# Kenya's Diverging Aquaculture Sector

## A study on small-scale fish farmers' struggles & upgrading opportunities and how these can impact food security

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# Abstract

Hunger is still a major concern in Kenya with roughly 11.1M Kenyans suffering from hunger in 2014. A potential sector that could help solve part of this issue has been identified as the aquaculture sector. With the use of Neilson & Pritchard's Global Value Chain framework together with a philosophical viewpoint of critical realism an in-depth understanding of Kenya's aquaculture sector have therefore been sought throughout this thesis with specific focus on the struggles currently facing small-scale fish farmers. These findings were used to explore different paths for the Kenyan aquaculture sector with inspiration from Petersen & Plenborg's concept of value drivers. The different aquaculture scenarios each leading to a distinctive forecast of output were further used to estimate each paths potential impact on food security in Kenya. Here two methods were used; the estimation of self-sustaining households together with FAO's Prevalence of Undernourishment (PoU) ratio, which required the application of various statistical methods.
Fish farming was found to be an important way to help improve the livelihoods for small-scale farmers and their families in Kenya. Various struggles were however still experienced especially in regard to acquiring high quality fish inputs while achieving optimal knowledge on best practice farming techniques further proved difficult. The result of these struggles was illustrated when comparing the yields and feed conversion rates to various other countries where the Kenyan farmers could be seen to be substantially behind countries like China and Vietnam. These two countries' export to Kenya further resulted in the Kenyan small-scale fish farmers being excluded from all high-end markets. For Kenyan small-scale fish farmers to overcome these various struggles all the findings pointed towards the Kenyan government's necessary role in creating an enabling environment so farmers could reach new upgrades. Enforcement of new quality standards for fish inputs, a revival of the farmer groups feed mills and hatcheries together with increased best practice knowledge being distributed was therefore found to be needed in order for fish farmers to reach new upgrades. These potential upgrades would in turn enable fish farmers to increase their Gross Profit seven fold. Various indications unfortunately pointed to a bleak outlook for the government's future support of the aquaculture sector especially driven by a divergence among the 47 counties since the devolution took place in 2012. The development path Kenya has been perceived most likely to follow were therefore the scenario Status Quo, which would mean a decrease in aquaculture output from today's levels.
The potential impact this chosen path would have on food security measured as the PoU was estimated to roughly 213,000 more Kenyans that would be suffering from chronic hunger in 10 years time relative to the Optimal scenario. A larger impact on food security was seen from the estimated number of self-sustaining Kenyans with the figure being 0.17M people by 2024 for Status Quo (lower than today) relative to 1.3M in the Optimal case.

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# 1. Introduction

## *1.1. Focus area and brief overview*

Global food security has improved significantly in the last few decades (FAO, IFAD & WFP, 2014). UN's Millennium Development Goals (MDG) lists eight different goals to help end poverty with the first being to completely eradicate extreme poverty and hunger (UN MDG 1 – web). One of the initial targets of this first goal is to half the proportion of people that suffers from hunger by end of 2015 relative to 1990-92 levels (UN MDG 2 - web). Globally this target is within reach with the proportion of undernourished people having declined from 18.7% in 1990-92 to 11.3% in 2012-2014 (FAO, IFAD, WFP, 2014). Within the developing world, which constitutes more than 98% of undernourished people, LATAM and the Caribbean has already reached its target and Asia is within reach (FAO, IFAD, WFP, 2014). Sub-Saharan Africa (SSA), which by it self comprises more than 25% of the worlds 805.3 million undernourished people managed to lower its proportion of undernourishment from 33.3% in 1990-92 to 23.8% by 2012-14 (FAO, IFAD, WFP, 2014). A similar progress has taken place in Kenya, which went from an undernourishment rate of 33% to 24.3% during the same period (FAO, IFAD, WFP, 2014). Although this is a substantial improvement, SSA and Kenya still has a long way to go before reaching the target of 16.65% by the end of 2015 (FAO, IFAD, WFP, 2014).

Undernourishment is especially severe for children where around 45% of all child mortalities can be linked to undernourishment (WHO Factsheet – web).

Within undernourishment generally two types are found, the first stem from a lack calories and proteins while the second is the result of insufficient micronutrients (minerals & vitamins) (World Hunger – web ). Both types can lead to mortality as well as other serious issues such as growth failure, anaemia, diarrhoea, oedema, and lack of energy (FAO Malnutrition – web, WHO nutrition – web).

Fish has a high protein content averaging around 15-20% as well as all essential amino acids, which cereals for instance are low in (FAO nutrition – web ). It is furthermore a valuable source of important micronutrients (FAO nutrition – web). FAO therefore sees the fish industry with its high level of proteins and other important nutrients as a vital sector for helping eradicate hunger world over (FAO World, 2014).

Globally and within Kenya the aquaculture sector has seen substantial growth within the latest years and this is expected to continue (cf. Section 3.2.). In Kenya as will later be discussed the intake of fish is however still substantially below the average of the world average as well as compared to many other African countries like Ghana, Uganda and Egypt (cf. Section 3.2).

This thesis will therefore try to uncover the potential of Kenya's aquaculture sector in helping to improve the food security within the country. The connection between aquaculture and food security will be explored through how future changes in aquaculture output will impact FAO's Prevalence of Undernourishment ratio (PoU) as well as how it can help increase the number of self-sustaining families. Small-scale fish farmers have further been chosen as the focal part of the thesis as they are perceived to constitute the largest potential for improving food security. Other value chain participants together with different supporting organizations will still be analysed, however primarily in regard to their influence on fish farmers.

The Global Value Chain framework will in section two and three first provide a mapping of the aquaculture sector detailing the most important players in context to their local setting in Kenya as well as the international influence on the Kenyan sector. A deeper discussion of the most significant struggles currently facing small-scale fish farmers will then in section four be performed with specific focus on the interplay between the governing mechanisms and the institutional changes affecting these struggles.

Section five will then look at potential upgrades arising from these struggles and the interplay between institutions and governing mechanisms, which will directly lead to three potential scenarios where Kenya's aquaculture output will be forecasted. The forecasted aquaculture output will finally be used to estimate the potential impact on food security each scenario could have in Section six.

## *1.2. Research questions*

Through the use of Neilson & Pritchard's enriched Global Value Chain framework the aim of this thesis is to explore the mechanisms behind the struggles currently facing Kenyan small-scale fish farmers as well as potential solutions that could help improve their social and economic situation. Various statistical forecasting methods including the use of FAO's methodology to estimate the Prevalence of Undernourishment ratio will further be applied to estimate the impact on food security these potential solutions might have.

The following questions are therefore sought answered.

- What are the main participants within the aquaculture sector in Kenya and how are they connected to small-scale fish farmers?
- How is Kenya's aquaculture sector embedded in international markets and what could it learn from a global context?
- How are the underlying mechanisms behind institutional and governance changes influencing the struggles currently facing small-scale fish farmers in Kenya?

- How are these struggles and the underlying mechanisms behind them related to fish farmers' potential upgrading trajectories?
- How might governance and institutional changes together with fish farmers' potential upgrading trajectories impact Kenya's future aquaculture output?
- What development path within aquaculture is Kenya most likely to follow?
- How would the different potential development paths for the aquaculture sector impact food security in Kenya explored through FAO's Prevalence of Undernourishment ratio and changes in the number of self-sustaining households?

## *1.3. Delimitation*

Only a brief analysis of capture fisheries, which has also been needed to forecast in order to estimate the Prevalence of Undernourishment has been carried out because of limited time and scope of this thesis.
The institutional analysis of the Kenyan aquaculture sector has been limited to only include the institutions of significant impact due to resource constraints.

Other possible case studies were considered in order to increase the adequacy of the results, especially one of Red Cross projects currently being developed in Kwale (approx. 40 km south of Mombasa). Resource limitations (time and money), did however not allow for this.
Some of the other delimitations of the thesis mainly stemming from lack of resources (e.g. time) during the field trip in Kenya and from the limited scope of the thesis according to the guidelines at Copenhagen Business School includes;

- Interviewing and analysing supermarkets, hotels and restaurants
- Deeper analysis of processors
- Visiting the government's Sagana training centre (aquaculture)
- Interviewing and analysing people involved in cage culture at the lakes and mariculture at the coast.
- Follow up interviews with case study participants and key stakeholders.

## ***1.4. Philosophical view*** *(ontology & epistemology)*

A philosophical view of critical realism has affected most of the phases within this thesis. Some of the phases can further be seen bordering Robert K. Yin's logical positivistic approach, which will be discussed more in depth in Section 7 (Yin, 2013). The ontology of critical realism follows the positivistic view of believing that a true reality exists (Ven, 2007). It differs however in the sense of going

beyond the cause and effect relationship favoured by positivists and tries to further seek out the mechanisms behind the phenomenon (Nygaard, 2005).
The epistemology deals with how the reality is perceived and how knowledge is created. Within critical realism it is believed that all knowledge is created within the social sphere. It builds on the ontological level that an objective reality does exist, however for the knowledge to be created and understood it has to go through the social sphere, which creates some uncertainty (Nygaard, 2005).

## *1.5. Methodology*

The methodology of critical realism builds on its ontology and epistemology.
A combination of intensive and extensive research designs has been used as Andrew Sayer describes in his work on critical realism (Sayer, 2000). The extensive research design includes using various statistical methods to find quantitative relations between variables often in large data samples (e.g. populations) (Sayer, 2000). The intensive research design uses qualitative methods and instead starts with the individual and focuses on uncovering the individual's various relations and the underlying meanings and mechanisms behind these relations (Sayer, 2000).
One of the methodological tools within critical realism is abductive reasoning, which aims at seeking out the best plausible explanation from a series of observations (Nygaard, 2005, Easton, 2010). A similar approach has been adapted within this thesis including multiple methods of data collection. Through the use of the Global Value Chain framework and by shedding light on the same phenomenon; 'fish farmers' from several point of views the mechanism behind cause and affect are tried uncovered in this study. Abudctive reasoning is further characterised by an integrated relationship between theory and empirical work, each affecting each other in various phases and both affecting the researchers understanding of reality, in line with the overall chosen philosophical view of critical realism (Ven, 2007). The interrelation between theory and empirical work together with a shift between using inductive and deductive reasoning have been applied throughout the various phases of this thesis and will be discussed below.

### *Initial phases*

At initiation the motivation for this thesis circled around the issue of food security in Kenya. At the beginning of the research phase inductive reasoning was used to gather and study various secondary literature about food security globally and in Kenya in order to look for patterns or influences within this field and what sectors might have the largest potential to influence food security.
A method that tries to capture patterns in food security is FAO's ratio of Prevalence of Undernourishment (PoU) that measure how many people that is suffering from

chronic hunger (insufficient access to food), which can be used to compare changes in food security over time and across countries (FAO, IFAD & WFP, 2014).
Comparing Kenya's Food Balance Sheet that details the average nutrition intake of the population with other countries further identified that very little fish was eaten in Kenya relative to other African nations like Ghana, Uganda and Egypt (FAO food balance sheet ). From this a possible relation arose between the potential to increase Kenya's fish output per capita (and thereby their intake) and through this lower its food security measured by the PoU. With research further describing how promising the growth of the aquaculture sector globally and in Kenya was relative to captured fishery it was decided to primarily focus on aquaculture (FAO World, 2014 and FAO fish stat., 2008-2014).

The initial idea was therefore to explore a quantitative relation between the development of aquaculture and food security in Kenya. It was however quickly recognized that this relationship and the various underlying mechanisms that causes changes to the aquaculture sector was extremely complex and that the extensive research design Sayer describes would not adequately be able to capture this. On the extensive research design Sayer notes how it can be useful to provide knowledge about quantitative relations between variables however that it does not help answering why the relationship is like this and what underlying mechanisms that affects it (Sayer, 2000).

Here instead the intensive research design was needed and a choice was therefore made to carry out empirical research in the form of case studies with additional other interviews within the aquaculture sector in Kenya (Sayer, 2000).

The intensive research design have therefore been applied in much of the first parts of the thesis where the theoretical Global Value Chain (GVC) framework have been found optimal to use in helping to bring a deeper understanding of the aquaculture sector in Kenya and its relation to food security.

One of the important things of the GVC framework is its objective to try and uncover in-depth mechanisms behind cause and affect similar to the intensive design within critical realism (Neilson & Pritchard, 2009). Using the authors Neilson & Pritchard further helped contextualize the discussion to agricultural value chains with their research on tea and coffee (Neilson & Pritchard, 2009). The authors use of GVC also provides a tool that tries to capture the complex nature of the many institutional changes and governing mechanisms at play at the same time and how these interactions affect fish farmers livelihood and potential development path (Neilson & Pritchard, 2009). The GVC tool was at this point used as a deductive tool to improve and create interview designs to be used on the later field trip. To acquire an initial pre-understanding of the many facets of fish farming as is advocated for within critical realism, various secondary literature was studied prior to venturing into the field and performing the case studies (Ven, 2007).
Through these initial studies and Neilson & Pritchard's GVC framework small-scale

fish farmers was further identified as showing the highest potential to affect food security and was therefore chosen to constitute the centre of this thesis.

***Fieldwork***

Throughout the fieldwork inductive reasoning was applied in order to try from the observations to understand the relations between fish farmers and the other parties they engage with as well as the deeper questions of the mechanisms behind these relations and what might have caused them to be this way. The fieldwork further indicated that the extra nutrition a household gets from having a fishpond together with the extra income farmers could earn from farming fish already substantially helped improve their livelihoods. These findings indicated an additional important relation between development in aquaculture and food security in addition to the initial one between aquaculture output and the PoU ratio. Changes in the number of self-sustaining households arising from aquaculture development were therefore added as a further relation to food security in Kenya.

***Analysis of observations***

After conducting the empirical research GVC was again used as a deductive tool to analyse fish farmers contextualised situation in Kenya and their relations to the other players and surrounding institutions and supportive organisation of the value chain. Especially the underlying mechanisms leading to the fish farmers current struggles was sought to be understood through Neilson & Pritchard's GVC framework and how institutions and the supportive organisation through various changes can help enable or constrain upgrading options leading out of these struggles (Neilson & Pritchard, 2009).

The underlying mechanisms that was found to create and change the social and economical context small-scale fish farmers are situated in through the use of intensive research design and the GVC theory was hereafter used as basis for applying Sayer's extensive research design to forecast aquaculture output.

The forecasting of the aquaculture output is carried out with inspiration from Petersen & Plenborg's work on value drivers where aquaculture upgrading enablers are first identified and analysed, which then have a direct impact on the two primary growth output drivers that finally leads to a forecast of aquaculture output (Petersen & Plenborg, 2012). Three scenarios are explored with different assumptions for the aquaculture upgrading enablers and growth output drivers resulting in various forecasts for aquaculture output in Kenya.

Moreover in order to estimate the final quantitative relation between changes in aquaculture output from the three scenarios and their effects on food security in Kenya measured as the PoU ratio and the changes in self-sustaining fish farming households additional forecast have also been necessary to carry out.

When using the extensive research design to conduct these additional forecasts the methodology applied have further been inspired by Donald T. Campbell's evolutionary critical realism view of how scientific progress evolves through a selectional approach (Ven, 2007). Campbell argues it is through the comparison of various evidence and arguments that the best alternative from the models available is chosen (Ven, 2007). This have to a large degree been applied throughout Section five & six when deciding on the most optimal model; be that of the output from captured fishery or the different parameters leading to the estimation of FAO's food security indicator the PoU ratio.
The theories and methods used to forecast various aquaculture scenarios and estimate these scenarios potential consequences for Kenya's food security will be discussed more in depth when presented in Section 5.3 & 6.

## 1.6. Primary & secondary data

### *Primary data*

All primary sources throughout this thesis will only be referenced to by their name. All details about the references can further be seen in Appendix 1.

#### *Kenya*

The majority of primary data collected in Kenya were gathered during one field trip from the 14-25th of March 2015. One Skype interview (with AFIPEK) was conducted later from Denmark.
A combination of using previously established contacts (mainly formed through an internship at Growth Africa running from June-November in 2014 in Nairobi), cold calling and use of gatekeepers to access respondents were used.
Four of the five fish farmers interviewed were from Kakamega and belonged to the same farmer group called Fish For Kenya hereafter shortened to FFK when referring to the these four fish farmers together. This group had a total of 18 members. The last fish farmer was based in Kisumu where he worked as a fishpond attender at Kisumu Polytechnic (college). Further information about the respondents can be seen from the table below.

| Date | Category | Name | Institution | Location of interview |
|---|---|---|---|---|
| Monday 16 March 2015 | Fish Farmer / University | David | Kisumu Polytechnic | Kisumu |
| Monday 16 March 2015 | Fish Farmer | Philip | Private / Fish For Kenya | Kakamega |
| Monday 16 March 2015 | Fish Farmer | Kennedy | Private / Fish For Kenya | Kakamega |
| Tuesday 17 March 2015 | Fish Farmer | Millington | Private / Fish For Kenya | Kakamega |
| Tuesday 17 March 2015 | Fish Farmer | Evans wife* | Private / Fish For Kenya | Kakamega |
| Tuesday 17 March 2015 | NGO | Charles Opanga | FarmAfrica | Kisumu |
| Wednesday 18 March 2015 | Government Agency | Anonymous | Ministry of Fisheries | Kisumu |
| Wednesday 18 March 2015 | Feed Producer | George Ambuli | Bidii Fish Feeds | Luanda |
| Wednesday 18 March 2015 | Feed Producer | Dave Okech | Sare Millers | Kisumu |
| Thursday 19 March 2015 | NGO | Elijah Muji | Red Cross | Nairobi |
| Monday 22 March 2015 | Parastatal | Anonymous | AAK | Nairobi |
| Friday 27 March 2015 | Independent Organization | Beth Wagude | AFIPEK | Nairobi |

**Table 1:** Overview of case studies and interviews - own creation. (*Evans was initially supposed to be the respondent, however he had to run to the veterinarian because his cow was sick, his wife therefore took his place)

***Denmark***

First hand data collected in Denmark, mainly phone conversations and emails were conducted throughout the projects lifetime, spanning from December 2014 until June 2015. A partnership consisting of knowledge sharing and sparring with the Danish organisation Access2Innovation was further established in December 2014. Access2Innovation provided invaluable information and sparring throughout the project and further helped in getting access to several sources both in Denmark and in Kenya.

***Other interviews & observations***

Several other interviews were carried out with key stakeholders of the aquaculture chain in Kenya. The other interviews carried out can be seen from Table 1 above.

In addition to the case studies and other interviews conducted first hand data have been collected through numerous sources. This data was collected through a combination of observation, phone calls and email correspondence. Details of this data can be seen in Appendix 1.

***Interview guides & data***

Prior to all interviews (incl. case studies) an interview guide was developed.

All interview guides were made with semi-structured design and open-ended questions to allow for a high level of flexibility (Easton, 2010).

The primary focus area on fish farmers throughout this whole project were implemented in the interview guides for the various respondents.

Although specific guides were made for several of the respondents a core part of the questions remained the same or were simply articulated differently to adapt to the different respondents.

All questions were organized into different sections and prioritized according to the most essential information at the beginning while still keeping in mind the respondents need to feel secure (first few questions not being to difficult and complex). Before asking the respondents the first question, careful explanation of the purpose of the study was carried out together with background information of the researcher and a promise of anonymity if this was the respondent's wish. An offer of receiving a summary or the full report was further suggested, which was opted for by most respondents.

All interview guides and transcribed interviews can be found in the attached Excel sheet (on CD) called 'Interviews' and an example of the interview guides and transcribed interviews can be seen for; Ken (fish farmer) and AFIPEK in Appendix 2-5. The questions are all in bold and for the ones marked in red colour indicate the respondent for some reason was not able to answer or the answer had already been covered from another question.

### *Secondary data*

Desk research was used to make a preliminary mapping of key processes and actors within the Kenyan aquaculture sector as well as to provide a broader perspective on trends and characteristics within the global aquaculture sector.
A combination of local (Kenyan) and global research reports, articles, and data from both the private and public sector were used. Several theoretical frameworks were considered prior to the field trip to Kenya and a final framework was additionally chosen before departure, which will be discussed in the next section.

# 2. Literature review

This section will discuss different theories that have been considered used as frameworks for the analysis of Kenya's aquaculture sector as well as argumentation for the theoretical framework finally chosen for this task.
Within the analysis of products or commodities Neilson & Pritchard divides the different schools of thought into two different overall views; the linear and the non-linear (Neilson & Pritchard, 2009). The linear approach uses vertical analysis of commodities/products flows and focuses on capturing the transformation and value addition between each stage. The non-linear method uses a network approach, which perceives the structures of sectors or value chains in a more multidimensional view with higher emphasis on geographical concepts like place and space influencing economic changes (Neilson & Pritchard, 2009). The most relevant of the non-linear schools; the Global Production Network will first be discussed where after a more detailed discussion will follow on the attributes of the chosen theoretical framework of this thesis – Global Value Chain (GVC) and its nuances (thesis limitations have confined the discussion to these two theories).

| Linear product/commodity | Non-linear product/commodity |
|---|---|
| **Global Value Chain (GVC)** | Commodity Circuits |
| French Filiere approach | Actor Network |
| Systems of Provision | **Global Production Networks** |
| Commodity System Analysis | |
| Food Supply Chains | |

**Table 2:** Overview of product/commodity frameworks – Neilson & Pritchard, 2009 and own work

### *Global Production Networks*

The Global Production Network (GPN) theory was created in a response to some of the critiques facing non-linear theories such as the Commodity Circuits and Actor

Network (Neilson & Pritchard, 2009). The Commodity Circuits and Actor Network theories are both heavily influenced by geographers, which enables them to capture a lot of place specific data and details, however this same feature also resulted in criticism of lacking a causal aspect and obstructing the analysis of economic profit and power relations among sector participants (Neilson & Pritchard, 2009). GPN can therefore be seen as a hybrid trying to capture both the (linear) distribution of economic power and profit between participants within a value chain as well as the spatial dimension of geographers (non-linear) (Neilson & Pritchard, 2009).
In their study of the car manufacturer BMW within different European and East Asian countries Coe et al. explains how they see the regional development being created by interdependent relational processes not just within the region but also in an increasingly global environment (Coe et al., 2004). Institutions still play a key role within Coe et al.'s description of the GPN framework where they can be seen to constitute an intermediary role between what they refer to as a 'strategic coupling' of global production networks and regional resources (Coe et al., 2004).

A more enriched relational approach to the GVC framework adapted by Neilson & Pritchard in their Indian coffee and tea studies to counter some of the criticism often listed by non-linear theories; as GVC's inadequate capturing of how the roles of space, place and territory affects value chains, relates in several ways to the GPN approach described by Coe et al (Neilson & Pritchard, 2009, Coe et al., 2004). In this way the enriched GVC framework can be seen as approaching the hybrid theory of GPN.
Neilson & Pritchard also describes this narrowing of the two approaches with a situation where clearly articulated GVC studies was included in a special study on GPN within the Journal of Economic Geography (Neilson & Pritchard, 2009). The differences between the two frameworks therefore sometimes seem to be fading.

Even though the two frameworks can be seen to be bridging each other, the GPN is often used in more complex production related industries, like the automobile industry analysed by Coe et al., where the increased number of relations across space and industries often makes the network approach more optimal (relative to GVC or other linear approaches) (Coe et al., 2004, Neilson & Pritchard, 2009). The GVC approach on the other hand according to Neilson & Pritchard can often provide a better framework when working with agricultural industries where it is essential to capture the vertical structures involved in the transformation and value addition of a commodity (Neilson & Pritchard, 2009). It is especially due to this reason an enriched GVC framework have been chosen (over the GPN) to analyse the Kenyan aquaculture sector. In the next section the specific attributes of GVC as well as various nuances within the framework will be discussed.

## ***Discussion on GVC theory and its appliance to the Kenyan aquaculture sector***

GVC research was first fully developed as a separate theory by Gereffi and Korzeniewitcz in1994 to analyse the footwear sector in regard to global trade patterns (first called global commodity chain) (Neilson & Pritchard, 2009, Gibbon & Ponte, 2005).

GVC theory has four different pillars; input-output, territoriality, governance and institutions, which all authors within GVC include to some degree (Institutions came later on) (Neilson & Pritchard, 2009).

All four pillars individual appliance in regard to analysing Kenya's aquaculture sector will be discussed in this section. Governance and recently also institutions are generally seen, as being the more focal part of the framework why these two pillars also comprises larger variances among the authors' approaches (Neilson & Pritchard, 2009, Gibbon & Ponte, 2005, Ponte & Sturgeon, 2014 Jespersen et al., 2014, Ponte et al., 2014). They will for this reason and because they are also seen as being central to the analysis of Kenya's aquaculture sector receive more attention in the following sections relative to input-output and territoriality which concepts various authors better tend to agree on.

### ***Input–output and territoriality***

The input-output and territoriality pillars can be seen as a useful tool to map a chosen value chain in its rightfully contextual setting, which is essential to reach the later stages of the analysis; governance and institutions (Neilson & Pritchard, 2009).

Input-output within the GVC theory is used to describe the most important parts of the value chain, in this case from the perspective of the fish farmers, which is the focal area of the thesis (Gibbon & Ponte, 2005, Neilson & Pritchard, 2009). It provides an overview of the characteristics and processes present within the value chain. The understanding of the different value chain participants is further essential when continuing the value chain analysis within the next three pillars.

The territorial pillar was originally designed to shed light on the sector of focus in a global context encompassing the many connections and interactions our ever more global world constitute (Gibbon & Ponte, 2005, Neilson & Pritchard, 2009). Kenya's aquaculture sector is at the moment not involved in exporting and it consequently does not have interactions with international downstream buyers as is often seen in the sectors analysed using the GVC framework including Neilson & Pritchard's work on the Indian tea and coffee sectors (Neilson & Pritchard, 2009, Jespersen et al., 2014, Ponte et al., 2014). The global aquaculture value chain does however hold significant influence over the Kenyan sector through the competition coming from international fish farmers (mainly China and Vietnam). The development and changes in the global world therefore still need to be included in the GVC analysis to properly account for Kenya's current contextualized setting. Kenya's trade policies in regard to its governance of import enabling this global interaction will further be analysed more in-depth in Sections 4 & 5. Additionally by comparing Kenya's performance to best practice cases from various countries it has been found easier to understand how well Kenya's aquaculture sector have fared so far as well as the potential for Kenya if the right paths are followed in the future.

***Governance and institutions***

In Gereffi's initial work governance was distinguished by two types of global value chains the producer driven and the buyer driven (Neilson & Pritchard, 2009, Gibbon & Ponte, 2005 and Gereffi et al., 2005). The producer driven chains were characterised by being capital and technology intensive and fitted sectors such as the automobile sector and electronic sectors where as the buyer driven chains involved large retailers and trading companies with heavy focus on branded products (Neilson & Pritchard, 2009, Gibbon & Ponte, 2005 and Gereffi et al., 2005). Gereffi's early work initiated within manufacturing sectors, especially footwear and textiles and therefore came to focus on the gradual shift seen within these sectors from producer driven chains towards buyer driven chains (Neilson & Pritchard, 2009, Gibbon & Ponte, 2005 and Gereffi et al., 2005). The power of large branded retailers could here be seen growing as globalization intensified (Neilson & Pritchard, 2009, Gibbon & Ponte, 2005 and Gereffi et al., 2005). Although the dual approach to governance might hold within textiles; the producer vs buyer driven chains came to be seen as too rigid a characterisation of most sectors in practice (Neilson & Pritchard, 2009, Gibbon & Ponte, 2005 and Gereffi et al., 2005). In 2005 Gereffi, Humphrey and Sturgeon brought together different forms of intermediary research to the originally coined buyer vs producer driven theory and created a new method for analysing governance within GVC (Neilson & Pritchard, 2009 and Gereffi et al., 2005). Their suggestion focused heavily on the coordination mechanism between different nodes of the value chain and includes five different types of governance coordination forms using three different variables and one characteristic as can be seen in Table 3 below (Neilson & Pritchard, 2009 and Gereffi et al., 2005).

**Table 1** Key determinants of global value chain governance

| Governance type | Complexity of transactions | Ability to codify transactions | Capabilities in the supply-base | Degree of explicit coordination and power asymmetry |
|---|---|---|---|---|
| Market | Low | High | High | Low |
| Modular | High | High | High | |
| Relational | High | Low | High | |
| Captive | High | High | Low | |
| Hierarchy | High | Low | Low | High |

**Table 3:** Reproduction of GVC governance types - Gereffi et al., 2005, page 87

The new coordination focused governance concept made it possible to capture a deeper understanding of the relationships between participants throughout the value chain opposed to the producer vs buyer drivenness, which was more focused on the broader mechanisms taking place between each end of the value chain (Neilson & Pritchard, 2009 and Gibbon & Ponte, 2005). The new coordination form of governance draws on transaction cost theory and centres on the complexity of transactions and how this through buyers implementation of higher standards for suppliers (who are/become able to codify this information) can help lower the level of explicit coordination needed to take place among value chain participants (Neilson & Pritchard, 2009 and Gibbon & Ponte, 2005).
One critique raised by Gibbon & Ponte of the coordination method however mentions how it misses the historical dynamics of drivenness happening within global value chains (Gibbon & Ponte, 2005).
A historical perspective within the GVC analysis can be extremely valuable in helping to understand the underlying dynamics of the sector and this is taken into account in Neilson & Pritchard's research on the Indian tea and coffee markets. Here several institutions established in colonial time can be seen to still bear significant influence (Neilson & Pritchard, 2009). A historical perspective has also been found useful for the Kenyan aquaculture. Although it has not been found relevant to include a deeper analysis of fish farming before 2009 in this thesis because fish farming in Kenya was almost none existent before the government launched its Fish Farming Enterprise Productivity Programme (FFEPP) in 2009.

Several other points of critiques on the GVC framework from geographers and GPN scholars however also still flourished, which claimed the linear and vertical approach taken by GVC end up missing much of the geographical complexity and importance of place and space earlier mentioned.
Neilson & Pritchard's work on the Indian tea and coffee sectors try to integrate much of this critique in their institutional enriched GVC framework.
Douglas North an economist, which have affected Neilson & Pritchard's framework argues how the institutional framework is essential in determining long-term changes within sectors or economies with path dependency being an important

part of the institutional analysis (Neilson & Pritchard, 2009). This is contrary to Gereffi's initial GVC framework, which saw governance as being the central part of the analysis and where institutions only constituted a smaller part of the analysis; being the external frame wherein governance mechanisms took place (Neilson & Pritchard, 2009).

Within the Kenyan aquaculture sector the institutional environment is perceived as having a central role in enabling the possible governance mechanisms and development paths that are able to take place. Neilson & Pritchard's GVC approach with institutions having a more significant role in deciding the trajectories of a sector is therefore seen as being better at capturing the underlying mechanisms playing out in the sector. Neilson & Pritchard goes one step further and argues how they see the governing mechanisms of value chains as being coproduced in a constant interplay with institutional changes (Neilson & Pritchard, 2009).

Within Kenya's aquaculture sector institutional (primarily government) initiatives can often be seen to either cause changes in governance mechanism or arise from changes in governance mechanisms. Adopting Neilson & Pritchard's method of the two pillars interplay therefore allows for a more complex understanding of the dynamics of the sector opposed to treating them separately.

A suggestion to present this more complex nature of governance and institutions is made through the concept of 'struggles', which are seen as the nexus between the two pillars and arising from their interplay (Neilson & Pritchard, 2009). Within this thesis three different struggles for small-scale fish farmers will similar to Neilson & Pritchard's four struggles from the Indian tea and coffee sectors be used to discuss and analyse the interplay of the two pillars (Neilson & Pritchard, 2009). Analysing the most significant struggles also helps to contextualize the governing mechanisms and institutional changes that are playing out within the specific situation Kenyan fish farmers are placed in. Including the concept of struggles in the GVC analysis further helps bringing the social aspects of fish farmers' life to the front of the analysis, which has been found highly relevant given the thesis overall emphasis on exploring ways to improve food security.

The four authors; Ponte, Kelling, Jespersen and Kruijssen's research on Aquaculture in Asia (Bangladesh, China, Thailand, Vietnam) materializing into two articles concerning the link between governance and upgrading together with the institutions role in influencing various upgrading trajectories have also been found relevant to include in this thesis (Ponte et al., 2014, Jespersen et al., 2014). Governance is here primarily explored through an elaborated version of the coordination method developed by Gereffi, Humphrey and Sturgeon in 2005 (Ponte et al., 2014, Jespersen et al., 2014, Gereffi, 2005).

An additional whole-chain governance concept that describes the overall drive by lead firms and the strength of this drive are further included (Ponte et al., 2014, Jespersen et al., 2014). This can be seen as an adapted version of the initial

producer vs buyer drivenness, which now allows for more nuances like several drives taking place at the same time (Ponte et al., 2014, Jespersen et al., 2014). The four authors combination of the two governance methods also helps respond to some of the earlier criticism raised by Gibbon & Ponte that using the coordination method singlehandedly to analyse governance missed some of the larger changes taking place within global value chains (Ponte et al., 2014, Jespersen et al., 2014, Gibbon & Ponte, 2005).
The concept of overall drive has been found less important in Kenya since fish farmers are currently being cut off from all large downstream producers and buyers, which are the only ones that seem to express a significant drive. To some extent this concept will still be explored on the basis of fish farmers managing to gain access to the these downstream players and the potential consequences resulting from this. The discussion will however more follow Neilson & Pritchard's use of the concept drive (Neilson & Pritchard, 2009).

Ponte et al. and Jespersen et al.'s work on aquaculture in Asia examines the institutional influence in the context of the link between governance mechanisms and upgrading trajectories earlier analysed and discussed in their article (Ponte et al., 2014, Jespersen et al., 2014). Although the institutional aspect does not take as central a role as seen in Neilson & Pritchard's work, it is still recognized as having a large influence on value chain participants potential upgrading trajectories and in their conclusion they also argue for using an integrated analysis of governance, institutions and upgrading within the GVC framework (Ponte et al., 2014, Jespersen et al., 2014). Several similarities within governance, institutions and upgrading can therefore be seen relative to Neilson & Pritchard's framework. Ponte and Jespersen et al.'s work on aquaculture and on countries used as best case examples in this thesis (e.g. Thailand) or China and Vietnam, which are the largest international influencers on Kenyan fish farmers (through import) further makes their findings highly tangible relative to the Kenyan aquaculture sector. Following this Neilson & Pritchard's theoretical framework and findings in the Indian tea and coffee sector will continue being the central theoretical piece of this thesis with occasional complementary findings from Ponte and Jespersen et al., when found relevant.

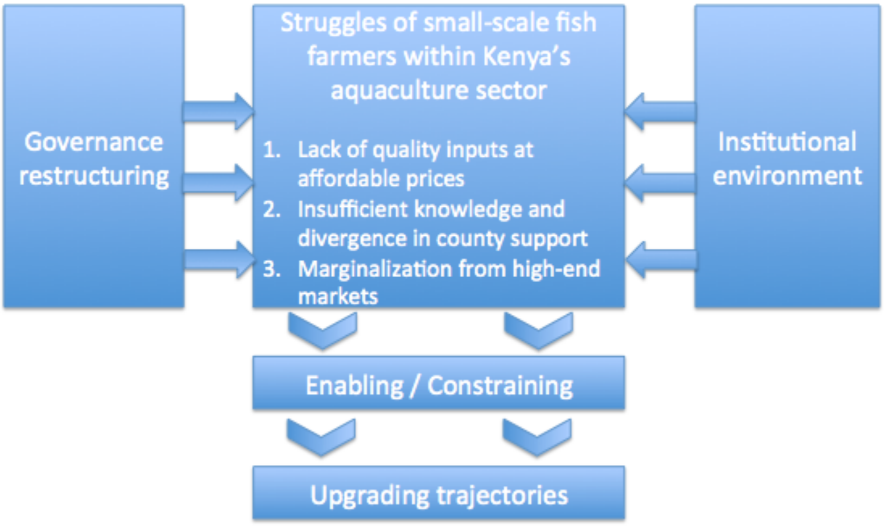


**Figure 1:** Moderated version of Neilson & Pritchard GVC figure – Neilson & Pritchard, 2009, Location 672 in E-book.

The figure seen above illustrates how Neilson & Pritchard's GVC framework will be used throughout this thesis.

***Upgrading***

It has for long been an important research question within GVC to answer if any specific upgrading trajectories could be linked to the type of governance existing within a value chain (Neilson & Pritchard, 2009). Humphrey and Schmitz classification of four different types of upgrading are commonly used to describe the potential upgrading paths that can be taken and will also be used in this thesis (Neilson & Pritchard, 2009).

- Process upgrading
- Product upgrading
- Functional upgrading
- Inter-sectoral upgrading

From Neilson & Pritchard's work it is further recognized that it is to a large extent the institutions that create the upgrading opportunities that are reachable for Kenyan fish farmers (Neilson & Pritchard, 2009). Neilson & Pritchard's GVC approach makes the link from the interwoven governance and institutions to upgrading very transparent hence it is the results of the struggles and solutions to them that will decide the economic and social situation for the fish farmers (Neilson & Pritchard, 2009). The current observed and potential upgrades for small-scale fish farmers will therefore directly follow the various discussions and findings from the struggling section in this thesis.
This will lastly lead to three different upgrading paths including their potential impact on food security in Kenya being forecasted and explored in Section 5 & 6.

# 3. Mapping of Kenya's aquaculture sector

## 3.1. Input – Output

This section will briefly describe the processes and characteristics of the main participants of Kenya's aquaculture sector and their relation to small-scale fish farmers (an illustration is shown in Figure 2 below).

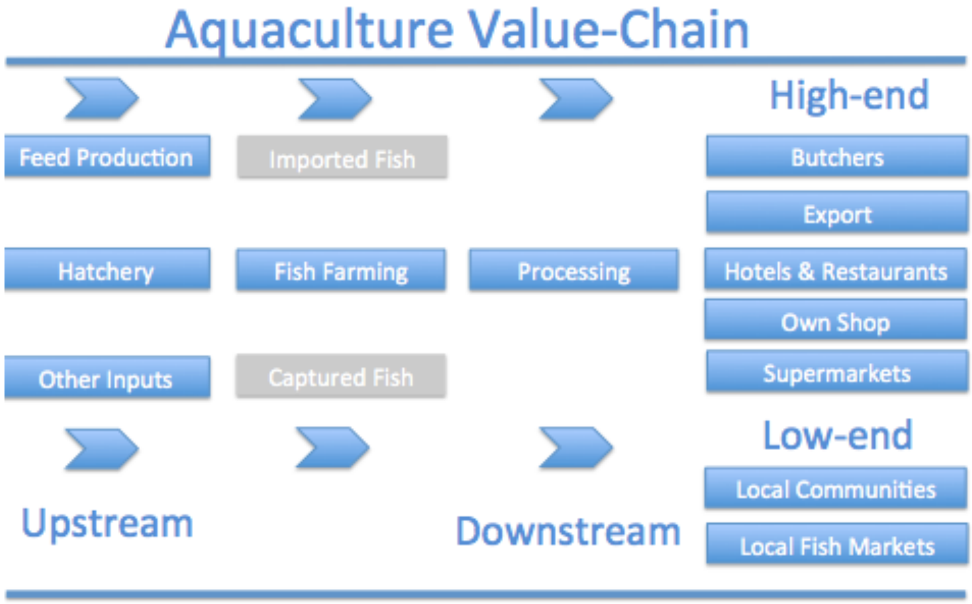


**Figure 2:** Illustration of the aquaculture sector in Kenya – own work

### *Fish feed producers*

Producers of fish feed constitute the most essential supplier for fish farmers. Differences in fish feed can have large influences on the growth of fish as well as the production costs for fish farmers as will later be explored in Section 3.2. & 5. Estimates from two different sources put the cost of fish feed for fish farmers to between 40-60% of total production costs in Kenya and between 41-84% from research done in China, India, the Philippines and Vietnam (Rana et al., 2013 and Munguti 2 et al., 2014). From the five case studies feed was observed to constitute 73.5% of total production costs on average (FFK, David and own work).
Fish feed in Kenya generally takes three different forms; natural feed, mashed or pelleted feed (either exclusively or in combination).
Natural feed made through agricultural by products is the cheapest one since the majority of this will be collected from farmers' own land. Examples of natural feed includes: chicken or cow manure to create phytoplankton and by products of various vegetables or cereals (Munguti 2 et al., 2014, FFK and David).

The ingredients most often used for mashed or pelleted fed are (Sare Millers and Bidii Fish Feed, Munguti 2 et al., 2014):

- *Protein content:* fish meal (fish by products), caridina (lake shrimp)
- *Other ingredients:* by products of soy maize, wheat, rice, cotton, sunflower limestone, premix trout (vitamins and minerals) and cassava as a binder.

Mashed feed is grounded into powder using various machines.
Pelleted feed comes in either sinking or floating pellets. Sinking or floating pellets can also be extruded, which increases its digestibility (FAO pellets - web).

