending on the size. Maintenance and repair cost items are based on 1% of the pond construction and equipment cost (De Graaf, 2005).

Application of this model helps to monitor the performance of the fish at all times. By the use of Tilapia Farming Support Tool (TFST) each individual fish is virtually followed in the pond throughout the rearing period. For example the length increment of each fish within the day is observed. Total number of fish in the pond is known as the model eliminates dead fish from the system. The new fish (fingerlings) that come in are also captured by the model and the male to female ratio in the system are also known. This helps the farmer to know exactly the expected outcome from his farm such as total biomass at harvest, weight of fish at harvest, Revenue at harvest as well as the amount that went into the production cycle as the farmer provide his/her own financial data on:Investments, Feed cost inputs, Labour cost

The price the farmer will get for the different categories of fish at harvest.However, it has certain constrains which includes:Firstly, it does not incorporate natural productivity or water quality of the pond but growth of fish depends on feeding.Secondly, growth of fish depends on the water temperature that is the higher the temperature, the higher the fish grow but areas with low water temperatures that are less than 23 degrees Celsius cannot use this model.

Table 4 Parameters of De Graaf Model

Description	Variables
Number of fish in ponds: $N_t=N_o e^{(Mt+Pt)t}$	N_t, number of fish at time$t$ N_o, initial numberof fish at t=0 M_t,natural mortality rate P_t, predator related mortality rate
Probability of dying: $Pd,t=1\text{-}e^{(m1+p1)t}$ Length- weight relationship: $Wt=\beta_3 L_t^{\beta 4}$ Natural mortality rate: $M_{w,\,t}=M_u\beta_3^{-0.3}L_t^{-0.3\beta 4}$	$Pd,t,$ probability of dying at time t $Wt,$weight of fish(g) at time t Tilapia:β_3=0.0015;β_4=3.077 Catfish:β_3=0.0073;β_4=2.99 $M_{w,t}$, natural mortality at weight W_t M_u, natural mortality at unit weight Tilapia: M_u=1.0 Catfish:1 M_u=4.5
Predation relation: $P_{p,t}=\beta_5 D_t L_t^{-\beta}{}_6$	$P_{d,t,}$ tilapia mortality due to predation at time$_t$ D_t,predator density Catfish: β_5=280;β_6=1.5

Information in Table 4 is the various modelling parameters, economic variables that are used to select the best management option. Above is a table of the parameters calculated.

B.Opportunities and Challenges in Aquaculture

Deji et al. (2012) also discussed the challenges and investment opportunities for large scale aquaculture farmers in Nigeria which is related to fish farming in Ghana. According to the paper, the unprofitable operation in fish farms could be attributed to mainly two factors namely: poor production planning and inadequate technical know-how. The paper stated that most farmers are subsistence farmers but few are commercial farmers. There are many investment opportunities for large scale aquaculture: however, the challenges override these opportunities. The aquaculture constraints include high cost of fish feed, poor quality fish seed, technical know-how, poor water quality management amongst others. Majority of the catfish farmers operating Earthen Pond Production System (EPPS) were 68.84%whilst 31.16% were Concrete Tank Production System (CTPS). This is an indication that fish thrive well in their natural environment. 44.2% of farmers operating both EPPS and CTPS were between the ages of 41-50years. 10.5% of the farmers operating EPPS are between the ages of 61-70% whilst 7.0% of those operating CTPS are above 70 years of age. The distribution showed that majority of the fish farmers are active and therefore have high productivity. High cost of fish feed and inadequate fund/capital were ranked first amongst all the problems of aquaculture. This was followed by high cost of labour and poor pricing by customers.

In Ghana, about 70% of EPPS are between the ages of 40-55years of age. Few farmers are between 61-70 years whilst small numbers are young adults' age around 30years.Few farmers operate CTPS; most of the Ghanaian farmers operate the EPPS. Most of the youth see fish farming as an avenue for the old which the Ministry of Fisheries and Aquaculture Development is trying hard to educate the public about the venture, which can be practiced by anyone, either young or old, whether employed or unemployed, male or female, amongst others since majority of fish farmers in Ghana are males.Fish farming creates employment for the unemployed and extra income for the employed. Ghana has a high opportunity for large-scale aquaculture production as in Nigeria but faces similar challenges. The first challenge is the high cost of complete compound feed. Access to loan facility from the bank is also a problem to the farmers. Good quality fish seed and availability of hatcheries for the production of quality fish seed especially the catfish seed is a problem since the catfish and tilapia are the two major species cultured in the country. It is therefore recommended that the Government through the Ministry provide more fish feed processing plants that will produce feed with subsidized price for farmers. Banks should equally make loan available to farmers. Lastly but not the least, more hatcheries should be established all over the country for easy access of good and quality fingerlings.

C. Profitability Assessment

According to Okechi, (2012) tilapia has been the main farmed species in Kenya but the problem with the commercial production of the species has been small harvest resulting from excessive reproduction and stunted and this calls for the need for alternative culture approaches (Lovshin et al. 1990). The ideal solution is the need to grow a ferocious feeder and fast growing fish, the African catfish which fits into that description.He worked on the profitability assessment, a case study of

African catfish (*Clarias gariepinus*) farming in the Lake Victoria Basin, Kenya. A one pond and twelve ponds in a budgetary unit of a hectare of catfish farm were used. Indicators of investment returns such as NPV, IRR, and Payback and debt service coverage ratio were calculated. There was positive NPV and accepted IRR. A sensitivity analysis on stocking density, survival rates, cost of feed, cost fingerlings and sales price was conducted and it was indicated that the enterprise was highly sensitive to stocking density, survival and sales price but less sensitive to costs of fingerlings and costs of feed used.

The study for the economic analysis for the three methods of tilapia production equally showed a positive NPV and acceptable IRR but NPV for all male tilapia production was the highest and it also indicated very high and fast returns as compared to the others. Cost was more sensitive in all the three scenarios but revenue was less sensitive in mixed sex without predation and all male tilapia production, and discount rate was less sensitive in Polyculture.

D. Economic model

Kaliba et al (2006) studied on the economic analysis of Nile tilapia (*Oreochromis niloticus*) production in Tanzania. According to the paper, economic profitability of small scale Nile tilapia production in Tanzania was analyzed using the De Graaf Model that helps to stimulate individual fish growth and takes into account fish population dynamics in the pond. The goal of the authors was to estimate the cost of producing Nile tilapia under different culture strategies and their specific objectives were to estimate the investment requirements and operating costs for each culture strategy to reflect constraints within the farming system as it was to provide a tool for economic information to new entrepreneurs and existing aquaculture farmers for generating useful enterprise budgets and business plan.Two pond sizes were used in their study. The sizes were 150^2 and $300m^2$. The outcome/results from the two ponds showed that, even though small ponds are easily manageable, yield are higher in big ponds. Mixed sex tilapia without predation, Polyculture and monosex tilapia were the three forms of tilapia culture in the paper but in all the three, yield was high in the $300m^2$ ponds. Monosex tilapia culture had the highest yield, followed by Polyculture and lastly, mixed sex culture without predation. The problem with the paper is that on the appendix where the enterprise budget of Nile tilapia production was, depreciation was added to opportunity cost of land to as well as total listed costs to make the fixed cost but depreciation is already part of the initial investment of the project and so results as double counting. The paper concluded that, the current mixed sex tilapia culture without predation is not economically sustainable therefore the need to adopt Polyculture and monosex culture for the sustainability of the production and industry.

3.2 Methodology:

Thestudy focuses on the different ways in which tilapia is cultured in Ghana. It tries to estimate the cost as well as the economic feasibility of the tilapia culture.

The approach taken by the study includes:

Literature review was done to have more knowledge about what others have done in relation to the culturing of tilapia. With information gained from the literature review, the De Graaf Model is used in stock assessment for all the three culture types.

Investment techniques such as NPV, IRR, BCR are used and sensitivity analysis undertaken. In addition, goal seek is employed to work the switching values.

3.2.1 The Three Culture Methods

There are three methods of culturing tilapia, namely: mixed sex tilapia, all male hand sexed tilapia and polyculture (tilapia and catfish). A pond size of 600m² was used for all the systems and one year was the period for all the production cycle. Three fingerlings per meter squared was the stocking rate for all the systems. In the polyculture system, one catfish was to two tilapias and 1800 fingerlings for the stocking density.A twenty years project plan was analysed to estimate the economic feasibility of the three systems. All parameters used are described below. One unskilled labourer was made to keep the maintenance as well as the daily feeding, weeding and staying at the pond site to keep watch on the farm to avoid poaching and paid US$2 per/day. According to Liti et al. (2005) high protein feed supplementation was important for fish weighing more than 140g apart from the supplementing natural food in the pond. Feed with the best crude protein (35-40%) requirement for the fish were provided. De Graaf Model was used to calculate the Fishing mortality and natural mortality in order to know the number of fish that will remain in the ponds at time *t*.

Two ways of pond construction namely: mechanical or manual. Manual iscommon amongst most farmers and US$1.5 is charged per metre squared. With a pond size of 600m² a total amount of US$900.00 is paid for each pond constructed.

A pond size of 600m² will be managed by one labourer particular a man who is paid US$2 per day and a yearly amount of US$720.00 per each pond.

All equipments with the exception of vehicle have a two year lifespan and needs to be replaced every two years. Vehicle needs to be replaced every five years as it has a lifespan of five years. With the exception of protective clothes and plastic containers which the farmer needs to buy two each, all other equipments, farmers purchases only one each. Prices of equipments are shown in Table 5.

Table 5 Information on Equipments

	Lifespan (years)	unit price (US$)	Quantity	total amount (US$)
wheel barrow	2	130	1	130
weighing scale	2	25	1	25
plastic containers	2	30	2	60
harvesting/sampling net	2	300	1	300
protective clothes	2	60	2	120
Vehicle	5	2000	1	2000

The weight of fingerlings at stocking, the stocking rate and total amount used to purchase fingerlings in the various systems are shown in Table 6

Table 6 Information on fingerlings

fingerlings price	weight (g) from	weight (g) to	price per unit (US$)	pond size	3fingerlings/m² Poly. 2 T:1 C	total amt (US$)
mixed tilapia	5	15	0.05	600	1800fing.	90
all male hand sexed	50	80	0.25	600	1800fing.	450
polyculture tilapia	5	15	0.05	600	1200 T fing.	60
catfish	5	20	0.15	600	600 C fing.	90

A total amount of US$ 22.50 will be used as fuel and US$30.00 will be used as transportation which includes stocking, sampling and harvesting.

A litre of fuel is 3.78 and a gallon costing US$4.50 of which 5 gallons will be bought making a total amount of US$22.50

Some information and data for this study came from secondary sources, particularly materials from the Internet: both printed and articles from research publications. Documents from the fisheries commission were also reviewed. Other information was derived from the personal experience of the author in the Ministry of Fisheries and Aquaculture development.

3.2.2Investment Appraisal Techniques

A. Net Present Value (NPV)

NPV of a project in financial terms is simply the sum of its discounted net cash flows. If the NPV is greater than zero, the project increases real wealth but if it's less than zero, the project decreases real wealth. This technique is sometimes referred to as *present worth analysis.* The equation for NPV is:

$$NPV = \sum_{t=1}^{N} \frac{NCF_t}{(1+r)^t} - I_o$$

Note: *NCF:Net cash flows in which cash outflows are deducted from cash inflows, in year t*
r:discount rate (opportunity cost of capital)
I_0:initial investment sum in period 0
N:life of the project
t :year

All projects with positive NPV's should be accepted but where there are mutually exclusive projects, the project with the highest NPV should be accepted.

It accounts for the time value for money, uses the correct opportunity cost of capital, it consistently selects mutually exclusive projects that maximizes wealth and finally it adheres to value additivelyprinciple, which means it considers projects independently from all other projects currently being undertaken by a particular agent.

B. Internal Rate of Return (IRR)

IRR for an investment is the percentage rate earned on each amount invested for each period it is invested. IRR is also another term people use for interest. Ultimately, IRR gives an investor the means to compare alternative investments based on their yield. Mathematically, the IRR can be found by setting the above NPV equation equal to zero (0) and solving for the rate of return (IRR).

$$0 = \sum_{t=1}^{N} \frac{NCF_t}{(1 + irr)^t} - I_o$$

Projects with IRR greater than opportunity cost of capital should be accepted.

IRR is easily misapplied and so there are four things to look out for:

A. Lending or borrowing? If a project offers positive cash flows followed by negative flows, NPV rises as the discount rate is increased. You should accept such projects if their IRR is less than the opportunity cost of capital.

B. Multiple rates of return. If there is more than one change in the sign of the cash flows, the project may have several IRR's or no IRR at all.

C. Mutually exclusive projects. Unlike NPV's, rates of return do not add up. If you tack a bad project onto a good project, the combined project may have a higher IRR than the good project on its own. you must make sure that you look at the IRR on each additional unit of investment. Also, the IRR rule may give the wrong ranking of mutually exclusive projects that differ in economic life or in scale of required investment.

D. Short – term interest rates may be different from long-term rates. The IRR rule requires you to compare the project's IRR with the opportunity cost of capital. But sometimes there is an opportunity cost of capital for 1-year cash flows, a different cost of capital for 2-years cash flows, and so on. In these cases there is no simple yardstick for evaluating the IRR of a project.

C. Benefit Cost Ratio (BCR)

Benefit-cost ratio, just like NPV gives a direct relationship between the benefits and the costs of a project and uses these relationships to decide whether a particular project is a good investment.The equation for BCR is:

$$BCR = \frac{\sum_{t=1}^{N} \frac{CIF_t}{(1+r)^t}}{\sum_{t=1}^{N} \frac{COF_t}{(1+r)^t} + I_o}$$

Note: *CIF :Cash inflow*
COF : cash outflow

Accept BCR greater than or equal to 1

BCR can lead to misleading results when choosing between mutually exclusive projectsthat is it's not an absolute measure of the marginal impact of the project.The ratio is very sensitive to the discount rate chosen, the higher the discount rate, the smaller the BCR.