### *Fish feed prices*

Mashed or pelleted feed can either be produced on the farm bought directly from the producer or through what is called an agrovet (sells all kinds of inputs to farmers). Producing on the farm, however requires that the farmer has his own machine(s) and this is not likely for many small-scale fish farmers where even buying fish feed from an agrovet is considered expensive or out of reach (FFK and Munguti 2 et al., 2014).
In Table 4 below a sample of different fish feed producers, their prices and feed types can be seen, details can be seen in Appendix 6.

| Fish Feed Producer | Type of feed | Protein content | Price pr. Kg (KES) |
|---|---|---|---|
| Sare Millers, Hesao, Bidii, Osifeeds, Mwea | Mashed | 25-35% | 46-150 |
| Hesao, Othaya, Bidii, Ugachick, Sigma, Zibag, Thoyu, Osifeeds | Floating pellets | 25-35% | 65-100 |
| Jambo, Osifeeds, Zibag Fish, Ugachick | Floating pellets | 36-44% | 90-190 |

**Table 4:** Kenya's fish feed sector – Own work.

High variances can be seen both for mashed and pelleted fish feed. The level of protein (which is often the most expensive part) is a contributor to higher prices (more clear from Appendix 6). If the prices between mashed and pelleted feed with the same level of protein is compared Table 4 also shows that pelleted fish feed in general are more expensive. Sare Millers was the cheapest fish feed and Bidii Fish Feed was also in the lower end.

## *Hatcheries*

Another highly important input for fish farmers is fingerlings, which can either be bred at farmers own farm or supplied by hatcheries. The majority of fish farmed in Kenya is tilapia and African catfish, which between 2007 and 2011 constituted between 70-75% and 18-22% of the total farmed fish production (Nyandat & Owiti, 2013).

### *Tilapia hatchery*

Generally three methods can be used to hatch tilapia fry, all where the spawn is collected from the brood stock and put into a separate pond or tank for rearing, details of the various methods can be seen in Appendix 7 (Ngugi et al., 2007).
Fish farmers only using male tilapia as their grow-out stock gain a clear advantage. Using only male relative to mixed sexes increases the growth rates with an

estimated 20%, why the demand for monoculture (male) fingerlings is also higher (Bhujel, 2013). There are two ways for a hatchery to produce male tilapia.

- Hand sexing: manually divide the fish where skilled workers can achieve up to 95% correctness. This method is cheaper and easier to manage however also rather inefficient compared to using hormones (Ngugi et al., 2007). David from Polytech reported a 75-80% success ratio (David).
- Use hormones, which are fed to fry kept in hapas or tanks for 21-28 days.

From the field trip in Kenya none of the case study participants or other interviewees mentioned using hormones for sex changing. Even the representative from AAK mentioned how the government-training centre in Sagana used hand sexing (AAK). Jambo Fish (a medium sized integrated fish farmer) does however sell Ovaprim from their webpage, which can be used as hormones to change the sex of tilapia (Jambo Fish – web ).

***African catfish hatchery***

Relative to the tilapia breeding catfish is much more complicated and expensive. In order to get catfish to spawn it is necessary to inject the females with a hormonal treatment (pituary glands from catfish/other species, Ovaprim, DOCA, or HCG) and the breeding process further involves several other more complicated phases relative to tilapia (Ngugi et al., 2007 and FAO catfish 3).

***Fingerling producers and prices***

The data gathered for fingerling prices as seen in Table 5 below presents some variations, although most sources provided similar figures. Of the interviewed fish farmers; David and Millington both had their own hatchery for tilapia (Millington just started this although it was currently dried out) (David and Millington).

| Source | Producer | Fish | Price KES |
|---|---|---|---|
| Mwea Aquafish Farm | Mwea Aquafish Farm | Tilapia | 10.0 |
| Millington | Dominon Farm / Others | Tilapia | 7.5 |
| Ken | Other farmers | Tilapia | 8.5 |
| Philip | Dominion Farm | Tilapia | 5.0 |
| Central Kakamega Aquaculture Cooperative Society | Different authorised hatcheries | Tilapia | 5.0 |
| Muuangano Fish Farmers | Jewlet Enterprises / Dominon Farm / Government fish farm / LBDA fry production centre | Tilapia | 6.0 |
| Tilapia Fish Farmers Group | Jewlet Enterprises / Government fish farm | Tilapia | 6.0 |
| Great Wangchieng Fish Farmers Community Based Organization | Jewlet Enterprises | Tilapia | 7.0 |
| Butula Pond Fish Farmers Cooperative Society Ltd. | From Uganda | Tilapia | 3.0 |
| Mwea Aquafish Farm | Mwea Aquafish Farm | Catfish | 7.0 |
| **Average** | | | **6.5** |

**Table 5:** Prices of fingerlings **-** Nyandat & Owiti, 2013, FFK and David, Mwea Aquafish Farm.

From the field trip to Kenya and from secondary research only three larger hatcheries were observed; Mwea Aquafish Farm; Dominion Farm (huge US integrated fish farmer) and Jewlet Enterprises, which together can produce between 20.4-32.4 million fingerlings (mix of catfish & tilapia) annually corresponding to 14-22.3% of the total needed amount of fingerlings for small-scale farmers in 2013 (Mwea 1 – web, Mwea 2 – web and Mwea Aquafish Farm; Jewlet – web; Dominion 2 – web, Dominion 3– web and Appendix 15).

## *Small-scale fish farmers*

Fish farming can be practised through the use of either ponds, dams/reservoirs or fish tanks (Munguti 1 et al., 2014). As mentioned in the previous Section on hatcheries the most common species farmed are tilapia and catfish constituting around 90% of all the fish farmed in Kenya why these species will also receive most attention throughout this thesis. From the case studies performed in Kenya harvest was observed to take place every 6-10 months (FFK and David). The fish was sold to local communities or local markets, either as fresh, smoked or fried (FFK and David).

Kenya's aquaculture sector is dominated by small-scale fish farmers. More than 95% of fish farmers in Kenya can be characterised as being small scale according to two different sources and by characterising the farms as having less than five full time employees (Nyandat & Owiti, 2013 and Munguti 1 et al., 2014). Indications from the field trip have showed fish farming in Kenya to be a very good income source for farmers relative to other possible crops and with limited land requirements (Red Cross, Ken and Evans wife). Both Evans wife and Millington mentioned that they were able to send their kids to college and university through the income they received from selling fish (Millington and Evans wife).

At the same time as being an important income generating source, fish farming is also a vital food source for the farmers family packed with much needed proteins and essential vitamins and minerals (FAO World, 2014).

### *Development*

In Kenya the number of fish farmers have increased significantly from around 6,328 fish farmers in 2009 to 49,050 in 2012 as can be seen from Table 6 below.

| Fish farming statistics Kenya | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 |
|---|---|---|---|---|---|---|---|
| Total Production (ton) | 1,012 | 4,240 | 4,452 | 4,895 | 12,154 | 22,135 | 21,488 |
| No. of farmers | 4,742 | 4,742 | 4,742 | 6,328 | 14,120 | 48,721 | 49,050 |
| No. of ponds | 7,477 | 7,471 | 7,530 | 9,116 | 15,529 | 45,745 | 69,998 |
| Area of ponds (m2) | 2,170,000 | 2,160,000 | 2,270,000 | 2,750,000 | 4,670,000 | 13,610,000 | |
| Area of dams, tanks, raceways (m2) | 5,048,289 | 5,001,347 | 5,002,413 | 5,493,085 | 5,493,085 | 5,763,085 | |
| Total Farmed area (m2) | 7,218,289 | 7,161,347 | 7,272,413 | 8,243,085 | 10,163,085 | 19,373,085 | |
| Average farmed area per farmer (m2) | 1,522 | 1,510 | 1,534 | 1,303 | 720 | 398 | |

**Table 6:** Source: FAO, Fishery and Aquaculture Statistics, 2014, Nyandat & Owiti, 2013 and own work.

The total area of land used for fish farming have increased as well, however not in the same scale because of the many new 300m$^2$ ponds from the FFEPP, which will be elaborated on in section four. Total farmed fish production can also be seen to have increased to 21,488 tons in 2012 from only 1,012 tons in 2006.

## *Large-scale integrated fish farmers and buyers*

Only two mid to large scale fish farming operations were currently found to take place in Kenya; Dominion Farm and Jambo Fish. Both mid to large scale fish farming companies can be seen to have chosen a path of vertical integration enabling them to have full control over the majority of their value chain (own feed & seed production and own processing unit), which further result in little interaction with the rest of the value chain (see Appendix 8 for more details).

## *Processors*

The current number of fish processors in Kenya is 14 according to AFIPEK (Kenyan Fish Processors and Exporters Association), six based near Lake Victoria and eight based in Mombasa. AFIPEK represents all fish processors and exporters of fish in Kenya and it has been mandatory since 2000 for a processing company to join their organization (AFIPEK).

When processing fish, usually into fillets, a percentage of the fresh fish will end up as a waste product. The percentage level varies among fish species (AFIPEK, Borderias et al., 2011, Prime Cuts).

- For tilapia the waste product constitutes between 65-70%.
- For Nile perch the waste product constitutes around 50%.
- For the African catfish the CEO of AFIPEK estimates it to be less than 50%, although she was not completely sure.

### *Tilapia*

Of all the fish processors involved in the production of tilapia in Kenya none of them buys tilapia from farmers or captured from the lakes, they all import it (mainly from China or Vietnam) (AFIPEK, Peche Foods, Farmers Choice, Alpha Foods, and Prime Cuts ). Some of the processors used to buy tilapia from fishermen (captured), however this has become too expensive relative to what they can buy the imported for. This can be seen from Table 7 below.

| Source | Seller | Tilapia (fresh) kg. Prices KES 2015 | Tilapia (fresh) kg. Prices USD 2015 |
|---|---|---|---|
| AFIPEK estimate | Imported | 92 | 1.00 |
| www.made-in-china.com | Imported from China | 102 | 1.11 |
| Manager of Peche Foods | Imported from Vietnam | 110 | 1.20 |
| Ministry of Fisheries | Captured fish avg. price Kenya | 250 | 2.73 |
| Fish For Kenya & David | Farmed fish avg. price Kenya | 314 | 3.43 |

**Table 7:** Tilapia prices when processors are buying – China - web, AFIPEK, FFK, David, and Department of Fisheries, EAC, 2007 and own work.

The main reason cited by AFIPEK on why its members are not buying farmed tilapia is the price which is too high together with the lack of continuous supply, since most are small-scale farmers that only harvest every 6-10 months (AFIPEK).

Comparing the different prices from Table 7 it can be seen that captured fresh tilapia is 147.6% more expensive than the average imported tilapia and farmed tilapia is 210.5% more expensive than imported tilapia.
The tilapia sold as fillets by processors are mainly sold to supermarkets and a few processors like Jambo Fish or Prime Cuts also have their own shops, none is exported (AFIPEK, Manyala, 2011, Prime Cuts, Jambo Fish). It is possible some processors sell tilapia to butchers however of the five different butchers visited in Nairobi all bought their tilapia from fishermen or traders at Lake Victoria.

***Other processed species***
Besides tilapia the processors are mainly processing Nile perch (50% of total fish processed), which is captured from Lake Victoria or different marine fish and crustaceans species captured out of the coast of Mombasa; none is involved in the processing of catfish (AFIPEK and AFIPEK - web).
Of all the fish and crustaceans exported in Kenya the Nile perch constituted 87.4% of the total quantity exported in 2009 and 84.7% of the total value (see Appendix 9 for export country distribution in 2009). For the domestic market the Nile Perch is sold to supermarkets and butchers (AFIPEK).

## *Different Markets*
In Kenya several different markets for fish currently exist, which can roughly be divided into a low-end and high-end market. The main factor differentiating the markets is the price and the form it is sold in.
It is possible for some of the different market constituents to be present both places or exist with varying price levels (e.g. hotels restaurants and butchers).

***Low-end markets***
- Local communities (neighbours, friends etc.)
- Local fish Markets

The local fish markets are highly governed by price with many local buyers and sellers (FFK, David, and own observations).
The fish is sold either whole fresh, smoked or fried. Different prices for the low-end market can be seen in Table 8 below (more details in Appendix 10). For fresh tilapia fishermen and the fish market in Kisumu provides the cheapest price at 250 KES/kg, followed by farmers at 314 and lastly by the fish market in Nairobi at 400.

| Fish type | Category | City | Price per kg. KES |
|---|---|---|---|
| Catfish Fresh Whole | Fishermen, Fish Market | Kisumu, Nairobi | 105-380 |
| Nile Perch Fresh Fillet | Fish Market | Nairobi | 550 |
| Nile Perch Fresh Whole | Fishermen, Fish Market | Kisumu, Nairobi | 200-380 |
| Tilapia Fresh Fillet | Fish Market | Nairobi | 600 |
| Tilapia Fresh Whole | Fishermen, Fish Farmer, Fish Market | Kakamega, Kisumu, Nairobi | 250-400 |
| Tilapia Fried Whole | Fish Farmer | Kakamega | 496 |
| Tilapia Smoked Whole | Fish Farmer, Fish Market | Kakamega | 436-500 |

**Table 8:** Fish prices Low-end markets 2015: Own fieldwork.

***High-end markets***

- Butchers
- Export
- Hotels & restaurants
- Own shop (integrated companies, e.g. Prime Cuts or Jambo Fish)
- Supermarkets

The fish is mainly sold as fillets both fresh and frozen. Other characteristics of the high-end markets are the requirement of continued supply of fish from the suppliers and higher safety standards. Prices observed for supermarkets and butchers in Kenya for fillets can be seen in Table 9 below (more details in Appendix 10).

| Fish type | Category | City | Brand | Price per kg. KES |
|---|---|---|---|---|
| Catfish Frozen Fillet | Own shop / Supermarket | Nairobi | Jambo Fish, Sunfish | 700-990 |
| Nile Perch Frozen Fillet | Supermarket | Nairobi | Alpha Foods, Lesano, Prime Cuts | 720-1095 |
| Tilapia Fresh Fillet | Butcher | Nairobi | N/A | 750-1090 |
| Tilapia Frozen Fillet | Own Shop | Nairobi | Jambo Fish | 700 |
| Tilapia Frozen Fillet | Supermarket | Kisumu, Nairobi | Seafood Ltd., Farmers Choice, Alpha Foods, Prime Cuts | 775-1120 |
| Tilapia/Catfish Smoked Whole | Own Shop | Nairobi | Jambo Fish | 450 |

**Table 9**: Fish prices high-end markets 2015 - Own fieldwork.

## 3.2. Territoriality

In this section the development within Kenya's aquaculture sector will be contextualised to changes seen taking place globally within both aquaculture and captured fishery to observe how these are currently influencing the Kenyan sector. Insights into international best practices within fish farming relative to the methods used in Kenya will further be outlined in order to better understand the potential Kenya's aquaculture sector have.

Global aquaculture production is highly dominated by Asia, which in 2012 constituted 88.4% of the world's production and its position has been stable since 1995. Americas and Europe in comparison produces less than 5% of the world's production as can be seen from Table 10 below and Africa only 2.2%.

Within Asia it is China who is the leading producer and although its share of world production has decreased slightly since 1995, it still constitutes more than 60%.

| Aquaculture production | 1995 - ton '000 | 1995 - % of total | 2012 - ton '000 | 2012 - % of total |
|---|---|---|---|---|
| Asia | 21,677 | 88.9% | 58,896 | 88.4% |
| *China* | 15,856 | 65.0% | 41,108 | 61.7% |
| *India, Vietnam & Indonesia** | 2,681 | 11.0% | 10,363 | 15.6% |
| Americas (North & South) | 920 | 3.8% | 3,187 | 4.8% |
| Europe & Oceania | 1,676 | 6.9% | 3,065 | 4.6% |
| Africa | 110 | 0.5% | 1,485 | 2.2% |
| *Sub-Saharan Africa* | 35 | 0.1% | 455 | 0.7% |
| **World** | **24,383** | **100.0%** | **66,633** | **100.0%** |

**Table 10:** Global aquaculture prod. Data excludes aquatic plants, *3 largest producers after China - FAO fish stat., 2008-2014, FAO World, 2014 and FAO fish prod. - web.

Global aquaculture has since the 1990's increased its influence on food security significantly by today constituting 49.7% of total fish production (2012) relative to only 19.2% in 1990 (rest is captured fish) (FAO Food Balance Sheet, FAO World, 2014). Growth rates for captured fish have stalled to almost 0% since 1990 with no expected changes for the future, therefore slowly being overtaken by aquaculture in dominance (FAO World, 2014). Since it still constitutes more than 50% of world fish production its influence on food security as well as the competitiveness of aquaculture for the coming years will however still be relevant. The leading producers of captured fish are again highly skewed towards Asia, which in 2012 constituted 55% of world production (FAO fish stat., 2008-2014). It is furthermore many of the same countries that are leading the aquaculture sector that are also dominating captured production (China still being the ultimate leader with 17% in 2012) (FAO World, 2014).
In a global value chain context having such a dominating position as China and as Asia in general has (aquaculture & captured) would not necessarily result in holding significant influence on the sector's development in other countries. If the dominating countries utilized most of its production for domestic consumption its global effects might be limited. This is however not the case. Looking at the worlds global export of fish (see Table 11) China and Vietnam can be seen to also dominate world trade together with Thailand (7th and 13th largest aquaculture and capture producer).

| Export of fish - top five | 2012 (USD Millions) |
|---|---|
| China | 18,288 |
| Norway | 8,912 |
| Thailand | 8,079 |
| Vietnam | 6,278 |
| US | 5,753 |
| **World total** | **129,107** |

| Import of fish - top five | 2012 (USD Millions) |
|---|---|
| Japan | 17,991 |
| US | 17,561 |
| China | 7,441 |
| Spain | 6,428 |
| France | 6,064 |
| **World total** | **129,388** |

**Table 11:** Top five exporters and importers of fish – FAO World, 2014.

Global import of fish is primarily dominated by Europe, US and Japan while China can also be seen to be a leading importer. Kenya's import of fish has seen a slight upwards-sloping trend since the 1990's indicating an increasing dependency on the international markets (see chart in Section 6.4 & Appendix 29). The level of imported fish has in the last 10 years on average been around 27,000 tons a year, meaning a higher level than its domestic aquaculture production in all years except for 2013. Unfortunately no data has been available for specifying what countries fish is imported from and what types of species, however as was noted in Section 3.1. all companies currently processing tilapia is importing it and mainly from China or Vietnam.

The imported tilapia has shown to constitute tough competition for Kenya's own domestic aquaculture sector and has at the moment excluded it from any high-end markets (cf. Section 3.1). Both China and Vietnam sell their tilapia at prices as low as 1/3 of the general price for farmed tilapia in Kenya.
One reason making this possible is that China and Vietnam have lower costs of feed inputs. Feed generally represent between 40-84% of fish farmers production cost (cf. Section 3.1) and therefore have profound implications on the price fish farmers are able to charge. From Table 12 below it can be seen that food prices in the last five years on average has been 27.8% and 30.5% lower in Vietnam and China relative to Kenya, given the countries a comparative advantage.

| Difference of food prices relative to Kenya - using FAO's Domestic food price level index | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Average** | Ghana | Uganda | Egypt | SSA | China | Vietnam | Thailand | World |
| **5 year** | -33.6% | -30.3% | -20.7% | -23.7% | -30.5% | -27.8% | -33.4% | -48.0% |
| **10 year** | -10.4% | -23.5% | -14.1% | -13.1% | -24.5% | -17.0% | -25.9% | -40.0% |

**Table 12:** Food prices relative to Kenya inflation and PPP adjusted – FAO food security indicators and own work.

Another reason why Kenya's aquaculture sector is currently behind countries like China is that the farmers in Kenya use much more feed for every kilo of output they attain. From Table 13 average ranges of Feed Conversion Ratio's (FCR) for different countries can be seen. FCR shows how many kilos of feed that is necessary to acquire one kilo of farmed fish.

| Countries - Semi-intensive ponds | FCR (tilapia) |
|---|---|
| Thailand | < 1 |
| Philippines | 1-1.6 |
| Egypt | 1.1-1.4 |
| China | 1.2-1.6 |
| **Kenya** | **2.6-3.0** |

**Table 13: FCR comparison -** FFK & David, El-Sayed 1, 2013, El-Sayed 2, 2013, Liu et al., 2013, Bhujel, 2013, Romana-Eguia et al., 2013

Kenya's FCR generally lies between 2.6-3 kilos of feed per kilo of farmed output, which is significant higher than other competing countries like China and Thailand, making it even more difficult to compete with international players who as was seen in Table 12 already have an advantage from lower costs of feed inputs.

***Best Practice - Semi-intensive small-scale fish farmers (tilapia, catfish & carps)***
A deeper insight into of some of the fish farming techniques used in various best practice countries have been made possible through some of FAO's conducted case studies within aquaculture describing semi-intensive systems for tilapia farming including studies from: China, Egypt, Ghana, Philippines and Thailand (El-Sayed 2, 2013, Awity, 2013, Liu et al., 2013, Bhujel, 2013, Romana-Eguia et al., 2013). Most examples were seen to showcase substantial better performance than the levels seen in Kenya with the best examples coming from Thailand and Egypt (these were

very similar). Throughout this section the best practice seen in Egypt will be used, because this method has been considered the one that could bring the most significant changes to Kenya, being easy to implement and since the environment in Egypt is considered to better resemble Kenya relative to e.g. China or Thailand. For Kenyan small-scale fish farmers to be able to adopt the new best practices; they would have to change their fish farming methods and the inputs they use. These changes are summed up in Table 14 below and more details can be seen from Appendix 11.

| Semi-intensive system requirements | Feed type | Feed technique / used | Seed used | Stocking density per m^3 | Stocking size in g | Fertilizer used per harvest per ha |
|---|---|---|---|---|---|---|
| Status quo | Mashed / low qual pellets / single ingredient feed & natural feed | Hand-feeding 2 times a day, same amount whole cycle. | Lower quality & mixed for tilapia | 3.03 | 1-3 | Various amounts of inorganic & organic fertilizer |
| **Best Practice from Egypt** | High qual commercial floating pellets 30% CP & natural feed | Hand-feeding, 3% BW a day or until saturation. Start feeding after 60 days. | High quality & Mono-male for tilapia | 2.0 | 1-3 | 8,571 kg chicken manure, 1,122 kg Super phosphate, 661 kg. Urea |

**Table 14:** Requirements for the two different semi-intensive systems; Best Practice from Egypt relative to status quo in Kenya for small-scale fish farmers – Own work.

If the best practice method from Egypt are used it is possible to reach yields of 1.70 kg per $m^3$ instead of Kenyan fish farmers yield of 0.91 at the moment.

| Semi-intensive Small-scale Results | Yield kg/m^3 annually | FCR | Number of harvest annually |
|---|---|---|---|
| Status quo | 0.91 | 2.73 | 1.40 |
| **Best Practice from Egypt** | 1.70 | 1.14 | 2.31 |

**Table 15:** Results from adopting Best Practices from Egypt relative to status quo – own work.

The new method could also save farmers a significant amount of feed and money through the new feeds increased digestibility as well as from sticking to a strict feeding schedule and only using chicken manure for the first 60 days (to create phytoplankton). It would be possible to lower the FCR from the current high level of 2.73 kg feed input per kg of output to only 1.14.

***Growth & importance of the aquaculture sector***

Aquaculture has globally experienced high growth rates for many years with the average annual growth since 2000 being 6.2%. Africa and SSA in particular have experienced extraordinary annual growth rates; Africa at 11.6% and SSA at 19.1% as can be seen from Table 16 below. Kenya and Uganda have achieved even higher rates reaching 36.5% and 48.7% respectively. The impressive growth rates within aquaculture historically together with a positive outlook for the future have also lead FAO to expect the sector will have a crucial role in improving food security going forward (FAO World, 2014).

| Countries & regions | Avg. Growth rates 2000-2012 | Aquaculture as % of total fish production - 2000 | Aquaculture as % of total fish production - 2012 |
|---|---|---|---|
| Africa | 11.6% | 6.5% | 15.3% |
| SSA | 19.1% | n/a | n/a |
| Uganda | 48.7% | 0.4% | 19.0% |
| Kenya | 36.5% | 0.2% | 12.0% |
| China | 5.5% | 59.5% | 71.8% |
| Vietnam | 16.4% | 24.4% | 51.2% |
| **World** | **6.2%** | **30.9%** | **49.7%** |

**Table 16:** Development of aquaculture production in selected countries & regions – FAO fish production, FAO food balance sheet and FAO, Fishery and Aquaculture Statistics, 2008-2014.

### *Global fish consumption*

FAO's food balance sheets from its online database provide valuable insight into countries average energy intake from food (measured as kilocalories) including the share attained from fish. This data is also vital for FAO's calculations off the Prevalence of Undernourishment ratio, which will later on be estimated.
From Table 17 below various countries have been compared on its daily energy intake and the part stemming from fish.

| Food & fish consumption summary 2011 | Kenya | Egypt | Ghana | Uganda | Africa | China | Thailand | Vietnam | World |
|---|---|---|---|---|---|---|---|---|---|
| Food supply kcal/capita/day | 2,189 | 3,557 | 3,003 | 2,279 | 2,615 | 3,074 | 2,757 | 2,703 | 2,868 |
| Fish Kcal/capita/day | 8.00 | 39.00 | 60.00 | 25.00 | 20.00 | 48.00 | 52.00 | 53.00 | 34.00 |
| Fish protein grams/capita/day | 1.30 | 6.20 | 9.00 | 3.90 | 3.10 | 8.00 | 7.80 | 8.60 | 5.20 |
| Aqua Fish production grams/capita/day | 1.44 | 34.05 | 2.11 | 6.68 | 4.71 | 75.62 | 49.44 | 93.01 | 33.01 |
| Capture Fish production grams/capita/day | 11.83 | 12.95 | 38.07 | 34.10 | 20.38 | 30.87 | 75.52 | 76.61 | 35.66 |
| Food Fish production grams/capita/day | 12.39 | 60.63 | 74.51 | 35.47 | 29.58 | 89.81 | 61.48 | 90.92 | 51.66 |

**Table 17:** Food & fish consumption 2011 – FAO food balance sheet and FAO, Fishery and Aquaculture Statistics, 2008-2014[1].

The level of kilocalories the average citizen in Kenya receives daily can be seen to be much lower than all the compared countries and regions (except Uganda which is similar). This large difference in daily food energy is also directly related to the higher undernourishment rate seen in Kenya relative to much of the rest of the world (24.3% in 2014 relative to the world average of 11.3%).
Looking at the level of food energy coming from fish, Kenyans on average only consumes between 13-40% of the level seen in other countries and the level of fish intake in Kenya has actually gone down since 2000 where it was 11 kcal capita/day (FAO food balance sheet ).
The data presented throughout this section shows that the aquaculture sector globally and in Kenya have shown impressive growth rates so far and with FAO seeing a positive outlook for the future this could continue. Comparing Kenya's development path to the international environment however also indicate that

[1] Differences between the aggregate of Aqua & capture fish production and Food fish production mainly stem from import and export of fish.

there is still significant room for increasing aquaculture production and fish consumption in Kenya e.g. through better fish farming techniques.

# 4. Governance and institution's interplay

Continuing using Neilson & Pritchard's GVC framework institutional support are not only seen as an external frame to the sector but more as shaping the sector's development path through a constant interaction with the sector's governing organizations (Neilson & Pritchard, 2009).

## *4.1. Institutions*

This section will begin with a brief introduction of the history of Kenya's aquaculture sector followed by an introduction of the most vital institutions and support organisations for the sector. The interplay between governing mechanisms and institutional changes will here after be analysed through various struggles facing small-scale fish farmers in Kenya.

***The historical path of Kenya's aquaculture sector***

In 2009 Kenya's former government launched the Fish Farming Enterprise Productivity Programme (FFEPP) on a national level aimed at kick starting the aquaculture sector. The initial strategy of the programme was to increase production from around 4,000 tons to 20,000 tons in the medium term and 100,000 tons in the long run (Musa et al., 2012).
This were to be done through digging numerous new ponds (300m$^2$ each) all over Kenya, and provide initial inputs like training, feed and fingerlings to new fish farmers as well as running 'Eat more fish' campaigns (Musa et al., 2012).
Today the number of ponds is estimated to have grown from around 9,000 in 2009 to more than 100,000 ponds today and aquaculture production has surpassed its initial medium term goal of 20,000 tons (Nyandat & Owiti, 2013, FAO fish stat., 2008-2014, Charo-Karisa, 2014). It is therefore not surprising that several sources list the programme as having been the main driver behind the large development of the aquaculture sector taken place since 2009 and further helped raise the living standards for many Kenyans (Department of Fisheries, AFIPEK, Red Cross and AAK, Munguti 2 et al., 2014).

The FFEPP initially being a national programme was in 2012 devolved into each of the 47 counties following the new 2010 constitution (AAK and Department of Fisheries). Today the decision on how many resources that should be allocated to developing the aquaculture sector is left to each individual county where as captured fisheries is still being governed on a national level (Department of Fisheries). According to the Department of Fisheries the national government has no power to control what is being done with the 34 million KES each county receives every year aimed for the aquaculture sector (Department of Fisheries). Shifting aquaculture authority from a national level out to each county should ideally make the decision-making process more flexible and easier to focus on each counties contextualised settings, however both AAK and AFIPEK have some worries it could instead create divergences between counties development of aquaculture, which will be explored further in the next sections (AFIPEK and AAK).

***Key formal institutions***

The State Department of Fisheries (former Ministry of Fisheries) is the most influential institution within captured fisheries and aquaculture in Kenya, and is seen as central for the industry's development and sustainability (AFIPEK, Farm Africa, and Red Cross). Its official mandate includes everything from research and development to quality control and regulation (MOALF - web).

Kenya Fish Processors and Exporters Association (AFIPEK) was created back in 2000 when EU suddenly banned fish import from Kenya because of lack of proper health standards and today the institution is 100% financed by its members (AFIPEK). Since year 2000 it has been mandatory for new processors or exporters of fish to join AFIPEK in order to secure international standards are upheld throughout the sector and AFIPEK have further managed to lift the standards of its members including ISO 2000 certifying all of them (AFIPEK, AFIPEK - web). Captured fisheries and export of especially Nile perch caught in Lake Victoria have existed for many decades where as aquaculture has first really taken off since 2009. The organization representing processors and exporters (at the moment only captured fish from Kenya) AFIPEK can therefore also be seen to have more influence within the fisheries industry relative to the newer organization AAK that is representing fish farmers, fish feed producers and hatcheries.
Aquaculture Association of Kenya (AAK) was started in 2007 and can currently be characterised as a parastatal institution; partly funded by the government and partly funded by members (AAK). The organization is still young and therefore its influence is still seen as limited by other institutions, however AFIPEK mention this is expected to increase going forward (Department of Fisheries, AFIPEK).

Research into new and better fish farming practices in Kenya is primarily carried out by various government agencies (incl. parastatal ones). At the moment the most significant of these include; nine Kenya Marine and Fisheries Research Institute (KMFRI) centres across Kenya, four stations of the National Aquaculture Research Development and Training Centre (NARDTC), one research centre of Lake Basin Development Authority (LBDA) together with research carried out by AAK (Department of Fisheries and AAK, NARDTC – web, KMFRI – web). KMFRI further extent its research operations through several universities who have their own fish farms (Department of Fisheries). Of independent organisations performing research on new best practices this mainly include the civil society organisation Farm Africa, which role within aquaculture will be elaborated upon in the next paragraph (Farm Africa – web and Farm Africa).

***Key supportive organisations***

Civil society organisations also influence the development of aquaculture in Kenya. The two NGO's Farm Africa and Red Cross have both helped bring significant changes to the sector in the areas they are currently present.

Farm Africa is a UK based NGO with operations across Eastern Africa with its presence in Kenya currently being within five counties all situated in the West (Farm Africa – web). Farm Africa's work within aquaculture involves most aspects essential for fish farmers and is especially focused on improving farmers' efficiency and through this the farmer and his/her family's living standards (Farm Africa – web and Farm Africa).

The global NGO Red Cross, which have been present in Kenya for many years are providing emergency aid and substantial development support within many areas with approximately 90% of their budget in Kenya going towards development projects (Kenya Red Cross – web, Access2Innovation workshop, April 30 2015). Red Cross have also moved into supporting aquaculture within the last few years with one completed project in Kibwezi (between Nairobi & Mombasa) and a new on-going project in Kwale (30 km south of Mombasa) (Red Cross).

In the next sections the following three struggles currently facing small-scale fish farmers in Kenya will be analysed.

1. *Fish farmers' lack of quality inputs at affordable prices*
2. *Fish Farmers insufficient knowledge and divergence in county support*
3. *Marginalization of fish farmers from high-end markets*

Continuing with the application of Neilson & Pritchard's GVC framework a deeper understanding of the underlying mechanisms behind these struggles will be sought answered with specific focus on the interplay between the governing organizations of the sector and the institutional environment (Neilson & Pritchard, 2009).

## *4.2. Struggle 1: Fish farmers' lack of quality inputs at affordable prices*

The first struggle involves fish farmers' limited access to high quality inputs that can have large effects on their level of competitiveness a topic that will be explored further in the third struggle as well as in later sections.

### *Shortage of quality fish feed*

The large increase in new fish farmers since the FFEPP's initiation in 2009 created a new unmet demand of fish feed of an estimated 14,000 tonnes bringing the total demand for fish feed up to more than 100,000 tonnes a year (Munguti 2 et al., 2014). A similar number was achieved through own calculations, where in 2013 the total need for fish feed was 118,521 tons (see Appendix 15).
Three of the interviewed fish farmers also stated that one of their largest problems was acquiring regularly feed supplies, while the two interviewed fish feed producers; Sare Millers and Bidii Fish Feeds both experienced a much higher demand than what they can currently serve (Sare Millers, Bidii Fish Feeds Philip, Ken and Millington).

The government's effort to stimulate the aquaculture through the FFEPP did include strategies to ensure enough supply of the two most essential inputs; fish feed and seed (fingerlings). The strategies involved supplying equipment and providing knowledge to various farmer groups enabling them to start their own hatcheries and feed production facilities (Farm Africa). However as previous mentioned their efforts fell substantial short of the extra demand for inputs created by the programme. According to Farm Africa most of these government supported hatcheries and feed mills set up within farmer groups are furthermore no longer working or only running at very low capacities with the primary reason being lack of sufficient technological knowhow (Farm Africa).
Connected to this is also that aquaculture is a rather new sector why farmers do not yet hold the same level of knowledge as can be seen within more common agricultural fields with a long history such livestock or crop farming (Red Cross). Farm Africa and Red Cross acknowledge the many positive achievement of the FFEPP and the good intentions of government officials, however they also agree that government officials simply did not and still do not have enough resources to secure proper and sustainable implementation of the programme (Farm Africa and Red Cross).
An example of government officials inadequate amount of resources can be seen from the fish farmer's Philip recent experience with the FFEPP. He was contacted last year in November by the Department of Fisheries where it was agreed he should receive equipment so he could start a hatchery and supply the local community with quality fingerlings (Philip). Philip was even sent on a training seminar in Uganda, however he has not heard from them since (Philip).
In addition to the indications of the governments insufficient resources deployed to support the new input industries these findings also suggests that the government's efforts lacked a sustainable aspect. Both Red Cross and Farm Africa therefore reason that the government in hindsight should have included the private sector and local organizations more in the implementation phase (Farm

Africa and Red Cross). These organizations tend to be more efficient and already possess a certain level of technological knowledge relative to farmer groups, which would also result in less follow-up visits needed from the government to sustain hatcheries or feed mills (Farm Africa).

It is further argued by Munguti et al. from KMFRI that the new unmet demand of fish feed coupled with no official fish feed standards lead to a substantial decrease in the actual quality of fish feed where some fish feed dealers took advantage of the situation and lowered the standards (Munguti 2 et al., 2014).
The decreasing level of fish feed quality and lack of governing mechanisms resulted in institutional changes and fish feed standards have now been created in Kenya. This chain of events demonstrates how institutional changes and shifts in governing mechanisms occur in a constant interplay and why analysing this interplay rather than each pillar as an individual concept as advocated by Neilson & Pritchard is relevant.
The new fish feed standards mean it is now mandatory for fish feed producers to adhere to KEBS standards and list the following things on their bags (Sare Millers, AAK and Bidii Fish Feeds):

- Production date
- Expiry date
- All ingredients
- What fish it is suited for

Additionally a certain level of protein content has to be reached and for floating pellets they need to float for at least 2 minutes (Sare Millers and Bidii Fish Feeds). According to AAK, Bidii Fish Feeds and Sare Millers these standards are however not being enforced and therefore have very little effect in securing that quality fish feed is available for fish farmers (Sare Millers, AAK and Bidii Fish Feeds).
Although official government standards for fish feed have now been introduced in Kenya they have unfortunately not succeeded in solving the actual problem of the low quality fish feed seen within Kenya.

***Too high feed prices***

AFIPEK in Kenya notes how fish feed is currently too expensive in Kenya (AFIPEK). Three mechanisms were found to influence the high feed prices.
The first mechanism at place involves the absence of any large-scale fish feed producers in Kenya able to utilize the advantage of economies of scale that normally follows (AFIPEK). This could lower the break-even price for the producer, which could then be passed on to the farmer. According to AFIPEK it would require at least one large-scale fish farmer (not an integrated like Dominion Farm and Jambo Fish) to create consistent and large enough demand for fish feed to incentivize the establishment of such a large-scale fish feed producer (AFIPEK).

The second mechanism contributing to the high fish feed prices in Kenya comprises the significant margin that is often added to the producers' price when farmers buy their fish feed from agrovets (sometimes their only option). Below in Table 18 production costs can be seen for a Kenyan feed producer (for livestock & poultry) together with the extra prices charged to distributors, agrovets and farmers (see Appendix 12 for more information)[2]. The feed producer either sells directly to agrovets who then re-sells the feed to farmers or first to distributors, which then re-sells to agrovets (same price will be charged for agrovets and farmers in both systems).

| Example of increases in feed prices from producer to farmer | | | | | | |
|---|---|---|---|---|---|---|
| **Product** | **Package** | **Production costs in KES** | **Extra price paid by distributors relative to production costs (Producer's GP margin)** | **Extra price paid by agrovets relative to production costs** | **Extra price paid by farmers relative to production costs** |
| **Product X kg** | 1 kg | 45 | 64% | 99% | 188% |
| | 2kg | 86 | 69% | 98% | 180% |
| | 5kg | 214 | 59% | 99% | 157% |
| | 10kg | 415 | 61% | 97% | 141% |
| **Product Y liters** | 5 litres | 86 | 234% | 307% | 423% |
| | 20 litres | 276 | 257% | 335% | 407% |
| **Product Z liters** | 0.5 liter | 20 | 310% | 400% | 650% |
| | 1 liter | 29 | 405% | 514% | 753% |
| | 5 litres | 93 | 696% | 868% | 1083% |
| | 20 litres | 306 | 701% | 880% | 1044% |
| **Average** | | | **286%** | **370%** | **503%** |

**Table 18:** Price increases in feed from producer to farmer – own work.

The final price paid by farmers when they buy the feed in agrovets ends up being on average roughly 500% higher than the actual production cost incurred by the feed producer. The feed producer of course still have to earn a profit, however since the production costs tend to constitute the majority of the producers costs (Growth Africa, 2014), there seems to be plenty of room for the feed producer to lower the price significantly while still being able to earn a sufficient amount of profit.

In a sector where feed in the five conducted case studies was observed to constitute 73.5% of total production costs, this huge price increase can have tremendous effects (cf. Section 3.1). The higher demand for fish feed from small-scale fish farmers relative to what the producers can supply along with the small-scale fish farmers high dependency on a limited number of feed producers creates an unequal relationship that is primarily governed by the feed producers (FFK, David, Sare Millers, and Bidii Fish Feeds). The higher level of information and

[2] The fish feed price variation within the market are assumed to be similar to the livestock and poultry examples from Table 18; since the feed also include many of the same ingredients & the price of 20 litres of product Y to distributors for instance resembles the price Sare Millers charge for 20 kg of fish feed.

mobility observed for fish feed producers relative to fish farmers further strengthen this (FFK, David, Sare Millers, and Bidii Fish Feeds).
It is this asymmetrical power relation between fish farmers and fish feed producers together with the absence of any official regulation in place to govern their relationship that seem to be enabling fish feed producers to charge substantial more than what should be necessary.

The third mechanism influencing the high fish feed prices in Kenya involves taking one steep further up the value chain and looking at the relationship and governing mechanisms between fish feed producers and raw material suppliers.
Sare Millers the fish feed producer located in Kisumu notes how the price of raw materials used for fish feed generally have increased within the last few years and that one important reason was the VAT put on agricultural inputs by the government (was under review in August 2012) (Sare Millers, Business Daily - web). The VAT on agricultural inputs was taken away again and from Kenya Revenue Authority 's (KRA's) webpage it can be seen it is 0% at the moment (KRA – website). The issue however according to Sare Millers is that the company's who supply inputs to the fish feed industry (and other feed industries) kept prices at the same level after VAT were taken away (Sare Millers).
The two interviewed fish feed producers Sare Millers and Bidii Fish Feeds are also facing problems with acquiring good quality raw materials, which can have a direct effect on the final quality of the fish feed being produced (Sare Millers and Bidii Fish Feed). It can be difficult to establish good relationships with raw material suppliers since many of them are short term minded and focus more on selling their current stock (Sare Millers). One problem arising from this relates to some suppliers using sand in the bags to add extra weight especially for caridina shrimps and fishmeal (Sare Millers and Bidii Fish Feed).
The issues experienced between fish feed producers and raw material suppliers indicates an asymmetrical power division between them skewed towards the raw material suppliers and a general lack of adequate regulation of the quality and price of raw materials.

***Shortage of quality fingerlings***

The FFEPP programme from 2009 similar to fish feed also created a huge lack of quality fingerlings, estimated to a shortage of 28 million certified tilapia and catfish fingerlings bringing the total demand of fingerlings up to over 100 million a year (Munguti 2 et al., 2014). From own calculations the total number of tilapia, catfish and carp fingerlings needed in Kenya in 2013 was estimated to 145.6 millions (see Appendix 15).
The representative from AAK acknowledged there previously had been a large unmet demand for sourcing of quality fingerlings (AAK). The issue should have

been at least partly resolved today and not constitute a major problem anymore (AAK). Acquiring monosex (male) tilapia could however still prove difficult (AAK). Two of the interviewed fish farmers who were also the only ones that farmed all male tilapia experienced difficulties with acquiring quality fingerlings from a few large-scale hatcheries why they sometimes had to settle with low quality fingerlings from other farmers (Ken and Millington). The fish farmers' high dependency on a few large-scale hatcheries for the supply of quality fingerlings could indicate a similar governing form as was seen between fish farmers and fish feed producers (governed by fish feed producers). The gravity of the dependency does however not seem as grave since the shortage is limited to quality (and not also supply) while the cost of fingerlings for the small-scale fish farmers on average only constituted 14.6% of their total cost relative to 73.5% for the feed (FFK and David).
Both AAK and Access2Innovation additionally reported of experiences with hatcheries having problems of finding enough buyers for their fingerlings, which could further indicate that part of the inadequate supply of quality fingerlings fish farmers are facing are caused by a lack of good coordination mechanisms being in place between fish farmers and hatcheries (Access2Innovation and AAK).

The considerable lack of access to affordable quality inputs for fish farmers has created an environment for small-scale fish farmers characterised by inefficient fish production and limited options to change this by themselves. This 'struggle' will be explored further in the section where small-scale fish farmers' level of competitiveness will be analysed in regard to captured fishing in Kenya and imported fish.

## *4.3. Struggle 2: Fish Farmers insufficient knowledge and divergence in county support*

Small-scale fish farmers' low level of competitiveness relative to fish farmers from countries like China, Thailand and Vietnam goes beyond their inadequate access to quality inputs and also involves their inadequate knowledge of optimal pond management techniques especially regarding feed and fertilizer.
From the five case studies carried out in Kenya all fish farmers were found to feed their fish with the same quantity of feed twice a day throughout the harvest cycle (FFK and David). Several sources state that optimal feed techniques involve feeding the fish a certain percentage of their body weight throughout the harvest cycle, normally 2-3% daily (Aller Aqua, El-Sayed 2, 2013, Bhujel, 2013). This mean the amount of feed used per day should increase as the fish grows in sizes, except when using the technique of feeding to saturation.

Regarding fertilization three fish farmers used organic fertilizer (chicken or cow manure) either by piling it in one corner of the pond or throwing it into the pond until it turned green, and the two last fish farmers used the chemical fertilizer DAP (FFK and David). Common for all of the fish farmers is that they either used too little of the fertilizer relative to best practices seen in Egypt or Thailand or had limited knowledge of the quantity used in each pond (all farmers using manure) (FFK and David, El-Sayed 2, 2013). Examples from best practice countries all use a much more systematic use of fertilizers, often a combination of organic and chemical fertilizer to achieve an optimal amount of natural feed and water standards (El-Sayed 2, 2013, Bhujel, 2013).
Kenyan fish farmers use of suboptimal feed and fertilizer techniques results in sizeable unrealized potential for their fish output and income generation relative to the levels seen in e.g. Thailand and Egypt, which will be analysed more in-depth in Section five & six. Two of the underlying mechanisms likely to be causing fish farmers struggle of acquiring optimal pond management knowledge will be discussed in the next paragraphs.

***Divergence within the allocation of government resources***

The inadequate level of training and guidance given by the government to fish farmers noted by Red Cross and Farm Africa (cf. Section 4.2.), was also expressed as being one of the vital things the government should do better by three of the interviewed fish farmers (Philip, David and Millington).
This issue seem to have been further enlarged from a divergence among counties taking place because of the devolution of aquaculture in 2012. A fear earlier raised by AAK and AFIPEK (cf. Section 4.1.).
A Fisheries Officer from Kenya's Department of Fisheries stated that some County Fish Officers have already started to abandon the implementation of the FFEPP and he even mentioned corruption taking place within some of the counties (Department of Fisheries). The devolutions negative side was also felt by Bidii Fish Feeds, which is based in Luanda belonging to Vihiga County. The manager George describes how the governments support towards new developing projects of the aquaculture sector have decreased substantially since the governance of this sector was devolved from national into county level (Bidii Fish Feeds). He further notes how the government of the neighbouring county Kakamega on the other hand are still providing significant support towards developing the aquaculture sector (Bidii Fish Feeds).
The people being most affected by this divergence are according to USAID and Farm Africa likely to be fish farmers and in particular the new fish farmers created by the FFEPP (Farm Africa and USAID, 2013). Since the initiation of the FFEPP an estimated 80,000 new fish farmers have emerged (by 2014) (Appendix 13).

The new fish farmers are especially vulnerable because the government's efforts to stimulate aquaculture through the FFEPP involved giving new farmers all inputs for free without a proper plan to include them into a commercialized setting (Farm Africa and AAK, and USAID, 2013). According to Farm Africa, AAK and USAID this ends up giving new fish farmers unrealistic ideas about the sector and creates an unnecessary dependency on continued government support (Farm Africa and AAK, and USAID, 2013). When the new farmers later on suddenly have to pay for their own inputs and possibly also with less guidance from the government several ends up failing (Farm Africa).

Although the goal of the FFEPP in no doubt was to improve the living conditions for many Kenyans the programme can be seen to have created an unnecessary large dependence on government help for new fish farmers, which unfortunately can result in failures for new fish farmers if the support is not upheld.

Small-scale fish farmers' ability to acquire knowledge on optimal farming techniques together with survival chances of new fish farmers therefore seems to become increasingly governed by each county's level of commitment to aquaculture. With the devolution potentially resulting in various development paths being followed by each county this can come to create largely different upgrading opportunities for fish farmers determined by their geographical setting.

***Suboptimal distributed information***

Four of the five interviewed fish farmers (all from FFK) had received various forms of training within aquaculture from their own group (FFK and David). Three of the farmers from FFK had also received training and guidance from the Department of Fisheries and these three had all been through courses in feeding techniques or pond management (FFK). It can further be noted that all five interviewed fish farmers fed their fish in the same way; hand feeding the same amount twice every day at the exact same time suggesting the initial source advocating for this feeding practice could be the same (FFK and David).

USAID visited Eldoret's University fish farm in May 2013 and describes the completely same method of feeding as was observed in the five case studies (USAID, 2013). One of the uses of the university's fish farm is to hold field days to showcase best practices within fish farming, meaning the communities around the university are likely to adopt similar feeding techniques (USAID, 2013). USAID further visited several fish farmers and met with one of the government's extension agent's whose job it is to advice new fish farmers in good practices (USAID, 2013). The general recommendation from USAID is that serious in-depth training within various topics are needed for fish farmers and especially for university staffs and government agents, which level of technical knowledge was found to be substandard in numerous cases (USAID, 2013).

Other sources of knowledge distribution to fish farmers was also observed in Kenya, which could help alleviate part of the shortage of allocated resources by the government (cf. Section 4.2). Sare Millers the fish feed producer regularly visits its customers to observe their management practises and come with advice on how to improve these methods and Red Cross also included various training sessions in their fish farming projects in Kibwezi and Kwale (Sare Millers and Red Cross).
Sare Millers are using Lake Basin Development Authority (government agency) as information source for optimal fish farming management and Red Cross are paying the Department of Fisheries to conduct its training sessions (Sare Millers and Red Cross). The initial source of information for both of them can therefore be seen to come from some form of government agency. The last observed knowledge distributor to fish farmers the NGO Farm Africa was relatively independent of government agencies in regard to the information used for training and mainly trained fish farmers through its own shops and demo-sites, while also supplying the app called ESOKO that sends agricultural tips to farmers (Farm Africa).
A substantial part of the various sources supplying knowledge to fish farmers seems to initiate from government agencies, which in it self should not provide any issues. However the government's dominating role in initiating best practice knowledge together with indications from the five conducted case studies and from USAID that this knowledge coming from government agencies sometimes are flawed or suboptimal can end up resulting in small-scale fish farmers continuing to use inefficient fish farming methods. Especially since knowledge sharing (often in the form of word of mouth) is common among fish farmer groups, which can result in flawed information like the observed feeding techniques easily being distributed to many other farmers (FFK and Nyandat & Owiti, 2013).
Small-scale fish farmers struggle with attaining best practice knowledge therefore seem to be driven by not only the insufficient resources allocated from the government but also involve the mechanism of suboptimal knowledge distribution.

## *4.4. Struggle 3: Marginalization of fish farmers from high-end markets*

Relative to the aquaculture sectors analysed throughout Ponte and Jespersen et al.'s research in Bangladesh, China, Thailand and Vietnam, Kenya differs in one significant way in regard to the impact and governance flowing from lead firms (Jespersen et al., 2014 and Ponte et al., 2014). As was seen in Section 3.1, in Kenya none of the fish farmers have access to the high-end markets and significant hurdles are currently at place before an opening would be possible.
The main constraints currently limiting fish farmers' access to the high-end markets are significant price differences and being unable to deliver a continued supply throughout the year (cf. Section 3.1.). A significant part of the first

constraint of fish farmers' prices not being competitive can be seen to stem from the first two struggles; inadequate access to quality inputs and best practice information.
Table 7 which showed the difference in prices for farmed, captured and imported tilapia clearly demonstrated how farmed tilapia was on average 210.5% more expensive than imported tilapia and 25.4% more expensive than captured fish. Within these high end markets both butchers and processors (whom fish farmers would need to sell to if their fish were to end up in supermarkets/exported) stated willingness to buy from fish farmers if their price were right and if the fish farmers could promise a continuous supply.

From Table 19 seen below the break-even prices for the five interviewed fish farmers can be seen (David and Millington were already making a small loss at the current selling price of 314 KES). The average break-even price for the five fish farmers is 255 KES slightly above the 250 KES for captured fish and still significant above imported fish at an average price of 101 KES (cf. Table 7). Two of the fish farmers (Philip and Ken) do have a break-even price lower than the current price of captured fish, however the lowest from Ken at 169 is still 67.3% above the average imported price. It should further be noted that it is not viable for any of the fish farmers to sell at break-even prices since it is exactly the income generated from fish farming that has been able to raise their living standards and e.g. send their kids to universities (also transport cost as well as other potential costs are not included) (Red Cross, Ken, Millington and Evans wife).

| Fish Farmer | Break-even price (KES) fresh tilapia |
|---|---|
| David | 314.09 |
| Philip | 200.32 |
| Ken | 169.46 |
| Millington | 320.30 |
| Evans wife | 270.77 |
| **Average** | **254.99** |

**Table 19:** Break-even tilapia prices per kg for the five fish farmers interviewed. Catfish prices were changed simultaneously with same % as for tilapia – FFK, David and own work.

The current situation for the fish farmers interviewed in Kakamega and Kisumu suggests they are to some extent able to compete with captured fish on prices, however they are still miles away from the prices seen on imported tilapia. Regarding the issue of delivering a continuous supply the five fish farmers interviewed, which on average harvested every eight month would have severe difficulties in generating a sufficient output to supply fish processors every week or month even with proper harvest coordination (harvesting different ponds at various times) (FFK and David ). Most fish farmers in Kenya would be in the same

situation since as mentioned in Section 3.1 small-scale fish farmers account for approximately 95% of all aquaculture in Kenya.
The potential consequences of small-scale fish farmers' lack of interaction with larger downstream organisations will be discussed and explored more in Section 5.

***Partial conclusion for struggles experienced by fish farmers***
Within Kenya's aquaculture sector the overall picture seems to be one of the institutional environment enabling or constraining the majority of available upgrading options for small-scale fish farmers (similar to what was found in the research done by Neilson & Pritchard, 2009). The small-scale fish farmers are further subject to various governing mechanisms being coproduced by other value chain participants and institutional changes. The first constrain that limited fish farmers access to high-end markets could be seen to be their uncompetitive prices relative to imported fish prices. This constrain could further be seen to especially be driven by the two first struggles experienced by the fish farmers; the inadequate access to high quality inputs and best practice knowledge.
The second constraint, which is the lack continuous supply, will be discussed further in the next section on Upgrading.

# 5. Upgrading & enablers

Following Neilson & Pritchard's GVC framework the upgrades fish farmers have been able to achieve based on the struggles they are currently facing will first be discussed in this section (cf. Section 2).
The environment enabling these realized upgrades will together with potential new enabling initiatives and upgrades then could lead to two overall growth output drivers that can be seen from Figure 3 below. The growth output drivers will in Section 5.3 and Section 6 be used to explore the potential consequences on produced aquaculture output and food security various development paths for the Kenyan aquaculture sector can have.

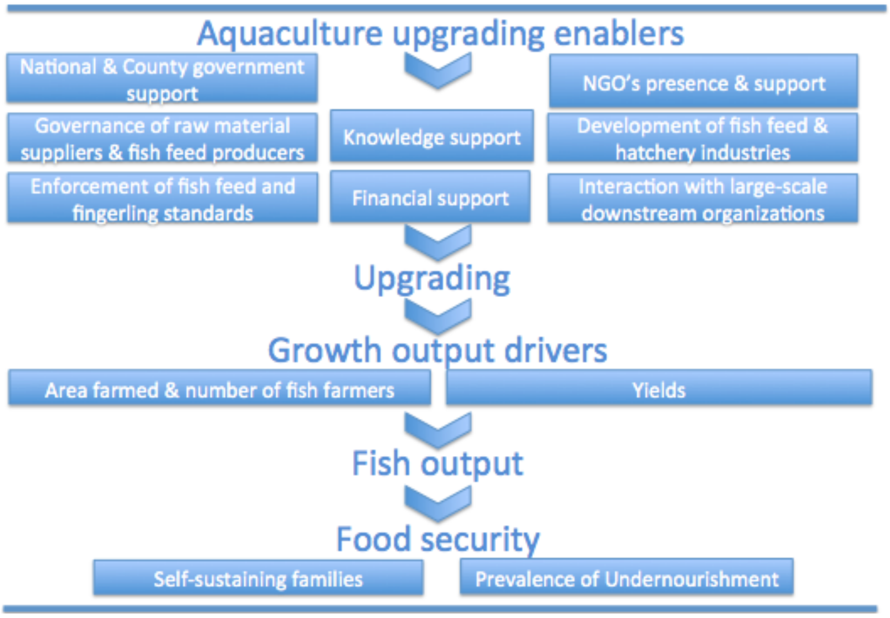


**Figure 3:** Enablers & drivers for fish output and food security – own work with inspiration from Petersen & Plenborg, 2012, page 175 on value drivers.

## *5.1. Current upgrades and enablers*

***Enabling initiatives from NGO's & various upgrades arising from this***

Farm Africa supplies quality inputs at reasonable prices through their own 12 one-stop shops and the 28 agrovets they are working with (Farm Africa). Using higher quality feed and seed increases the fish farmers' efficiency and output while also serving to ensure higher quality of the fish output.

Farm Africa works in close collaboration with various input producers (e.g. sells Bidii Fish Feeds which is high quality extruded pellets) to guarantee the inputs sold from their shops to fish farmers have the highest quality (Farm Africa). Farm Africa further has a close relationship to many small-scale fish farmers and are very active in providing best practice information to fish farmers through their shops, demo-sites and electronic platform; ESOKO (Farm Africa). Farm Africa can therefore be seen to enable both product and process upgrading for small-scale fish farmers.

By engaging in close interaction with both high quality input producers and small-scale fish farmers Farm Africa can further be seen as a form of facilitator that can secure better coordination between these parties and even out the power and information asymmetries that currently tend to govern these parties relationships (cf. Section 4.2).

The NGO Farm Africa has further launched three sales outlets / aggregation centres (Busia, Kakamega and one other place) equipped with cooling facilities, where individual farmers can sell their fish at a fixed price (Farm Africa ). The sales outlet then aggregates and re-sells the fish after having preserved the fish smoking or freezing methods (Farm Africa). The Sales Outlet creates a certain market for fish farmers, limit their post harvest losses and through the quality checks that are performed it can also help improve fish farmers' standards and farming efficiency. In addition to these efforts Farm Africa as well as Red Cross have also managed to influence some of the county governments within their operating areas to increase their support towards aquaculture (Farm Africa and Red Cross). The current presence of the two NGO's however limits the potential impact to only a few counties out of all the 47 counties that exist today.

***Conversion to monosex male tilapia***

One of the process upgrades currently taking place for small-scale fish farmers in Kenya is the conversion to farming mono male tilapia instead of mixed sexes (Nyandat & Owiti, 2013). The use of only male tilapia enable the farmers to achieve an estimated 20% faster growth relative to using mixed sexes (cf. Section 3.1). In three of the five conducted case studies this process was seen taking place and it is further an important part of the Department of Fisheries support towards fish farmers (Ken, Millington, David and Department of Fisheries). Hand sexing was used to ensure only male tilapia was farmed in the case studies and from the Department of Fisheries, which is a manual selection method of the sexes (Ken, Millington, David and Department of Fisheries). The fish farmers further used the carnivorous catfish to control the spawn from occasional incorrect included females (Ken, Millington and David). The conversion to only male tilapia can be an important method for fish farmers to reach higher production levels and this is also seen in Thailand; one of the most sophisticated fish farming countries where around 80% of semi-intensive farmers uses mono male tilapia (Bhujel, 2013). In two of the three cases where the conversion to all male tilapia where seen, the initiative was driven by the government's FFEPP (Ken and David).

***Smoking & frying***

An important product upgrade observed within all four FFK farmers as well as in various other farmer groups across Kenya is to either fry or smoke the fish before they are sold (FFK and Nyandat & Owiti, 2013). This method provides two important features; firstly it helps preserve the fish, which is important since none of the interviewed fish farmers had cooling boxes (FFK). Only one of the four fish farmers from FFK experienced preservation issues (post-harvest losses), he was however also the one preserving the least amount of his fish (20-25%) (FFK). Secondly these preserving methods enable the fish farmers to achieve between 39-58% higher prices for the fish with very limited extra costs involved (own estimates show these to only constitute 12.3% and 16.5% of the extra price) as can be seen in Table 20 below.

| Prices from Interviewed Sources | Tilapia fresh 1 kg. KES | Price in USD | Smoked % extra | Deep fried % extra |
|---|---|---|---|---|
| David (polytech) | 300 | 3.28 | n/a | n/a |
| Philip | 300 | 3.28 | 50% | 100% |
| Ken | 333 | 3.64 | 25% | 50% |
| Millington | 320 | 3.50 | n/a | 25% |
| Evans | 315 | 3.44 | 43% | n/a |
| **Average** | **314** | **3.43** | **39%** | **58%** |

**Table 20:** Fish farmers' value addition - FFK and David.

It is not certain where the knowledge to preserve fish through smoking or frying stem from however it works well to increase farmers income and limit post harvest losses.
Similar to what Neilson & Pritchard found within tea and coffee the two primary forms of upgrading that have been seen taking place for small-scale fish farmers are product and process upgrading with no real examples of functional or inter-sectoral upgrading (Neilson & Pritchard, 2009).
The government have to some extent helped spur the process upgrading of using only male tilapia. Its role in enabling other forms of upgrading have however so far been limited even though its presence could be seen to be central in many of the small-scale fish farmers' struggles.
The main enabler behind the process and product upgrading seen so far seem to more be driven by the support organisations Farm Africa and Red Cross. Their geographical radius is however still limited to primarily including Western Kenya and the area around Mombasa (cf. Section 4.1) why many small-scale fish farmers are likely to stay unaffected by their support.
In especially the research conducted by Ponte and Jespersen et al. and also to a large extent in Neilson & Pritchard's research on tea and coffee significant support from government agencies have been highly important for the small-scale farmers ability to reach new upgrades (Ponte et al., 2014 and Jespersen et al., 2014 and Neilson & Pritchard, 2009). The aquaculture sector in Kenya is still young and it would therefore not be expected for Kenya to have reached a level of sophistication as is seen in Thailand, which have taken many years of development with on-going institutional support (Ponte et al., 2014 and Jespersen et al., 2014).
The limited support from the government so far towards aquaculture, which going forward will be the role of County governments does nevertheless indicate that sizeable institutional changes within the County governments are needed in order to enable small-scale fish farmers to reach an upgrading trajectory that have the potential to release them from their remaining struggles.

## *5.2. Upgrading opportunities & potential solutions*

This section will discuss and explore additional upgrading enablers and upgrades (process & product) that could help eliminate the remaining struggles small-scale fish farmers are experiencing. The potential solutions will be driven by a mixture of changes within governing mechanisms and institutions and will lead to a forecast of three potential development paths for the Kenyan aquaculture sector.

### *Potential enabling initiatives and upgrades in regard to Struggle 1*

If the small-scale fish farmers are to be able to implement the best practice farming methods seen in Egypt they need to shift to using only high quality fish feed and fingerlings (cf. Section 3.2). This should turn into both product and process upgrades from increasing the efficiency of their farming methods while also improving the output of the fish through higher quality inputs.

For this to take place the high quality inputs first need to be made readily available and it is difficult to see this taking place across Kenya without government intervention.

In the Indian tea sector and aquaculture sector of Bangladesh similar problems with low quality inputs or commodities have also been experienced. Neilson & Pritchard describes how a combination of product upgrades for the small-scale farmers in India made available through the support of NGO's and government agencies together with better enforcement of quality standards from the government helped solve this issue (Neilson & Pritchard, 2009).

In Bangladesh on the other hand they are still struggling with large issues of food safety standards (Ponte et al., 2014 and Jespersen et al., 2014). Ponte and Jespersen et al., further notes that the lack of upgrading seen in Bangladesh relative to China, Thailand and Vietnam are especially driven by the country's weak institutional support and regulative enforcement (Ponte et al., 2014 and Jespersen et al., 2014).

The Department of Fisheries or KEBS with the help from County governments should adopt an equivalent strategy as was seen in India with a first step being initiating new enforcement procedures including on-going quality tests of feed and fingerlings together with higher penalties for failing to live up to the standards. These enforcement procedures should however also extent to raw material suppliers, since they were also seen to be part of the problem leading to low quality fish feed.

AAK that both represents fish farmers, hatcheries and fish feed producers ought to help with these new enforcement procedures similar to the large role AFIPEK have been seen to play within captured fisheries (cf. Section 4.1).

If AAK were to help in the enforcement of new standards within the fish input industries it would however require more resources allocated to the organization and since it is not fully financed by its members like AFIPEK but still dependent on government funding this might prove difficult. A complete switch to member financing could help AAK become more flexible in securing the needed funding but again it might not be possible for its current members to lift this responsibility before they have reached a more developed stage.

In order for the fish feed industry and hatcheries to be able to live up to these potential enforced standards, additional process and product upgrading would be needed across the sector as was also seen contributing to the solution within the Indian tea industry. The scale needed to enable this upgrading seems most likely to come from the county governments together with additional support from organizations like AAK and NGO's.
The obvious place to start would be to revive many of the failed or low performing hatcheries and fish feed production facilities the FFEPP have left across Kenya (cf. Section 4.2). The farmer groups operating them should receive new training on how to produce quality inputs together with funding needed to get the equipment up and running again and to buy initial raw materials.

As advocated by both Red Cross and Farm Africa bringing in the private sector more in this process could help increase the sustainability and efficiency of the input sectors. One way to help develop the private sector within feed and seed would be to create the right incentives for medium-large scale producers to emerge as according to AFIPEK was how the chicken feed industry overcome similar problems to what is seen in the fish feed and fingerling sectors at the moment (AFIPEK). The chicken industry is today dominated by a few large and efficient production companies; Kenchick, QMP and Farmers Choice, which increasing continuous demand for chicken feed helped expand the feed sector with new emerging large scale chicken feed producers (AFIPEK, Access2Innovation).
The four established government fish processing factories (meant for aquaculture) once operational could together with Farm Africa's three sales outlets help provide the incentives needed for the emergence of large-scale suppliers (MOALF, 2014)[3].
If the factories and sales outlets were to aggregate all the needed inputs for fish farmers and facilitate the procurement and distribution of this it could create a large enough continuous demand for quality fish inputs to bring in new input producers. This would differ from the earlier seen increasing input demand arising from the FFEPP since back then the demand was driven by sporadic small-scale individuals with no enforced quality regulation in place.
An emergence of new large-scale fish input producers could also help drive down the high prices seen for fish feed through the economies of scale expected for these producers as was seen in the chicken feed case (AFIPEK).

[3] Located in Kakamega, Meru, Migori and Nyeri.

***Specific product upgrades within hatcheries***

Within fingerling production the governments efforts so far to enable product upgrading into the production of all male tilapia fingerlings have to some extent been successful, however some farmers are still struggling with finding quality fingerlings (cf. Section 4.2) why more efforts are still needed.

One way to help fish farmers' better reach the process upgrades of farming male tilapia instead of mixed sexes would be to provide better conditions for hatcheries to reach the product upgrade of only hatching the male tilapia. This could be done if the government agencies producing fingerlings and conducting research within this field (LBDA, KMFRI, NARDTC) would adopt the more efficient method of using hormones for sex change (cf. Section 3.1) and help distribute this technique to the private sector and farmer groups operating hatcheries.

***Governance issues***

One of the primary issues for fish feed prices being so high in Kenya was the fish feed producers current ability to charge prices multiple times their production cost to fish farmers because of their higher bargaining power and lack of regulation within this area (cf. Section 4.2). Farm Africa are helping bridging this governance issue through their own shops and collaborating agrovets however their efforts will not be enough to solve this struggle across the whole of Kenya. Better governance mechanisms set by the government to regulate the profit distribution between fish farmers and fish feed (e.g. a maximum price charged by fish feed producers).

Similar government controls on raw material suppliers price setting will also be needed to ensure their current dominating role governing their relationship with fish feed producers do not result in them overcharging on suboptimal quality.

### *Potential enabling initiatives and upgrades in regard to Struggle 2*

Although various sources are currently helping to distribute important knowledge on to small-scale fish farmers it was only Farm Africa's information that was seen to not come directly from one form of government agency (cf. Section 4.3).

Since the majority of information therefore seem to stem from government agencies some of the knowledge issues could help be resolved by allocating more government resources to aquaculture especially towards training of government agents in up to date best practices and to employ a larger workforce of government agents. The increased number of government agents with higher technical knowledge should make it possible to distribute the best practice techniques to current and new fish farmers across Kenya and their continued presence will also serve as limiting the failure rate of new fish farmers.

The government's fish farming factories could further help distribute optimal farming knowledge to fish farmers through an on-going dialog between the parties and the higher standards fish farmers would have to live up to, similar to what Farm Africa is already doing at its sales outlets.

***Devolution and divergence***

The lobbying effects from Red Cross and Farm Africa will to some extent be expected to counter the divergence between county government's support towards aquaculture seen taking place after the devolution in 2012 (cf. Section 5.1). The limited scale of their current operations as was further noted (cf. Section 5.1) will however mean that the majority of counties will stay untouched from their enabling efforts.

There is therefore a substantial need for the government to establish some form of national governance for the various counties to create a coherent development path for aquaculture. If more resources were to be allocated to each county government to help distribute best practices to fish farmers, national governance would especially be necessary since corruption are already taking place within aquaculture and in the rest of the country (PWC, 2014 and Section 4.3).

***Transition to best practices***

If the quality of fish inputs were to be improved and the supply of these quality inputs increased sufficiently and Kenyan small-scale fish farmers were to implement the best practices from Egypt (assuming this information could be distributed to them) this would materialize into substantial product and process upgrades and improvements in their income generation. Using the five case studies as examples it is possible to showcase this (see Table 21 below, Appendix 11 and attached Excel sheet 'Data Thesis' for more details).

Only three of the fish farmers actually earn a positive Gross Profit at the moment.

| Status quo | Grow-out Pond area m2 | Output in kg annually (incl. Eaten fish) | Amount of feed needed in kg annually | Total Costs per harvest | Cost of feed in % of total cost | Gross Profit annually KES |
|---|---|---|---|---|---|---|
| David | 5,880 | 6,060 | 13,693 | 837,222 | 61.0% | (334) |
| Philip | 1,400 | 2,246 | 4,890 | 243,156 | 77.7% | 198,363 |
| Ken | 408 | 311 | 524 | 37,843 | 64.2% | 46,398 |
| Millington | 600 | 357 | 1,397 | 68,748 | 85.5% | (1,943) |
| Evans wife | 495 | 435 | 1,397 | 70,147 | 79.1% | 16,099 |
| **Avg.** | **1,757** | **1,882** | **4,380** | **251,423** | **73.5%** | **51,717** |
| **Best Practice (Egypt)** | Grow-out Pond area m2 | Output in kg annually (incl. Eaten fish) | Amount of feed needed in kg annually | Total Costs per harvest | Cost of feed in % of total cost | Gross Profit annually KES |
| David | 5,880 | 10,008 | 11,437 | 726,750 | 51.8% | 976,666 |
| Philip | 1,400 | 2,383 | 2,723 | 143,606 | 62.4% | 374,643 |
| Ken | 408 | 694 | 794 | 47,487 | 55.0% | 124,012 |
| Millington | 600 | 1,021 | 1,167 | 70,036 | 54.8% | 187,770 |
| Evans wife | 495 | 842 | 963 | 52,531 | 60.3% | 145,799 |
| **Avg.** | **1,757** | **2,990** | **3,417** | **208,082** | **56.8%** | **361,778** |

**Table 21:** Current & Best practice fish farming systems for the five fish farmers – own work.

The fish farmers would on average be able to increase their fish output with 59% annually using the same area of ponds. At the same time (except Ken who currently uses quite low levels of feed) they would be able to lower the amount of feed used annually even though their number of harvest per year would increase from 1.40 to 2.31.
The most significant change would be the huge increase in Gross Profit, which on average would grow from 51,717 KES (565 USD) to 361,778 KES (3,952 USD), meaning the Gross Profit would be seven times higher. A change like this could really help improve the lives for many small-scale farmers and encourage more to start fish farming.
What is also a very important feature of this farming method is that a transition into this method for the five interviewed fish farmers does not require any substantial extra upfront costs as can be seen from Table 21 above. In fact estimations show that the total production costs per harvest for three of the fish farmers would actually decrease substantially, while Millington would experience similar costs and Ken that currently uses a low amount of feed would have to pay an extra cost of approximately 10,000 KES, which should still be manageable.
This therefore indicate that if the quality fish feed and fingerlings are made easily available for small-scale fish farmers and that they at the same time are properly informed on the best practice farming method seen in Egypt the small-scale fish farmers would be able to perform this transition without being dependent on any additional finance options made available for them making this farming method extremely viable and scalable.

### *Potential enabling initiatives and upgrades in regard to Struggle 3*

The most developed sectors within aquaculture in Asia according to Jespersen et al.'s research were found to be led by large-scale supermarkets and processors while also receiving substantial institutional support (Jespersen et al., 2014). For the fish farmers in Kenya being excluded from interaction with downstream organization could therefore mean they will not receive the same influence as was e.g. seen in Thailand and therefore not be able to achieve the same level of upgrading (Jespersen et al., 2014).

An analysis of what would happen to the break-even price for farmers if they implemented the system from Egypt have been conducted to explore the potential the best practice method would have in enabling fish farmers to compete with imported prices. The five fish farmers would on average now break-even at a price of 156.3 KES per kg of fresh tilapia relative to the old price of 255 KES/kg. As earlier mentioned it is not viable for the farmers to lower the price this much (cf. Section 4), however it is still a significant improvement in competitiveness that can be seen from Table 22 below.

| Break-even prices fresh tilapia per kg | Current system | Best Practice |
|---|---|---|
| David | 314.1 | 198.5 |
| Philip | 200.3 | 147.5 |
| Ken | 169.5 | 147.4 |
| Millington | 320.3 | 145.3 |
| Evans wife | 270.8 | 142.6 |
| **Avg.** | **255.0** | **156.3** |

**Table 22:** Break-even analysis for the current system and best practice system for the five interviewed fish farmers using tilapia fresh prices per kg – own work.

Relative to the average price for imported fresh tilapia at 101 KES (cf. Section 3.1), there is however still a need for a substantial improvement in the fish farmers' competitiveness for them to be able to match such a price.
Using Evans wife's fish farm as an example, the price of fish feed would need to be cut by 50% (meaning around 38 KES/kg for feed relative to 76 today) for her to be able reach a break-even price of 100 (and more if she also are to earn a living).
A substantial reduction in fish feed prices would of course normally be advantageous for small-scale fish farmers, however if the selling prices fell with the same amount (e.g. to 100/kg) it would not help them. A discussion on a potential solution to a fair profit sharing system between small-scale fish farmers and downstream players will therefore follow later.

***Constrain of continuous supply***

The new government factories together with the Sales Outlets operated by Farm Africa would be able to deliver a continuous supply of fish to buyers, if harvests among farmers is coordinated properly, which could help fish farmers overcoming the second constraint of entering into high-end markets.

***Banning of imported tilapia***

Although the various earlier discussed efforts to help lower fish feed prices are expected to materialize at some point, this is expected to happen slowly over several years. To cut the fish feed prices with 50%, which would be needed for Kenyan fish farmers to become competitive with imported tilapia is therefore not perceived likely in the near future. The final factor that could enable small-scale fish farmers to achieve access to high-end markets in the near term would instead be dependent on Kenya's future trade policies.
Ghana's aquaculture sector has previously experienced many of the same problems with being outperformed by Asian countries (mainly tilapia), why they in the end of 2014 choose to ban all imported tilapia in order to nurture and protect their (less developed) aquaculture sector (Globefish 2 - web).

In order to support and protect its aquaculture sector, which is similar to Ghana in its early development phases (relative to global industries) Kenya should choose a similar road, either banning tilapia import or applying heavy tariffs. As explained by Ross Jackson in his book 'Occupy World Street' the historical evidence for how the current developed countries protected their industries in their infant stages is massive (Jackson, 2012). Free market movement has never been advantageous for any developing country's infant industries (Jackson, 2012).
With the ban (or high tariff) on imported tilapia (and catfish & carps) the downstream organizations in Kenya would have to seek new suppliers either through domestic captured fishery or aquaculture thereby making it possible (if continuous supply are secured) for fish farmers to gain access to the high-end markets. This new interaction with larger downstream players could help spread more efficient farming techniques to the small-scale fish farmers and thereby create important upgrading opportunities for them as was seen in China, Vietnam and Thailand (Ponte et al., 2014 and Jespersen et al., 2014).

In this regard it is however also important to bring in the experiences between upstream producers and downstream sellers observed by Neilson & Pritchard within the Indian tea and coffee sectors (Neilson & Pritchard, 2009). The authors note how the drive from large-scale downstream organization might result in upgrading for the upstream producers however this upgrading is also often forced in order not be downgraded and with very little if any actual gains for the upstream producers (Neilson & Pritchard, 2009).
If the current entry barriers (price and continuous supply) for Kenyan small-scale fish farmers were to be overcome and they would start interacting with larger downstream players the right institutional environment would also have to be in place to secure small-scale fish farmers were treated fairly by downstream organizations. Otherwise small-scale fish farmers could end up being marginalized as described by Neilson & Pritchard often happen when the right regulations are not in place (and enforced) (Neilson & Pritchard, 2009). The result would in that case be that the small-scale fish farmers went from one struggle to another struggle.
In India they introduced a legal binding profit sharing scheme that helped solve this issue where a minimum price had to be paid to small-scale farmers based on a certain percentage of the processors final selling price (Neilson & Pritchard, 2009). This solution could also help govern the potential new interaction between small-scale fish farmers and larger downstream buyers in Kenya. In fact according to Neilson & Pritchard India's solution was inspired by already established profit sharing schemes in the more developed tea sectors of Kenya and Sri Lanka (Neilson & Pritchard, 2009). Extending this system into aquaculture (and possibly captured fisheries) should therefore also be possible for Kenya, and easier to

control if the government factories represented the role as small-scale fish farmers' processors.

## 5.3. Aquaculture development paths

In the previous section potential upgrades for Kenyan small-scale fish farmers were discussed in regard to how these could help solve their remaining struggles. The various upgrades were driven and made possible by different institutional changes that affect and are affected by governing mechanisms. Following Neilson & Pritchard's framework the institutional environment can be seen as enablers for upgrading (Neilson & Pritchard, 2009). In this section the previous discussed enablers will be applied in various degrees to three different scenarios that will lead to different upgrading trajectories for small-scale fish farmers and fish input producers together with three different development paths for the Kenyan aquaculture sector. The institutional and governing changes leading to these trajectories and as a direct response to small-scale fish farmers remaining struggles are first presented in detail for the Optimal case in Table 23 below, where these same changes have been applied in various degrees to the Intermediate and Status Quo case, which can both be seen in Appendix 16 and 17.

| Institutional & governance changes - Optimal case |
|---|
| **Struggle 1** |
| - Substantial increased enforcement of fish input quality standards by county governments, Department of Fisheries and AAK.<br>- Price controls on fish feed producers and raw material suppliers - National legislation enforced by county gov.<br>- New entrants of medium-large scale fish farmers & fish input producers |
| **Struggle 2** |
| - Increased training in best practices for government officials and farmers driven by county governments and Farm Africa<br>- Continued lobbying by Red Cross & Farm Africa leading to more counties support of Aquaculture<br>- Credit options will be made more available from the efforts of Farm Africa & Red Cross leading to less new farmers failing<br>- New national governance mechanisms of counties introduced<br>- More resources to be used on aquaculture allocated to county governments |
| **Struggle 3** |
| - Government processing factories will start operating efficiently from 2016 with good coordination of farmers harvest cycle<br>- Farm Africa's sales outlets and the government factories will further be scaled to other counties<br>- Profit sharing scheme between downstream processors, buyers and fish farmers drawing on Kenya's tea example<br>- Ban of imported tilapia |

**Table 23:** Institutional and governance changes in the Optimal case – own work.

The devolution has already lead to a divergence in aquaculture development among the different counties (cf. Section 4.3) the different degrees of enabling environment in the three scenarios will therefore also lead to three different forms

of county support; Supportive, Unsupportive; Deteriorating that will be assigned different weights in each scenario.
The different weights for each scenario can be seen in Table 24 below that further detail the degrees of enablers and upgrading trajectories for each scenario.

| Scenario Enablers & Upgrades | | | |
|---|---|---|---|
| | **Status Quo** | **Intermediate** | **Optimal** |
| **Enablers / Disablers** | - Huge divergence between counties with overall low government support with<br>- Overall lack of vital quality inputs leading to increasing prices for these inputs<br><br>- Increase in best practice knowledge only in supportive counties, rest stagnant or deteriorating<br>- **County characteristics 2015-2024:** Supportive 25%; Unsupportive; 25%; Deteriorating; 50% | - Medium-high support in majority of counties - still some divergence between counties<br>- Some increase in supply of high quality fish inputs however still issues with poor quality, fish feed prices at same level<br><br>- Increase in best practice knowledge however limited to the supportive counties<br>- **County characteristics 2015-2024:** Supportive 65%; Unsupportive; 35%; Deteriorating; 0% | - High uniform support across Kenya<br>- Access to high end markets<br>- Large increase in supply of high quality fish inputs together with decreasing fish feed prices<br><br>- Widespread knowledge of best practices for small-scale fish farmers<br><br>- **County characteristics 2015-2024:** Supportive 100%; Unsupportive; 0%; Deteriorating; 0% |
| **Product & Process upgrades input suppliers** | - Few input producing farmer groups will continue operating, more will fail / operate at low capacity | - Some process and product upgrades for input producing farmer groups in supportive counties | - Process & product upgrades for fish input producers (both farmer groups and private players) |
| **Product & Process upgrades fish farmers** | - Process & product upgrades from adapting best practices are limited to supportive counties | - Process & product upgrades from adapting best practices are limited to supportive counties | - Substantial process and product upgrades for all small-scale fish farmers from adapting best practices. |

**Table 24:** Scenario Enablers & Upgrades – own work.

***Growth output drivers***

The resulting upgrades (or downgrades) caused by the various institutional and governance changes showcased in Table 24 above have led to various assumptions for each scenario's growth output drivers, with a summary shown below (details can be seen in Appendix 13 & 16-18).
The percentage of counties being supportive in each scenario have also been applied as the same percentage of small-scale fish farmers that are expected to implement the best practice methods from Egypt, hence it is not perceived likely that they will be able to reach these upgrades without substantial support from NGO's or the government. The adoption of best practices will mean substantial increases in the small-scale fish farmers' yields, which will be part of one of the growth output drivers. Furthermore each county category is accompanied by a different growth rate of new ponds, which is the second growth output driver.

| Growth output drivers summary | Actual - 2013 | Status Quo - 2024 | Intermediate - 2024 | Optimal - 2024 |
|---|---|---|---|---|
| % of small-scale farmers using best practices | 0% | 25.0% | 65.0% | 100.0% |
| **Total yield kg/m^3** | **1.35** | **1.35** | **1.50** | **2.01** |
| **Net growth in ponds (Avg. from 2015-2024)** | **n/a** | **-5.6%** | **6.50%** | **14.90%** |

**Table 25:** Summary of growth output drivers – own work.

***Medium-large scale intensive fish farmers***
The forecasts of the two medium-large scale fish farmers (cf. Section 3.1) can be seen in Appendix 14 & 16-18 together with all the assumptions for the new emerging players assumed in the Optimal case.