D. Replicable Project

Simple NPV no longer holds at a particular time, therefore the need to:
Replicate at constant scale infinite number of times. Replicable projects are applied to projects that at the end of the production cycle, it's anew at the

same scale. This uses the NPV rule assuming that projects are replicated indefinitely at constant scale(e.g. Fish farming, tree planting among others) (Copeland et al, 1946). The equation for replicable project is:

$$\mathrm{NPV}(\mathrm{n}, \infty) = \mathrm{NPV}(\mathrm{n}) \left[\frac{(1+\mathrm{r})^{\mathrm{n}}}{(1+\mathrm{r})^{\mathrm{n}} - 1}\right]$$

D. Sensitivity Analysis

Sensitivity analysis helps to take into account uncertainties that may occur as the project is being undertaking. It also determines how sensitive a project worth is to a change in a project variable, that's what if prices fall by a certain percentage and operating cost also rise by a certain percentage.In my study, +10% and -10% were used on the initial investment, revenue, cost and discount rate in order to see the most sensitive of all. The results can be found in the various scenarios explained in the other chapters.
Advantages of sensitivity analysis are:

Sensitivity analysis is an investigative tool for financial control eg. What cost item needs to be observed.

It highlights what data variables or sets may need to be reconsidered where best guess estimates were used.

It also highlights the potential problem areas in project implementation.

Steps in Sensitivity Analysis are:

A. The NPV of the Base case must be calculated

B. The key factors likely to have an effect on the project's outcome must be decided. These include, initial cash outlay, net cash flow, economic life of the project and discount rate.With fisheries, sensitivity analysis may well look at operating costs, effort/yield, price forecasts and key government policies with respect to pricing, trade etc.

C. Determine the most likely changes in the value or quality of each key variable

D. Re-worked the analysis to determine the effects of the changes in variables on the cost and benefits streams and on the final measures of project worth

E. Interpret the results of the previous steps

Switching Value is when NPV is made of usinggoal seek in excel. This means the extent to which any one value can vary from its best estimate before the project becomes unacceptable.

Sensitivity Indicators is a measure which indicates the sensitivity of the IRR to the rate of change in the variable.

$$SI = \frac{\%\ \text{change in IRR}}{\%\ \text{Change in the variable tested}}$$

3.2.3 Discount Rate

Richard O. Zerbe, Jr. and Dwight D. Dively in their book,"Benefit-Cost Analysis, In Theory and Practice", described that the choice of a discount rate is often critical to the outcome of a benefit-cost calculation. The selection of a discount rate is often related to the choice of an inflation rate. According to Pyo (2001) the determination of an appropriate discount rate is difficult because the factors affecting the discount rate are varied and uncertain, depending on the characteristics which determine the business to be evaluated. The paper went on to state that even in a perfect capital market when marginal investment profit in the private sector, the opportunity cost of the public sector, the consumer's interest rate, the producers interest rate and the market interest rate may all be the same, the level of discount rate can be different due to the different levels of uncertainties and risks. According to him, in principle, the nominal interest rate is deemed to be the sum of the real interest rate, risk premium of the goods and expected inflation rate. Consistency is very important in the application of a discount rate and cash inflows and outflows. So when the cash inflow and outflow is a real cash flow based on a constant price, the discount rate reflects a real rate of interest and an actual purchasing power.

According to the Ghana Statistical Service, inflation affects the economy in three ways.

Inflation is directly linked to **interest rates**. The interest rates prevailing in an economy at any point in time are nominal interest rates, i.e., real interest rates plus a premium for expected inflation. Due to inflation, there is a decrease in the purchasing power of money earned due to interest in the future. Therefore, the interest rates must include a premium for expected inflation. In the long run, other things being equal, interest rates rise in direct correlation to the rise in inflation.

Inflation affects **exchange rates**. Exchange rates between the currencies of two countries depend upon the level of inflation prevailing in the two countries. According to the Purchasing Power Parity principle, the change in the value of one currency vis-a-vis another is approximately equal to the inflation differential of the two countries. So the inflationlevels provide an indication of the movement of currencies against each other.

Inflation has an inverse relationship to **economic growth**. Other things being equal, economic growth is equal to the difference between money supply growth & inflation.

3.2.4 Interest Rate

In Ghana, Bank of Ghana reports the Interest Rate. Ghana's Interest Rate averaged 16.55 Percent from 2002 until date (2013),the highest interest rate was first recorded in June, 2003 at 27.50 Percent.The lowest was also recorded at 12.50 Percent in December 2006.Interest rates decisions are taken by the Monetary Policy Committee of the Bank of Ghana. The official interest rate is the Monetary Policy Rate (MPR). The real interest rate has the equation:

$$RR \doteqdot RN - IN$$

$$RR \doteqdot 16.55\% - 11.20\% = 5.35\%$$

Note: *RR: real interest rate*
RN: interest rate
IN: Inflation rate

The above equation shows that, the real interest rate is 5.35% when the interest rate was 16.55% and inflation rate as of June 2013 was 11.20%. This is the same as the ODA received in Ghana in the year, 2010. Even though, real interest rate is 5.35, 10% discount rate was used for this work because of the reasons below.

According to a World Bank report published in 2012,the Net official development assistance (ODA) received (% of GNI) in Ghana was last reported at 5.35 in 2010. The report included that the Net ODA consists of disbursements of loans made on concessional terms (net of repayments of principal) and grants by official agencies of the members of the Development Assistance Committee (DAC), by non-DAC countries and by multilateral institutions to promote economic development and welfare in territories and countries in the DAC list of ODA recipients. This report stated includes loans with a grant element of at least 25 percent (calculated at a rate of discount of 10 percent).

CHAPTER 4 RESULTS

Three scenarios were used in this study namely, mixed sex tilapia culture without predation, Polyculture, that is mixed sex tilapia with African catfish and then monosex tilapia culture. Tilapia culture has been long practiced by Ghanaian farmers especially the mixed sex culture but the problem has been excessive and early reproduction by the female tilapia causing over population and stunted growth. This has been a problem amongst the farmers as most restaurants and tilapia consumers in Ghana prefer big tilapia. According to them, it is easy to work on the big tilapia and also more enjoyable compared to the small ones. The big tilapia also has high value in terms of the pricing and so the sales of small tilapia are problem that calls for immediate attention. To solve this menace, incorporation of a predator such as African catfish is used so that the larvae and fingerlings produced by the female tilapia can be consumed to control the tilapia population. Another solution is the rearing of only male tilapia as there will be no reproduction. This method results in big and uniform fish size. In addition to that, the fish grow faster and result in good yield. The various scenarios are described below and the outcome of each after the economic analysis was done to come out with the best of all the three scenarios.

4.1 Scenario 1 Mixed sex tilapia culture (without predator)

Mixed sex tilapia culture is the rearing of both male and female tilapia in a pond orothermedia such as reservoirs, cages, tanks etc. According to Guerrero (1980), the problem facing the mixed sex tilapia production is the early reproduction before the fish reach marketable size, leading to over population and smaller fish at harvest. The marketing of this fish becomes a problem and it also takes a longer period of time to get few ones of an average sizes. Even though the initial investment cost is lower as compared to the other systems, yield is also poor. The only advantages of this system is the sales of the fingerlings to other farmers or hand sex the males of the average sized ones and restock to other pond. Another alternative is by the use of all male tilapia hybrids (Balarin and Hatton, 1979) and hand sexing to get rid of the females (Brown and Van Someren, 1953).