***Aquaculture output results***
The three possible development paths for Kenya's aquaculture sector can in the chart below be seen to end up producing substantial different amounts of farmed fish. From a overall realized aquaculture production of 48,790 ton in 2013 by 2024 Kenya could end up only producing 37,997 if they were to follow Status Quo, whereas the Optimal scenario would yield an aquaculture production of 6.5 times the 2013 level and reach 319,464 ton by 2024.

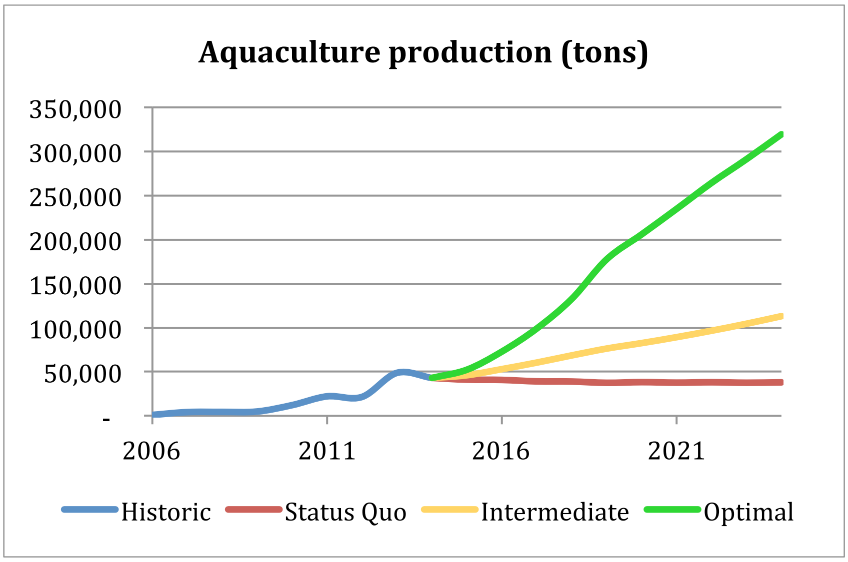


**Chart 1:** Scenario and historic aquaculture – own work.

The various findings that have been discussed throughout the previous sections in regard to struggles, enablers and upgrades showed how small-scale fish farmers to some extent have been able to improve their social and economic situations through product and process upgrading with examples like the transition to farming male tilapia and smoking or frying their fish. The two supporting NGO's Red Cross and Farm Africa have furthermore helped in various ways to create a more enabling institutional environment, which should help create more opportunities for the small-scale fish farmers located in the few areas they are currently present.
The previous discussions however also exposed how central the support from the government is in making new upgrading trajectories possible for small-scale fish farmers and how this support until today have been inadequate in enabling various potential upgrading trajectories for small-scale fish farmers. The devolution of government powers into county level has furthermore resulted in

some counties showing a decreasing level of support towards the aquaculture sector with indications that this divergence among counties is growing.
It has for these reasons been considered most likely that the path the Kenyan aquaculture will follow forward will be that of the Status Quo scenario especially driven by the weak government support and the increasing divergence between the 47 counties that seem to be taking place.
The Optimal case as the name suggests is meant to illustrate the substantial development potential Kenya's aquaculture sector have if the 'right' path were to be followed. This would again especially be lead by various institutional changes primarily initiated by the government to create an optimal enabling environment for small-scale fish farmers (See Table 23 for actions required).
The Intermediate scenario illustrates a development path that is still optimistic given the current circumstances of the Kenyan aquaculture, however with actions that lies within a more realistic range. This scenario will achieve some of the same upgrading trajectories as seen in the Optimal case, however some headwinds will still be felt especially through a divergence in development levels between the counties.
In the next section the potential consequences on Kenya's food security from these different aquaculture forecasts will be explored. All forecasted outputs and additional assumptions for all the scenarios can be seen in Appendix 13 & 16-18 while all the presupposed various produced levels of inputs and their quality can be seen in Appendix 15 (all calculations can be accessed from the attached Excel file).

# 6. Food security analyses

In order to be able to estimate the potential consequences the aquaculture sector could have on food security in Kenya various forecasts and assumptions have been necessary to conduct. A discussion of the methodology and tools used for these forecasts will first follow where after the results on food security will be presented.

## 6.1. Methodology for estimating FAO's PoU ratio

Prevalence of Undernourishment (PoU) is FAO's food security ratio used to measure the percentage of people experiencing chronic hunger within a population (FAO Stat. Div., 2014). PoU and the Number of Undernourished (NoU), which is the absolute number of people suffering from chronic hunger within a population, are currently being used to measure the development towards reaching the Millennium Development Goal target and the World Food Summit goal of halving PoU and NoU by 2015 relative to 1990-1992 (3 year avg.) (FAO, IFAD & WFP, 2014).

To calculate PoU a form of a probability density function have to be chosen together with the estimation of three parameters and one threshold (FAO Stat. Div., 2014):

- The threshold is called the Minimum Dietary Energy Requirement (MDER). MDER is the average minimum amount of energy needed for light activity and to retain a minimum acceptable weight according to ones height within a population (FAO Stat. Div., 2014).
- DEC is mean level of dietary energy consumption per capita measured in kilocalories per day.
- The Coefficient of Variation (CV) is a statistical ratio that measures the dispersion of data relative to the mean, calculated as the Std. dev. / mean of a given dataset (if this data is available) (Makridakis et al., 1998). In the situation of food security it is used to measure the food inequality in a population (FAO Stat. Div., 2014).
- Skewness (SK) is the asymmetry of food consumption within a population.

***MDER***

To estimate the MDER a weighted average following the populations age and sex distribution are used while also taking into account the level of physical activity by applying a Physical Activity Level (PAL) of 1.55 corresponding to a sedentary lifestyle (FAO Stat. Div., 2014). The UN's 'World Population Prospects 2012' version FAO uses for data on age distribution includes two different age distributions, one dividing the population into three categories and one that divides them into four categories (UN Pop, 2013). The other report needed to calculate MDER is the 'Human Energy Requirement', which lists various needed requirements of calorie consumptions dependent on age and level of active lifestyle (PAL). However this report does not include age groups in comparable age categories (FAO, WHO, UNU, 2001). Due to this fact and since it was not possible to achieve further information on FAO's exact method of calculating the MDER for Kenya (FAO did not reply to questions about this), own estimations of the MDER have not been applied.

***DEC***

The DEC is generally found via FAO's food balance sheets, where the total available food sources within each country are calculated from data on total production, import, export and wastage numbers (FAO Stat. Div., 2014). The aggregated number for each food source is then divided by the population number and assigned its rightful calorie intake to arrive at the per capita kilocalories per day (DEC) (FAO Stat. Div., 2014).

***CV, SK and data treatment***
The direct way to estimate CV and SK involves using household data on consumption patterns, where three different methods can be used for data treatment (see Appendix 21) (FAO Stat. Div., 2014).
According to Nathan Wanner one of the authors of the newest methodology for PoU unfortunately there is not any reliable household data available for Kenya, why it has not been possible to use and replicate one of FAO's methods (Nathan Wanner).
Instead an indirect method to calculate CV may be applied, however this requires calculated Gini coefficients, which is again unavailable for Kenya (FAO Stat. Div., 2014 and World Bank Gini - web). Several attempts to acquire more information into FAO's methodology of calculating CV for Kenya were tried however Nathan Wanner from FAO's Statistics Division (co-author of the newest PoU methodology) did not reply to these requests. It has therefore not been possible to try and recreate either the CV or SK for Kenya. The values estimated by FAO for CV and SK will still be used up until year 2014 where after the parameters will be forecasted.

***Forecasting DEC (no fish), CV and MDER***
Only simple forecasting models have been tried out since the data available only dates back to 1992 together with the fact that one of these models was found to fit all three dataset very well and following Makridakis et al.'s notion on choosing the simplest possible model (Makridakis et al, 1998).

Three different Autoregressive models with trend found through the use of the Linear Stepwise Autoregressive method was seen to constitute the best fit for all three dataset (CV, MDER, DEC no fish) and were therefore chosen as the forecasting model (see general formula below). Details on the forecasts, other tried models and the individual formulas for each dataset can be found in Appendix 19-21.

- $\mathbf{Y_t = c + \Phi_1 * Y_{t-1 \ldots} + L*t + e_t}$, where $Y_t$ is the dependent variable, c is the constant, $\Phi_1$ is the AR coefficient at lag 1, L is the linear trend, and $e_t$ is the error term.

It is the DEC that will be used to calculate the potential effects on PoU for the three different aquaculture scenarios. This will be done through various steps.
First, the forecasted aquaculture output seen from Section 5.3 will be turned into kilocalories per capita per day using the average conversion between grams and kilocalories for fish seen between 1992-2014 of 66.9%. This will then be added to a forecasted DEC excluding kilocalories from fish (using the Linear Stepwise Autoregressive model) for each year (2015-2024).
Moreover, fish production from captured fish together with imported and exported fish (and stock variations and fish used as feed) also have to be estimated in order

to reach a final figure of fish consumption per capita a day. The methods to forecast these will be explained more in depth later on.
Putting all this together three different DEC time series (one for each scenario) are estimated for the period of 2015-2024, which will be used to calculate three different PoU ratios.

***Functional form***

A functional form for the PoU also have to be chosen and here three different ones may be used with the choice of the most optimal form to use on a given country depending on the asymmetry present in the consumption data (SK) (FAO Stat. Div., 2014). Since no reliable consumption data are currently available for Kenya and since it is neither possible to calculate CV and SK through an indirect measure it has further not been possible to achieve sufficient indication on what functional form that would best fit the Kenyan data.
A choice have therefore been made to use the simplest functional form; Function 1, which assumes a lognormal distribution and further results in SK being a direct function of CV, why SK will not need to be forecasted separately but instead can be derived from the forecasted CV. Function 1 can be seen below, while the other possible forms can be seen in Appendix 22.
**Function 1** (FAO Stat. Div., 2014, replication from page 5 and 6):

$PoU = PoU_{LN}$ (DEC, CV, SK, MDER), $SK = (CV^2+3)*CV$

***Estimating PoU and adjustment to PoU forecasts***

After having chosen a functional form for PoU and estimated the various parameters (and threshold) needed the Statistical program SAS was used to write a code that can estimate the PoU (see Appendix 22)[4].

First, it was tested if the estimation technique for PoU resulted in the same values FAO have published. This was not the case, likely because FAO are using some other form of data treatment or another functional form. However the difference between the estimated PoU for the years 1992-2014 relative to FAO's actual estimated values were rather consistent with an on average too low estimation of 5.17 percentage points in this period. An estimation of PoU for five other countries (resembling Kenya's development in PoU) was conducted and similar variations to the actual data could be seen ranging from 3.37 6.24 percentage points (see Appendix 22).
Because the difference between the estimated PoU and actual PoU seemed to be consistent and stable, and since the primary focus in this thesis is to evaluate the

[4] With help from Lisbeth La Cour (secondary supervisor)

differences in effects on food security between the three possible aquaculture scenarios the PoU estimates are still considered relevant.
To adjust the final different PoU estimates in the three aquaculture scenarios, DEC data excluding calories stemming from fish was used to forecast a PoU excluding fish using the SAS code. The difference between the PoU excluding fish and the normal forecasted PoU (using a linear Stepwise Autoregressive method) has been added to all the three different scenarios (see Appendix 22-23 for details).
Additional sensitivity analyses of CV, MDER and DEC will further be carried out in order to better understand the importance of each parameter and the threshold relative to the PoU (not for SK though since it directly follows CV).

## 6.2. Price elasticity

A better understanding of the relationship between the forecasted changes in fish consumption (demand) in Kenya and the future price of fish could help provide indications on whether more or less people would be able to afford fish in the future.
Efforts were therefore made to estimate the historic price elasticity together with the 'inverse price elasticity' through linear regressions, which showcases the relationship between demand and price (Gujarati et al., 2009).
Price elasticity can be defined as the percentage change in fish demand caused by a 1% change in the price of fish and the formula can be written as this (Gujarati et al., 2009): $\frac{\%\Delta\ Fish\ Q}{\%\Delta\ Fish\ P}$.
The inverse price elasticity was also tried.
The idea was to first use the demand-price relationship to forecast fish prices in Kenya from the already forecasted fish consumption in the various scenarios. The forecasted fish price could then by using cross price elasticity be used to forecast changes to the consumption of other food sources (all this should then be included in the final estimation of DEC and PoU in Kenya).
Cross price elasticity can be defined as the percentage effects on other food consumption (cereals, starchy roots, meat (excl. fish)) from a 1% change in the price of fish and the formula can be written as this $\frac{\%\Delta\ Other\ Meat\ Q}{\%\Delta\ Fish\ P}$.

***Data collection***

Historical fish prices in Kenya proved extremely difficult to acquire, even from the Department of Fisheries (see details in Appendix 32). Other possible data sources were then investigated and the only available sufficient data history (to 1990) for Africa (Kenya not possible) was whitefish real prices (includes tilapia and Nile perch) stemming from imported fish data to Europe, US and Japan. Average global fish prices were also found. For consumption data FAO's food balance sheets were used, where production of each food source are adjusted for import, export, wastage and stock changes. Data from 1990-2010 were used.

### *Data treatment*

The natural logarithm was used on all data before using the linear regression analysis. The various tested food outputs were further listed in kg per capita before taking the natural logarithm of them. All prices were in real terms.
The general equations for the linear regression can be seen below, while three of the linear regressions (all for Africa) can be seen from Appendix 32 (Gujarati et al., 2009).

- $\ln(Y_i) = \alpha + \beta_1 * \ln(X_i) .... + u_i$

### *Elasticity results*

Using data from Africa, the price elasticity could be seen to be 0.3952%, meaning if the price of whitefish increased with 1% the demand should increase with 0.3952%. The result is highly significant at a 5% level with P-value <0.001 and all the results can be seen in Table 26 and Appendix 32.
The result is however contrary to the usually expected relationship you would find and it is difficult to argue why an increase in real fish prices in Africa should increase the demand for fish (Gujarati et al., 2009).
The same relationship between fish price and demand for fish was shown when estimating the inverted price elasticity (same sign) and still significant (at 5%).

| Elasticity results | Africa | | World | |
|---|---|---|---|---|
| | Elasticity | P-Value (5% level) | Elasticity | P-Value (5% level) |
| Price | 0.395% | <0.001 | 0.758% | <0.001 |
| Inverse Price | 2.030% | <0.001 | 0.720% | <0.001 |
| Cereal Cross Price | 0.032% | 0.001 | -0.052% | 0.030 |
| Meat Cross Price | 0.266% | <0.001 | 0.519% | <0.001 |
| Starchy Roots Cross Price | 0.133% | <0.001 | 0.079% | 0.224 |

**Table 26:** Elasticity results (price, output and cross price) – FAO food balance sheet, Globefish 1 – website, FAO et al., 2011 and own work.

Using global data, similar results for the relationship between fish prices and fish demand was achieved while also being significant at a 5% level.
The cross price elasticity results can for cereal, meat and starchy roots all (except starchy roots & cereals using world data) be seen to be significant at a 5% level and indicating they are substitutes to fish and the consumption of these will decline if fish prices decrease.

### *Possible explanations of the results*

From looking at the data on the development in world fish prices (real terms) and fish output per capita this indicate the same strange relationships between fish output and fish prices observed from the elasticity analysis, where both the average fish price and average fish output per capita has increased from 1990-2010 (see Chart 2 below).

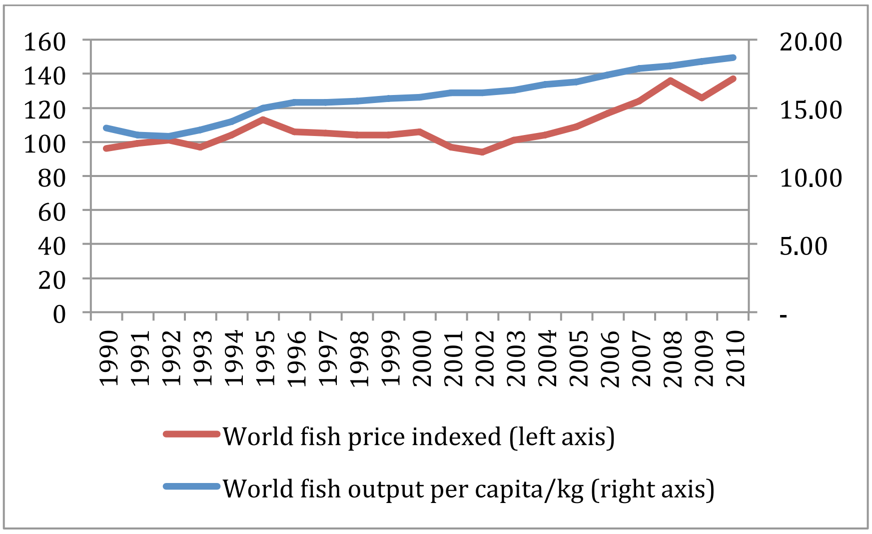


**Chart 2:** Global fish output per capita (right axis) and global fish prices (left axis) – FAO food balance sheet and Globefish 1 – webpage.

A few possible explanations for why the price elasticity results were not as expected are given by FAO. One of the reasons they mention is how the global fish prices to some degree in the last two decades have been driven by price increases in aquaculture inputs used for feed as can be seen from Appendix 32 (FAO et al., 2011).

Aquaculture has as was seen in Section 3.2 come to constitute a larger percentage of the total fish production in the world and relative to captured fish production, which have been almost stagnant since 1990 it has been aquaculture that has driven the increase in total fish production within the last two decades. Further recalling from Section 3.1, that fish feed is the single highest constituter of aquaculture production cost lying between 40-84% globally the notion from FAO that changes in world fish prices are mainly to come from aquaculture does therefore seem plausible.

FAO additionally mention that an increasing middleclass (especially seen in Asia) are contributing to the real increases in fish prices (FAO et al., 2011). This is happening through an increasing demand for fish, which should drive up prices - ceteris paribus - and from a consumption shift to higher valued fish products (FAO et al., 2011).

***Use of elasticity results***

The strange relationship observed between fish prices and fish consumption together with the various other factors that seems to be driving fish prices makes it extremely difficult to make reliable forecasts of the development of fish prices in Kenya. The lack of optimal data further increases the uncertainty of this task.

Due to these issues it has been considered too uncertain to estimate future fish prices in Kenya. The estimated cross price elasticities indicating that they were caused by changes in fish prices will therefore also not be used to adjust the forecasted consumption of other food sources when estimating the final levels of DEC and PoU (since future fish prices will not be estimated).
The results from Africa do however point in the direction of developing countries often being supply driven (in regard to food) as FAO noted and that it is other factors that are causing the changes in fish prices (instead of only demand). Following these results and indications it has further been assumed that there will be sufficient demand for the increase in fish output per capita in the Optimal case.

## 6.3. Forecasting Capture Fishery

In order to estimate the potential effects on food security from the three different forecasted scenarios of aquaculture in Kenya it has been necessary to also forecast the production of captured fish.

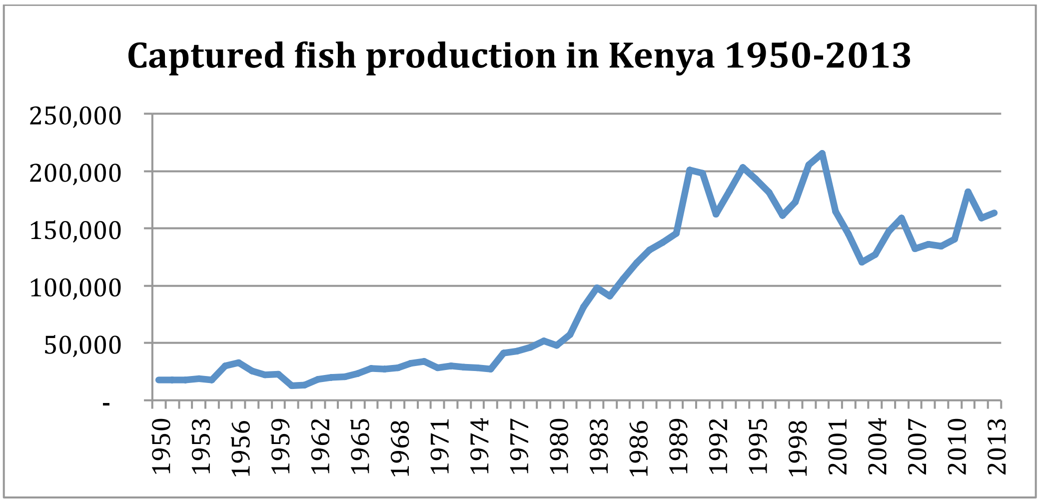


**Chart 3:** Captured fish production in Kenya in tons - FAO fish database & own work.

Looking at the historical data available (see chart above) it can be seen how captured fishery until 1990 experienced an upwards-sloping trend. Since 1990 the captured fish in Kenya has experienced more fluctuations (higher variance) with a stagnating to slight decreasing trend. This trend is consistent with global captured production, which is generally stagnating with one of the reasons being overfishing (also an issue experienced in Kenya) (FAO World, 2014 and Section 3.2). AFIPEK noted that the largest issue within captured fishing relates to the sustainability of the sector (AFIPEK). Standards to ensure that fish are only captured when they are larger than a certain minimum (e.g. 50 cm long for Nile perch) are currently not being enforced by the government (AFIPEK). The lack of control from the government risks causing a depletion of future needed fish stocks thereby leading to a potential significant decrease in future captured fish production. FAO

furthermore expects the majority of future growth in world fish production to come from aquaculture (FAO World, 2014).
Historically more than 90% of captured fish in Kenya has come from freshwater fishing with the majority stemming from Lake Victoria. Between 2007 and 2009 only 5.5%-6.4% of captured fish came from the Marine equivalent to less than 9,000 tons (Manyala, 2011).
Kenya has a long coastline stretching 640 km between Somalia and Tanzania and their Exclusive Economic Zone reaches 200 nautical miles off the coast (zone where Kenya holds the legal rights for fishing) (Manyala, 2011). The Marine sector is highly dominated by small artisanal fishermen with limited presence of larger commercial companies (Manyala, 2011).
Within Kenya's Marine sector there exist a huge potential with production estimates of 150,000-300,000 tons fish annually (Manyala, 2011). However to achieve this potential substantial efforts from the government in promoting the sectors development is considered to be needed. In essence the captured fishing sector in Kenya can go either way in the future. Although the potential to develop is substantial especially via marine fishing, the current effort from the government together with historic figures does not provide indications that this is the way Kenya is heading. Instead it seems more plausible that captured fishing will continue stagnating or declining.

## *Choosing the optimal model*

From a time series perspective a first glance at the data available for captured fisheries in Kenya suggests it will be difficult to find a model that can fully capture such a dramatic structural shift that happened around 1990.
Several models have been tried and only the most promising will be discussed in this section. First relevant simple forecasting models will be discussed where after ARIMA models will be evaluated.

### *Simple models*

Three different simple forecasting models were tried out; Holt Winters, Exponential Smoothing and an Autoregressive (AR) model where the optimal form of this is chosen through the Stepwise Autoregressive method. All these time series models further include the aspect of trend to determine long-term patterns.
Previous values of the variable being forecasted are assigned a certain weight and used to forecast future values in both Holt Winters and the Exponential Smoothing model (Makridakis et al, 1998).
The Stepwise Autoregressive method also uses previous values to forecast the future, it however estimate parameters for any significant lagged (previous) values using a regression formula. It also uses previous error terms to improve the fit of the model (SAS support ). The same AR model that the Stepwise Autoregressive

method estimates is also part of the larger framework of ARIMA models, which will later be discussed.
For all three models the trend aspect can take three different forms; which have all been tested.

- Constant= no trend ; Linear= linear trend ; Quadratic= quadratic trend.

The ratio Mean Absolute Percentage Error (MAPE) have been used to evaluate the simple models together with a comparisons of the forecasts to the actual data to see which model best fitted the data (the formula for MAPE can be seen in Appendix 24). Table 27 below shows the different results for the models including their forecast for year 2024 and their standard deviation for the same year (also see Appendix 24.

| Forecasting captured fishing - Simple forecasting models - Data from 1950 | Quadratic | | | Linear | | | Constant | | |
|---|---|---|---|---|---|---|---|---|---|
| | MAPE | 2024 | Std. Dev. | MAPE | 2024 | Std. Dev. | MAPE | 2024 | Std. Dev. |
| Holt Winters | 59,8 | 216.675 | 45.402 | 30,8 | 178.943 | 41.945 | 20,9 | 155.155 | 31.717 |
| Exponential Smoothing | 35,0 | 190.005 | 42,873 | 23,3 | 176.493 | 33.562 | 20,9 | 155.155 | 29.364 |
| Stepwise Autoregressive | 17,0 | 211.831 | 40.676 | 16,5 | 219.143 | 34.831 | 20,2 | 133.576 | 55.873 |

**Table 27:** Forecasted results for Holt Winters, Exponential Smoothing and Stepwise Autoregressive model. Data=1950-2013 – SAS output & own work.

The optimal model with the lowest MAPE and which best captured the data was an AR 1 model with trend found through the Linear Stepwise Autoregressive method.

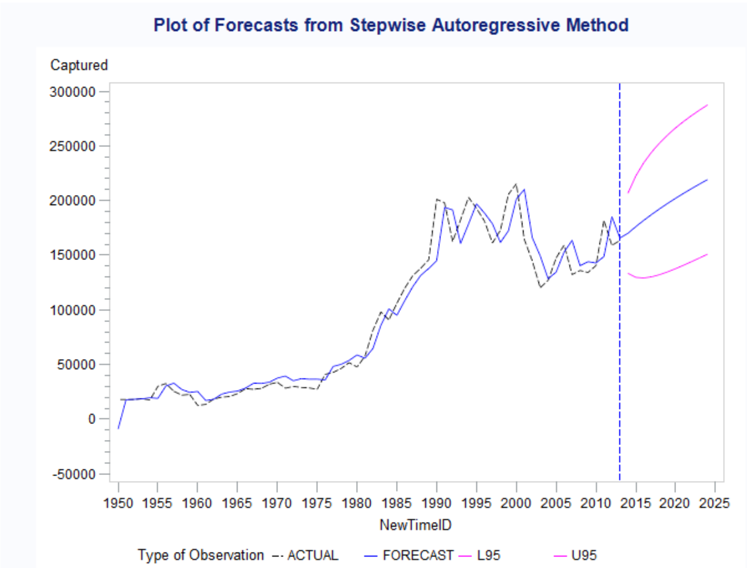


**Chart 4:** Stepwise Autoregressive (linear) forecast of captured fishery output in Kenya. Data=1950-2013 – SAS output. See equation in Appendix 24.

From Chart 4 it can be seen that the forecasted values of captured fisheries lies very close to the actual observed data. The forecasted values shows an upward sloping trend with an estimated value for 2024's captured fishery output of 219,143 tons and a standard deviation of 34,831 tons.

***ARIMA models***

Developed by Box & Jenkins' in the 1970's these models are more advanced than the models described above (Makridakis et al, 1998). The ARIMA models include three parameters, which can all be used independently or together to forecast future values for the chosen variable (Makridakis et al, 1998).

- AR= Uses lagged (previous) values of the forecasted variable.
- I= Takes the first (or second, etc.) difference of the data until it is stationary in variance and mean (if this is required). It is a necessary condition for the data to be stationary in order to use the model for forecasting why this is the first step in the process.
- MA= Uses lagged values of the error term.

From the ACF (and PACF) plot of the captured fish series below it can be seen the data is not stationary (lying outside the critical values illustrated as the shaded area without quickly cutting off into the shaded area).

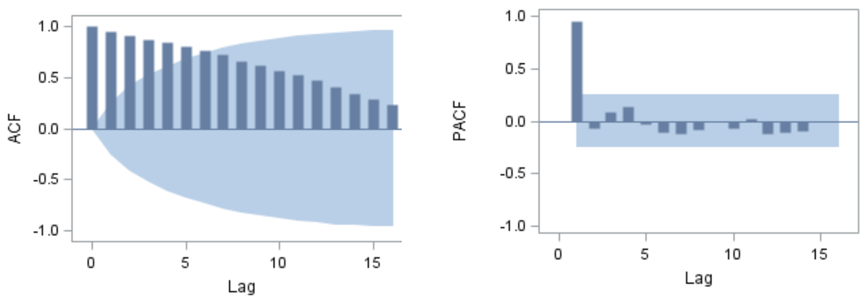


**Figure 4:** ACP & PACF plot of captured fishery output, 1950-2013 data - SAS output.

First difference is therefore taking of the data. The ACF and PACF plot now shows one significant lag at spike two in both the ACF and PACF plot.

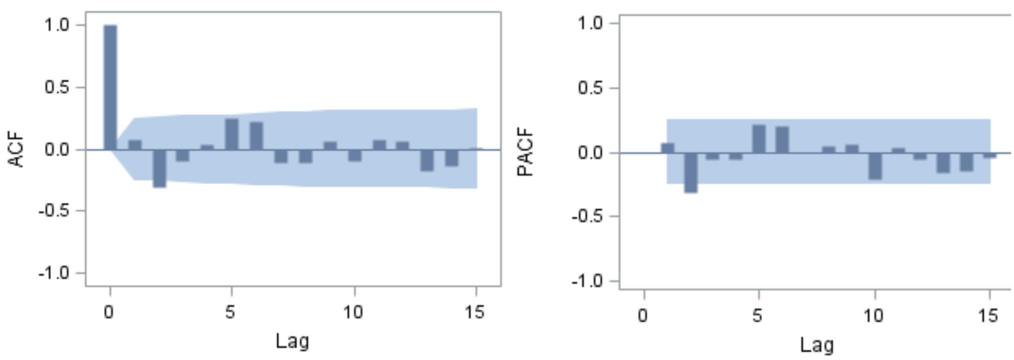


**Figure 5:** ACP & PACF plot of captured fishery output after taking first difference, 1950-2013 data - SAS output.

This could suggest either to add an AR 2 (from the PACF plot) or MA 2 parameter (from the ACF plot) (Makridakis et al, 1998 and Duke – web ). Both measures were tried with similar results, the AR 2 however shows slightly lower AIC (used to measure fit of model) than the MA 2 model, why its results can be seen below in Chart 5 and the MA 2 can be seen in Appendix 25 (both models parameter coefficients can also be seen here). The AIC values together with the forecasts for year 2024 and the standard deviation from the same year can be seen in Table 28 below for both models as well as from a Random Walk model (only taking first difference).

| Forecasting captured fishing - ARIMA forecasting models - Data | AIC | 2024 | Std. Dev. |
|---|---|---|---|
| Random Walk (only first difference) | 1.401,8 | 188.780 | 53.734 |
| AR 2 with first difference | 1.396,6 | 195.478 | 41.121 |
| MA 2 with first difference | 1.397,2 | 192.867 | 40.084 |

**Table 28:** AR 2, MA 2 and Random Walk results for captured fishery forecast. Data=1950-2013 – SAS output & own work.

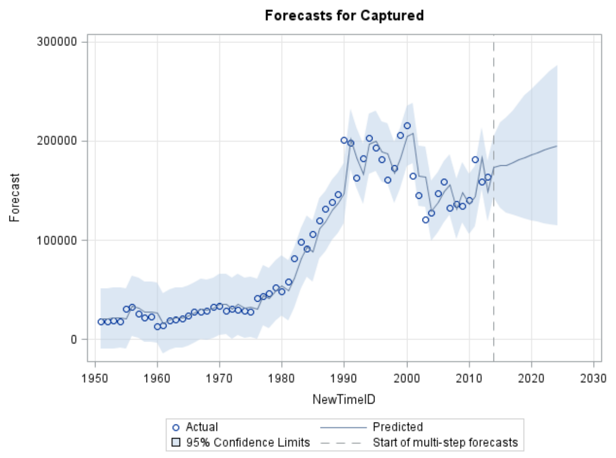


**Chart 5:** Forecast & actual values of captured fishery using an AR 2 parameter after taking first difference. Data=1950-2013 – SAS output.

Chart 5 shows the forecasted values of the of the model using an AR 2 parameter and it can be seen to have an upwards rising trend with an estimated value of captured fisheries output of 195,478 tons in 2024 (std. dev. of 41,121).

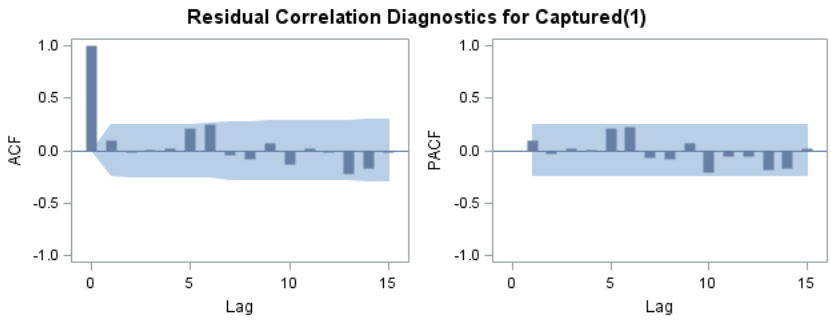


**Figure 6:** ACF & PACF plot using an AR 2 parameter after taking first difference. Data=1950-2013 – SAS output.

All spikes within the residual (not the series) ACF and PACF plot can further now be seen to lay inside the critical values indicating white noise of the residuals (see Figure 6 above).

Other models with various AR and MA parameters have also been tried; however none with superior results to the ones presented.
Both the AR 2 model with first difference and the AR 1 model found through the linear Stepwise Autoregressive method seem to fit the data quite well, with similar predicted upwards sloping trends (AR 1 slightly more steep and with lower std. dev.). Considering the projected scenarios in context to the earlier described situation currently in place in Kenya; a scenario with an increasing captured output does not seem to be the most likely trajectory for captured fishery. A stagnating or slightly downward sloping scenario would be more likely given the sectors circumstances.
Looking at the initial plot of the actual data from Chart 3, it is however not surprising that the forecasted models would see an upwards sloping trend being present since a much larger part of the data seems to be experiencing an upward trend (roughly 1960-1990) relative to the more fluctuating stagnating / slightly decreasing period from 1990 onwards.
Using data only from 1990 onwards have therefore been tried in order for the models to better capture the newest trend (and more realistic scenario).

***Forecasting models only using data from 1990***

All the similar models presented when using data back from 1950 have been tried again. It should however be noted that when using data from 1990 onwards (24 obs.) instead of data all the way back to 1950 (64 obs.) it does significantly reduce the number of observations and thereby also the estimation power of the model.
A few models could be seen to fit the data well in some degrees however none of the models ended up being chosen as the final model to forecast capture fisheries.
All details on the most relevant of the models tried out with data from 1990 can be seen in Appendix 26 & 27.

## *Summary and final choice of model*

All the models presented in the previous sections, which generally fitted the data all include either an upward sloping trend (all models using data from 1950) or a downward sloping trend (AR model found through the Stepwise Autoregressive method with data from 1990)[5].
It has been determined that in order to achieve sufficient evidence to justify either a substantial upward or downward development of the future capture production

[5] Random Walk model was discarded due to having too large standard deviations; its minimal declining trajectory could however have been accepted.

it would require more research into what exact plans the government has for the future and of the strategies and prospects of the current and potential new players of the sector.
Due to this reason a model predicting a more conservative development for captured fishery, have been chosen. Two models fulfilled this requirement both with almost identical forecasts and MAPE. The one with the lowest standard deviation was chosen, which was the Exponential Smoothing method with a constant trend (no trend) using data back from 1950 (the other was Holt Winters). The equation can be written like this (Makridakis et al., 1998):

- **Ft+1= Ft + α * (Yt – Ft) et**, where α =a constant forecast error, Yt is the actual value, Ft is the forecasted value and e=error term
- **Captured fishery Ft+1= Captured fishery Ft + 0.2 * (Captured fishery Yt – Captured fishery Ft) et,**

The results of its forecasts can be seen in Chart 6 below and Appendix 28.

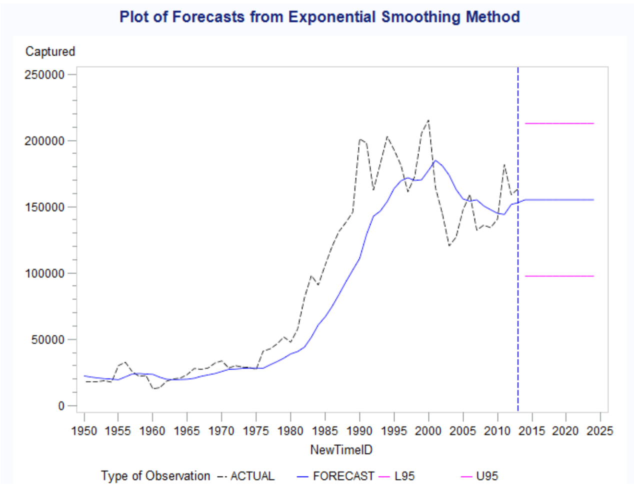


**Chart 6:** Forecasted & actual values for captured fishery using the Exponential Smoothing (constant) model. Data=1950-2013 – SAS Output & own work.

## 6.4. Forecasting import, export, fish output used as feed and stock variations

### *Stock variations & Fish output used as feed*

Both had limited impact on the total fish output in Kenya and a discussion on their forecast assumptions has therefore been limited to Appendix 31.

### *Import of fish*

The exact same selection process of various forecasting methods as was described in detail in Section 6.3 on Captured Fishery have been used to find the optimal model for import of fish. Given this and taking into account the limitations (scope) of this thesis it has not been found necessary to perform the same explaining steps again. The model that was considered the best fit of the data was an AR 1 model with the coefficient 0.55 found through the Linear Stepwise Autoregressive method. The equation can be written as follows (Makridakis et al, 1998):

- **Imported fish$_t$ = 4,862 + 0.55 * Imported fish$_{t-1}$ +451*t + e$_t$**

The forecasting results from this model together with some notes and a few of the 'best' of the other considered models can be seen in Appendix 29.

***Export of fish***

Export of fish is highly related to the amount of captured fish produced, since no farmed fish species in Kenya is currently being exported (AFIPEK). Depicting export as a percentage of captured fish from 1990 onwards it can be seen it has been lying fairly stable in an interval of 16-25% except for a few high speaks in 2002, 2003 and 2004 (see Appendix 30). Taking a 10-year and 20 year average result in 22.5% and 24% of captured fishery production respectively (until 2013). Since export is likely to continue being dependent on the level of captured fish production it has been chosen to use a 20 year average of export as a percentage of captured output and multiplying this with the forecasted captured years for the period.

All the forecasted values for import and export of fish, stock variations and fish output as feed can be seen in Appendix 31.

## 6.5. Scenario results for food security

***Food security results***

By applying FAO's PoU method to the three different forecasted scenarios, it can be seen how the total impact of consumed fish would result in 362,000 less people being undernourished in the Optimal case scenario relative to 149,000 in the Status Quo case scenario (see Table 29 below). The maximum difference between the Status Quo and Optimal case can therefore be seen to constitute 213,000 people. Although this is a substantial number of people to save from chronic hunger comparing the results to the 10,365,000 people still suffering from undernourishment by 2024 in the Optimal case it can be seen to only constitute a small percentage of the total figure. The significant changes in institutional support and governance mechanisms enabling substantial upgrades for small-scale fish farmers that the Optimal case includes therefore unfortunately seem to have limited effect on food security measured as the Prevalence of Undernourishment.

| Effects on undernourishment | No fish - 2024 | Status Quo - 2024 | Intermediate - 2024 | Optimal - 2024 |
|---|---|---|---|---|
| Alleviated from undernourishment in % of population | n/a | 0.26% | 0.36% | 0.62% |
| Alleviated from undernourishment absolute | n/a | 149,108 | 209,676 | 362,347 |
| Alleviated from undernourishment in % of total number of undernourished without fish | n/a | 1.39% | 1.98% | 3.44% |
| Prevalence of Undernourishment | 18.48% | 18.22% | 18.12% | 17.85% |
| Total number of undernourished | 10,728,162 | 10,579,055 | 10,518,486 | 10,365,815 |
| Total number of small-scale fish farmers | n/a | 46,896 | 165,539 | 357,223 |
| Total number of people with improved and self-sustained living standards | n/a | 168,827 | 595,939 | 1,286,004 |

**Table 29:** Effects on undernourishment – KNBS, 2008-2009 and own work.

A larger impact can be seen from the increasing number of small-scale fish farmers established by 2024 in the Intermediate and Optimal case, which if assuming the average rural household contains 4.6 people (as was the case in the latest published household data from 2008-2009) would mean roughly 600,000 or 1.3 million people would be self-sustaining with easy access to high nutritional food and with an income enabling them to increase their livelihood (cf. Section 3.1, 3.2 & 5.2).