Table 7 Mixed sex culture parameters

YEAR	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Total Revenue		2650	2650	2650	2650	2650	2650	2650	2650	2650	2650	2650	2650	2650	2650	2650	2650	2650	2650	2650	2650
weighted Price (Pw)	0	2.04	2.04	2.04	2.04	2.04	2.04	2.04	2.04	2.04	2.04	2.04	2.04	2.04	2.04	2.04	2.04	2.04	2.04	2.04	2.04
Quantity	0	1300	1300	1300	1300	1300	1300	1300	1300	1300	1300	1300	1300	1300	1300	1300	1300	1300	1300	1300	1300
Total cost																					
Initial invest																					
construction cost (mannual)	900																				
land cost	2000																				
farm house	1000																				
wheel barrow	130		130		130		130		130		130		130		130		130		130		130
weighing scale	25		25		25		25		25		25		25		25		25		25		25
plastic containers	60		60		60		60		60		60		60		60		60		60		60
harvesting/sampling net	300		300		300		300		300		300		300		300		300		300		300
protective clothes	120		120		120		120		120		120		120		120		120		120		120
Vehicle	2000					2000					2000					2000					2000
TOTAL	**6535**		**635**		**635**	**2000**	**635**		**635**		**2635**		**635**		**635**	**2000**	**635**		**635**		**2635**
Variable cost																					
Labour cost		720	720	720	720	720	720	720	720	720	720	720	720	720	720	720	720	720	720	720	720
feed (mixed tilapia)		230.4	230.4	230.4	230.4	230.4	230.4	230.4	230.4	230.4	230.4	230.4	230.4	230.4	230.4	230.4	230.4	230.4	230.4	230.4	230.4
fingerlings (T)		90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90
transportation		30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30
fuel		22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5
sub total	0	**1092.9**	**1092.9**	**1092.9**	**1092.9**	**1092.9**	**1092.9**	**1092.9**	**1092.9**	**1092.9**	**1092.9**	**1092.9**	**1092.9**	**1092.9**	**1092.9**	**1092.9**	**1092.9**	**1092.9**	**1092.9**	**1092.9**	**1092.9**
Total cost	**6535**	**1092.9**	**1727.9**	**1092.9**	**1727.9**	**3092.9**	**1727.9**	**1092.9**	**1727.9**	**1092.9**	**3727.9**	**1092.9**	**1727.9**	**1092.9**	**1727.9**	**3092.9**	**1727.9**	**1092.9**	**1727.9**	**1092.9**	**3727.9**
net cash flow	**-6535**	**1557.1**	**922.1**	**1557.1**	**922.1**	**-442.9**	**922.1**	**1557.1**	**922.1**	**1557.1**	**-1077.9**	**1557.1**	**922.1**	**1557.1**	**922.1**	**-442.9**	**922.1**	**1557.1**	**922.1**	**1557.1**	**-1077.9**

Table 8 Results from mixed sex tilapia culture.

NPV	$1,358.13
IRR	13%
BCR	1.06
Discount rate	10%
replicable project	1,595.25

The above outcome is the results of NPV, IRR, BCR and the replicated results from the above data. Using a 10% discount rate, NPV was US$1,358.13 resulting in IRR of 13%. When the project was replicated, it had a value of 1,595.25. Even though the NPV rule indicates that projects with positive NPV's should be accepted but comparing between mutually exclusive projects, the project with the highest NPV should be accepted. Comparing the three scenarios, mixed sex culture without predation has the least NPV and so should not be chosen or accepted.

In other words, NPV is 0 when 13% (IRR) was used as a discount rate. This then states that, if there is more than one change in the sign of the cash flows, the project may have several IRRs (multiple rates of return) or no IRR at all (Brealey and Myers, 2004).

Table 9 Net cash flow for mixed tilapia culture (Base case)

Base case				
year	Investment	revenue	costs	NCF
0	6535.0			-6535.0
1		2650	1093	1557.1
2		2650	1728	922.1
3		2650	1093	1557.1
4		2650	1728	922.1
5		2650	3093	-442.9
6		2650	1728	922.1
7		2650	1093	1557.1
8		2650	1728	922.1
9		2650	1093	1557.1
10		2650	3728	-1077.9
11		2650	1093	1557.1
12		2650	1728	922.1
13		2650	1093	1557.1
14		2650	1728	922.1
15		2650	3093	-442.9
16		2650	1728	922.1
17		2650	1093	1557.1
18		2650	1728	922.1
19		2650	1093	1557.1
20		2650	3728	-1077.9

Table 10 Results from the Base case from the mixed sex culture are shown below

NPV	$1,358.13
IRR	13%
Discount rate	10%

Table 11 Sensitivity analysis for mixed sex tilapia culture

	NPV		*ranking calculation, which one is more sensitivity*
Base case	1,358.13		
(+10% inv)	705	2	0.4811763
(-10% inv)	4801	2	-2.5347357
(+10% rev)	6403	4	-3.7147365
(-10% rev)	1891	4	-0.3923823
(+10% cos)	-109	1	1.0800007
(-10% cos)	2825	1	-1.0800007
(+10% dis)	3468	3	-1.5536227
(-10% dis)	7325	3	-4.3931639

Table 11 above is to know which of the parameters is more sensitive to the others, that is in case of any uncertainty that may arise in any of them, what needs to be done eg. If there if fall in price or rise in operating cost

It could be observed from the above graph that, when the various parameters were all individually multiplied by 1.1 (+10%) and also 0.9 (-10%) cost was found to be more sensitive than the others having 1.0800007 and -1.0800007. This was followed by Investment, Discount rate and revenue.

Table 12 Sensitivity indicators and switching values for mixed sex

Sensitivity indicators and switching values					goal seek
Parameter	Base est.	switch value	permissible variation	ranking	NPV
Initial inv.	-6535	-7893.13	20.78240218	4	$0.00
Revenue	2650	1822.25	31.24	3	$0.00
Operating Costs	1092.9	1487.12	36.07	2	$0.00
Discount rate	0.1	0.17	65.01279532	1	-$900.00

Using goal seek helped in the switching value as the results from the base case was used. This helped in acquiring new values from the base case. It resulted in Initial investment having new value of -7893.13. Revenue became 1822.25, operating cost 1487.12 and 0.17 discount rate.

Using the permissible variation, discount rate was ranked the first and followed by operating cost,revenue was the third, and finally by Initial investment.

Table 13 IRR with +10% and – 10% results from the switching values

IRR	SI (+10%)		ranking	SI (-10%)		ranking
Inv	- 1.332650544	decrease	2	5.749742983	increase	1
Rev	7.269698011	increase	1	0.554288087	decrease	3
Cost	- 2.763532351	decrease	3	2.466174574	increase	2

Note: SI (+10%) was obtained by the equation:
IRR (base case)-new IRR/new IRR * 100. This applies to SI (-10%)
In +10%, revenue was 7.27 being first among the ranking followed by Cost at 2.77 and lastly 1.33 for cost. On the contrary, in -10% investment ranked first at 5.75, 2.47 for cost and 0.55 for revenue.

Table 14 Stock assessment (mixed sex)

Time (months)	Wt (g)	Length	M_u	$M_{w,t}$	M_t	N_t
0	15.50	10.14	1	0.83	0.05	1800
1	20.30	13.20	1	0.65	0.04	3447
2	24.20	15.51	1	0.56	0.03	5516
3	28.60	17.53	1	0.50	0.03	8069
4	40.10	19.40	1	0.46	0.03	11128
5	48.50	21.13	1	0.42	0.02	14764
6	64.00	23.40	1	0.38	0.02	17922
7	80.60	24.30	1	0.37	0.02	23982
8	98.50	25.21	1	0.36	0.02	31452
9	108.00	27.22	1	0.33	0.02	36091
10	123.30	27.90	1	0.33	0.02	46720
11	154.20	28.42	1	0.32	0.02	60902
12	178.50	30.31	1	0.30	0.02	67204

Note: M_u :natural mortality at unit weight
$M_{w,t}$:natural mortality rate
M_t :natural mortality
N_t :number of fish at time t

It can be seen from Table 14 that, at the end of the production cycle, the biomass increased greatly of which three fourth of this biomass is made of recruits. Due to the continues reproduction, very little number of the biomass can grow to a medium or big size.

4.2 Scenario 2 Polyculture: (Tilapia and African catfish)

Polyculture is when the male and female tilapia is incorporated with a predator in the same pond within the production cycle in order to control the larvae and fingerlings produced by the female tilapia. It is an alternative for controlling the effect of fingerlings or over population of the mixed sex tilapia with predator that eats the tilapia fingerlings and fry. Example is the African catfish. This has been proposed by Guerrero (1980), De Graaf (1996), El-Gamal et al. (1998), and Fagbenro (2004). The ratio is normally 2T-1C of the same size to avoid predation. One advantage of the polyculture of tilapia and a predator like the catfish is that, it increases the productivity by a more efficient utilisation of the ecological resources in the pond (Lutz 2003). The production period is mostly 8-12months. Fish are fed with nutritious feed. Sampling is done to adjust feeding and check average fish weight. Feeding is done thrice daily and broadcasted all around the pond for all the fish to get access to the feed.

Table 15 Data on Polyculture

YEAR	**0**	1.00	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Total Revenue	0	4215	4215	4215	4215	4215	4215	4215	4215	4215	4215	4215	4215	4215	4215	4215	4215	4215	4215	4215	4215
weighted Price (tilapia)	0	2.64	2.64	2.64	2.64	2.64	2.64	2.64	2.64	2.64	2.64	2.64	2.64	2.64	2.64	2.64	2.64	2.64	2.64	2.64	2.64
Quantity	0	980	980	980	980	980	980	980	980	980	980	980	980	980	980	980	980	980	980	980	980
weighted price (catfish)	0	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Quantity	0	650	650	650	650	650	650	650	650	650	650	650	650	650	650	650	650	650	650	650	650
Total cost																					
Initial invest																					
construction cost (mannual)	900																				
land cost	2000																				
farm house	1000																				
wheel barrow	130		130		130		130		130		130		130		130		130		130		130
weighing scale	25		25		25		25		25		25		25		25		25		25		25
plastic containers	60		60		60		60		60		60		60		60		60		60		60
harvesting/sampling net	300		300		300		300		300		300		300		300		300		300		300
protective clothes	120		120		120		120		120		120		120		120		120		120		120
Vehicle	2000					2000					2000					2000					2000
sub total	**6535**	**0**	**635**	**0**	**635**	**2000**	**635**	**0**	**635**	**0**	**2635**	**0**	**635**	**0**	**635**	**2000**	**635**	**0**	**635**	**0**	**2635**
Variable cost																					
Labour cost		720	720	720	720	720	720	720	720	720	720	720	720	720	720	720	720	720	720	720	720
feed (complete feed)		598	598	598	598	598	598	598	598	598	598	598	598	598	598	598	598	598	598	598	598
catfish (fingerlings)		90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90
fingerlings (mixed tilapia)		60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60
transportation		30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30
fuel		22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5
sub total		**1520.4**	**1520.4**	**1520.4**	**1520.4**	**1520.4**	**1520**	**1520**	**1520.4**	**1520.4**	**1520**	**1520**	**1520.4**	**1520**	**1520**	**1520**	**1520**	**1520.4**	**1520.4**	**1520**	**1520**
TOTAL COST	**6535**	**1520.4**	**2155.4**	**1520.4**	**2155.4**	**3520.4**	**2155**	**1520**	**2155.4**	**1520.4**	**4155**	**1520**	**2155.4**	**1520**	**2155**	**3520**	**2155**	**1520.4**	**2155.4**	**1520**	**4155**
net cash flow	**-6535**	**2694.6**	**2059.6**	**2694.6**	**2059.6**	**694.61**	**2060**	**2695**	**2059.6**	**2694.6**	**59.61**	**2695**	**2059.6**	**2695**	**2060**	**694.6**	**2060**	**2694.6**	**2059.6**	**2695**	**59.61**

Table 15 shows the outcome from the above data. It shows the NPV, IRR, BCR and the replicated results.

Table 16 Results from the polyculture

NPV	$11,042.41
IRR	34%
Benefit Cost ratio	1.44
Discount rate	10%
Replicable project	12,970.37

Table 17 Net cash flow for polyculture (Base Case).

Base case				
Year	Investment	revenue	costs	NCF
0	6535			-6535
1		4215	1520.39	2694.612
2		4215	2155.39	2059.612
3		4215	1520.39	2694.612
4		4215	2155.39	2059.612
5		4215	3520.39	694.612
6		4215	4155.39	59.612
7		4215	1520.39	2694.612
8		4215	2155.39	2059.612
9		4215	1520.39	2694.612
10		4215	4155.39	59.612
11		4215	1520.39	2694.612
12		4215	2155.39	2059.612
13		4215	1520.39	2694.612
14		4215	2155.39	2059.612
15		4215	3520.39	694.612
16		4215	4155.39	59.612
17		4215	1520.39	2694.612
18		4215	2155.39	2059.612
19		4215	1520.39	2694.612
20		4215	4155.39	59.612

Table 18 Results from the base case (polyculture)

NPV	$11,042.41
IRR	34%
discount rate	10%

Table 18 provides the results from the base case for the Polyculture system. With a discount rate of 10%, NPV, IRR results are shown above

Table 19 +10% and -10% of NPV of all the parameters

	NPV		*ranking calculation, which one is more sensitive*
Base case	11,042.41		
(+10% inv)	12102.64	2	-0.276891738
(-10% inv)	1610.59	2	0.830074612
(+10% rev)	13066.67	3	-0.378601983
(-10% rev)	5889.74	3	0.378601983
(+10% cos)	1185.37	1	0.874936823
(-10% cos)	11465.35	1	-0.209654327
(+10% dis)	14923.08	4	-0.574462665
(-10% dis)	18062.89	4	-0.9057289

Using the +10(1.1) and -10 (0.9), cost was more sensitive than others. Initial investment was next to cost, followed by revenue and then discount rate.