***Sensitivity of PoU***

A brief sensitivity analysis of PoU in regard to what impact changes in its different parameters and the threshold might have will in this section be discussed. This has especially been found relevant since it has not been possible to replicate FAO's estimations of CV, SK and MDER as was earlier discussed.

A sensitivity analysis of how changes in the Coefficient of Variation (CV) would affect the PoU level can be seen in the table below (see more details in Appendix 33). Increasing the CV with just 5% meaning more inequality in food consumption in Kenya would result in PoU increasing 1.36 percentage points and adding almost 800,000 people to the total figure. This shows that the overall level of PoU is rather sensitive to changes in consumption inequality.

| Sensitivity CV (using Intermediate) 2024 | CV -15% | CV -10% | CV -5% | Intermediate | CV +5% | CV +10% | CV +15% |
|---|---|---|---|---|---|---|---|
| CV | 17.85% | 18.90% | 19.95% | **21.00%** | 22.05% | 23.10% | 24.15% |
| PoU | 13.94% | 15.34% | 16.74% | **18.12%** | 19.48% | 20.80% | 22.09% |
| Diff. in % points | -4.18% | -2.78% | -1.38% | **0%** | 1.36% | 2.68% | 3.98% |
| Diff. in number of undernourished people | (2,424,153) | (1,612,948) | (802,305) | - | 788,315 | 1,558,677 | 2,308,431 |

**Table 30:** Sensitivity of PoU from changes in CV (Intermediate case) – Own work.

Changes in DEC measured relative to the Normal DEC (forecasted current DEC using the Stepwise Autoregressive method) would have even more substantial impacts on the Prevalence of Undernourishment, with a 1% increase in DEC resulting in 566,000 less people being categorized as undernourished.

| Sensitivity DEC (relative to normal DEC) 2024 | DEC -5% | DEC -3% | DEC -1% | **Normal** | DEC +1% | DEC +3% | DEC +5% |
|---|---|---|---|---|---|---|---|
| DEC | 2,155 | 2,200 | 2,245 | **2,268** | 2,291 | 2,336 | 2,381 |
| PoU | 24.20% | 21.63% | 19.34% | **18.30%** | 17.32% | 15.56% | 14.02% |
| Diff. in % points | 5.90% | 3.33% | 1.04% | **0.00%** | -0.98% | -2.74% | -4.28% |
| Diff. in number of undernourished people | 3,425,333 | 1,931,024 | 603,969 | - | (566,147) | (1,591,007) | (2,483,051) |

**Table 31:** Sensitivity of PoU in regard to changes in DEC relative to the normal forecasted DEC – Own work.

Changes in MDER can be seen to have similar significant effects on the Prevalence of Undernourishment as the DEC.

| Sensitivity MDER (using Intermediate) 2024 | MDER - 5% | MDER - 3% | MDER - 1% | **Intermediate** | MDER +1% | MDER + 3% | MDER + 5% | **MDER (PAL 1.75) +8.31%** |
|---|---|---|---|---|---|---|---|---|
| MDER | 1,665.35 | 1,700.41 | 1,735.47 | **1,753** | 1,770.53 | 1,805.59 | 1,840.65 | 1,899 |
| PoU/PoFI | 13.70% | 15.33% | 17.14% | **18.12%** | 19.14% | 21.31% | 23.65% | 30.24% |
| Diff. in % points | -4.41% | -2.79% | -0.97% | **0.00%** | 1.02% | 3.19% | 5.53% | 12.12% |
| Diff. in number of undernourished people | (2,562,809) | (1,617,960) | (565,873) | - | 591,980 | 1,852,212 | 3,209,603 | 7,037,652 |

**Table 32:** Sensitivity of PoU in regard to changes in MDER using the Intermediate case – Own work.

FAO assumed a PAL of 1.55 for the average Kenyan in its normal MDER (and PoU) calculations corresponding to a sedentary lifestyle with limited physical activity. This assumption has attracted some criticism arguing that in developing countries the average person will often be involved in more physical activity than a sedentary lifestyle, a criticism FAO also acknowledge in their 2014 report 'The State of Food Insecurity in the World' (FAO, IFAD & WFP, 2014). With a rural population constituting 79% in the latest household report in 2008-2009 this could also be the case for Kenya (KNBS, 2008-2009). FAO therefore also calculates a ratio called Prevalence of Food Inadequacy (PoFI) calculated in the same way as PoU just using a PAL of 1.75 (to estimate MDER) corresponding to a more physical average level of activity (FAO food security indicators). The relevance of PoFI is further that it should also include people being seriously affected by their inadequate access to food that however would not qualify as being chronic undernourished (FAO food security indicators).
In Table 32 above it can be seen how only changing the MDER through adopting a higher level of PAL to estimate the PoFI would result in the estimate of people living with inadequate access to food rising to 30.24% of the Kenyan population meaning more than seven million more people than when using a PAL of 1.55.

The sensitivity analysis presented above showed that it is important to acknowledge how sensitive the PoU ratio is to small changes in the parameters and/or the threshold. This is especially important in the case of Kenya where without proper household data it is for instance not possible to adequately assess the distribution of food consumption within the country (CV) and its asymmetry (SK) as well as the changes taking place over time within these two parameters. All in all the Prevalence of Undernourishment ratio can be a useful method to provide valuable information about the level of food security in a country as long as its limitation and uncertainties are recognized and may especially be useful if comparing the impacts various scenarios can have.

***Mechanisms limiting aquaculture's impact on food security***

One of the potential reasons for fish consumptions limited effect on overall undernourishment is that the growth is only driven by aquaculture since capture fishery is expected to stagnate. Aquaculture only constituted 23% in 2013 meaning that even though substantial growth is seen in both the Intermediate and Optimal case the net effect on extra fish per capita will be considerable less.

This also shows how more research is needed within improving capture fisheries if fish are to have a more significant impact on lowering undernourishment. Especially within the marine sector, which was earlier shown had an annual production potential of 150,000-300,000 tons relative to the less than 9,000 tons that was produced annually between 2007-2009 (cf. Section 6.3).

Another highly important issue for Kenya in general is the large population growth, which is illustrated in Chart 7 below.

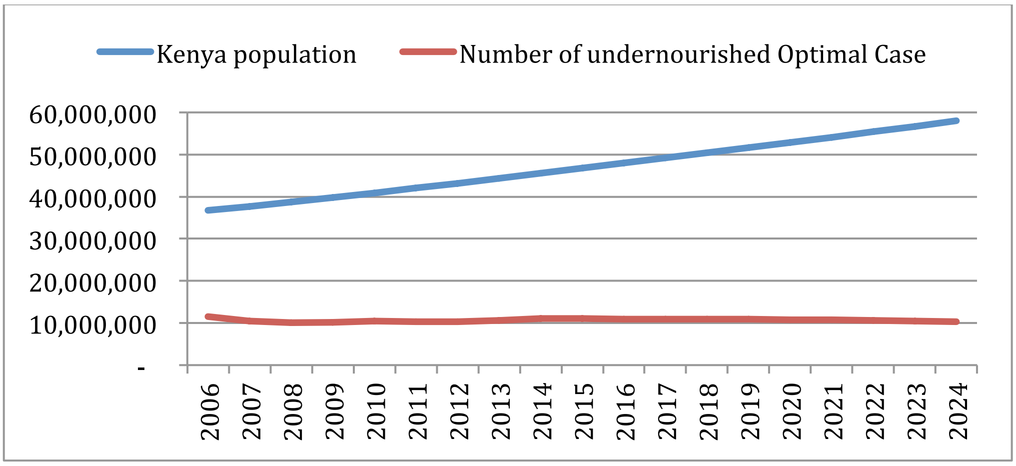


**Chart 7:** Population & number of undernourished forecast for Kenya using the Optimal case - World Bank Pop. - web & own work.

Kenya's population has within the last 10 years experienced an average population growth of 2.72% annually and according to the World Bank this is forecasted to continue although at a slightly lower rate of 2.46% annually for the next 10 years (World Bank Pop. - web). This means Kenya will have to feed roughly 12.5 million new mouths by 2024 relative to the 45.5 million today (2014).

In the Intermediate case the fish per capita per day will actually have fallen from 13.97 grams to 12.17 even though aquaculture output are now 2.3 times larger.

So although the Prevalence of Undernourishment is expected to decrease to between 17.85% and 18.22% (Optimal & Status Quo) from the 2014 level of 24.30% the total number of undernourished people in Kenya will almost be the same by 2024 (10.4 million in the Optimal case relative to 11.1 million in 2014).

Although the various aquaculture trajectories only had limited effect on the overall PoU, the potential to ensure 600,000 to 1.3 million people could reach a self-sustaining improved lifestyle through aquaculture (Intermediate and Optimal case) should however still be considered a major step in the right direction.
Here it is further important to bring in the findings from Section five, which indicated that the most likely path the Kenyan aquaculture looks to follow is the scenario Status Quo. The potential consequences of this in addition to the lower expected aquaculture output will be that today's number of 312,000 self-sustaining Kenyans (87,000 fish farmers) will decrease to only 169,000 people by 2024 (cf. Table 29 Appendix 13).
Much of the substantial development that have been seen to take place within the aquaculture sector since the FFEPP initiation in 2009 and its positive impact on food security will therefore be lost if the Kenyan government does not initiate new efforts to choose a different path.
Furthermore the new 2010 constitution, which outlines the devolution of aquaculture also apply to numerous other sectors including health care and other agricultural sectors (KLR, 2010). One can therefore not refrain from fearing that the indications of negligence and divergence within county governments that have been observed in regard to aquaculture could spread (or have already spread) to other sectors.
Considering additionally how small a part fish still is of the total calorie intake in Kenya and how the divergence in counties might affect some of the much more important sectors of food sources e.g. livestock, maize or tubers the potential impact of this on food security could end up being at a whole other level than what has been shown for aquaculture in the Status Quo case.
More research should therefore be carried out into the government's role in shaping other food sectors' development path in Kenya particularly in regard to the devolution with a preference to the food sectors currently constituting the largest calorie intake for the population. Additional research into exploring potential incentives to help lower the large population growth would further be beneficial, especially if Kenya are to ever reach the World Food Summit's objective of halfing the actual number of undernourished people relative to 1990-92 levels – meaning lowering the number to 4.13 millions (cf. Section 6.1 and FAO food security indicators).

# 7. Method & theory critique

***Adequacy of findings***

The ontology and epistemology of the philosophical view of critical realism used throughout this thesis believes there is an objective true reality but false (incorrect) awareness of the reality can lead to misunderstandings of the reality (Nygaard, 2005, Easton, 2010). Throughout the various research phases of this thesis a use of triangulation methods have therefore been applied where a combination of many different sources both primary and secondary have been used to analyse small-scale fish farmers from various angles in order to help make it easier to identify the true reality from the false reality (or identify the best possible explanation) (Nygaard, 2005, Easton, 2010).

Moreover a continuing shift between the influence from theory and empirical work has further been applied throughout the various phases of this thesis as discussed in Section 1.5, which should also help make it easier to identify the true reality and which Sayer advocates for should be used (Sayer, 2000).

Through the philosophical view of critical realism together with the GVC framework applied throughout this thesis it is also acknowledged that the empirical research conducted in primarily Western Kenya is contextualised in both time and space and might therefore not represent the situation existing in the rest of Kenya (Sayer, 2000).

The triangulation method described above that also includes interviews with various organisations and institutions that have engaged with many small-scale fish farmers across Kenya together with the use of various other secondary literature including case studies from Kenya and other countries should to some extent help account for these potential place specific issues.

Other potential issues could arise when transitioning the underlying mechanisms constraining or enabling the ability of fish farmers to reach various upgrades (from intensive design) into forecasts of the aquaculture output (extensive design). Here especially the divergence in counties' support towards fish farmers are important, which could potentially result in 47 different aquaculture paths going forward. It has been sought to as best as possible to capture these underlying mechanisms resulting in the divergence and transfer the potential effects of these into the three scenarios, however it is recognized that this task is extremely complex and with the sources available (primary & secondary) some potential mechanisms might not either have been adequately uncovered through the qualitative research or represented adequately in the forecasts. Ideally to capture all this potential contextualised variance case studies in each of the 47 counties should have been

carried out, however this would have been an enormous task, which the resources and scope of this thesis have not allowed for.
Furthermore the forecasts are only meant as illustrations to the potential consequences arising from different aquaculture development paths and should therefore not be seen as a way to generalise the qualitative findings from this thesis.

***Use of logical positivism***

The philosophical view of logical positivism share both similarities and differences with critical realism with one of the main differences being that the former accepts and utilizes axiomatic logic to help validate empirical findings, which can then be generalized (where as this is rejected within critical realism) (Ven, 2007). Some of the similarities of critical realism and logical positivism have further also been identified in some of the phases carried out throughout this thesis (cf. 1.5). A brief discussion on the potential implications of having used logical positivism throughout this thesis instead of critical realism with emphasis on their approaches to case studies will now follow.
According to Robert K. Yin (representing logical positivism), applying a logical positivistic perspective throughout this thesis would not allow for the empirical findings to be generalized in a statistical way because the nature of conducting case studies most often infer having very few observations that are not randomly selected (Yin, 2013). Yin instead argues it can be possible to generalize to other concrete situations through analytical generalization, which could potentially have helped with the transition from qualitative to quantitative data (when estimating aquaculture output) (Yin, 2013). One of the important ways to increase the generalizability of a case study according to Yin is to relate the empirical findings with already existing literature on the field to compare similarities and potential gaps (Yin, 2013). This notion in many ways resembles the shift between influence from theory and empirical work that characterise critical realism (and GVC) and have also been applied throughout this thesis. Yin and Easton (representing critical realism) both argue for not just looking at the case but also explore the context in which the chosen case engages in (Easton 2010, Yin, 2013). Yin also mentions how qualitative and quantitative methods in some cases can be a useful combination, which resembles Andrew Sayer's notion on extensive and intensive research designs that have been used in this thesis (Yin, 2013, Sayer, 2000).
In his work on case studies Robert K. Yin however later goes on to discuss 'realists' research questions where he argues; *"Moreover, the 'whom, when, where, and why' portion of the framework leaves the impression that the responses will identify a set of constraining and enabling conditions related to generalizing to other situations. However, the complexity of an intervention and its context may yield such a large*

*number of conditions, not to speak of their distinctiveness or uniqueness, that they cannot be itemized in any practical way"* (Yin, 2013, page 328-329).

It is agreed that the research questions followed within this thesis with a critical realist perspective have made the discussions rather complex and that it is not possible to generalize from this, however that they cannot be 'itemized' in any practical way and as he also mentions in his article that they may only end up being correlative and not causal is not perceived to be the case (Yin, 2013).

This is especially one of the strengths of critical realism, in that it goes beyond just causality and further identifies and analyses the underlying mechanisms driving this causality. For instance it would not have been enough to identify that there is a causality between the initiation of the governments FFEPP and how this have caused numerous new fish farmers to start, and then potentially use this causality to infer that this could be expected to continue going forward when forecasting the aquaculture output.

Instead what was uncovered through the use of GVC with an overall view of critical realism was that numerous underlying mechanisms were at play simultaneously and moving in different directions. This includes the devolution that now seem to have created different development paths for counties, and how several elements of FFEPP are not sustainable with fish farmers and the input industries failing (or operating at inefficient levels) while the FFEPP in combination with a lack of quality standards have further ended up causing a substantial decrease in the quality of inputs. The recognition from critical realism and GVC that events and circumstances are place based following the question of 'where' is additionally considered to have enabled a better capture of the diverging mechanisms at play among the 47 Kenyan counties leading to different expected development paths. As noted in this section the forecasts were further only meant as illustrations and never with the aim of generalising the empirical findings.

Therefore although several similarities could be seen to Yin's case study approach from a logical positivistic viewpoint it is the author's belief that within the complex nature of the topic studied throughout this thesis it is the exact use of critical realism and the GVC framework that have allowed to go beyond cause and effect and capture many of the underlying mechanisms and nuances at play, which would not otherwise have been possible.

***Elasticity***

The assumption that the demand in Kenya would be sufficient to consume the extra fish output from the Optimal Case following the price elasticity estimates and the notion from FAO that this is often the case in developing countries could have been explored further. FAO's suggestion about a rising middleclass being one of the causes of the increasing consumption of fish despite the concurrent increase in real fish prices could for instance be studied closer by adding a form of income measure like GDP per capita in real terms in the price elasticity regression. However due to the limited scope (and space left) of the thesis it was considered adequate to rely on the above mentioned indications of there being sufficient demand for the increased forecasted fish output in the Optimal case. This decision was also made in order keep focus on the various forms of underlying mechanisms already impacting aquaculture output and food security and thereby abstaining from adding extra complexity to the already dense situation.

***Captured fishery***

A log transformation of the captured data could possibly have eliminated some of the challenges caused by the level shift in the data series taking place from the 90'ties and onwards, thereby making the time series stationary before modeling. This could have narrowed the confidence intervals for the observed values, however the effects on the actual forecast values would not be expected to change substantially.

The real issue lies with using only lagged data from captured fishery to estimate its future development, which excludes any potential causal relations. Capture fisheries is similar to the aquaculture sector complex with many different underlying mechanisms at play as briefly mentioned in Section 6.3, why to substantially improve the forecasting model it would be needed to gain in-depth insight into these and how they could be expected to impact the future. This could have been done through a similar approach as has been carried out through this thesis for aquaculture where several of the same mechanisms would be expected to be at play. Another method would be using a linear regression model where numerous exogenous variables such as Global/African fishing production, an overfishing index, growth in population and demand could be run through statistic test to gain indications of their potential to help explain and through this forecast captured fishery production in Kenya. Limited resources have unfortunately not allowed for this and engaging in one of these larger scale methods would also have shifted focus away from small-scale fish farmers and aquaculture's potential impact on food security, why a decision was made to settle with the more simple forecasting method (similar arguments can to some extent be made for the estimation of DEC and MDER).

# 8. Conclusion

Through the use of Neilson & Pritchard's GVC framework together with an overall philosophical view of critical realism one of the largest struggles identified within Kenya's aquaculture sector facing small-scale fish farmers was the lack of available quality fish feed and fingerlings. This inadequate supply of essential inputs have especially been driven by the governments FFEPP, which spurred a substantial

increase in new fish farmers but was unable to secure an adequate amount of inputs being available for the growing aquaculture sector.
The struggle for adequate inputs is directly linked to the asymmetrical power relationship observed between small-scale fish farmers' and input suppliers (governed by the input suppliers), which was found to be gravest in regard to fish feed producers. This power asymmetry together with a lack of official regulation to govern this relationship further seem to have enabled fish feed producers to charge unnecessary high feed prices to fish farmers.
A second struggle that is currently impacting small-scale fish farmers is the insufficient knowledge of best practice farming methods. The knowledge flow was identified to predominantly initiate from various government agencies. Several sources further indicated that the mechanisms driving this struggle were a combination of insufficient allocation of government resources to help train fish farmers together with suboptimal knowledge being distributed to farmers because some government officials themselves lacked knowledge on best practices.
The devolution of government powers (into counties) that took place in 2012 could further be seen to aggravate this struggle, where some counties had already started to neglect their support towards aquaculture.
The combination of these two struggles have resulted in small-scale fish farmers achieving low yields with unnecessary high uses of feed (FCR), in the end substantially lowering the farmers' income. Comparing these results to yields and FCR from best practice countries in Asia and other African countries helped illustrate the gravity of the unlocked potential that can currently be seen for Kenyan fish farmers. Kenyan small-scale fish farmers' were at the moment achieving yields of around 0.91 $kg/m^2$ relative to yields seen in Egypt of 1.7 $kg/m^2$, while also using more than twice the same amount of feed per kg output as was observed in several other countries.
The substantial higher yields and better FCR observed in Asian countries like China and Vietnam have also resulted in these two countries who are dominating the global scene of aquaculture currently causing Kenyan small-scale fish farmers to be excluded from high-end markets. Vietnam and China were therefore able to sell their fish at roughly 1/3 of the price Kenyan fish farmers normally sold their fish for at the low-end markets. The underlying mechanisms causing Kenyan Small-scale fish farmers' poor efficiency relative to imported fish was found to be driven by their first two struggles.
The institutional environment and especially the government was throughout the research conducted in this thesis found to in a high degree either enabling or constraining small-scale fish farmers ability to reach new upgrading trajectories, much like was seen within the GVC research conducted in both India and Asia. At the moment the government's role could more be seen as having constrained

potential upgrades for small-scale fish farmers with limited influence on the few upgrades they were observed to have achieved.
In order for Kenya's small-scale fish farmers to be able to achieve new process and product upgrades in the form of applying the best practice methods seen in Egypt institutional changes would first have to enable this. Although various important supportive initiatives from organisations such as Red Cross and Farm Africa were observed their presence in Kenya was unfortunately still very limited why the actions that would be required for small-scale fish farmers across the country to adopt new best practices to a large degree would depend on the Kenyan government. The Kenyan government would have to properly enforce quality input standards while also supporting a revival of farmer groups run-down feed mills and hatcheries to make quality fish inputs easily available. The Kenyan government would further have to be allocated additional resources, which should be used to train and educate government agents in best practice farming methods while also serving to help better distribute this information. Assuming these actions were to be taken and the fish farmers were able to adopt the best practises this would enable them to earn an average annual Gross Profit seven times their current figure without incurring any extra upfront costs, a tremendous advance that could really help improve the livelihood for the farmers and their families.
A further constraint identified for fish farmers to gain access to the high-end markets was found to be a lack of continuous supply since they on average only harvested every eight months. Here the government fish processing factories that have not yet started would need to become operational and through proper coordination of the fish farmers harvest cycle it would be possible to aggregate enough individual fish farmers output to secure the continuously supply the larger downstream organization demand.
The potential improved competiveness from the adaptation of the best practice method from Egypt together with the ability of being able to supply a continuous supply of fish to downstream organisation would in the near term unfortunate still not make it possible to compete with the prices on imported tilapia from Vietnam and China. If this were to be overcome Kenya's government would have to revise its trade policies and ban or increase tariffs on imported fish similar to what Ghana did in December 2014. An institutional change like this would enable fish farmers to gain access to large-scale downstream organizations and through this potentially be able to reach new upgrades. As Neilson & Pritchard notes government regulation of this new potential relationship between fish farmers and processors/buyers would however have to be put in place to secure fish farmers were not marginalized as has been seen in India's tea and coffee sector.

The Kenyan aquaculture sector was found to include substantial development potential, especially if best practice methods from Egypt were to be implemented across the country. This potential is however constrained by the actions taking by the Kenyan government with the final decision-making power now left to the 47 different county governments. The negative consequences already seen taking place with some counties abandoning their support to aquaculture and with indications of a growing divergence among the counties much of this potential are however not expected to be reached. The most likely path for the Kenyan aquaculture sector to follow the coming years therefore seem to be that of the explored scenario Status Quo, with the insufficient level of government support currently seen expected to continue together with an increasing divergence between the counties. The result for small-scale fish farmers will be a future where their opportunities to a large degree will come to be shaped by their geographical settings. The forecasted aquaculture output are for these reasons also expected to decline to 38,000 tons by 2024 from the 49,000 tons that was realized in 2013. This should be seen in contrast to the Optimal case where the forecasted aquaculture output would be expected to reach 319,000 tons instead.

The estimated Prevalence of Undernourishment ratio from FAO's methodology was applied to estimate the effects from the aquaculture output on food security including conducting numerous time series analyses to forecast additional inputs and parameters. The results showed how roughly 213,000 more people are expected to be undernourished by 2024 from choosing the path of Status Quo relative to the Optimal case. Although this is a large amount of people that could potentially be alleviated from chronic hunger, relative to the total number of 10.4 million people that is expected to be undernourished in the Optimal case it is limited. The changes in the different aquaculture paths therefore seem to have limited impact on food security measured as the PoU ratio.
The potential number of self-sustaining Kenyans (fish farmers and their families) resulting from the different scenarios showed to have a larger effect with the figure being 169,000 people by 2024 for Status Quo (lower than today) relative to the potential of 1,286,000 self-sustaining Kenyans in the Optimal case, indicating a larger impact on food security from aquaculture relative to what was seen for the PoU ratio. A final point is to due with the large population growth seen in Kenya where 12.5 million new people are expected relative to the current 45.5 million by 2024. This mechanism can be seen to act as a serious opposing effect to potential efforts to increase food security. With the bleak outlook for Kenya's aquaculture sector from the expectations of following the Status Quo path going forward together with the substantial impact the growing population looks to have on food security the overall findings are that more efficient initiatives are needed in Kenya if the large amount of people suffering from hunger are to be overcome sometime in the future.

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# 10. Appendix List

# Appendix 1: Primary sources

## Interviews

- **(AAK)** Anonymous, AAK, Nairobi.
- **(AFIPEK)** Beth Wagude, CEO AFIPEK, Nairobi.
- **(Bidii Fish Feeds)** George Ambuli, MD/Founder of Bidii Fish Feeds, Luanda.
- **(David)** David, fish pond attender at Kisumu Polytech.
- **(Department of Fisheries)** Anonymous Fish Officer, Department of Fisheries, Kisumu.
- **(Evans wife)** Evans wife, fish farmer from Kakamega, part of Fish For Kenya farmer group.
- **(Farm Africa)** Charles Opanga, Senior Project Officer at Farm Africa, HQ is in Kakamega.
- **(FFK)** When using all four fish farmers from Fish For Kenya.
- **(Ken)** Ken, fish farmer from Kakamega, part of Fish For Kenya farmer group.
- **(Millington)** Millington, fish farmer from Kakamega, part of Fish For Kenya farmer group.
- **(Philip)** Philip, fish farmer from Kakamega, part of Fish For Kenya farmer group.
- **(Red Cross)** Elijah Muji, Disaster Manager Advisor, Kenya Red Cross, HQ is in Nairobi.
- **(Sare Millers)** Dave Okech, MD/Founder of Sare Millers, Kisumu.

## Correspondence

- **(Peche Foods)** Email correspondence with Pals Wagenaar manager of Mayfair Holdings (bread) and Peche Foods and one of the board of directors in AFIPEK on March 26 2015.
- **(Aller Aqua)** Email correspondence with Niels Lundgaard, International Relationship Manager at Aller Aqua
- **(Nathan Wanner)** Email correspondence with Nathan Wanner, FAO Statistics Division, 26th of March 2015**.**

## Conversations

- **(Access2Innovation)** Henrik Anker Ladefoged - Program Manager, Ole Stein – Program Manager, Birgitte Nielsen – Project Coordinator and Jacob Ravn – Head of Secretariat, Access2Innovation, December 2014 until May 2015.

- **(Prime Cuts)** Manager of Prime Cuts' butcher at Village Market (Nairobi), 25th of March 2015.

## Phone conversations

- **(Alpha Foods)** Alpha Foods, 24th of March 2015.
- **(Farmers Choice)** Farmers Choice, 24th of March 2015.
- **(Jambo Fish)** Jambo Fish, 24th of March 2015.
- **(Mwea Aqaufish Farm)** Mwea Aqaufish Farm, 24th of March 2015.
- **(Other fish feed producers)** Hesao Integrated Fish Farming Organisation, Othaya Fish Feeders S.H.G, Ugachick (Uganda), Sigma Feeds Limited, Zibag Fish producers & Processors, Thoyu Feed Limited, Osifeeds Ltd, Jambo Fish, 24th of March 2015.

## Consultant work

- **(Growth Africa, 2014)** Growth Africa – June-November 2014

## Workshop

- **(Access2Innovation workshop, April 30 2015)** Access2Innovation workshop, Business Opportunities in East Africa, Aalborg April 30 2015.

***Observations and other data collected***

- 13 supermarkets and butchers were visited to gather information on fish brands and prices for frozen and fresh fish (plus a few more that did not sell fish).
- More than 10 fish feed producers have been called to retrieve information about the prices and content of their fish feed.
- Six major fish processors were contacted to gather information on the prices they buy and sell fish for, where they buy fish from and how large a percentage of fresh fish turns into wastage. Some of these had integrated operations spanning most of the value chain, and will later be analysed more in depth.
- Three fish markets (Kakamega, Kisumu and Nairobi) were visited to gather data on fish prices.
- Joseph Okech (the father of Dave Okech) who is a Director at Kenya Agricultural Research Institute (KARI) in Kisumu helped retrieve historic fish prices from the Department of Fisheries. However the Department of Fisheries were only able to provide numbers for 2013 and 2015 although a request was made for 2000-2015.

# Appendix 2 – Interview guide fish farmers

### *1. Financial Questions*

1. How many fish? And what Species?
2. What weight do they come in as seedlings?
3. When do you sell them (how old) ?
4. What weight are they when you sell them?
5. What do you use on them in feed? (cost & quantity)
6. What do you use on them of other inputs ? (antibiotica, fertilizer --> As detailed as possible, quantity & costs)
7. What can you sell them for at maturity?
8. How many can you sell at maturity ?
    - How many are dead?
    - What were the causes, give % distribution? (diseases, predators, post harvest losses)?
9. What is your maximum production of fish capacity at the moment? (preferably in total and per pond)
    - How many ponds can be on his land? And how big is his land?

### *2. Procurement*

1. What kind of inputs do you buy from your suppliers?
2. Can you describe your relationship with your suppliers ? (input, feed & seed)
    - How do you communicate?
    - Do you set any requirements to them?
    - What are the terms when you do business ? (e.g. contract)
3. What kind of feed do you use? * (picture of bag)
    - Which form does it come in? (pellets floating or sinking, mashed)
    - Where do you buy it / make it? (name of brand)
    - How is the general quality of this (and do it vary)?
    - **Composition of fish feed:**
        - What are the major ingredients (fishmeal, wheat, maize, soy)?
        - How much protein content?
    - Do you have other options for feed?
4. Do you use fertilizer ? (and what kind)
5. Where do you source your seeds from?
6. Other inputs needed? (e.g. Medicine)
    - And where do you get these?
7. Is it easy to source the different inputs ?
8. How have the prices developed for inputs?

### *3. Pond Management*

1. What are the measurements of your ponds ? (width, length, depth)
2. How do you feed ? (when they are hungry / random)

- And how often do you feed ? (are there any left after having fed)

3. How often do you use fertilizer ?
4. Do you measure water quality ?
    - And how do you do this ? (plankton, oxygen, PH)
    - What do you do to ensure high water quality?
5. Do you clean your ponds ?
    - And how do you do this?
6. Do you use an Aeration system?
7. How often do you harvest?
    - And how do you do this?

### *4. Sales & Markets*

1. Where do you sell your products ? And to whom?
2. Do you process your fish before sale ? (smoked or deep fried)
3. Can you describe your relationship with your customers?
    - How do you communicate?
    - Do they set any requirements to you?
    - What are the terms when you do business ? (e.g. contract)
4. Do you use any kind of marketing material?
5. How is the current demand for fish relative to what you can supply (and what others can supply) ?
6. What other sales options do you have ?
    - And what would you need fulfil to be able to sell here? (especially quality factors)
7. Have you considered selling to supermarkets & Restaurants ? (why not?)
    - What would it require? (what would be the terms?)
8. How do you get your products to the market ? (time and costs)
    - *Do you use cooling methods ?*
    - *How much of your earlier mentioned post harvest losses stem from lack of cooling systems? (mentioned in financial question 8, to use estimate potential for solar-driven cooling systems manufactured by Danish companies in touch with A2I)*
9. Have sales prices varied last few years ? (why is that?)
10. How many farmers are you in your area?

### *5. Governance & Institutions*

1. Where do you seek technical advice and new knowledge?
2. Are you involved in any kind of farmer groups or do you know of some?
    - How is your relationship to other farmers?
3. What kind of formal standards do you currently have to live up to? (feeding, seed, management, what kind of certificates, safety requirements)
4. Who regulates these?
5. Are there any kind of informal norms or consumer preferences you take into account ?
6. Do the standards have any actual value in practice ? (why / why not?)

7. Have you received any kind of inputs from government ?
    - Were these subsidized?
    - Where there any requirements in order to receive them (like land tenure) ? What was your experience with these inputs?
    - Are they still subsidized ? (if not received, ask if know of some and what requirements are)
8. Have you interacted with the government in other ways in regard to your fish farming?
    - And how has this experience generally been?
9. What is your current view of the FFEPP? (Fish Farming Enterprise Productivity Plan)
10. How is the process of requiring new land (land tenure) ?
11. Is there anything the government is lacking or could do better ?
12. What has changed in the industry in the last 5 years ? (better or worse?)
13. Have you experienced any kind of corruption and from what sources ?
    - Has this gotten worse or better over the years?

## *6. General*

1. What is your background ? (education, work experience)
2. Why and when did you start fish farming ?
3. What did it require for you to open your business? (entry barriers; investments, certifications, knowhow)
4. Number of ponds, sizes of ponds ?
5. Number of fulltime employees & casual labor ?
    - What will you need of new employees in 1 years time?
    - How easy is it for you to find new and qualified employees? *(education + skilled)*
6. How is the competition currently in the fish farming industry? (are there many new players, price competition)
7. What are your 3 largest issues at the moment ? **(touch on feed, seed, post harvest losses incl. cooling, diseases)**
    - And how are you planning to solve these?
8. Have you received training in fish farming ?
    - And within what areas ?(e.g. Feed formulation, how to feed, cleaning, building ponds, stocking, marketing)
9. What could add extra value to your products ? (ask specific about new product features & process improvements if he doesn't cover this)

# Appendix 3 – Interview Ken

Red colour= either not asked question since already been answered, not relevant or the respondent did not know. Notes in brackets of questions were only asked if respondent could not answer the initial question.

## *1. Financial Questions*

***1. How many fish? And what Species?***

Has 2 ponds, 1 is 300m^2 and one is 108m^2, depth mainly 1m, lowest place is 95 cm.

Monosex and only has tilapia 1,250 in total, 1,000 in large pond, and 250 in small pond.

***2. What weight do they come in as seedlings?***

5 grams, costs 7-10 KES.

***3. When do you sell them (how old) ?***

6-10 months old.

***4. What weight are they when you sell them?***

Approx. 200-250 grams.

***5. What do you use on them in feed? (cost & quantity) à Per day if total not possible***

Feed them 2 times a day, 10am and 4pm. 1kg per day of Sare Millers fish feed.

***6. What do you use on them of other inputs ? (antibiotica, fertilizer --> As detailed as possible, quantity & costs)***

Lake shrimps 0.5kg a day as feed.

Before used own compost as fertilizer. Now uses DAP, large pond uses 0.5kg per 3 weeks, and small uses 0.25kg per 3 weeks.

***7. What can you sell them for at maturity? à Relative to when he sells them?***

Small (150-200g) can be sold fresh for 50KES, large (250g +) for 100KES.

***8. How many can you sell at maturity ?***

- ***How many are dead?***

Out of 250 (which were put in) can approx. Sell 150, there will still be some left that are just too small.

- ***What were the causes, give % distribution? (diseases, predators, post harvest losses)?***

Main predators: birds.

No diseases.

***9. What is your maximum production of fish capacity at the moment? (preferably in total and per pond)***

- ***How many ponds can be on his land? And how big is his land?***

Planning 2 new ponds of the large size (300m^2) on his current land.

## *2. Procurement*

***1. What kind of inputs do you buy from your suppliers?***

Feed: Sare Millers mashed fish feed, 920 per 20kg. Extruded Pellets from agrovet at 1,800 per 20 kg. And Lake shrimps.

Fertilizer (DAP), and fingerlings.

***2. Can you describe your relationship with your suppliers ? (input, feed & seed)***

***--> How do you communicate?***

Buy Sare Millers feed through the group, which is delivered to the local (nearby) market (some other farmers said it was delivered to their farm).

Rest is mainly bought from agrovets.

- ***Do you set any requirements to them?***
- ***What are the terms when you do business ? (e.g. contract)***

No direct contracts.

***3. What kind of feed do you use? * (picture of bag)***

Uses either 1kg of Mashed Sare Millers or 1kg of extruded pellets per day. + 0.5kg of lake shrimps (was not completely clear about if he uses this every day)

- ***Which form does it come in? (pellets floating or sinking, mashed)***
- ***Where do you buy it / make it? (name of brand)***
- ***How is the general quality of this (and do it vary)?***
- ***Composition of fish feed:***
  - ***What are the major ingredients (fishmeal, wheat, maize, soy)?***

Mentions maize in Sare Millers feed (which is correct), however not aware what else is in it, not aware of what is in the pelleted feed as well.

- ***How much protein content?***

Not sure.

- ***Do you have other options for feed?***

***4. Do you use fertilizer ? (and what kind)***

DAP, which costs 2,000 KES per 20 kg.

***5. Where do you source your seeds from?***

Different farmers and experience issues with lack of quality fingerlings, mentions one supplier which is called Juliet.

Received county grant for fingerlings under the FFEPP programme (a onetime deal).

***6. Other inputs needed? (e.g. Medicine)***

***--> And where do you get these?***

***7. Is it easy to source the different inputs ?***

***8. How have the prices developed for inputs? àEspecially feed***

Same, not aware if changed.

## *3. Pond Management*

1. ***What are the measurements of your ponds ? (width, length, depth)***
2. ***How do you feed ? (when they are hungry / random)***
   - ***And how often do you feed ? (are there any left after having fed)***

Says nothing left after having fed them.

3. ***How often do you use fertilizer ?***
4. ***Do you measure water quality ?***

With a water thermometer. Do not measure PH value.

***-And how do you do this ? (plankton, oxygen, PH)***

***What do you do to ensure high water quality?***

Clean and drain ponds after harvest (also some ongoing cleaning).

5. ***Do you clean your ponds ?***
   - ***And how do you do this?***
6. ***Do you use an Aeration system?***

No.

7. ***How often do you harvest?***

Every 6-10 months. Takes 1 day to harvest.

***And how do you do this?***

Uses nets. Currently only has small nets which were given by the farmer group. Needs larger nets.

## *4. Sales & Markets*

1. ***Where do you sell your products ? And to whom?***

Some sold directly from the farm to local communities.
Some through the local market (nearby). Sometimes borrow cooling boxes.

2. ***Do you process your fish before sale ? (smoked or deep fried)***

Deep fry some, which enable him to charge 150 KES for a fish that would cost 100 KES as fresh.
Also smoke / sundry some (first mentioned last in interveiw), can get 120-130 for smoked fish which would cost 100 KES as fresh. (less costs than fried)

3. ***Can you describe your relationship with your customers?***

Anyone who comes by the market (+local community).

***How do you communicate?***

Advertise through agents who comes to the farm and ask when the harvest is (also learns approx when his harvest is). Then spread the word. He pays them a little for this.

***Do they set any requirements to you?***

Most like the small fish, because they have limited income/cash.

***What are the terms when you do business ? (e.g. contract)***

4. ***Do you use any kind of marketing material?***
5. ***How is the current demand for fish relative to what you can supply (and what others can supply) ?***

High for fresh fish.

***6. What other sales options do you have ?***

Not really sure about other options and their requirements

- ***And what would you need fulfil to be able to sell here? (especially quality factors)***

Just keep them cold.

***7. Have you considered selling to supermarkets & Restaurants ? (why not?)***

***--> What would it require? (what would be the terms?)***

***8. How do you get your products to the market ? (time and costs)***

Says it takes 2-3 hours --> Only sells smoked or fried fish at market. (however this will have to be Kakamega market, since local market would not take that long to get too).

***--> Do you use cooling methods ?***

***--> How much of your earlier mentioned post harvest losses stem from lack of cooling systems? (mentioned in financial question 8, to use estimate potential for solar-driven cooling systems manufactured by Danish companies in touch with A2I)***

***9. Have sales prices varied last few years ? (why is that?)***

Price 70-80 KES 2-3 years ago for what he calls big fish, which now sells at 100 KES.

***10. How many farmers are you in your area?***

Many.

## *5. Governance & Institutions*

***1. Where do you seek technical advice and new knowledge?***

Ministry of Fisheries or FFK (farmer group).

***2. Are you involved in any kind of farmer groups or do you know of some?***

Yes, and 18 farmers in this group.

- ***How is your relationship to other farmers?***

Good, share experiences with each other.

***3. What kind of formal standards do you currently have to live up to? (feeding, seed, management, what kind of certificates, safety requirements)***

Need KEBS registration, says on the way / in process.

***4. Who regulates these?***

***5. Are there any kind of informal norms or consumer preferences you take into account ?***

***6. Do the standards have any actual value in practice ? (why / why not?)***

No, customers don't ask.

***7. Have you received any kind of inputs from government ?***

Received fingerlings, feed and DAP for free under the FFEPP programme.

- ***Were these subsidized?***

- ***Where there any requirements in order to receive them (like land tenure) ? What was your experience with these inputs?***

Needed to have a standard pond measuring at least 300m^2.

- ***Are they still subsidized ? (if not received, ask if know of some and what requirements are)***

Maybe, but more likely it was only a time deal. Also so many others who wants this (secondly from what you know the counties are not as efficient as programme was before on a national level).

***8. Have you interacted with the government in other ways in regard to your fish farming?***

Ministry of Fisheries, came here to the farm.

- ***And how has this experience generally been?***

***9. What is your current view of the FFEPP? (Fish Farming Enterprise Productivity Plan)***

Good.

***10. How is the process of requiring new land (land tenure) ?***

Expensive.

***11. Is there anything the government is lacking or could do better ?***

Factory in Kakamega is not yet operating (processing of fish) --> It should be operating.

He would be able to sell all or most here.

***12. What has changed in the industry in the last 5 years ? (better or worse?)***

He earns more from increased prices + from having 1 more pond now (2 in total).

***13. Have you experienced any kind of corruption and from what sources ?***

Within the sugar cane industry, more corrupt industry (probably been dealing with largest sugar company from the West which is currently under serious corruption charges).

Suppliers of fingerlings --> low varying quality.

- ***Has this gotten worse or better over the years?***

## *6. General*

***1. What is your background ? (education, work experience)***

Level-4. Farmed sugar cane and maize before and still do. Considering starting to only farm fish.

***2. Why and when did you start fish farming ?***

Uses small portion of land and gives high income relative to other crops (especially sugar cane and maize which is very common in this part of Kenya). -->(did not mention this but it also gives his family higher food security / better nutrition).

Says he can get in gross income; 100,00 KES for a 300m^2 pond.

***3. What did it require for you to open your business? (entry barriers; investments, certifications, knowhow)***

20,000 KES in capital to set up first pond which was 300m^2.

***4. Number of ponds, sizes of ponds ?***

2

***5. Number of fulltime employees & casual labor ?***

Uses some casual labor for cleaning and harvesting.

- ***What will you need of new employees in 1 years time?***

Need more casual labor with 2 new planned ponds.

- ***How easy is it for you to find new and qualified employees? (education + skilled)***

***6. How is the competition currently in the fish farming industry? (are there many new players, price competition)***

Depends on management. If you are properly managing your ponds and through this get quality fish it is not a problem selling the fish.

***7. What are your 3 largest issues at the moment ? (touch on feed, seed, post harvest losses incl. cooling, diseases)***

Getting proper quality fingerlings.

Need large harvesting nets (20-30m) which are expensive (FFK provided small nets).

- ***And how are you planning to solve these?***

***8. Have you received training in fish farming ?***

Yes through the seminars held in the farmer group.

- ***And within what areas ?(e.g. Feed formulation, how to feed, cleaning, building ponds, stocking, marketing)***

Pond construction, pond management, harvesting, marketing.

***9. What could add extra value to your products ? (ask specific about new product features & process improvements if he doesn't cover this)***

Mentions smoking, which he already does.

## *Extra notes*

- 2 ponds
- To get into farmer group: Need to have an established pond + be serious and honest
- Been fish farming in 3 years and in the group in 3 years
- Mentions different price for fingerlings than Philip.
- Water comes from underground source.
- When having asked about fish left at maturity they will of course also having eaten some of them by themselves.
  Average price of Tilapia, assuming large on average=300g selling for 100 KES and small 150g at 50 KES =333.33

# Appendix 4 – Interview guide AFIPEK

## *0. General*

1. *When was the organisation started?*
2. *How many fish processors do you represent ? (mandatory ?)*
   - ➢ *And approx. how big a % do these constitute of the whole Kenyan Market?*
3. *How do you see the demand for fish having developed within the last 5 years?*
4. *How have the prices developed for fish?*
5. *Do they use written contracts in the industry or how are the terms normally? (both to suppliers + buyers)*
6. *Where do the fish processors normally buy their fish from ? (fish farmers or only captured fish?)*
7. *How do you see the role of Aquaculture relative to Fisheries going forward?*
8. *Approx. Price when buying Tilapia and Nile Perch from fishermen?*
9. *Price that they can sell fillets for to supermarkets (or hotels)(per kg)? (frozen and fresh fillets)*
10. *How many kg of fresh tilapia does it take to get 1 kg. of fish fillet (also for Nile Perch)?*

## *1. Governance & Institutions*

1. *Where do you receive funding from? (members or government)*
   - ➢ *How much does it cost to be a member ?*
2. *What projects are you currently involved in?*
   - ➢ *How are the projects going?*
   - ➢ *What have been difficult with the projects?*
   - ➢ *Do you do Quality Checks on your projects ? And how is this done? (Farmers, hatcheries, feed producers)*
3. *Where do you seek technical advice and new knowledge?*
4. *Are you involved with any kind of fish farmer groups or fishermen groups ? How is your relationship to fish farmers?*
5. *What kind of formal standards do you and your members currently have to live up to? (processing, safety requirements)*
6. *Who regulates these?*
7. *Are there any kind of informal norms or consumer preferences you take into account ?*
8. *In practice how important are the standards? (why / why not?)*
9. *What do you see as the most critical issues for Fish Processors at the moment ?*
   - ➢ *What can be done to accommodate this?*
   - ➢ *And for fish farmers and fishermen?*
   - ➢ *What can be done to accommodate this?*
10. *In your view how has the objectives for the government programme FFEPP (Fish Farming Enterprise Productivity Programme) been reached? (why not and has it brough other issues with it?)*
    - ➢ *What is the current status of the programme (continuing or being replaced etc.)?*

- *And what impact do you see the programme having in the future? (or if not continuing)*

*11. What impact do the following institutions have on the Aquaculture /Fishery industry ? (either Support/ or Challenges limitations involved)*

- *Ministry of Agriculture, Livestock and Fisheries*
- *Kenya Marine and Fisheries Research Institute (training centres)*
- *Aquaculture Association of Kenya,*
- *Any other significant institutions ?*

*12. Any issues with double mandates?*

*13. Do you by any chance have statistics of prices for Tilapia, Nile Perch or other fish?*

## Appendix 5 – Interview AFIPEK

Red colour= either not asked question since already been answered, not relevant or the respondent did not know. Notes in brackets of questions were only asked if respondent could not answer the initial question.

### 0. General

***1. When was the organisation started?***

Started in 2000 under the companies act (CAP 486) / Statutory act. (all companies registered under)
The association was started because the EU in 2000 excluded Kenya from importing to them because of food safety reasons.
--> It was created by the Kenyan government and the EU union in order to get consistency of quality/safety for processors/exporters and to ensure,
all members could live up to any requirements and to improve food security (proper safety) in domestic market.

***2. How many fish processors do you represent ? à All required to ?***

Currently represents 14 members (6 from Lake Victoria, 8 from Mombasa).
Since 2000 been mandatory for processors/exporters to join the organization in order to ensure everybody is in compliance with standards.
AFIPEK is notified by the government everytime a new processor/exporter is established in Kenya, and they then make sure everybody is compliant with code of conduct.
--> Had some issues recently with members from Mombasa thinking it is to expensive to be a member, and some stopped paying, however members from Lake Victoria do not think fees should be lowered.
--> Also first mentions some issues with members from Lake Victoria (however current seems to be issues with Mombasa) --> Also mentions earlier had almost all ass members (implies that there should be more than 14 in total of Kenya).
Not all 14 are processing.

- ***And approx. how big a % do these constitute of the whole Kenyan Market?***

***3. How do you see the demand for fish having developed within the last 5 years?***

The domestic market has gone higher and higher.
This can also be seen from the Nile Perch, where now only 30% is exported and 70% is used domestically.

***4. How have the prices developed for fish?***

***5. Do they use written contracts in the industry or how are the terms normally? (both to suppliers + buyers)***

Suppliers: 3 kind of suppliers.
1. Loose (non-written) contractual obligations to the industry, informal only deliver to specific factories.
2. Independent suppliers who sell to the highest bidder (not obligated to anyone).
3. Ad hoc suppliers (not continually supply, once in a while).
Customers: International market has written standard contracts.
--> Supermarkets in Kenya, have written obligations with them.

***6. Where do the fish processors normally buy their fish from ? (fish farmers or only captured fish?)***

No one currently buys Tilapia from Aquaculture fish farmers. No one buys Tilapia from Fishermen anymore (did that earlier) and sell to supermarkets, all Tilapia is imported from Vietnam (at least Alpha Foods & Farmers Choice).
--> Alpha Food also imports its Tilapia fish (and deliver to Prime Cuts according to their manager from Village Market) + Farmers Choice the same. Alpha Foods capture its own nile perch.
--> Also when AFIPEK investigated the market in West Kenya, the Aquaculture fish farmers not able to supply regularly. Only able to supply 27 tons a year, and then have to wait 9 months until getting 10 more tons (next harvest).
--> And the fish were too expensive, fish farmers wanted 3-4 $ per kg. Of fresh fish (276-368 KES) (and that was a few years ago).
-Nile Perch sold in Supermarkets are often from own factories at Lake Victoria (at least for Alpha Foods).

***7. How do you see the role of Aquaculture relative to Fisheries going forward?***

Aquaculture and fish industry looking very good going forward.
Aquaculture has issue with too high feed costs right now though (meals need to be cheaper).
--> Spending 2$ dollars per fish on feed, excluding overheads.
--> Mentions the solution that sorted out the expensive feed for chicken earlier in Kenya could be used

***8. Approx. Price when buying Tilapia and Nile Perch from fishermen?***

Tilapia 3-4 $ from Kenyan fishermen. Too expensive, says imported as low as 1-2 dollar per whole fish per kg. (corresponds to Pals Wagenaar's answer)

***9. Price that they can sell fillets for to supermarkets (or hotels)(per kg)? (frozen and fresh fillets)***

Not sure.

***10. How many kg of fresh tilapia does it take to get 1 kg. of fish fillet (also for Nile Perch)?***

- Tilapia --> 30% is left as fillet from whole fish.
- Nile Perch --> 50% is left as fillet from whole fish.

- Catfish --> Not sure, but has more meat so higher than Nile Perch (above 50%), has never worked with catfish (since she is the CEO of AFIPEK which includes all processors in Kenya and that they do regular checks on their members --> This implies that none of the members are involved in Catfish procesing).

## *1. Governance & Institutions*

***1. Where do you receive funding from? (members or government)***

--> Funded 100% by members for all recurrent costs.

- ***How much does it cost to be a member ?***

They pay 20K KES a month + an initial fee of 60K KES. (mentions sometimes grants on webpage and on different programs they have had like ISO 2000 by DANIDA).

***2. What projects are you currently involved in?***

Sustainability is the main project issue at the moment. However some constraints due to lack of finance, why they have stopped project now, so no major development project right now.

- ***How are the projects going?***
- ***What have been difficult with the projects?***
- ***Do you do Quality Checks on your projects ? And how is this done? (Farmers, hatcheries, feed producers)***

Not directly. Did Quality Check 2 years ago, and got all members ISO 2000 certified (this is not a mandatory standard), funding supplied by DANIDA.

***3. Where do you seek technical advice and new knowledge?***

***4. Are you involved with any kind of fish farmer groups or fishermen groups ? How is your relationship to fish farmers?***

***5. What kind of formal standards do you and your members currently have to live up to? (processing, safety requirements)***

***6. Who regulates these?***

***7. Are there any kind of informal norms or consumer preferences you take into account ?***

***8. In practice how important are the standards? (why / why not?)***

***9. What do you see as the most critical issues for Fish Processors at the moment ?***

Overfishing not so much an issue according to recent scientific research reports. More working on the fishing effort.

The main issue the sustainability, to make sure that fishers don't fish sizes under a certain level (says 50cm on webpage for Nile Perch) --> It is the Ministry of Fisheries that needs to enforce this, and so far it is has not been done properly!.

- ***What can be done to accommodate this?***

--> Have started their own monitoring and surveillance team funded by Kenya BDS Program and USAID managed by Emergin Markets Group.
--> Especially focusing on Nile Perch, where min. Size is set to 50cm.
--> Also expanded into rest of East Africa where Kenya (AFIPEK), TZ (through UFPEA), UG (through TIFPA) each gets 1 representative Inspector into the team --> Regional association East African Industrial Fishing and Fish Processors Association (EAIFFPEA).
- Should be much better in 6 months time from now.

- ***And for fish farmers and fishermen?***

Too expensive (the price the fish is sold at, not competitive) and lack of reliable supply.
- Residue Monitoring Plan regarding access the EU market has been approved (last year), report was from 2013, so no issues here in regard to exporting to Europe.
***What can be done to accommodate this?***
***10. In your view how has the objectives for the government programme FFEPP (Fish Farming Enterprise Productivity Programme) been reached? (why not and has it brough other issues with it?)***
ESP Programme has been very good for the fish farmers, increased the amount they can supply + made the supply more reliable.

- ***What is the current status of the programme (continuing or being replaced etc.)?***
- ***And what impact do you see the programme having in the future? (or if not continuing)***

--> Devoluiton will be good in the sense that each county (in charge) now will be slightly more focused on a specific group of farmers.
--> Some potential issue though for the counties in making it a priority to develop aquaculture. (before a priority for the National Ministry).
***11. What impact do the following institutions have on the Aquaculture /Fishery industry ? (either Support/ or Challenges limitations involved)***

- ***Ministry of Agriculture, Livestock and Fisheries?***

The common authority, has to sign and confirm everything for processors (AFIPEK work with them daily on many tasks) --> e.g. all amounts of fish that is exported (or any other crop).
AFIPEK and their members have no choice, have to work with them.
--> What they could do better: Would be to better enforce sustainability requirements (only catch fish over a certain size). This has so far been a major failure from their side (small fish still being fished).
(certification of exports has already been properly developed)

- ***Kenya Marine and Fisheries Research Institute (training centres) ?***

Not so much influence in the industry, AFIPEK to not interact with them very much.

- ***Aquaculture Association of Kenya ?***

Rather new organisation. Well placed and should be able to do well for its members and interact with the government, especially with a bit more training be able to fill in the gap well.

- ***Any other significant institutions ?***

Commercial Aquaculture Society of Kenya (CASK) --> Representing the large fish farmers (not able to find their webpage) --> Can better influence Policy directions (AAK to young still), very useful (relative to AAK)
KEFAP has fishery department earlier, but never significant.

- ***Any issues with double mandates?***

Not anymore. There were some issues earlier where the Publich Health Force were in charge of Safety Requirements also for the fishery sector together with the Ministry of Fisheries.
--> However since 2000 when AFIPEK was created, this was something they delt with, and since then it has only been the Ministry of Fisheries in charge of this (no more issues).
Public Health Force however still deal with by-products like the fish bladder, but this is not exported anymore so not an issue anymore.
Fishing Origin is closely watcheh by KRA, and this is being done very well to ensure the fish coming into the Kenyan market have proper health qualities.(work closely with Ministry of Fisheries).

- ***Do you by any chance have statistics of prices for Tilapia, Nile Perch or other fish?***

On certificate for export it says 3$ per kg. Of Nile Perch Fillet (however this has not been updated) --> Really around 9-11$ (829-1,013 KES)
- Says fishermen supplies Nile Perch at around 280-450 KES per kg. Of the whole fish.
Tilapia is not exported, exporting members don't deal with Tilapia.

## *Extra notes*

- Pals Wagenaar --> Board of directors of AFIPEK (and manager of Mayfair Holdings (bread) and Peche Foods.
    - ➔ Answer 26 March: Right now we are not buying any farmed fish. An indicative price for Tilapia would be usd 1.2 per kg based on the current exchange rate to stay competitive with imported Tilapia fillets (110.5 KES).
- East African Seafood Ltd. Is owned by Alpha Group.
- Prime Cuts is independent according to AFIPEK and manager of butchery at Village Market.
- Exporters sell to wholesalers in Europe, not directly to supermarkets (so less safety requirements).

- ➔ Capital Fish previously supplied to Israel (the only one), however it has not been in production the last year.

- In October 2014 Kenya was excluded from the European market, because certification ran out (it was whole of East Africa, also TZ and UG, however they were able to continue supplying right away).
  - ➔ This meant 5% tax on Nile Perch and up to 24% on other fish
  - ➔ Kenya first got back into the European market in January 2015 again, until then explored other markets, so diversified some, for instance more sale to Middle-East right now.
- Possible (now that) that Butchers still sell Fresh Tilapia from Lake Victoria (several butchers said this + Prime Cuts).

### *Email answer 22nd April 2015*

Dear Rasmus,
Good morning.  Sorry I have been out of office.

Your question: You mentioned how the high price of fish feed is currently hindering fish farmers of being competitive with fishermen and imported fish. And how a solution to the same problem within the poultry sector had been implemented earlier and that this could help the aquaculture industry as well. I was therefore wondering if you could elaborate a bit about what this solution included or point me towards some articles where I can read more about it?

To enable me answer it I shall paraphrase it into points according to what I said:

1. the high price of fish feed is currently hindering fish farming from being competitive – today the feed conversion ratio is 2:1 at the prevailing cost of feed ($1/Kg) it is almost impossible to break even for most fish farmers with 1 or 2 ponds.
However if there was a large fish farm then there would be justification to have a fish feed industry dedicated to this sector.  In which case the large production of feed would reduce the cost of feeds due to economies of scale during production. This industry would supply the large scale sector and the out growers benefit.

2. how the poultry sector has overcome the fish feed production challenges to enable small scale out growers to benefit?
the poultry sector has a large chicken production unit (Kenchic, QMP and farmers choice) with clear distribution channels and a large market share.
The high demand for the chicken meat has driven the feed sector to expand massively with a number of factories dedicated to chicken feed production.

The small scale out growers have automatically benefited from this channel. When the sector also started taxation burden was also removed to jump start the sector but this has been reintroduced.

3. the cheap imported fish is a threat to the infant fish farming industry – farmed fish arrives into the country FOB $1/Kg. The local sector cannot compete, as we need $3/Kg to break even.

4. articles where I can read more about it: I shall see what articles I can send you.

I hope these answers address your concerns

Kind Regards

Beth Wagude
Chief Executive officer

## Appendix 6 – Fish Feed producers & prices

| Fish Feed Producer | Type of feed | Protein content | Price pr. Kg (KES) |
|---|---|---|---|
| Hesao Integrated Fish Farming Organization | Floating pellets | 28.0% | 65 |
| Othaya Fish Feeders S.H.G | Floating pellets | 26.0% | 70 |
| Bidii Fish Feeds | Floating pellets | 26.0% | 75 |
| Ugachick (Uganda) | Floating pellets | 30.0% | 76 |
| Sigma Feeds Limited | Floating pellets | 26.0% | 80 |
| Zibag Fish producers & Processors | Floating pellets | 28.0% | 80 |
| Thoyu Feed Limited | Floating pellets | 33.5% | 95 |
| Osifeeds Ltd | Floating pellets | 35.0% | 100 |
| Osifeeds Ltd | Floating pellets | 40.0% | 120 |
| Ugachick (Uganda) | Floating pellets | 40.0% | 182 |
| Jambo Fish Products | Floating pellets | 44.0% | 185 |
| Zibag Fish producers & Processors | Floating pellets Catfish | 36.0% | 90 |
| Jambo Fish Products | Floating pellets Catfish | 44.0% | 190 |
| Sare Millers | Mashed | 27.0% | 46 |
| Hesao Integrated Fish Farming Organization | Mashed | 29.0% | 60 |
| Bidii Fish Feeds | Mashed | 26.0% | 65 |
| Bidii Fish Feeds | Mashed | 35.0% | 90 |
| Osifeeds Ltd | Mashed | 30.0% | 100 |
| Mwea Aquafish farm | Mashed | 25.0% | 150 |

Own work

## Appendix 7 – Hatcheries

| Method | Brood stock per m^2 | Male to female ratio | Harvest fry every | Fry per m2 a month | Fry per female a month | Management level | Feed needed | Cost |
|---|---|---|---|---|---|---|---|---|
| Open Pond | 90-300 g, 100-200 kg per hectare | 1-3 to 1.4 | 15-21 days | 6-15 | 35-100 | Low | None | Low |
| Hapa | 100-200 g, 4-5 brooders pr m2 | 1-5 to 1-7 | 14 days | 150-880 | 50-400 | High | Feed daily | Medium |
| Tank | 100-200 g, 3-5 brooders pr m2 | 1 male to 2-7 females | 10-14 days | 400-3,000 | 200-1,500 | Medium | Feed daily | Expensive |

**Tilapia hatchery methods:** Ngugi et al., 2007 & own work

## Appendix 8: Medium-large scale integrated fish farmers

**Dominion Farm** is a large US integrated agricultural company involved in the production of several crops like corn, soy, rice as well as the whole aquaculture value chain. It operates a farm in Siaya (Western Kenya) of 17,050 acres where its aquaculture operations includes its own hatchery, feeding mill, fish farming and a processing unit. It even has its own hydropower dam to generate electricity for its production machines. According to its website its annual production capacity of tilapia should be up to 10,000 tons (Dominion 1 – web).

**Jambo Fish** is currently involved in all stages of the aquaculture value chain. It has its own hatchery for tilapia and catfish, it sells nets, liners and aeration materials as well as selling high quality pelleted fish feed. At the moment Jambo Fish imports its fish feed from its partner Skretting (owned by Otreco, a listed Dutch company), however according to George the Managing Director of Bidii Fish Farm they are in the process of starting their own pelleted feed production (Bidii Fish Farm interview). Jambo Fish have their own fish farm, processing unit and sells its farmed fish through its own shop either fresh or smoked (Other fish feed producers).

**Alpha Foods Group** is a large international conglomerate with a turnover of more than 150M USD. It is involved in deep-sea fishing, lake fishing, aquaculture and processing of fish. Its products are sold through supermarkets, exported and sold to other companies who then resell to supermarkets in Kenya e.g. Prime Cuts (Prime Cuts).
Within aquaculture Alpha Group is however only involved in shrimp farming and runs an integrated farm and processing station at Mafia Island in Tanzania able to process up 20 tons a day (Alpha Group 1). All the tilapia it sells to supermarkets and Prime Cuts is imported from Vietnam (AFIPEK, Alpha Foods). Because it has no aquaculture operations in Kenya it has therefore not been mentioned throughout this thesis (while obviously also not being included in the forecast for medium-large scale fish farmers).

# Appendix 9 – Country distribution of Nile perch export in 2009

In 2009 the Nile perch was exported to the following countries[7]:

- Israel 45%
- Netherlands 18%
- Portugal 6%
- Greece 5%
- UAE 5%
- Australia 4%
- Others 17%

# Appendix 10 – Detailed fish prices low & high-end markets

### Low-end markets

| Category | Source | City | Fish type | Price per kg. KES |
|---|---|---|---|---|
| Fishermen | Ministry of Fishery | Kisumu | Fresh catfish whole | 105 |
| Fish Market | Own observation | Kisumu | Fresh catfish whole | 140 |
| Fish Market | Own observation | Nairobi | Fresh catfish whole | 380 |
| Fish Market | Own observation | Nairobi | Fresh Nile perch fillet | 550 |
| Fishermen | Ministry of Fishery | Kisumu | Fresh Nile perch whole | 200 |
| Fish Market | Own observation | Kisumu | Fresh Nile perch whole | 300 |
| Fish Market | Own observation | Nairobi | Fresh Nile perch whole | 380 |
| Fishermen | Ministry of Fishery | Kisumu | Fresh Omena whole | 120 |
| Fish Market | Own observation | Nairobi | Fresh tilapia fillet | 600 |
| Fish Market | Own observation | Kisumu | Fresh tilapia whole | 250 |
| Fishermen | Ministry of Fishery | Kisumu | Fresh tilapia whole | 250 |
| Farmer | Avg. price from case studies | Kakamega / Kisumu | Fresh tilapia whole | 314 |
| Fish Market | Own observation | Nairobi | Fresh tilapia whole | 400 |
| Farmer | Avg. price from case studies | Kakamega / Kisumu | Fried tilapia whole | 496 |
| Farmer | Avg. price from case studies | Kakamega / Kisumu | Smoked tilapia whole | 436 |
| Fish Market | Own observation | Kakamega | Smoked tilapia whole | 500 |

Table XX - Fish prices Low-end markets 2015: Own fieldwork.

### High-end markets

[7] Manyala, 2011

| Category | Company | City | Fish type | Price per kg. KES | Brand |
|---|---|---|---|---|---|
| Butcher | Butcher (Prestige) | Nairobi | Fresh Red Snapper | 750 | N/A |
| Butcher | Nakumatt (Junction) | Nairobi | Fresh Red Snapper | 1,090 | N/A |
| Butcher | Butcher (Prestige) | Nairobi | Fresh Tilapia Fillet | 750 | N/A |
| Butcher | Butcher (Valley Arcade) | Nairobi | Fresh Tilapia Fillet | 780 | N/A |
| Butcher | Butcher (Uchumi Ngong Road) | Nairobi | Fresh Tilapia Fillet | 780 | N/A |
| Butcher | Butcher (Adams Arcade) | Nairobi | Fresh Tilapia Fillet | 795 | N/A |
| Butcher | Nakumatt (Junction) | Nairobi | Fresh Tilapia Fillet | 1,090 | N/A |
| Supermarket | Chandarana (Yaya) | Nairobi | Frozen Catfish Fillet | 990 | Sunfish |
| Supermarket | Naivas (Greenhouse) | Nairobi | Frozen Nile Perch Fillet | 720 | Lesano |
| Supermarket | Tuskys (City Centre) | Nairobi | Frozen Nile Perch Fillet | 980 | Alpha Foods |
| Supermarket | Nakumatt (Junction) | Nairobi | Frozen Nile Perch Fillet | 1,090 | Prime Cuts |
| Supermarket | Nakumatt (Prestige) | Nairobi | Frozen Nile Perch Fillet | 1,095 | Prime Cuts |
| Supermarket | Nakumatt (Prestige) | Nairobi | Frozen Salmon Fillet | 2,840 | Seastar |
| Supermarket | Nakumatt (Prestige) | Nairobi | Frozen Smoked Hering Fillet | 2,260 | Seastar |
| Supermarket | Naivas (Greenhouse) | Nairobi | Frozen Tilapia Fillet | 775 | Seafood Ltd. |
| Supermarket | Chandarana (Yaya) | Nairobi | Frozen Tilapia Fillet | 1,075 | Alpha Foods |
| Supermarket | Chandarana (Yaya) | Nairobi | Frozen Tilapia Fillet | 1,075 | Alpha Foods |
| Supermarket | Nakumatt (Junction) | Nairobi | Frozen Tilapia Fillet | 1,075 | Alpha Foods |
| Supermarket | Tuskys (City Centre) | Nairobi | Frozen Tilapia Fillet | 1,075 | Alpha Foods |
| Supermarket | Karrymart (City Centre) | Nairobi | Frozen Tilapia Fillet | 1,075 | Alpha Foods |
| Supermarket | Eastmatt | Nairobi | Frozen Tilapia Fillet | 1,075 | Alpha Foods |
| Supermarket | Nakumatt (Prestige) | Nairobi | Frozen Tilapia Fillet | 1,105 | Prime Cuts |
| Supermarket | Nakumatt (Junction) | Nairobi | Frozen Tilapia Fillet | 1,105 | Prime Cuts |
| Supermarket | Chandarana (Yaya) | Nairobi | Frozen Tilapia Fillet | 1,120 | Farmers Choice |
| Supermarket | Eastmatt | Nairobi | Frozen Tilapia Fillet | 893-1488 | Farmers Choice |
| Supermarket | Ukwala | Kisumu | Frozen Tilapia Fillet | 929-1,548 | Farmers Choice |

Table XX – Fish prices high-end markets 2015: Own fieldwork.

# Appendix 11: Best Practice (from Egypt) assumptions

- For the first 60 days use Chicken manure as fertilizer to create natural feed, where after day 60 start using a combination of Urea and Super Phosphate instead.
- Only use high quality pellets with 30% crude protein and first start feeding pellets after 60 days (rely on natural feed from fertilizing the first 60 days).
- Vary the amount of feed given per day according to the weight of the fish (3% of body weight).
- Only use high quality fingerlings and only males for tilapia.
- Stock the fish at 2 per $m^3$, with 90% being tilapia (rest catfish or carps).

- **Feeding Schedule** using a pond size of 495$m^3$ (Evans wife), stocking density of 2/$m^3$, survival rate of 90% (assuming the 10% are dead before reaching day 60, they are often more vulnerable when young), first start feeding pellets after day 60 (approx. from week 10).

| Feed & Fertilizer calculations | | | | | |
|---|---|---|---|---|---|
| **Week** | **Size (kg)** | **feed in kg** | **Chicken manure** | **Super phosphate** | **Urea** |
| 1-9 | <0.059 | n/a | 424.3 | n/a | n/a |
| 10 | 0.059 | 11 | n/a | 4.6 | 2.7 |
| 11 | 0.070 | 13 | n/a | 4.6 | 2.7 |
| 12 | 0.083 | 16 | n/a | 4.6 | 2.7 |
| 13 | 0.100 | 19 | n/a | 4.6 | 2.7 |
| 14 | 0.119 | 22 | n/a | 4.6 | 2.7 |
| 15 | 0.142 | 27 | n/a | 4.6 | 2.7 |
| 16 | 0.169 | 32 | n/a | 4.6 | 2.7 |
| 17 | 0.202 | 38 | n/a | 4.6 | 2.7 |
| 18 | 0.242 | 45 | n/a | 4.6 | 2.7 |
| 19 | 0.288 | 54 | n/a | 4.6 | 2.7 |
| 20 | 0.344 | 64 | n/a | 4.6 | 2.7 |
| 21 | 0.410 | 77 | n/a | 4.6 | 2.7 |
| **Per Harvest** | | **416.7** | **424.3** | **55.5** | **32.7** |
| **Annually** | | **962.8** | **980.2** | **128.3** | **75.5** |

- The same prices for fresh tilapia and catfish has been used as observed from the case studies (314 and 122.5 KES/kg).
- The same pond sizes as the fish farmers currently operate have been applied.
- The same percentage distribution of fresh, smoked and fried fish have been assumed, together with the same price increases for smoked and fried fish (39% and 58%).
- For the costs of labor, smoking and frying fish, the same costs as was used in each of the case studies were applied.
- The following additional prices & sources can be seen from the table below.

| **Prices for feed, seed and fertilizer** | KES |
|---|---|
| Seed price per piece (avg. Found in case studies & 2ndary literature) | 6.5 |
| Chicken manure cost per kg *(Essentia Kanan source 2014)* | 1.6 |
| Cost of Urea per kg (Essentia Kanan source) | 55 |
| Cost of Super Phosphate per kg (Essentia Kanan source) | 68 |
| Feed cost per kg of 30% CP pelleted *(Ugachick 30% source)* | 76 |

# Appendix 12 - Gross Profit Calculations for feed Producer X, and price paid at Retail level in Kenya in 2015

- The information stem from a recent advisory job on the producer's price strategy (in 2015), company and product names are made anonymous due to the sensitive nature of the information.

| | | Production costs | Prices in KES (that they buy for) | | |
|---|---|---|---|---|---|
| **Product** | **Package** | **Producer X** | **Distributors** | **Agrovets** | **Retail** |
| **Product X kg** | 1 | 45 | 74 | 90 | 130 |
| | 2 | 86 | 145 | 170 | 240 |
| | 5 | 214 | 340 | 425 | 550 |
| | 10 | 415 | 670 | 820 | 1000 |
| **Product Y liters** | 5 | 86 | 287 | 350 | 450 |
| | 20 | 276 | 984 | 1200 | 1400 |
| **Product Z liters** | 0.5 | 20 | 82 | 100 | 150 |
| | 1 | 29 | 148 | 180 | 250 |
| | 5 | 93 | 740 | 900 | 1100 |
| | 20 | 306 | 2450 | 3000 | 3500 |

# Appendix 13: General assumptions aquaculture forecasts

## *General*

- The growth in new farmed fish area is only expected to come from new ponds, especially following the trends from the government FFEPP programme and because this is currently the most used technique.
- Assumed same area for dams and tanks in 2012. For ponds for 2012 applied same growth rate of ponds to areas since they were the same in 2010 & 2011 (only number of ponds were available for 2012)
- In 2014 the increase in new farmed areas (new ponds) from the governments FFEPP programme is expected to slow because of the devolution, an average of 20% increase in new ponds is expected.
- Needed amount of organic/inorganic fertilizer has not been forecasted, hence it is currently not an issue to acquire and this is not expected to change.
- Corrected 2011 area of dams, looked like there was missing a 5. (so corrected to 574 instead of 74)
- Since both Jambo Fish & Dominon Farm (Tilapia and Catfish medium-large Intensive) has an integrated farm and produces their own feed & fingerlings; their feed & fingerlings requirements are not included in "Total needed feed". Same assumptions have been used for Trout.

- Jambo fish is assumed to produce 75% catfish and 25% of Mono Tilapia from it intensive tank systems (according to its webpage it can produce a total of 1,5 ton a week equalling 78 tons in 2014).

## *Species grown in semi-intensive conditions by small-scale farmers*

***Tilapia***

- Constituting the majority of total aquaculture output, between 70-75% from 2007-2011, this is the species receiving the main focus (and where there existed the largest amount of data).

***Catfish***

- Observations showed same yields for catfish as tilapia when grown together.
- The rate which catfish were applied was generally 10% of the tilapia population, however farmers like Philip used a rate of around 70% catfish per tilapia.
- Catfish constituted 20% of total aquaculture output between 2007-2011 and besides Jambo Fish (only known medium-large scale catfish farmer) catfish is assumed to be grown in polyculture with tilapia in all the forecasted period. Small-scale semi-intensive Tilapia and catfish farmers will therefore use the same yield.

***Common carp***

- Will often be done together with tilapia as well in Polyculture systems (very common in Asia) so expects same yields for Common Carp as tilapia.

## *Species grown in intensive conditions by medium-large scale farmers*

***Tilapia***

- Dominion Farm and Jambo Fish are the only two producers known to use intensive systems for tilapia.
- Used yields and FCR etc. found from case studies in Egypt and the Philippines for intensive systems.

***Catfish***

- For the intensive grown catfish at Jambo Fish; a FAO case-study has been used on Striped Catfish to determine the yield.
- Striped Catfish from Vietnam are similar to African Catfish, however grow slightly faster why the African Catfish yields has been adjusted equivalent to this.

***Trout***

- For trout there is generally a lack of information, it also only constitute 1% of total output and this has been stable.

- It has been assumed it will have same yields as Intensive tilapia (medium large scale, which it is normally grown as). And output will grow with GDP growth rate from 2013.

## *Aquaculture forecasted output all three scenarios*

| Aquaculture Output | Status Quo (tons) | | | Intermediate (tons) | | | Optimal (tons) | | |
|---|---|---|---|---|---|---|---|---|---|
| Year | Small-scale | Medium-large | Total | Small-scale | Medium-large | Total | Small-scale | Medium-large | Total |
| 2006 | 1,001 | 11 | **1,012** | 1,001 | 11 | **1,012** | 1,001 | 11 | **1,012** |
| 2007 | 4,193 | 47 | **4,240** | 4,193 | 47 | **4,240** | 4,193 | 47 | **4,240** |
| 2008 | 4,403 | 49 | **4,452** | 4,403 | 49 | **4,452** | 4,403 | 49 | **4,452** |
| 2009 | 4,844 | 51 | **4,895** | 4,844 | 51 | **4,895** | 4,844 | 51 | **4,895** |
| 2010 | 12,032 | 122 | **12,154** | 12,032 | 122 | **12,154** | 12,032 | 122 | **12,154** |
| 2011 | 19,905 | 2,230 | **22,135** | 19,905 | 2,230 | **22,135** | 19,905 | 2,230 | **22,135** |
| 2012 | 18,225 | 3,263 | **21,488** | 18,225 | 3,263 | **21,488** | 18,225 | 3,263 | **21,488** |
| 2013 | 43,494 | 5,296 | **48,790** | 43,494 | 5,296 | **48,790** | 43,494 | 5,296 | **48,790** |
| 2014 | 36,629 | 6,327 | **42,956** | 36,629 | 6,327 | **42,956** | 36,629 | 6,327 | **42,956** |
| 2015 | 34,203 | 6,842 | **41,044** | 38,733 | 7,342 | **46,074** | 45,002 | 7,342 | **52,343** |
| 2016 | 33,369 | 7,379 | **40,748** | 44,590 | 8,399 | **52,989** | 64,334 | 8,521 | **72,855** |
| 2017 | 31,201 | 7,897 | **39,098** | 51,015 | 9,417 | **60,432** | 89,400 | 9,699 | **99,100** |
| 2018 | 30,430 | 8,456 | **38,886** | 58,057 | 10,516 | **68,573** | 121,759 | 10,918 | **132,677** |
| 2019 | 28,497 | 8,977 | **37,473** | 65,772 | 10,549 | **76,321** | 159,619 | 18,011 | **177,630** |
| 2020 | 28,722 | 9,518 | **38,240** | 71,945 | 10,584 | **82,529** | 174,776 | 31,118 | **205,893** |
| 2021 | 27,827 | 9,811 | **37,638** | 78,643 | 10,621 | **89,264** | 191,448 | 43,340 | **234,788** |
| 2022 | 28,016 | 10,105 | **38,121** | 85,909 | 10,661 | **96,570** | 209,788 | 54,547 | **264,335** |
| 2023 | 27,154 | 10,394 | **37,548** | 93,788 | 10,703 | **104,491** | 229,961 | 61,253 | **291,214** |
| 2024 | 27,312 | 10,685 | **37,997** | 102,332 | 10,748 | **113,079** | 252,152 | 67,312 | **319,464** |

## *Yields kg/m³ all three scenarios*

| Yields kg/m^3 | Status Quo | | | Intermediate | | | Optimal | | |
|---|---|---|---|---|---|---|---|---|---|
| Year | Small-scale | Medium-large | Total | Small-scale | Medium-large | Total | Small-scale | Medium-large | Total |
| 2006 | 0.14 | 2.95 | **0.14** | 0.14 | 2.95 | **0.14** | 0.14 | 2.95 | **0.14** |
| 2007 | 0.59 | 2.95 | **0.59** | 0.59 | 2.95 | **0.59** | 0.59 | 2.95 | **0.59** |
| 2008 | 0.61 | 2.95 | **0.61** | 0.61 | 2.95 | **0.61** | 0.61 | 2.95 | **0.61** |
| 2009 | 0.59 | 2.95 | **0.59** | 0.59 | 2.95 | **0.59** | 0.59 | 2.95 | **0.59** |
| 2010 | 1.19 | 2.95 | **1.20** | 1.19 | 2.95 | **1.20** | 1.19 | 2.95 | **1.20** |
| 2011 | 1.07 | 2.97 | **1.14** | 1.07 | 2.97 | **1.14** | 1.07 | 2.97 | **1.14** |
| 2012 | 0.71 | 2.97 | **0.81** | 0.71 | 2.97 | **0.81** | 0.71 | 2.97 | **0.81** |
| 2013 | 1.26 | 2.97 | **1.35** | 1.26 | 2.97 | **1.35** | 1.26 | 2.97 | **1.35** |
| 2014 | 0.91 | 2.97 | **1.01** | 0.91 | 2.97 | **1.01** | 0.91 | 2.97 | **1.01** |
| 2015 | 0.91 | 2.97 | **1.03** | 0.91 | 2.97 | **1.02** | 0.95 | 2.97 | **1.05** |
| 2016 | 0.95 | 2.98 | **1.08** | 0.99 | 2.98 | **1.11** | 1.15 | 3.01 | **1.24** |
| 2017 | 0.95 | 2.97 | **1.10** | 1.07 | 2.97 | **1.19** | 1.35 | 3.03 | **1.43** |
| 2018 | 0.99 | 2.98 | **1.16** | 1.15 | 2.99 | **1.27** | 1.55 | 3.06 | **1.62** |
| 2019 | 0.99 | 2.98 | **1.18** | 1.23 | 2.99 | **1.34** | 1.71 | 3.42 | **1.80** |
| 2020 | 1.03 | 2.98 | **1.23** | 1.27 | 2.99 | **1.37** | 1.71 | 4.52 | **1.89** |
| 2021 | 1.03 | 2.99 | **1.24** | 1.31 | 2.99 | **1.40** | 1.71 | 5.02 | **1.95** |
| 2022 | 1.07 | 2.99 | **1.29** | 1.35 | 3.00 | **1.44** | 1.71 | 5.57 | **2.00** |
| 2023 | 1.07 | 2.99 | **1.30** | 1.39 | 3.00 | **1.47** | 1.71 | 5.63 | **2.00** |
| 2024 | 1.11 | 2.99 | **1.35** | 1.43 | 3.00 | **1.50** | 1.71 | 5.73 | **2.01** |

## *Feed Conversion Rates all three scenarios*

| Feed Conversion Rate | Status Quo | Intermediate | Optimal |
|---|---|---|---|
| Year | Small-scale | Small-scale | Small-scale |
| 2006 | 2.73 | 2.73 | 2.73 |
| 2007 | 2.73 | 2.73 | 2.73 |
| 2008 | 2.73 | 2.73 | 2.73 |
| 2009 | 2.73 | 2.73 | 2.73 |
| 2010 | 2.73 | 2.73 | 2.73 |
| 2011 | 2.73 | 2.73 | 2.73 |
| 2012 | 2.73 | 2.73 | 2.73 |
| 2013 | 2.73 | 2.73 | 2.73 |
| 2014 | 2.73 | 2.73 | 2.73 |
| 2015 | 2.73 | 2.73 | 2.65 |
| 2016 | 2.65 | 2.57 | 2.25 |
| 2017 | 2.65 | 2.41 | 1.85 |
| 2018 | 2.57 | 2.25 | 1.46 |
| 2019 | 2.57 | 2.09 | 1.14 |
| 2020 | 2.49 | 2.01 | 1.14 |
| 2021 | 2.49 | 1.93 | 1.14 |
| 2022 | 2.41 | 1.85 | 1.14 |
| 2023 | 2.41 | 1.77 | 1.14 |
| 2024 | 2.33 | 1.69 | 1.14 |