Table 20 sensitivity analysis and switching values for polyculture

	Sensitivity indicators and switching values				goal seek
Parameter	Base est.	switch value	permissible variation	ranking	NPV
Initial inv.	6535	-22940.75096	724.123484	1	-6927.55
Revenue	4215	-335544.32	-38.53132251	4	$9,478.20
Operating Costs	1520.39	-335544.32	97.96760162	3	$9,478.20
Discount rate	0.1	0.316418881	351.8036661	2	$0.00

New values where obtained for initial investment, revenue, operating cost as well as discount rate when the values where switched and it can be observed at the switching values from the above table. Initial investment was more sensitive than the rest at permissible variation of 724.12.this was followed by discount rate, operating cost and lastly, revenue being the least sensitive of all.

Table 21 IRR from +10 and – 10 results for polyculture

IRR	SI (+10%)		ranking	SI (- 10%)		ranking
Invest.	-9.297888681	decrease	2	-65.186	decrease	2
Rev.	17.1361625	increase	1	-26.4262	decrease	1
cost	-67.16922612	decrease	3	-77.8665	decrease	3

Note: Comparing the IIRR, revenue was more sensitive at both +10% and -10%, followed by initial investment and cost was less sensitive at -10% and +10%.

Table 22 Stock assessment (polyculture)

Time(months)	Wt (g)	Length-T	Length-C	D_t	M_u-T	Pp,t	P_t	M	M_t	N_t
0	15	10.1	15.1	1.000	1.00	4.77	0.21	59.47	0.05	1800
1	25	13.2	17.2	0.983	1.00	3.86	0.25	76.13	0.05	1991
2	37	15.5	20.4	0.953	1.00	2.90	0.33	88.30	0.05	2124
3	50	17.5	23.3	0.933	1.00	2.32	0.40	98.77	0.05	2244
4	62	19.4	25.2	0.900	1.00	1.99	0.45	108.63	0.05	2366
5	75	21	29.3	0.863	1.00	1.52	0.57	116.87	0.05	2467
6	87	23.4	34.4	0.833	1.00	1.16	0.72	129.15	0.05	2564
7	100	24.3	38.8	0.783	1.00	0.91	0.86	133.73	0.05	2679
8	112	25.2	42.6	0.752	1.00	0.76	0.99	138.29	0.05	2805
9	125	27.2	46.4	0.717	1.00	0.63	1.13	148.40	0.05	2934
10	150	27.9	50.5	0.687	1.00	0.54	1.28	151.92	0.05	3074
11	163	28.4	55.2	0.650	1.00	0.44	1.46	154.43	0.05	3220
12	175	30.3	70.2	0.587	1.00	0.28	2.10	163.94	0.05	3348

Note: D_t: predator density
M_u: natural mortality at unit weight
Pp,t: predation relation
P_t: predator related mortality rate
$M_{w,t}$: natural mortality rate
M_t: natural mortality
N_t: number of fish at time t

Predator density decrease with time but predatorrelated mortality increased with time which is an indication that as African catfish are known to be carnivorous fish and so feed on themselves causing their reduction in number, the remaining catfish,(small in number but big in size), consume more of the tilapia larvae and fingerlings. This therefore implies that the bigger they grow, the higher they prey on the tilapia fingerlings.

4.3 Scenario 3 All male tilapia production/hand sexed tilapia culture

In simple terms, it is the rearing of only male tilapia with the idea of no reproduction in the system. This is one of the ways to control reproduction in mixed-sex population.(Phelps and Popma, 2000). Moreover, sex-specific differences in growth were significant in *O. niloticus* where males grow significantly faster, larger and more uniform in size than females (Bwanika *et al*., 2007). The desirability of monosex male populations of tilapia is well established for increased production potential and low management requirements (Pillay, 1993; Beardmore *et al*., 2001; El-Sayed, 2006).

All male tilapia production can be done in several ways but the most common ways practised by the Ghanaian farmers are two. The first one is farmers purchasing the supposed all male tilapia from a reputable source but mostly far from most farmers making them adopt the other way of the all male tilapia practice. These fingerlings are usually small in size (5-15g) and production period is usually 8-12months.

The second method of the all male tilapia production is attaining an average weight male tilapia (80-100g), normally from a mixed sex farm. In this case, the males are hand sexed and selected for the farmers. In this practise, the stocking rate is $3m^2$ and production period is between 8-12 months but can be less depending on the weight of the fish. Complete compound feed of 30-35% crude protein is fed to them and feeding is done 4 times daily and also broadcasted to enable all fish to get access to the feed. Wheat bran mixed with other ingredients can also be fed to the fish. Monitoring is done at all times (once a month) to check the average weight of the fish and to adjust the feeding so sampling is done. Feeding is done by 8% of total biomass from the first month of stocking and changes as they grow.

Table 23 All male/monosex tilapia culture data

YEAR	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Total Revenue		4870	4870	4870	4870	4870	4870	4870	4870	4870	4870	4870	4870	4870	4870	4870	4870	4870	4870	4870	4870
weighted Price (Pw)	0	4.39	4.39	4.39	4.39	4.39	4.39	4.39	4.39	4.39	4.39	4.39	4.39	4.39	4.39	4.39	4.39	4.39	4.39	4.39	4.39
Quantity	0	1110	1110	1110	1110	1110	1110	1110	1110	1110	1110	1110	1110	1110	1110	1110	1110	1110	1110	1110	1110
Total cost																					
Initial invest																					
construction cost (mannual)	900																				
land cost	2000																				
farm house	1000																				
wheel barrow	130		130		130		130		130		130		130		130		130		130		130
weighing scale	25		25		25		25		25		25		25		25		25		25		25
plastic containers	60		60		60		60		60		60		60		60		60		60		60
harvesting/sampling net	300		300		300		300		300		300		300		300		300		300		300
protective clothes	120		120		120		120		120		120		120		120		120		120		120
Vehicle	2000					2000					2000					2000					2000
TOTAL	**6535**	**0**	**635**	**0**	**635**	**2000**	**635**	**0**	**635**	**0**	**2635**	**0**	**635**	**0**	**635**	**2000**	**635**	**0**	**635**	**0**	**2635**
Variable cost																					
Labour cost		720	720	720	720	720	720	720	720	720	720	720	720	720	720	720	720	720	720	720	720
feed (pelletted feed)		777.6	777.6	777.6	777.6	777.6	777.6	777.6	777.6	777.6	777.6	777.6	777.6	777.6	777.6	777.6	777.6	777.6	777.6	777.6	777.6
fingerlings (all male)		450	450	450	450	450	450	450	450	450	450	450	450	450	450	450	450	450	450	450	450
transportation		30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30
fuel		22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5
sub total		**2000.1**	**2000.1**	**2000.1**	**2000.1**	**2000.1**	**2000.1**	**2000.1**	**2000.1**	**2000.1**	**2000.1**	**2000.1**	**2000.1**	**2000.1**	**2000.1**	**2000.1**	**2000.1**	**2000.1**	**2000.1**	**2000.1**	**2000.1**
TOTAL COST	**6535**	**2000.1**	**2635.1**	**2000.1**	**2635.1**	**4000.1**	**2635.1**	**2000.1**	**2635.1**	**2000.1**	**4635.1**	**2000.1**	**2635.1**	**2000.1**	**2635.1**	**4000.1**	**2635.1**	**2000.1**	**2635.1**	**2000.1**	**4635.1**
Net cash flow	**-6535**	**2869.9**	**2234.9**	**2869.9**	**2234.9**	**869.9**	**2234.9**	**2869.9**	**2234.9**	**2869.9**	**234.9**	**2869.9**	**2234.9**	**2869.9**	**2234.9**	**869.9**	**2234.9**	**2869.9**	**2234.9**	**2869.9**	**234.9**