## *Number of fish farmers*

| Fish farmers | Status Quo (number) | | | Intermediate (number) | | | Optimal (number) | | |
|---|---|---|---|---|---|---|---|---|---|
| Year | New | Growth | **Total** | New | Growth | **Total** | New | Growth | **Total** |
| 2006 | - | - | **4,742** | - | - | **4,742** | - | - | **4,742** |
| 2007 | - | 0.0% | **4,742** | - | 0.0% | **4,742** | - | 0.0% | **4,742** |
| 2008 | - | 0.0% | **4,742** | - | 0.0% | **4,742** | - | 0.0% | **4,742** |
| 2009 | 1,586 | 33.4% | **6,328** | 1,586 | 33.4% | **6,328** | 1,586 | 33.4% | **6,328** |
| 2010 | 7,792 | 123.1% | **14,120** | 7,792 | 123.1% | **14,120** | 7,792 | 123.1% | **14,120** |
| 2011 | 34,601 | 245.0% | **48,721** | 34,601 | 245.0% | **48,721** | 34,601 | 245.0% | **48,721** |
| 2012 | 329 | 0.7% | **49,050** | 329 | 0.7% | **49,050** | 329 | 0.7% | **49,050** |
| 2013 | 22,502 | 45.9% | **71,552** | 22,502 | 45.9% | **71,552** | 22,502 | 45.9% | **71,552** |
| 2014 | 15,000 | 21.0% | **86,552** | 15,000 | 21.0% | **86,552** | 15,000 | 21.0% | **86,552** |
| 2015 | (6,750) | -7.8% | **79,802** | 5,853 | 6.8% | **92,404** | 18,000 | 20.8% | **104,552** |
| 2016 | (6,244) | -7.8% | **73,558** | 6,233 | 6.7% | **98,637** | 21,600 | 20.7% | **126,152** |
| 2017 | (5,775) | -7.9% | **67,782** | 6,638 | 6.7% | **105,276** | 25,920 | 20.5% | **152,072** |
| 2018 | (5,342) | -7.9% | **62,440** | 7,070 | 6.7% | **112,346** | 31,104 | 20.5% | **183,176** |
| 2019 | (4,942) | -7.9% | **57,498** | 7,530 | 6.7% | **119,876** | 37,325 | 20.4% | **220,500** |
| 2020 | (2,286) | -4.0% | **55,213** | 8,020 | 6.7% | **127,895** | 22,395 | 10.2% | **242,895** |
| 2021 | (2,200) | -4.0% | **53,013** | 8,541 | 6.7% | **136,436** | 24,634 | 10.1% | **267,530** |
| 2022 | (2,117) | -4.0% | **50,896** | 9,096 | 6.7% | **145,533** | 27,098 | 10.1% | **294,627** |
| 2023 | (2,038) | -4.0% | **48,858** | 9,688 | 6.7% | **155,221** | 29,808 | 10.1% | **324,435** |
| 2024 | (1,961) | -4.0% | **46,896** | 10,318 | 6.6% | **165,539** | 32,788 | 10.1% | **357,223** |

## *Number of ponds and farmed area*

| Ponds & area farmed | Status Quo (m^2) | | | Intermediate (m^2) | | | Optimal (m^2) | | |
|---|---|---|---|---|---|---|---|---|---|
| Year | Ponds (number) | Pond area | **Total area** | Ponds (number) | Pond area | **Total area** | Ponds (number) | Pond area | **Total area** |
| 2006 | 7,477 | 2,170,000 | **7,218,289** | 7,477 | 2,170,000 | **7,218,289** | 7,477 | 2,170,000 | **7,218,289** |
| 2007 | 7,471 | 2,168,265 | **7,161,347** | 7,471 | 2,168,265 | **7,161,347** | 7,471 | 2,168,265 | **7,161,347** |
| 2008 | 7,530 | 2,186,051 | **7,272,413** | 7,530 | 2,186,051 | **7,272,413** | 7,530 | 2,186,051 | **7,272,413** |
| 2009 | 9,116 | 2,664,496 | **8,243,085** | 9,116 | 2,664,496 | **8,243,085** | 9,116 | 2,664,496 | **8,243,085** |
| 2010 | 15,529 | 4,593,063 | **10,163,085** | 15,529 | 4,593,063 | **10,163,085** | 15,529 | 4,593,063 | **10,163,085** |
| 2011 | 45,745 | 13,582,892 | **19,373,085** | 45,745 | 13,582,892 | **19,373,085** | 45,745 | 13,582,892 | **19,373,085** |
| 2012 | 69,998 | 20,798,617 | **26,588,810** | 69,998 | 20,798,617 | **26,588,810** | 69,998 | 20,798,617 | **26,588,810** |
| 2013 | 100,000 | 29,705,932 | **35,496,124** | 100,000 | 29,705,932 | **35,496,124** | 100,000 | 29,705,932 | **35,496,124** |
| 2014 | 120,000 | 35,643,746 | **41,433,938** | 120,000 | 35,643,746 | **41,433,938** | 120,000 | 35,643,746 | **41,433,938** |
| 2015 | 111,000 | 32,971,729 | **38,761,922** | 127,803 | 37,960,499 | **43,750,692** | 144,000.00 | 42,769,122 | **48,559,315** |
| 2016 | 102,675 | 30,500,114 | **36,290,307** | 136,114 | 40,427,908 | **46,218,100** | 172,800.00 | 51,319,574 | **57,109,767** |
| 2017 | 94,974 | 28,213,870 | **34,004,063** | 144,965 | 43,055,767 | **48,845,960** | 207,360.00 | 61,580,117 | **67,370,310** |
| 2018 | 87,851 | 26,099,095 | **31,889,288** | 154,392 | 45,854,512 | **51,644,705** | 248,832.00 | 73,892,768 | **79,682,961** |
| 2019 | 81,262 | 24,142,927 | **29,933,120** | 164,432 | 48,835,254 | **54,625,447** | 298,598.40 | 88,667,949 | **94,458,142** |
| 2020 | 78,215 | 23,238,200 | **29,028,393** | 175,125 | 52,009,828 | **57,800,021** | 328,458.24 | 97,533,058 | **103,323,250** |
| 2021 | 75,282 | 22,367,400 | **28,157,592** | 186,513 | 55,390,840 | **61,181,033** | 361,304.06 | 107,284,677 | **113,074,870** |
| 2022 | 72,459 | 21,529,255 | **27,319,447** | 198,642 | 58,991,713 | **64,781,905** | 397,434.47 | 118,011,459 | **123,801,652** |
| 2023 | 69,742 | 20,722,540 | **26,512,733** | 211,559 | 62,826,744 | **68,616,937** | 437,177.92 | 129,810,918 | **135,601,111** |
| 2024 | 67,126 | 19,946,077 | **25,736,270** | 225,316 | 66,911,160 | **72,701,353** | 480,895.71 | 142,790,324 | **148,580,517** |

# Appendix 14: Overview medium-large scale fish farmers forecast

### *Medium-large scale intensive fish farmers*

Only two medium-large scale fish farmers have been found present in Kenya at the moment and their expected changes in production capacity will vary somewhat in the different scenarios, however not as much as the small-scale fish farmers since they are both completely integrated and therefore less dependent and affected by what takes place of changes in the institutional environment and governing mechanisms of the Kenyan aquaculture sector (together with one assumed Trout producer). In all the three scenarios the same yields and FCR have been used for the intensive fish farmers in order to keep focus and the main effects on changes in small-scale fish farmers, which are the focal area of this thesis. In the Optimal case it is further expected new medium-large scale fish farmers would emerge (see Appendix on the Optimal scenario for details, similar further details can also be seen in both the Status Quo and Intermediate Appendix.

| Intensive fish farming | Yield kg/m^3 annually | FCR | Stocking per m^3 | Harvests per year |
|---|---|---|---|---|
| Tilapia Egypt | 3.21 | 1.15 | 7.50 | 1.83 |
| Tilapia Philippines | 2.69 | 0.92 | 7.50 | 2.44 |
| **Average tilapia** | **2.95** | **1.04** | **7.50** | **2.14** |
| **African Catfish *(using Striped catfish from Vietnam and adj. for size)*** | **36.93** | **2.09** | **48.20** | **1.34** |

**Intensive fish farming details - El-Sayed 2, 2013 and Romana-Eguia et al., 2013, Nguyen, 2013, Ugachick & USAID, catfish, 2011 and FAO catfish 4.**

# Appendix 15: Needed aquaculture inputs all three scenarios

The three different upgrading trajectories presuppose various produced levels of inputs and their quality as can be seen from the table below. The quality of feed and fingerling inputs are as previous mentioned a major determinant for the yields farmers are able to reach, and as can be seen the Optimal case for instance rely solely on high quality input where as in Status Quo fish farmers are primarily using low quality inputs. In the table below the large difference in the FCR small- scale fish farmers are able to reach can also be seen, with farmers in the Optimal case able to lower the amount of feed input to 1.14 kg per kg output from all adopting the best practice method from Egypt relative to the Status Quo case of 2.33 where only 25% of the small-scale fish farmers are expected to have adopted this method.

| Needed inputs | Actual - 2013 | Status Quo - 2024 | Intermediate - 2024 | Optimal - 2024 |
|---|---|---|---|---|
| FCR small-scale farmers | 2.73 | 2.33 | 1.69 | 1.14 |
| Low quality feed (tons) | 11,852 | 13,366 | 85,588 | - |
| High quality feed (tons) | 106,669 | 50,237 | 87,839 | 370,377 |
| **Total needed feed (tons)** | **118,521** | **63,603** | **173,427** | **370,377** |
| Mixed species low quality (millions) | 14.56 | 36.28 | 225.67 | 681.47 |
| Mono (male) high quality (millions) | 131.05 | 70.40 | 95.48 | - |
| **Total needed fingerlings (millions)** | **145.61** | **106.69** | **321.15** | **681.47** |

**Inputs (fish feed and fingerlings) needed in all three scenarios relative to 2013 – own work. *Excluding fish feed and fingerlings needed for integrated farms, which produces their own.***

- **Fish feed:** Excluding fish feed needed for integrated medium-large scale fish farms, hence they produce to themselves. Natural feed produced through fertilizing is also excluded, no proper way to measure this.
- **Fingerlings:** Excluding fingerlings needed for integrated medium-large scale fish farms, hence they produce to themselves.

| Needed fish feed | Status Quo (tons) | | | Intermediate (tons) | | | Optimal (tons) | | |
|---|---|---|---|---|---|---|---|---|---|
| Year | Low Quality | High Quality | Total | Low Quality | High Quality | Total | Low Quality | High Quality | Total |
| 2006 | 2,729 | - | **2,729** | 2,729 | - | **2,729** | 2,729 | - | **2,729** |
| 2007 | 11,426 | - | **11,426** | 11,426 | - | **11,426** | 11,426 | - | **11,426** |
| 2008 | 11,998 | - | **11,998** | 11,998 | - | **11,998** | 11,998 | - | **11,998** |
| 2009 | 13,201 | - | **13,201** | 13,201 | - | **13,201** | 13,201 | - | **13,201** |
| 2010 | 32,787 | - | **32,787** | 32,787 | - | **32,787** | 32,787 | - | **32,787** |
| 2011 | 54,240 | - | **54,240** | 54,240 | - | **54,240** | 54,240 | - | **54,240** |
| 2012 | 49,663 | - | **49,663** | 49,663 | - | **49,663** | 49,663 | - | **49,663** |
| 2013 | 106,669 | 11,852 | **118,521** | 106,669 | 11,852 | **118,521** | 106,669 | 11,852 | **118,521** |
| 2014 | 89,833 | 9,981 | **99,814** | 89,833 | 9,981 | **99,814** | 80,849 | 9,981 | **90,831** |
| 2015 | 83,882 | 9,320 | **93,202** | 94,992 | 10,555 | **105,547** | 94,364 | 14,215 | **108,578** |
| 2016 | 77,745 | 10,540 | **88,285** | 98,422 | 16,019 | **114,441** | 99,401 | 34,274 | **133,675** |
| 2017 | 72,694 | 9,856 | **82,550** | 100,091 | 22,753 | **122,844** | 88,798 | 67,017 | **155,815** |
| 2018 | 67,167 | 10,932 | **78,099** | 99,670 | 30,930 | **130,599** | 53,750 | 117,680 | **171,430** |
| 2019 | 62,900 | 10,237 | **73,137** | 96,783 | 40,745 | **137,528** | - | 199,812 | **199,812** |
| 2020 | 59,875 | 11,564 | **71,439** | 97,045 | 47,691 | **144,735** | - | 236,172 | **236,172** |
| 2021 | 58,008 | 11,204 | **69,212** | 96,436 | 55,542 | **151,978** | - | 272,407 | **272,407** |
| 2022 | 54,967 | 12,495 | **67,462** | 94,811 | 64,399 | **159,210** | - | 304,082 | **304,082** |
| 2023 | 53,276 | 12,111 | **65,387** | 92,006 | 74,374 | **166,380** | - | 336,156 | **336,156** |
| 2024 | 50,237 | 13,366 | **63,603** | 87,839 | 85,588 | **173,427** | - | 370,377 | **370,377** |

| Needed fingerlings | Status Quo (Millions) | | | Intermediate (Millions) | | | Optimal (Millions) | | |
|---|---|---|---|---|---|---|---|---|---|
| Year | Mixed | Mono (male) | **Total** | Mixed | Mono (male) | **Total** | Mixed | Mono (male) | **Total** |
| 2006 | 30.54 | - | **30.54** | 30.54 | - | **30.54** | 30.54 | - | **30.54** |
| 2007 | 30.25 | - | **30.25** | 30.25 | - | **30.25** | 30.25 | - | **30.25** |
| 2008 | 30.71 | - | **30.71** | 30.71 | - | **30.71** | 30.71 | - | **30.71** |
| 2009 | 34.82 | - | **34.82** | 34.82 | - | **34.82** | 34.82 | - | **34.82** |
| 2010 | 42.85 | - | **42.85** | 42.85 | - | **42.85** | 42.85 | - | **42.85** |
| 2011 | 78.83 | - | **78.83** | 78.83 | - | **78.83** | 78.83 | - | **78.83** |
| 2012 | 107.91 | - | **107.91** | 107.91 | - | **107.91** | 107.91 | - | **107.91** |
| 2013 | 131.05 | 14.56 | **145.61** | 131.05 | 14.56 | **145.61** | 131.05 | 14.56 | **145.61** |
| 2014 | 153.67 | 17.07 | **170.75** | 153.67 | 17.07 | **170.75** | 153.67 | 17.07 | **170.75** |
| 2015 | 143.49 | 15.94 | **159.44** | 162.50 | 18.06 | **180.55** | 171.78 | 30.05 | **201.83** |
| 2016 | 127.37 | 22.28 | **149.66** | 154.71 | 38.04 | **192.75** | 149.38 | 94.24 | **243.62** |
| 2017 | 119.10 | 20.84 | **139.93** | 145.53 | 60.30 | **205.82** | 113.62 | 181.05 | **294.67** |
| 2018 | 105.58 | 25.96 | **131.54** | 134.80 | 85.05 | **219.85** | 59.88 | 297.15 | **357.03** |
| 2019 | 98.87 | 24.31 | **123.18** | 122.36 | 112.53 | **234.89** | - | 431.39 | **431.39** |
| 2020 | 90.45 | 29.41 | **119.86** | 118.81 | 131.10 | **249.92** | - | 472.35 | **472.35** |
| 2021 | 87.63 | 28.49 | **116.12** | 114.45 | 151.53 | **265.98** | - | 517.41 | **517.41** |
| 2022 | 79.92 | 33.11 | **113.03** | 109.18 | 173.98 | **283.16** | - | 566.98 | **566.98** |
| 2023 | 77.46 | 32.09 | **109.55** | 102.89 | 198.62 | **301.52** | - | 621.50 | **621.50** |
| 2024 | 70.40 | 36.28 | **106.69** | 95.48 | 225.67 | **321.15** | - | 681.47 | **681.47** |

# Appendix 16: Status Quo case assumptions

| Institutional & governance changes - Status Quo case |
|---|
| **Struggle 1** |
| - No enforcement of fish input quality standards |
| **Struggle 2** |
| - Only 25% of the counties will be able to increase training in best practices for officials and farmers (driven by Farm Africa and county governments).<br>- Limited effects of Red Cross & Farm Africa's lobbying efforts |
| **Struggle 3** |
| - Government factories will not become operational<br>- Farm Africa's sales outlets will continue however with no replication to other counties |

- **Growth in farmed area:** The overall result for farmed areas in Kenya will be a decrease in ponds for the next 10 years with negative growth rates of 7.5% between 2015-2019 slowing to 3.75% from 2019-2024.

| Counties - Status Quo | % of total | Avg. growth 2015-2019 | Avg. growth 2020-2024 |
|---|---|---|---|
| Supportive | 25% | 10% | 5% |
| Stagnant | 25% | 0% | 0% |
| Deteriorating | 50% | -20% | -10% |

### *Intensive systems*

- The negative effects arising from the devolution; increased corruption, lack of institutional support and a divergence between counties, is also expected to influence the medium-large scale producers.
- The effect relative to small-scale farmers will be less hence they are stronger financially, already have the needed technological knowledge and therefore are less dependent on institutional support.
- Jambo Fish and Dominion Farm's investment in new capacity is however expected to be postponed some years relative to the Intermediate case scenario.
- Jambo fish is expected to grow its total output to 200 tons by 2022 (relative to 2018 in the Intermediate case), where after it is expected to grow with the expected GDP rate.
- Dominion Farm, assumed to produce 50% of listed capacity from their webpage (10,000 tons) in 2013 and reach a capacity of 10,000 tons by 2024 (relative to 2018 in the Intermediate case).

**Output intensive details – Status Quo case**

| Status Quo - Intensive output details (tons) | Jambo Fish tilapia | Dominion Farm tilapia | Trout | Jambo Fish catfish | Total |
|---|---|---|---|---|---|
| Year | | | | | |
| 2006 | - | - | 11 | - | **11** |
| 2007 | - | - | 47 | - | **47** |
| 2008 | - | - | 49 | - | **49** |
| 2009 | - | - | 51 | - | **51** |
| 2010 | - | - | 122 | - | **122** |
| 2011 | 5 | 2,000 | 210 | 15 | **2,230** |
| 2012 | 10 | 3,000 | 223 | 30 | **3,263** |
| 2013 | 15 | 5,000 | 236 | 45 | **5,296** |
| 2014 | 20 | 6,000 | 249 | 59 | **6,327** |
| 2015 | 20 | 6,500 | 264 | 59 | **6,842** |
| 2016 | 25 | 7,000 | 281 | 74 | **7,379** |
| 2017 | 25 | 7,500 | 299 | 74 | **7,897** |
| 2018 | 35 | 8,000 | 318 | 104 | **8,456** |
| 2019 | 35 | 8,500 | 339 | 104 | **8,977** |
| 2020 | 40 | 9,000 | 360 | 119 | **9,518** |
| 2021 | 45 | 9,250 | 383 | 134 | **9,811** |
| 2022 | 50 | 9,500 | 407 | 149 | **10,105** |
| 2023 | 53 | 9,750 | 433 | 158 | **10,394** |
| 2024 | 56 | 10,000 | 461 | 168 | **10,685** |

# Appendix 17: Intermediate case assumptions

| Institutional & governance changes - Intermediate case |
|---|
| **Struggle 1** |
| - Periodic enforcement of fish input quality standards by county governments |
| **Struggle 2** |
| - Some increased training in best practices for government officials and farmers, however only in supportive counties (driven by Farm Africa & county governments)<br>- Continued lobbying by Red Cross & Farm Africa leading to more counties support of Aquaculture<br>- Some improvement in credit options for farmers driven by Red Cross & Farm Africa but only in supportive counties |
| **Struggle 3** |
| - Government processing factories will start operating from 2016, however with various problems pf corruption lack of consistent standards and inadequate coordination of farmers harvest cycle<br>- Farm Africa's sales outlets will continue however with no replication to other counties<br>- Factories & sales outlets will still be outperformed by imported tilapia and private processors; why they will be limited to sell to lower-end butchers, hotels & restaurants and different government institutions<br>- Limited best practice knowledge seeping through from farmers relation with government factories and sales outlets |

- **Growth in farmed area:** From 2015 until 2024 the areas/counties with good potential for aquaculture development will grow with an average of 10% in farmed area, where as the rest of the areas/counties will be stagnant.

### *Intensive systems*

- Jambo fish is expected to grow its total output to 200 tons a year in 2018, where after it is expected to grow with the expected GDP growth rate.
- Dominion Farm is assumed to produce 50% of listed capacity from their webpage (10,000 tons) in 2013 and reach a capacity of 10,000 tons in 4 years (in 2018), where after it is expected to grow with the expected GDP growth rate.

  **Output intensive details – Intermediate case**

| Intermediate case - Intensive output | Jambo Fish tilapia | Dominion Farm tilapia | Trout | Jambo Fish catfish | Total |
|---|---|---|---|---|---|
| Year | | | | | |
| 2006 | - | - | 11 | - | **11** |
| 2007 | - | - | 47 | - | **47** |
| 2008 | - | - | 49 | - | **49** |
| 2009 | - | - | 51 | - | **51** |
| 2010 | - | - | 122 | - | **122** |
| 2011 | 5 | 2,000 | 210 | 15 | **2,230** |
| 2012 | 10 | 3,000 | 223 | 30 | **3,263** |
| 2013 | 15 | 5,000 | 236 | 45 | **5,296** |
| 2014 | 20 | 6,000 | 249 | 59 | **6,327** |
| 2015 | 20 | 7,000 | 264 | 59 | **7,342** |
| 2016 | 30 | 8,000 | 281 | 89 | **8,399** |
| 2017 | 30 | 9,000 | 299 | 89 | **9,417** |
| 2018 | 50 | 10,000 | 318 | 149 | **10,516** |
| 2019 | 53 | 10,000 | 339 | 158 | **10,549** |
| 2020 | 56 | 10,000 | 360 | 168 | **10,584** |
| 2021 | 60 | 10,000 | 383 | 179 | **10,621** |
| 2022 | 63 | 10,000 | 407 | 190 | **10,661** |
| 2023 | 67 | 10,000 | 433 | 202 | **10,703** |
| 2024 | 72 | 10,000 | 461 | 215 | **10,748** |

# Appendix 18: Optimal case assumptions

- **Growth in farmed area:** The development path of the Optimal case is expected to result in an average annual growth rate of 20% for new ponds between 2015-2019 slowing to 10% from 2019-2024.

### *Intensive systems*

- Jambo fish is expected to grow its total output to 600 tons a year by 2018, and to 1,600 tons by 2024 - corresponding to a farmed area of 16.8 ha.
- Dominion Farm is assumed to produce 50% of listed capacity from their webpage (10,000 tons) in 2013 and reach a capacity of 10,000 tons in 4 years (in 2018).
- It is further expected Dominion Farm will be able to increase its production to 20,000 tons in 2024 corresponding to a use of 678.3 ha farmed area (less than 10% of their total area of 6,900 ha)

- Because of the large support from institutions and favourable environment of Kenya's aquaculture sector, several former small-scale farmers emerges as new medium-large scale producers using intensive systems from 2019-2024.

- By 2024 20 new medium-large scale tilapia (male) producers and 10 new medium-large scale catfish producers will have emerged.
- The new medium-large producers are expected to implement the same farming methods as the existing Dominion Farm and Jambo Fish and achieve the same yields and FCR.
- Taking into account a transition period into using intensive systems, the first year of their emergence as intensive players the yields will however only represent 50% of the optimum and their FCR will following this be double the usual ratio.
- The new medium-large intensive producers will be expected to produce their own fingerlings but not their own feed.

**Average farmed areas expected for the new intensive players:**

| Size in ha of farmed area | Year 1 | Year 2 | Year 3 | Year 4 | Year 5 | Year 6 |
|---|---|---|---|---|---|---|
| Tilapia intensive | 8 | 11 | 14 | 16 | 18 | 20 |
| Catfish intensive | 4 | 6 | 7 | 8 | 9 | 10 |

**Details of new medium-large scale intensive tilapia and catfish farmers**

| Optimal case - New intensive players | Total new tilapia producers | Total new catfish producers | Total new area farmed for tilapia in ha | Total new area farmed for catfish in ha |
|---|---|---|---|---|
| Year | | | | |
| 2019 | 10 | 5 | 80 | 20 |
| 2020 | 15 | 8 | 150 | 42 |
| 2021 | 20 | 10 | 235 | 61 |
| 2022 | 20 | 10 | 285 | 73 |
| 2023 | 20 | 10 | 330 | 83 |
| 2024 | 20 | 10 | 370 | 93 |

**Output intensive details – Optimal case**

| Optimal case -Intensive output details (tons) | Jambo Fish tilapia | Dominion Farm tilapia | Trout | Jambo Fish catfish | New tilapia producers | New catfish producers | Total |
|---|---|---|---|---|---|---|---|
| Year | | | | | | | |
| 2006 | - | - | 11 | - | - | - | **11** |
| 2007 | - | - | 47 | - | - | - | **47** |
| 2008 | - | - | 49 | - | - | - | **49** |
| 2009 | - | - | 51 | - | - | - | **51** |
| 2010 | - | - | 122 | - | - | - | **122** |
| 2011 | 5 | 2,000 | 210 | 15 | - | - | **2,230** |
| 2012 | 10 | 3,000 | 223 | 30 | - | - | **3,263** |
| 2013 | 15 | 5,000 | 236 | 45 | - | - | **5,296** |
| 2014 | 20 | 6,000 | 249 | 59 | - | - | **6,327** |
| 2015 | 20 | 7,000 | 264 | 59 | - | - | **7,342** |
| 2016 | 60 | 8,000 | 281 | 180 | - | - | **8,521** |
| 2017 | 100 | 9,000 | 299 | 300 | - | - | **9,699** |
| 2018 | 150 | 10,000 | 318 | 450 | - | - | **10,918** |
| 2019 | 200 | 12,000 | 339 | 600 | 1,179 | 3,693 | **18,011** |
| 2020 | 240 | 14,000 | 360 | 720 | 3,612 | 12,186 | **31,118** |
| 2021 | 280 | 16,000 | 383 | 840 | 5,897 | 19,940 | **43,340** |
| 2022 | 320 | 17,500 | 407 | 960 | 8,404 | 26,956 | **54,547** |
| 2023 | 360 | 19,000 | 433 | 1,080 | 9,730 | 30,649 | **61,253** |
| 2024 | 400 | 20,000 | 461 | 1,200 | 10,910 | 34,341 | **67,312** |

## Appendix 19: DEC no fish forecast

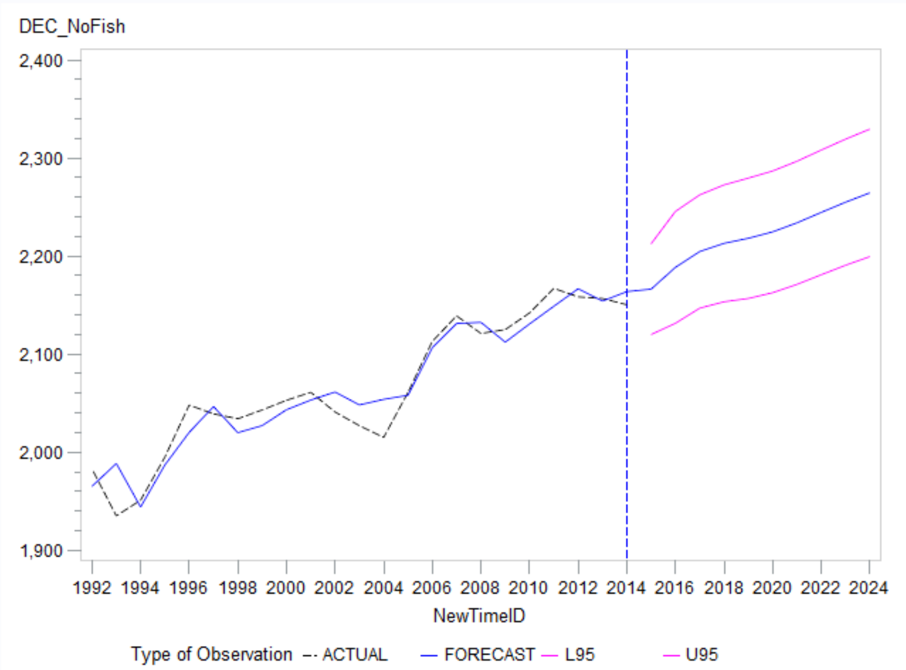
- An AR 1,2 model was found to be the best fit. Both the Stepwise Autoregressive linear and quadratic method of finding this showed very good fit to the data and had almost the same forecast values. Linear however has lower std. Dev. why it is chosen.
- **$Y_t = c + \Phi_1 * Y_{t-1} .... + L*t + e_t$,** where $Y_t$ is the dependent variable, c is the constant, $\Phi_1$ is the AR coefficient at lag 1, L is the linear trend, and $e_t$ is the error term.
- **DEC no fish$_t$ = 1,956 + 0.78 * DEC no fish$_{t-1}$ - 0.50 * DEC no fish$_{t-2}$ + 9.33*t + $e_t$** (AR 1,2 model with trend)

**Parameter estimates**

Parameter Estimates

| Obs | _TYPE_ | NewTimeID | DEC_NoFish |
|---|---|---|---|
| 1 | N | 2014 | 23 |
| 2 | NRESID | 2014 | 23 |
| 3 | DF | 2014 | 19 |
| 4 | SIGMA | 2014 | 21.154986 |
| 5 | CONSTANT | 2014 | 1955.7276 |
| 6 | LINEAR | 2014 | 9.3341011 |
| 7 | AR1 | 2014 | 0.7830876 |
| 8 | AR2 | 2014 | -0.495021 |
| 9 | AR3 | 2014 | . |
| 10 | AR4 | 2014 | . |
| 11 | SST | 2014 | 103692.65 |
| 12 | SSE | 2014 | 8220.6103 |
| 13 | MSE | 2014 | 432.6637 |
| 14 | RMSE | 2014 | 20.80057 |
| 15 | MAPE | 2014 | 0.7346812 |

Plot of Forecasts from Stepwise Autoregressive Method

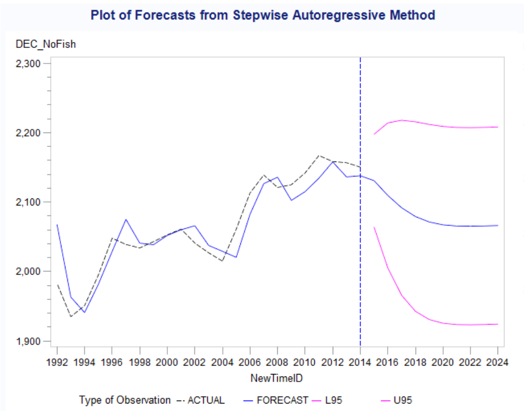


## Stepwise Autoregressive linear

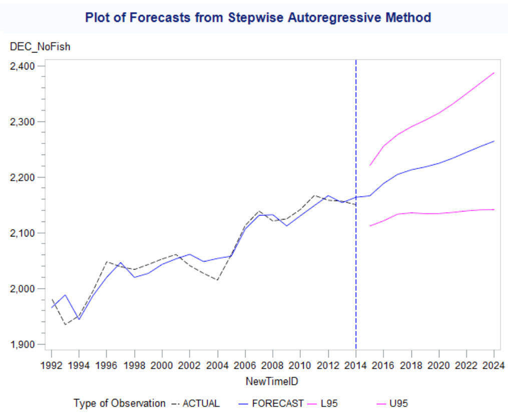
### Forecasted values

| Forecasted DEC No Fish - using the Linear Stepwise | | | | |
|---|---|---|---|---|
| Year | Forecast | L95 | Std Dev | U95 |
| 2015 | 2,166 | 2,120 | 24 | 2,212 |
| 2016 | 2,188 | 2,131 | 29 | 2,245 |
| 2017 | 2,205 | 2,147 | 29 | 2,262 |
| 2018 | 2,213 | 2,153 | 30 | 2,273 |
| 2019 | 2,218 | 2,157 | 31 | 2,279 |
| 2020 | 2,225 | 2,163 | 32 | 2,287 |
| 2021 | 2,234 | 2,171 | 32 | 2,297 |
| 2022 | 2,244 | 2,181 | 32 | 2,308 |
| 2023 | 2,255 | 2,191 | 33 | 2,319 |
| 2024 | 2,264 | 2,199 | 33 | 2,329 |

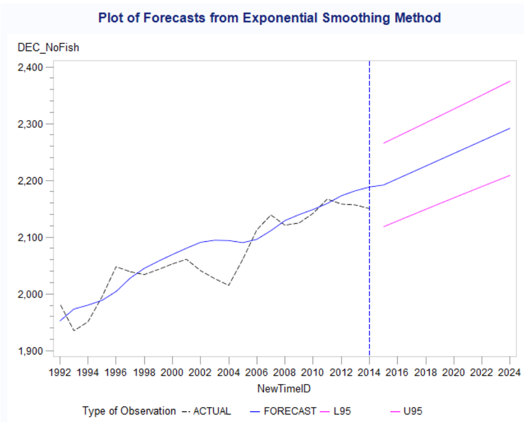
### Other models



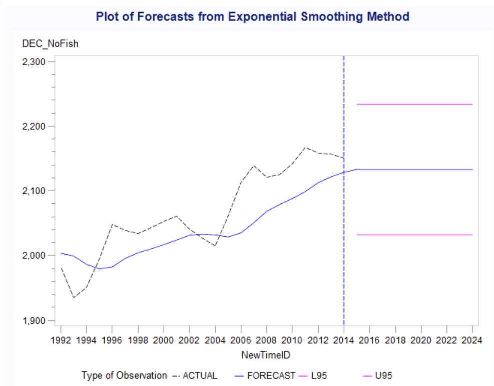

Stepwise Autoregressive Constant



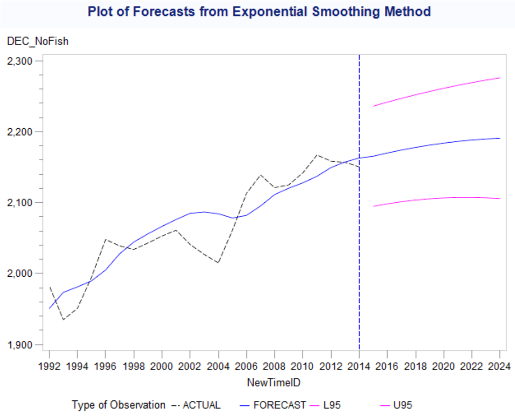

Stepwise Autoregressive Quadratic



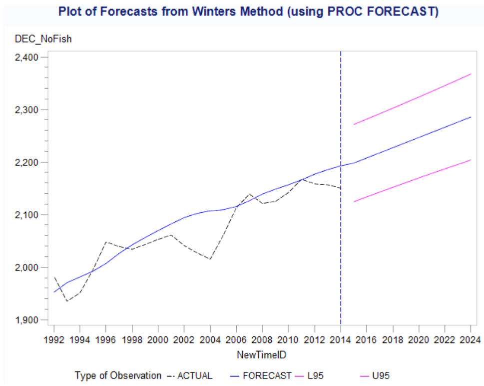

Exponential Smoothing Linear



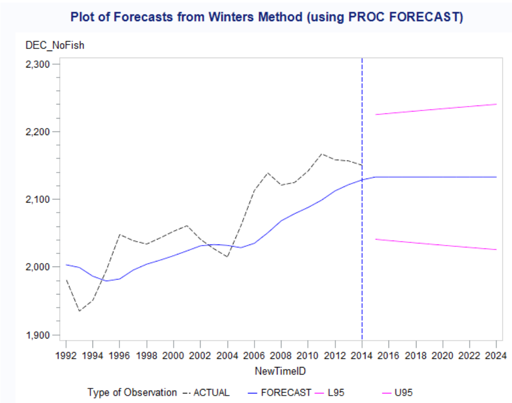

Exponential Smoothing Constant



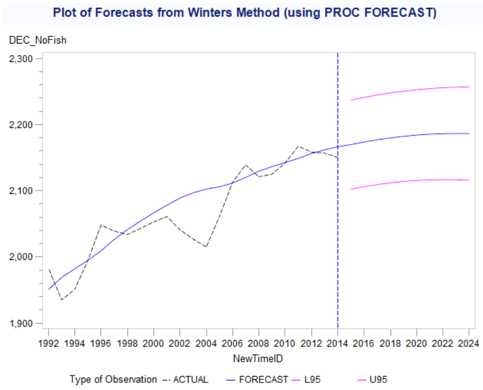
Exponential Smoothing Quadratic



Holt Winters Linear



Holt Winters Constant



Holt Winters Quadratic

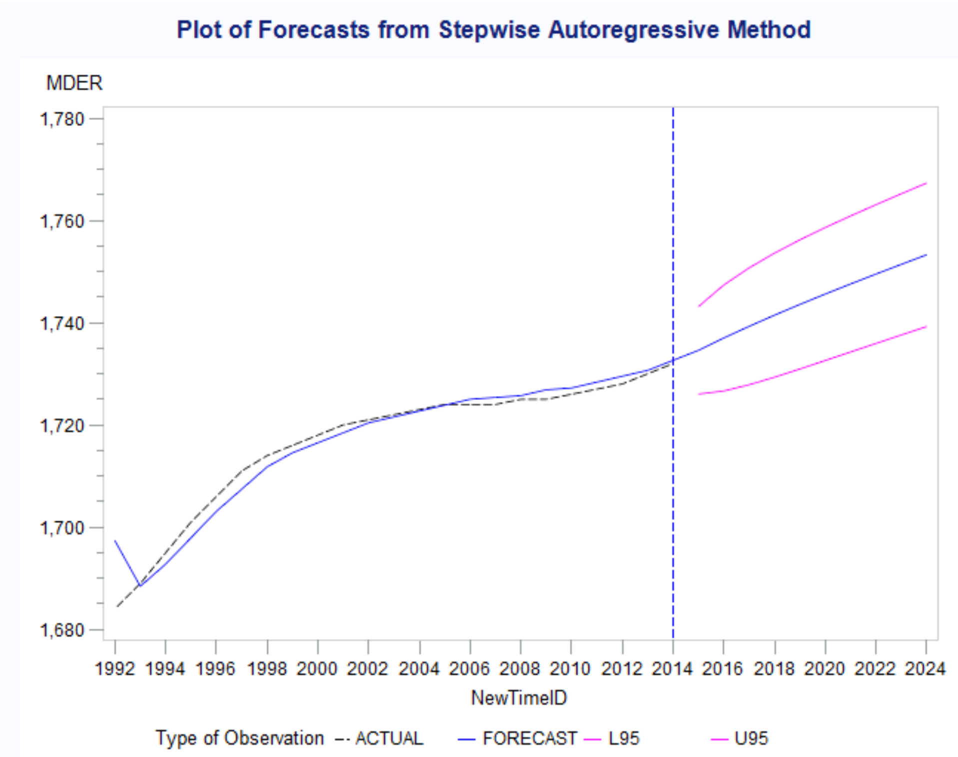
# Appendix 20: MDER forecast

- It was clear just from looking at the forecasted plots that the model best fitting the data was an AR 1 model found through the linear Stepwise Autoregressive method (the Quadratic version also showed okay fit, however the forecasted decline in MDER was found too steep and unrealistic).
- $\mathbf{Y_t = c + \Phi 1 * Y_{t-1} \ldots + L*t + e_t}$, where $Y_t$ is the dependent variable, c is the constant, $\Phi 1$ is the AR coefficient at lag 1, L is the linear trend, and $e_t$ is the error term.
- $\mathbf{MDER_t = 1{,}696 + 0.80 * MDER_{t-1} + 1.76*t + e_t}$ (AR 1 model with trend)

**Parameter estimates**

**Parameter Estimates**

| Obs | _TYPE_ | NewTimeID | MDER |
|---|---|---|---|
| 1 | N | 2014 | 23 |
| 2 | NRESID | 2014 | 23 |
| 3 | DF | 2014 | 20 |
| 4 | SIGMA | 2014 | 3.5424614 |
| 5 | CONSTANT | 2014 | 1695.6087 |
| 6 | LINEAR | 2014 | 1.7608696 |
| 7 | AR1 | 2014 | 0.8004497 |
| 8 | AR2 | 2014 | . |
| 9 | AR3 | 2014 | . |
| 10 | AR4 | 2014 | . |
| 11 | SST | 2014 | 3836.4348 |
| 12 | SSE | 2014 | 240.16442 |
| 13 | MSE | 2014 | 12.008221 |
| 14 | RMSE | 2014 | 3.465288 |
| 15 | MAPE | 2014 | 0.1127628 |