Table 24 Results from all male tilapia culture data

NPV	$12,534.74
IRR	37%
Benefit cost ratio	1.43
Discount rate	10%
Replicable project	14,723.25

The above outcome is the results of NPV, IRR, BCR and the replicated results from the above data.

Table 25 Net cash flow for all male tilapia culture (Base case)

Base case				
year	Investment	revenue	costs	NCF
0	6535.0			-6535.0
1		4870	2000.1	2869.9
2		4870	2635.1	2234.9
3		4870	2000.1	2869.9
4		4870	2635.1	2234.9
5		4870	4000.1	869.9
6		4870	2635.1	2234.9
7		4870	2000.1	2869.9
8		4870	2635.1	2234.9
9		4870	2000.1	2869.9
10		4870	4635.1	234.9
11		4870	2000.1	2869.9

12	4870	2635.1	2234.9
13	4870	2000.1	2869.9
14	4870	2635.1	2234.9
15	4870	4000.1	869.9
16	4870	2635.1	2234.9
17	4870	2000.1	2869.9
18	4870	2635.1	2234.9
19	4870	2000.1	2869.9
20	4870	4635.1	234.9

Table 26 Results from the net cash flow

NPV	$12,534.74
IRR	37%
discount rate	10%

Table 26 provides the results from the Base case for the monosex tilapia.

Table 27 Results from the sensitivity analysis for the NPV in all male tilapia culture

	NPV		*ranking calculation, which one is more sensitive*
Base case	12,534.74		
(+10% inv)	11881	3	0.0077176
(-10% inv)	-189	3	1.0158191
(+10% rev)	18606	4	-0.5539400
(-10% rev)	10314	4	0.1385987
(+10% cos)	-3373	1	1.2817384
(-10% cos)	1105	1	0.9077283
(+10% dis)	-1196.69	2	1.0999434
(-10% dis)	-448.07	2	1.0374212

Using the switching values to compare all NPV's at the base case. 1.1and 0.9 were added to all the parameters. As shown in Table 27 above, using the ranking calculations, cost was ranked the most sensitive whilst revenue was ranked the least sensitive.

Table 28 sensitivity indicators and switching values for all male tilapia

	Sensitivity indicators and switching values				goal seek
Parameter	Base est.	switch value	permissible variation	ranking	NPV
Initial inv.	6535.0	-21297.64448	-425.9012162	2	-$2,789.00
Revenue	4870	2936.588922	-39.70043281	4	-$2,000.00
Operating Costs	2000.1	3731.947402	86.58804069	3	$0.00
Discount rate	0.10	0.578400766	478.4007659	1	-$2,227.33

It can be observed that when goal seek was used to switch the values, Discount rate was ranked first indicating that it was more sensitive than the others. Initial investment was next after discount rate followed by operating cost and then revenue.

Table 29 IRR from +10 and – 10 results for all male culture

IRR	SI (+10%)		ranking	SI(-10%)		ranking
inv	-9.777418786	decrease	3	-74.11046432	decrease	3
rev	25.28187506	increase	1	-16.52834422	decrease	1
cost	6.45672637	increase	2	-72.76611958	decrease	2

It can be observed from the table 29 above that by ranking, revenue was more sensitive at both +10% and -10% and investment was less sensitive.

Table 30 Stock assessment (All male tilapia)

Time(months)	Wt (g)	length	*Mu*	*Mw,t*	*Mt*	*Nt*
0	51.61	16.30	1	0.53	0.03	1800
1	82.07	18.21	1	0.48	0.03	1849
2	112.22	21.14	1	0.42	0.02	1886
3	151.55	24.22	1	0.37	0.02	1915
4	182.30	26.97	1	0.34	0.02	1940
5	205.90	28.99	1	0.31	0.02	1964
6	240.36	31.42	1	0.29	0.02	1984
7	284.48	34.23	1	0.27	0.01	1999
8	335.64	35.11	1	0.26	0.01	2024
9	392.36	36.32	1	0.26	0.01	2045
10	432.72	37.31	1	0.25	0.01	2067
11	474.94	38.10	1	0.24	0.01	2090
12	520.32	39.40	1	0.24	0.01	2108

Number of fish increased slightly every month because male tilapia selection was manually done and due to human error, few females may have been selected which lead to the increase in fish number (recruits). This does not have much effect on the target fish (male tilapia) because the recruits are few and very small in size(juvenile & larvae) and so cannot actively feed on the feed been fed to the target ones.

It can be observed from the above table that, natural mortality and natural mortality rate decrease with time. This is an indication that small fish are vulnerable to die compared to big or matured fish.

Table 31 Comparative Analysis for the three tilapia culture types

Culture type	All male Tilapia culture	Polyculture	Mixed sex without predation
NPV	$12,535	$11,042.41	$1,358.13
IRR	37%	34%	13%
BCR	1.43	1.44	1.06

Comparing NPV, IRR and BCR in all the systems as shown in Table 31

This table provides the output of the three ways of tilapia culture.

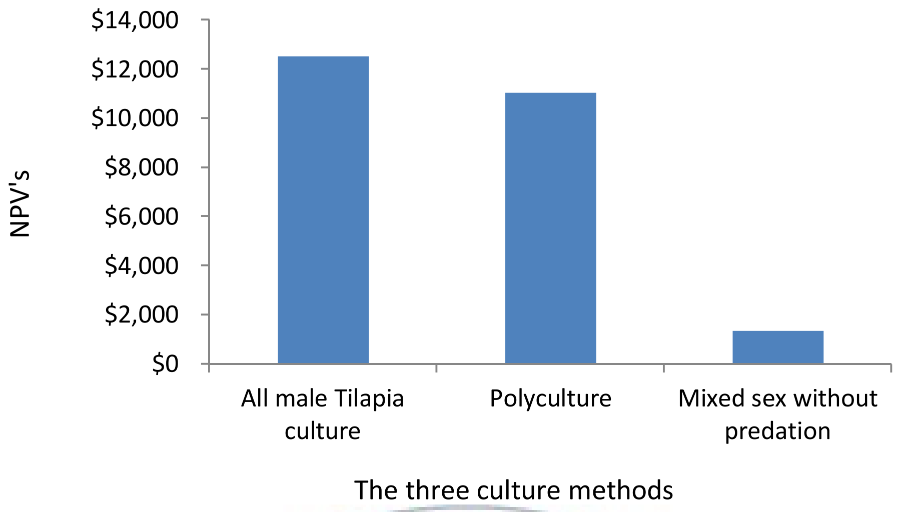

Fig. 3 NPV of all 3 culture methods

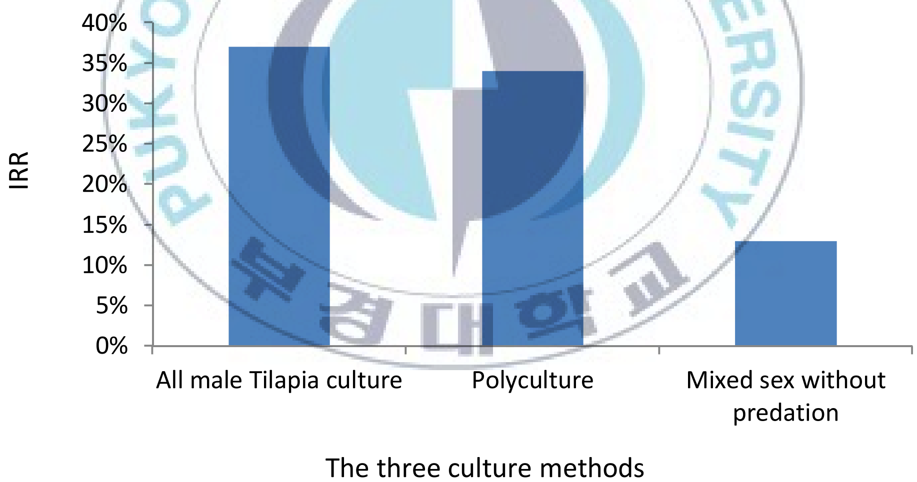

Fig. 4IRR of all 3 culture methods

CHAPTER 5 DISCUSSIONS

Three scenarios of farming or culturing tilapia were analysed. The scenarios included mixed sex with or without catfish predation and all male hand sex culture. The NPV for all male tilapia culture was $12,534.74. Polyculture and mixed sex without predation had NPV's of $11,042.41 and $1,358.13 respectively. Since NPV accounts for the time value of money and uses the correct opportunity cost of capital and consistently selects mutually exclusive projects that maximizes wealth therefore it's an absolute measure.NPV adheres to value additivity principle as projects are selected independently from all other projects currently undertaken by the agent. Even though other discounted cash flows such as IRR were also used, NPV is the best for the assessment of the project. The Investment decision rule states that all projects with positive NPV's should be accepted but it continued to include that, in a situation to choose between mutually exclusive projects, the project with the highest NPV should be chosen or selected.In all the scenarios, positive NPV's were obtained meaning they could all beaccepted but all male tilapia culture had the highest NPV indicating that it is the most feasible project of all. It could be realized that all male tilapia culture and polyculture had close NPV’sbut choosing between mutually exclusive projects, all male tilapia culture should be preferred to polyculture.IRR for all male tilapia culture, polyculture and mixed sex without predation were 37%,34% and 13% in that order but as described earlier, IRR is a relative measure and makes the wrong reinvestment assumption.Cash flows for mixed sex without predation had both positive and negative values and according to the investment decision rule for IRR, there is no IRR when all cash flows including initial investments are positive.If a project has positive cash flows followed by negative flows, NPV rises as the discount rate is increased. The project should be accepted if their IRR is less than the opportunity cost of capital. (Richard and Stewart, 1984).Revenue from all male tilapia production was \$4,870 as compared to that of polyculture and mixed sex culture were \$4,215 and \$2,650 respectively. Sensitivity analysis was calculated in order to know which of the parameters was more sensitive to the others and the results showed that cost was more sensitive for all the three culture systems but Revenue was less sensitive in both mixed sex without predation and all male tilapia culture and for polyculture, discount rate was less sensitive.For the data on the stock assessment, it’s obvious that the number of recruits in the mixed sex without predation was increasingly high every month and during harvesting time had a lot of biomass in the ponds which three fourth were made of recruits. For all male tilapia culture, it equally had some number of recruits but in a smaller number since the male tilapia was manually done, there were some human errors and so still had some females in it causing the existence of recruits in the pond but quiet a smaller number. In polyculture, predator density decreased with time as catfishes are known to be highly carnivorous and voracious predators. It also had some recruits at the end of the production cycle but equally in a little amount. Comparing the three systems, at harvest time, monosex culture had the least number of tilapia followed by Polyculture and lastly, mixed sex culture. This is because there is supposed to be no reproduction in the monosex culture but due to human error during the selection lead to few recruits. Even though the catfish prey on the larvae and fingerlings of the tilapia, still there were quiet some number of recruits but in the mixed sex without predation, reproduction was very high as fish starts reproduction from three months and so, when recruits also reach three months, they start reproducing and the cycle continues. In all, it could be concluded that, all male tilapia culture is more feasible compared to polyculture and mixed sex tilapia production.

Conclusions and recommendations

In conclusion, monosex tilapia culture is the best out of the three but in an environment where it's difficult to obtain the male tilapia fingerlings, or do not have the technique for the male selection, Polyculture could be the next alternative.

I therefore recommend that the government should provide more hatcheries for the male tilapia production to make it more easy and accessible to farmers for better production.

I also recommended that more training on the manual selection on the male tilapia should be organized for the fisheries staff to reduce the probability of females being incorporated during the male selections.

Monosex tilapia production or sex reversal system is practiced in more advanced countries eg. China and so more fisheries staff should be taken to such countries on the training of the all male tilapia production.

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Acknowledgements

My first thanks goes to the Almighty God for making this thesis a successful one.

My next thanks go to the Government of Korea through KOICA for giving me this great opportunity to undertake my masters' degree course in their country.I learnt a lot from one of the best universities in the country PKNU.

I would like to say a big thank you to my Professor, Heedong Pyo for his good supervision, kindness, guidance and advice given to me during my stay in Korea. I will always remember you for all you taught me and I pray we meet again sometime. One thing always rings in my mind all the time which I will never forget, your usual say 'Diana, I already told you' when I forget something you've taught me. That's the sign of a good leader and it always kept me on my toes.

I thank all the professors I came into contact with when I came to Korea. I know I've learnt a lot from all of you which is going to be very helpful to me when I go back home especially Prof. Kim Do hoon who guided and encouraged me when things were rough. Prof Sang-Go Lee also gave useful advice for this work and I'll like to say thank you, I'm grateful.

To my mates I say thank you to everybody for your cooperation and encouragement especially Mila and An who helped with the editing of this work. Isaac, Louis and Hashim, you'll always be remembered.I hope we meet again someday.

To Dr. Kang, KOICA coordinator, I say thank you, you were like a sister and a friend to me. God richly bless you.

Lastly, but not the least, I dedicate this work to my lovely daughter, Josephine and my husband, Joseph. I say a big thank you to all my siblings namely, Irene, Ophelia, Patience, Eric, Kingsley, Susan and Junior not forgetting my lovely parents Mr Stephen Obuobi and Md. Florence Addobea.