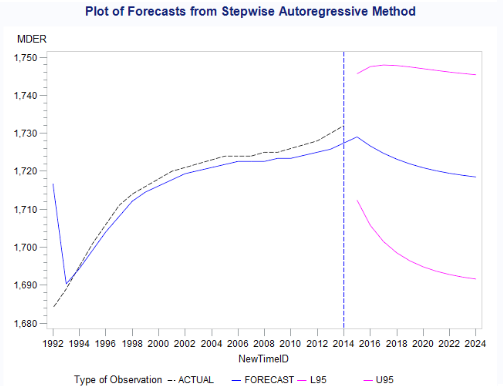



**Stepwise Autoregressive linear**

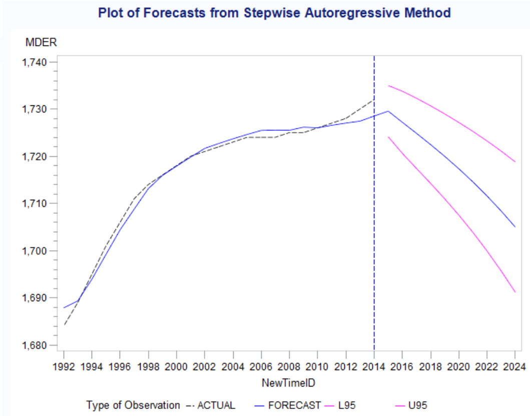
## Forecasted values

| Forecasted MDER - using the Linear Stepwise | | | | |
|---|---|---|---|---|
| **Year** | **Forecast** | **L95** | **Std Dev** | **U95** |
| 2015 | 1,735 | 1,726 | 4 | 1,743 |
| 2016 | 1,737 | 1,727 | 5 | 1,747 |
| 2017 | 1,739 | 1,728 | 6 | 1,751 |
| 2018 | 1,741 | 1,729 | 6 | 1,754 |
| 2019 | 1,744 | 1,731 | 6 | 1,756 |
| 2020 | 1,746 | 1,733 | 7 | 1,759 |
| 2021 | 1,748 | 1,734 | 7 | 1,761 |
| 2022 | 1,750 | 1,736 | 7 | 1,763 |
| 2023 | 1,751 | 1,738 | 7 | 1,765 |
| 2024 | 1,753 | 1,739 | 7 | 1,767 |

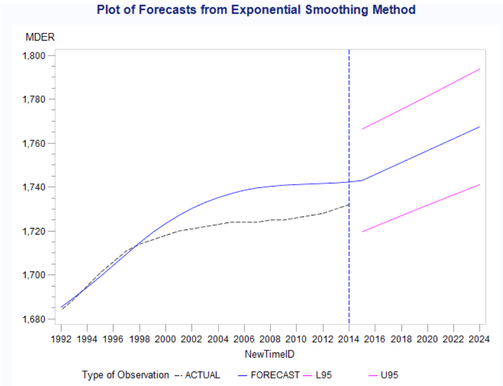
## Other models



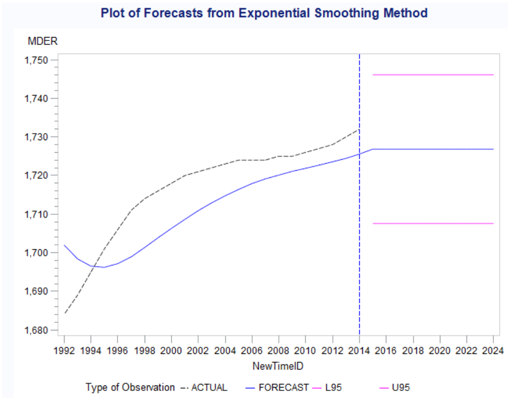

Stepwise Autoregressive Constant



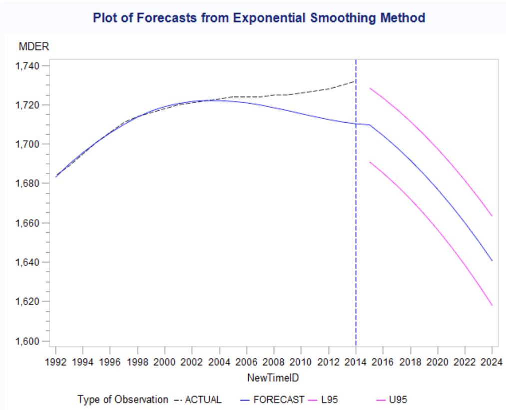

Stepwise Autoregressive Quadratic



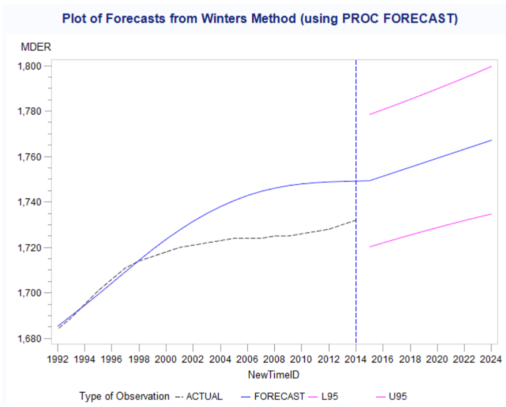

Exponential Smoothing Linear



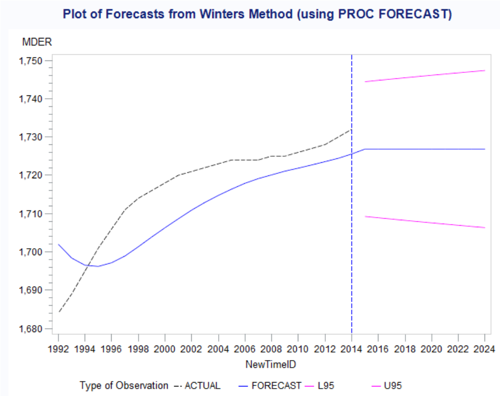

Exponential Smoothing Constant



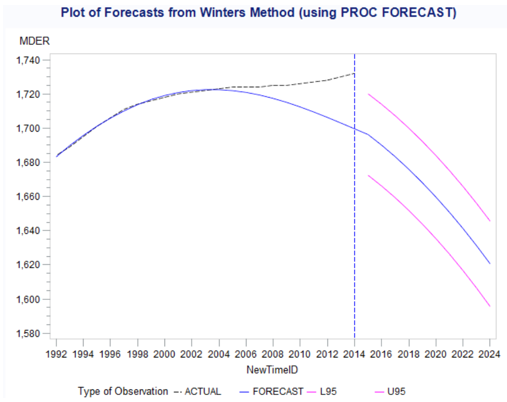

Exponential Smoothing Quadratic




Holt Winters Linear




Holt Winters Constant




Holt Winters Quadratic

# Appendix 21: CV forecast

***Direct ways to measure CV & SK***

- Method 1: involves using interquartile ranges
- Method 2: uses a jackknife method that systemically leaves out each observation from the sample in order to analyze and remove outliers.
- Method 3: uses a linear regression method that relates food consumption to income.

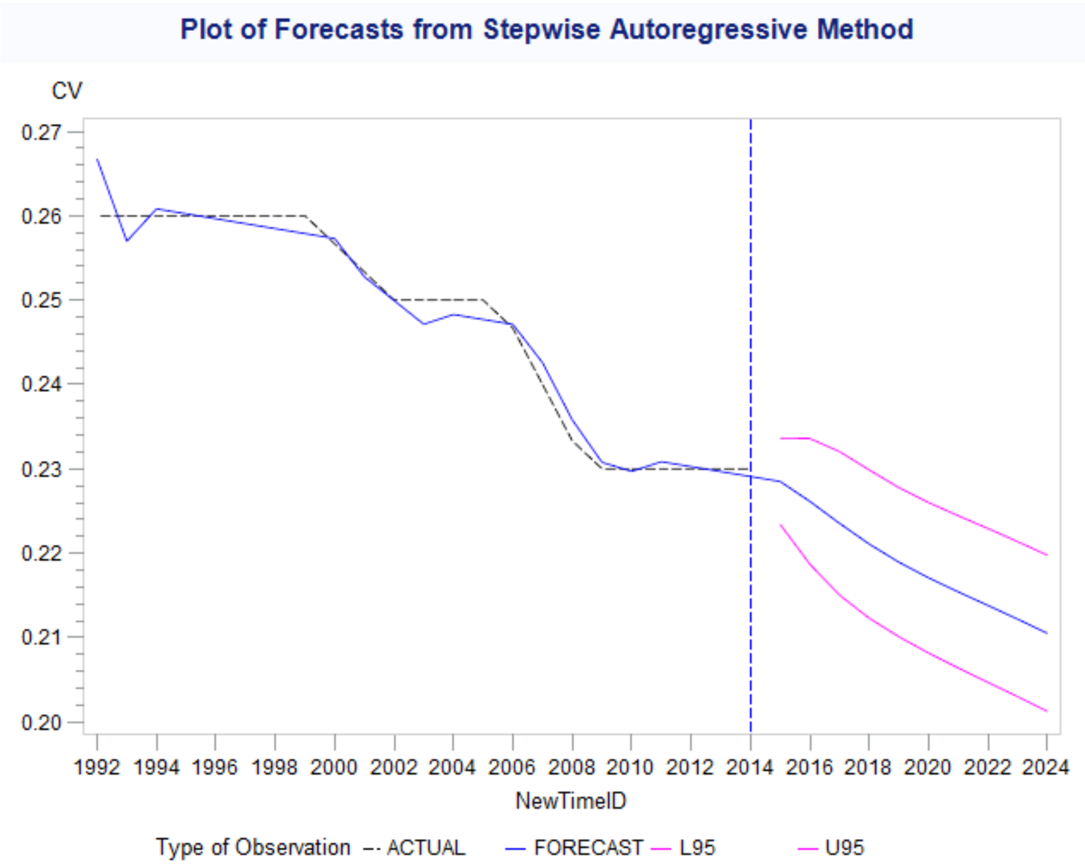
*Optimal method would be to have individual data for the whole population on the food consumption habits, however this is generally not available.*

- **The optimal model** with the best fit and lowest std. dev. was an AR 1,2 model found through the Stepwise Autoregressive Linear method. The Stepwise Autoregressive Constant was the only contender, however it had higher std. Dev. and it forecasts a slight increase in CV, where as it would more be expected that the CV should decrease (less inequality).
- **$Y_t = c + \Phi_1 * Y_{t-1} .... + L*t + e_t$,** where $Y_t$ is the dependent variable, c is the constant, $\Phi_1$ is the AR coefficient at lag 1, L is the linear trend, and $e_t$ is the error term.
- **$CV_t = 0.27 + 1.19 * CV_{t-1} - 0.52 * CV_{t-2} - 0.002*t + e_t$** (AR 1,2 model with trend)

**Parameter estimates**

**Parameter Estimates**

| Obs | _TYPE_ | NewTimeID | CV |
|---|---|---|---|
| 1 | N | 2014 | 23 |
| 2 | NRESID | 2014 | 23 |
| 3 | DF | 2014 | 19 |
| 4 | SIGMA | 2014 | 0.0023116 |
| 5 | CONSTANT | 2014 | 0.268498 |
| 6 | LINEAR | 2014 | -0.001759 |
| 7 | AR1 | 2014 | 1.187453 |
| 8 | AR2 | 2014 | -0.519908 |
| 9 | AR3 | 2014 | . |
| 10 | AR4 | 2014 | . |
| 11 | SST | 2014 | 0.0034879 |
| 12 | SSE | 2014 | 0.0000956 |
| 13 | MSE | 2014 | 5.0294E-6 |
| 14 | RMSE | 2014 | 0.0022426 |
| 15 | MAPE | 2014 | 0.5694679 |

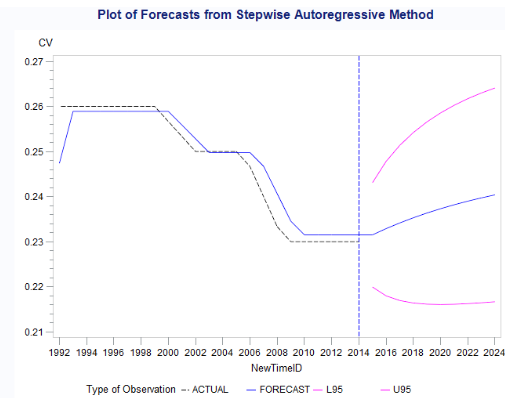



**Stepwise Autoregressive linear**

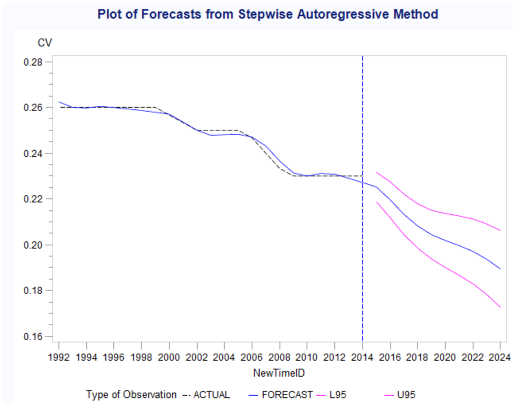
## Forecasted data

| Forecasted CV - using the Linear Stepwise | | | | |
|---|---|---|---|---|
| Year | Forecast | L95 | Std Dev | U95 |
| 2015 | 0.23 | 0.22 | 0 | 0.23 |
| 2016 | 0.23 | 0.22 | 0 | 0.23 |
| 2017 | 0.22 | 0.22 | 0 | 0.23 |
| 2018 | 0.22 | 0.21 | 0 | 0.23 |
| 2019 | 0.22 | 0.21 | 0 | 0.23 |
| 2020 | 0.22 | 0.21 | 0 | 0.23 |
| 2021 | 0.22 | 0.21 | 0 | 0.22 |
| 2022 | 0.21 | 0.2 | 0 | 0.22 |
| 2023 | 0.21 | 0.2 | 0 | 0.22 |
| 2024 | 0.21 | 0.2 | 0 | 0.22 |

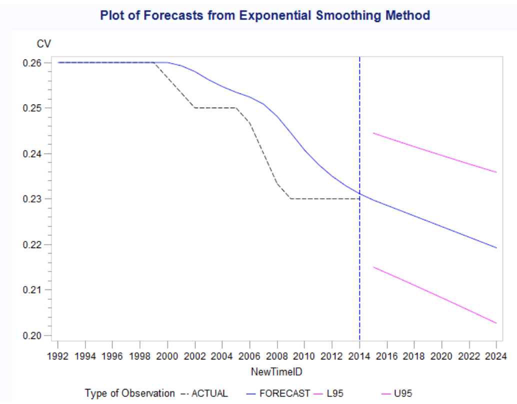
## Other Models



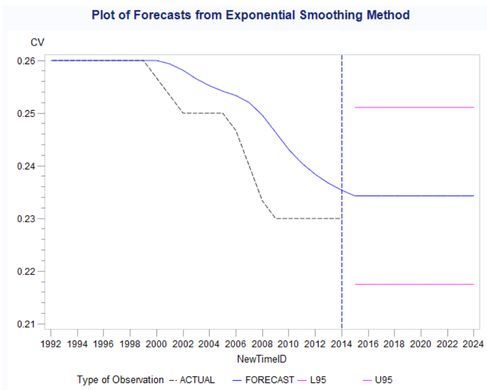

Stepwise Autoregressive Constant



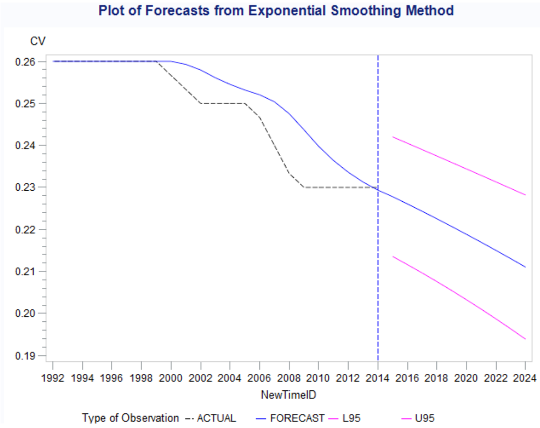

Stepwise Autoregressive Quadratic



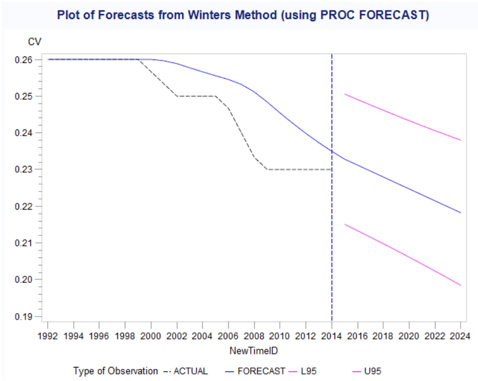

Exponential Smoothing Linear



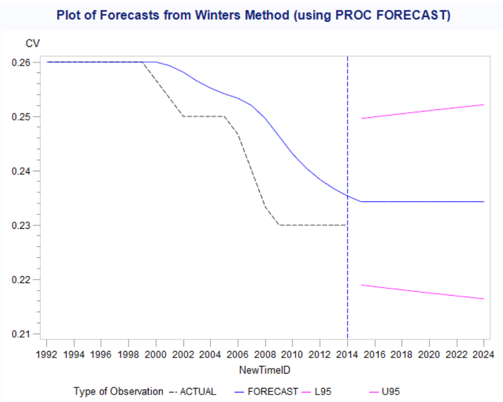

Exponential Smoothing Constant



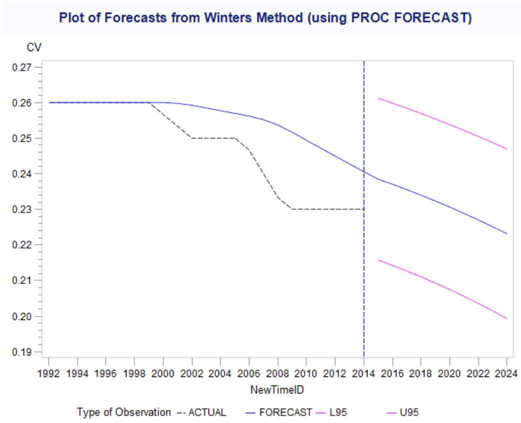

Exponential Smoothing Quadratic




Holt Winters Linear




Holt Winters Constant




Holt Winters Quadratic

# Appendix 22: PoU assumptions and details

## *Other functional forms*

**Function 2:**

$$PoU = PoU_{LN}\,(DEC, CV, SK, MDER), \qquad SK \geq W$$

$$PoU = PoU_{SN}\,(DEC, CV, SK, MDER), \qquad SK < W$$

**Function 3:**

$$PoU = PoU_{LN}\,(DEC, CV, SK, MDER), \qquad SK \geq (CV^2 + 3)CV$$

$$PoU = PoU_{LSN}\,(DEC, CV, SK, MDER), \qquad W < SK < (CV^2 + 3)CV$$

$$PoU = PoU_{SN}\,(DEC, CV, SK, MDER), \qquad SK \leq W$$

## *PoU adjustment*

| PoU Adjustment | PoU No_Fish foreacsted with Stepwise Autoregressive | PoU foreacsted with Stepwise Autoregressive | Difference in % points |
|---|---|---|---|
| 2015 | 19.39% | 23.70% | 4.65% |
| 2016 | 18.32% | 23.10% | 4.99% |
| 2017 | 16.27% | 22.50% | 6.43% |
| 2018 | 15.99% | 21.90% | 6.16% |
| 2019 | 15.93% | 21.30% | 5.67% |
| 2020 | 15.71% | 20.70% | 5.24% |
| 2021 | 15.39% | 20.10% | 4.95% |
| 2022 | 13.72% | 19.50% | 6.02% |
| 2023 | 13.27% | 18.90% | 5.81% |
| 2024 | 12.98% | 18.30% | 5.50% |

- The difference in % points relative to the actual estimates had little fluctuations in all cases.

| PoU Adjustment Comparison | Kenya | Bolivia | Botswana | Laos | Sri Lanka | Uganda |
|---|---|---|---|---|---|---|
| Average difference in % points from 1992-2014 | -5.17% | -6.24% | -4.49% | -4.87% | -3.37% | -5.84% |

## SAS Code used to calculate PoU

- DEC, CV and MDER would then be changed when running either different scenarios or sensitivity analyses, while 'set' specifying the data to use would also change when different data was used.

```
libname spec 'S:\Desktop\Thesis_16_May';
data a;
set spec.forecasted_pou_input;
shape = sqrt(log(CV**2 + 1));
location = log(DEC_Best)-0.5*shape**2;
test = cdf('lognormal',MDER,location,shape);
run; quit;
```

# Appendix 23: PoU forecast using Linear Stepwise Autoregressive model & PoU excl. fish using SAS code

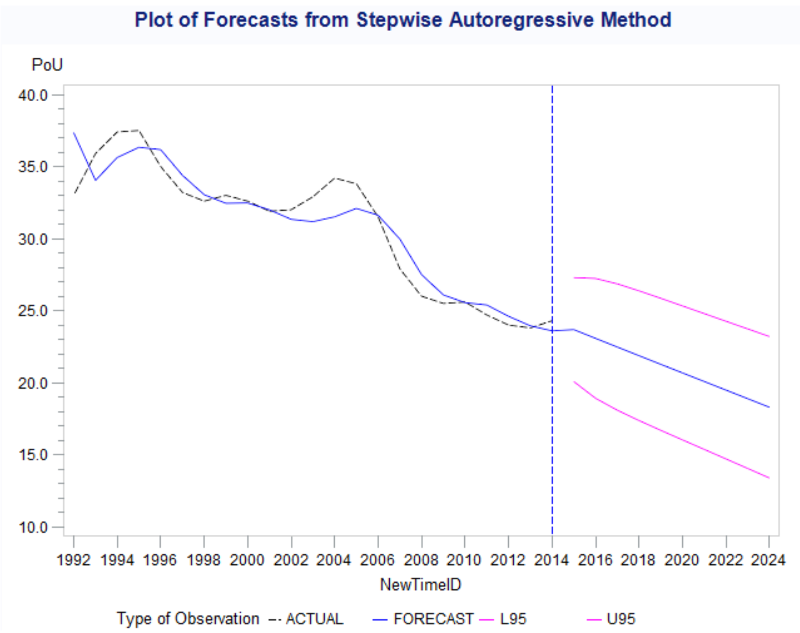
– The best fit for the data was an AR 1 model found through the Linear Stepwise Autoregressive method. Both the Quadratic and Constant were discarded because of forecasting too extreme values (e.g. not likely PoU will increase to more than 30% in 10 years from the current 24% unless some huge shock to the country takes place, as was forecasted in the Quadratic). The Linear Stepwise Autoregressive model was therefore chosen as the most optimal model.

### Parameter estimates & equation

$PoU_t = 37.94 + 0.62 * PoU_{t-1} + 0.56*t + e_t$ (AR 1 model)

**Parameter Estimates**

| Obs | _TYPE_ | NewTimeID | PoU |
|---|---|---|---|
| 1 | N | 2014 | 23 |
| 2 | NRESID | 2014 | 23 |
| 3 | DF | 2014 | 20 |
| 4 | SIGMA | 2014 | 1.611498 |
| 5 | CONSTANT | 2014 | 37.938735 |
| 6 | LINEAR | 2014 | -0.595257 |
| 7 | AR1 | 2014 | 0.6226645 |
| 8 | AR2 | 2014 | . |
| 9 | AR3 | 2014 | . |
| 10 | AR4 | 2014 | . |
| 11 | SST | 2014 | 443.40957 |
| 12 | SSE | 2014 | 51.937458 |
| 13 | MSE | 2014 | 2.5968729 |
| 14 | RMSE | 2014 | 1.6114816 |
| 15 | MAPE | 2014 | 3.5642743 |

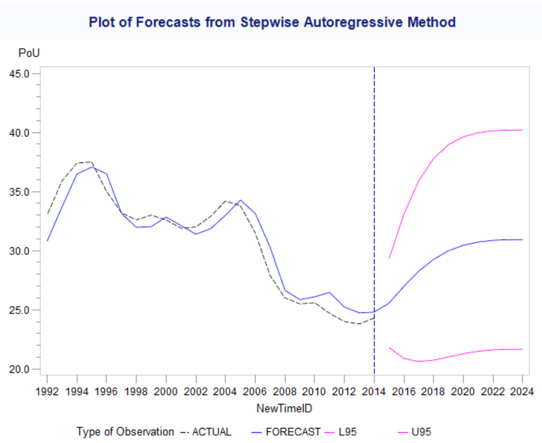



**Stepwise Autoregressive linear**

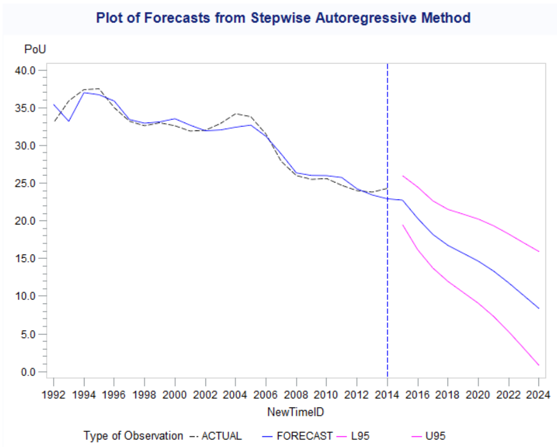
**Forecasted data**

| Forecasted PoU - using the Linear Stepwise | | | | |
|---|---|---|---|---|
| **Year** | **Forecast** | **L95** | **Std Dev** | **U95** |
| 2015 | 23.7 | 20.1 | 1.8 | 27.3 |
| 2016 | 23.1 | 18.9 | 2.1 | 27.2 |
| 2017 | 22.5 | 18.1 | 2.2 | 26.9 |
| 2018 | 21.9 | 17.4 | 2.3 | 26.4 |
| 2019 | 21.3 | 16.7 | 2.3 | 25.9 |
| 2020 | 20.7 | 16 | 2.4 | 25.3 |
| 2021 | 20.1 | 15.4 | 2.4 | 24.8 |
| 2022 | 19.5 | 14.7 | 2.4 | 24.3 |
| 2023 | 18.9 | 14 | 2.5 | 23.7 |
| 2024 | 18.3 | 13.4 | 2.5 | 23.2 |

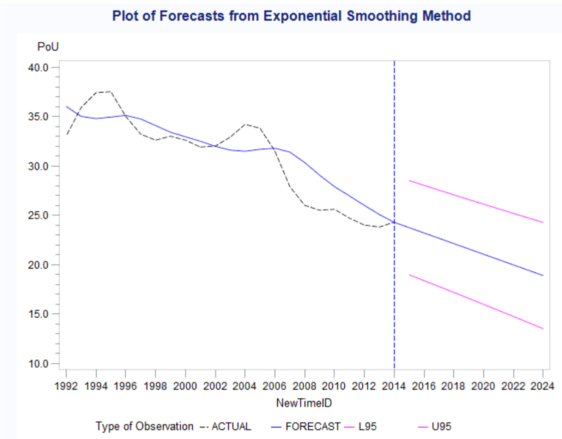
## Other Models



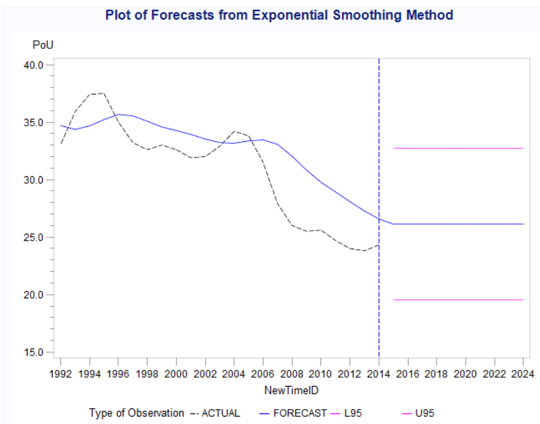

Stepwise Autoregressive Constant



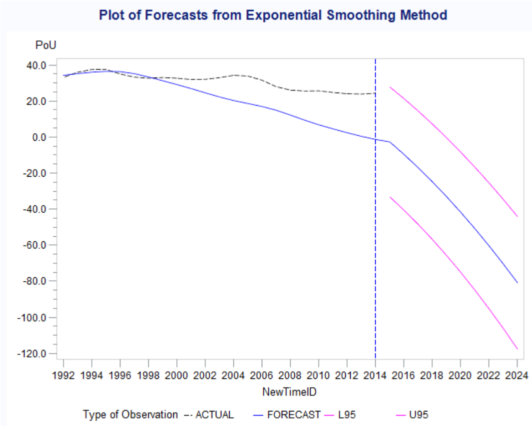

Stepwise Autoregressive Quadratic



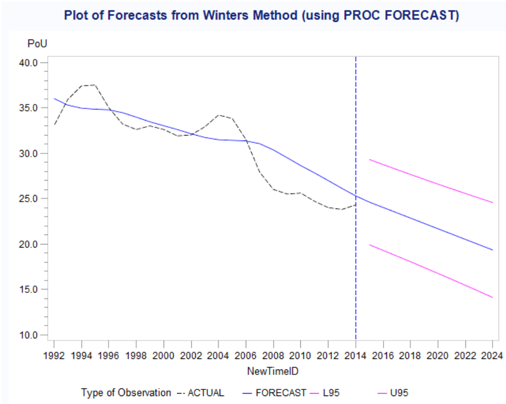

Exponential Smoothing Linear



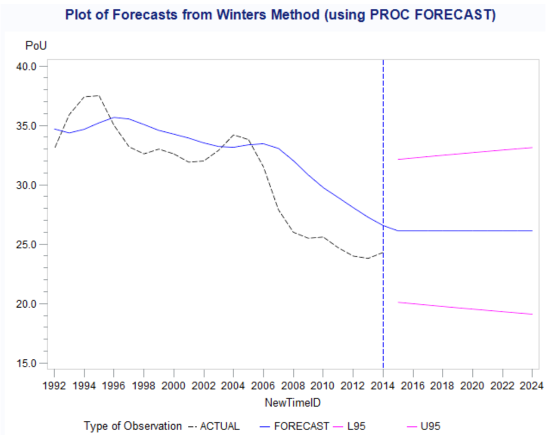

Exponential Smoothing Constant



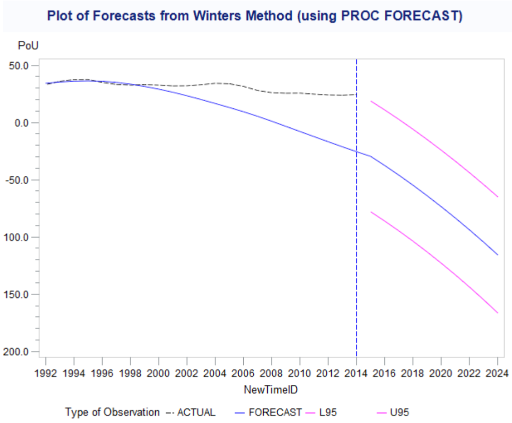

Exponential Smoothing Quadratic




Holt Winters Linear




Holt Winters Constant




Holt Winters Quadratic

### *PoU excl. fish using SAS code*

| Date | PoU_No_Fish |
|---|---|
| 2015 | 19.39% |
| 2016 | 18.32% |
| 2017 | 16.27% |
| 2018 | 15.99% |
| 2019 | 15.93% |
| 2020 | 15.71% |
| 2021 | 15.39% |
| 2022 | 13.72% |
| 2023 | 13.27% |
| 2024 | 12.98% |

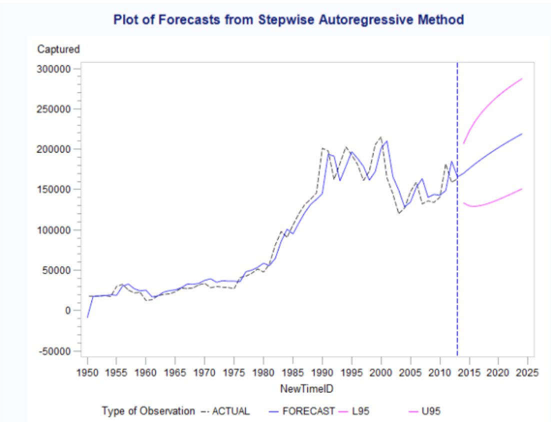
# Appendix 24: Captured all simple models -Data=1950-2013.

### *Holt Winters Additive & Multiplicative*

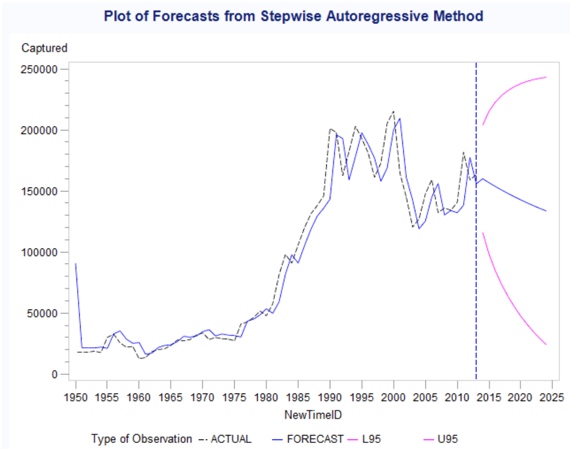
Holt Winters both has an Additive and Multiplicative version related to have it treats seasonal data, for this data since there are no seasonal data they will return the same results and just be referred to as Holt Winters (Makridakis et al, 1998).

**The MAPE formula can be written as this:** $\text{MAPE}= \frac{1}{n}\sum_{t=1}^{n}|PEt|$

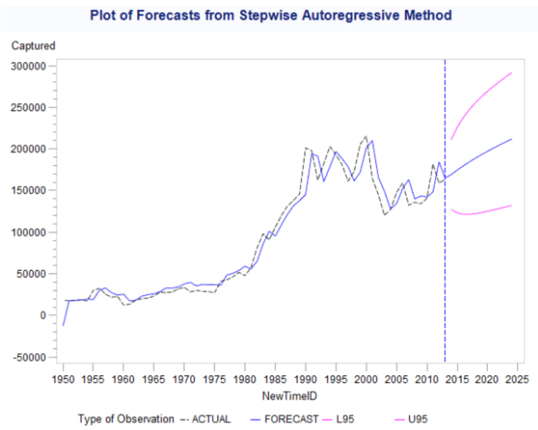
Where PEt= $\left(\frac{Yt-Ft}{Yt}\right)$ x 100.



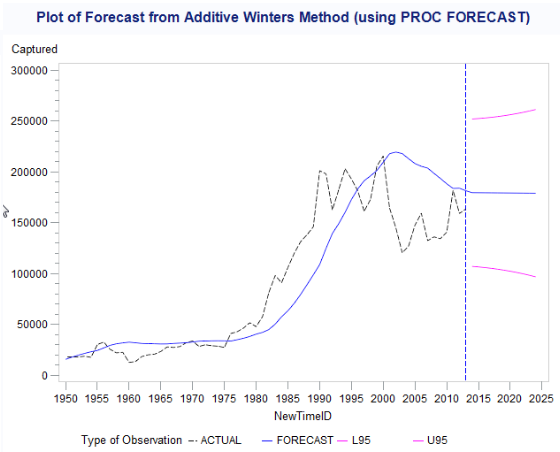

**Stepwise Autoregressive Linear**



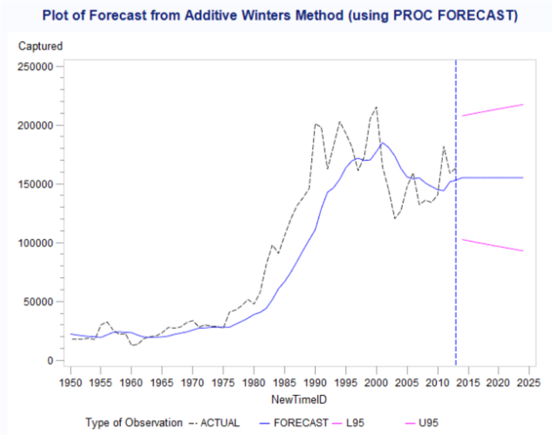

**Stepwise Autoregressive Constant**



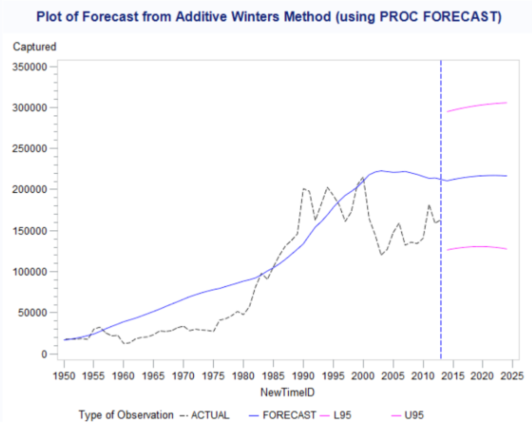

**Stepwise Autoregressive Quadratic**



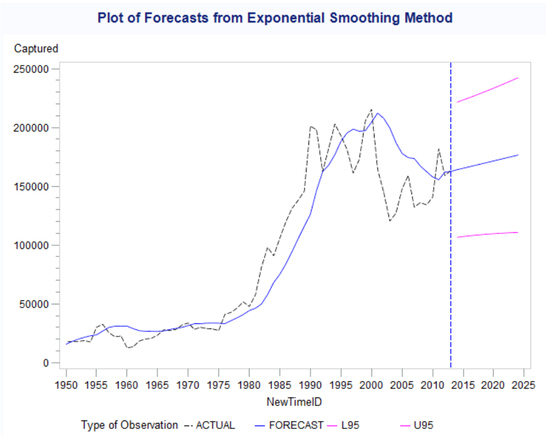

**Holt Winters Linear**



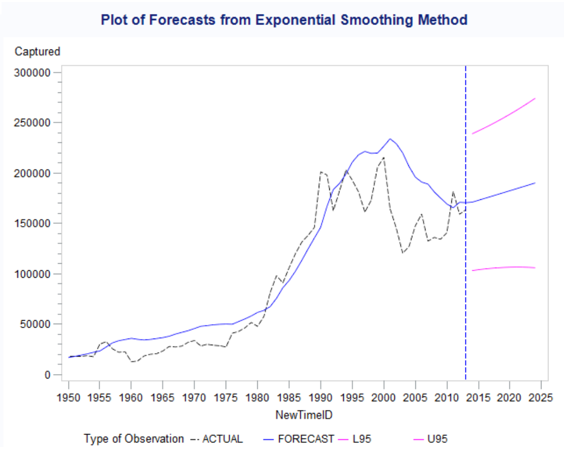

Holt Winters Constant




Holt Winters Quadratic




Exponential Smoothing Linear




Exponential Smoothing Quadratic

***Equation AR 1 Model with trend (Stepwise Autoregressive Linear method)***

The equation for the AR 1 model with trend found through the Linear Stepwise Autoregressive method using data from 1950-2013 can be written as this (Makridakis et al, 1998):

- $\textbf{Captured fish}_t = -12{,}142 + 0.87 * \textbf{Captured fish}_{t-1} + 3{,}166 * t + e_t$

***Parameters AR 1 model with trend) (Stepwise Autoregressive Linear method)***

**Parameter Estimates**

| Obs | _TYPE_ | NewTimeID | Captured |
|---|---|---|---|
| 1 | N | 2013 | 64 |
| 2 | NRESID | 2013 | 64 |
| 3 | DF | 2013 | 61 |
| 4 | SIGMA | 2013 | 16528.863 |
| 5 | CONSTANT | 2013 | -12141.54 |
| 6 | LINEAR | 2013 | 3166.2638 |
| 7 | AR1 | 2013 | 0.8742961 |
| 8 | AR2 | 2013 | . |
| 9 | AR3 | 2013 | . |
| 10 | AR4 | 2013 | . |
| 11 | SST | 2013 | 2.8969E11 |
| 12 | SSE | 2013 | 1.6104E10 |
| 13 | MSE | 2013 | 263996752 |
| 14 | RMSE | 2013 | 16247.977 |
| 15 | MAPE | 2013 | 16.517525 |

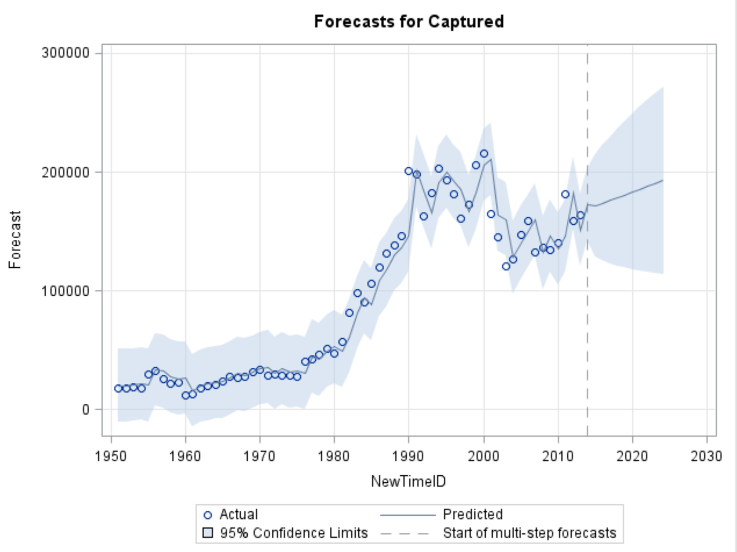
# Appendix 25: Captured ARIMA - Data=1950-2013.

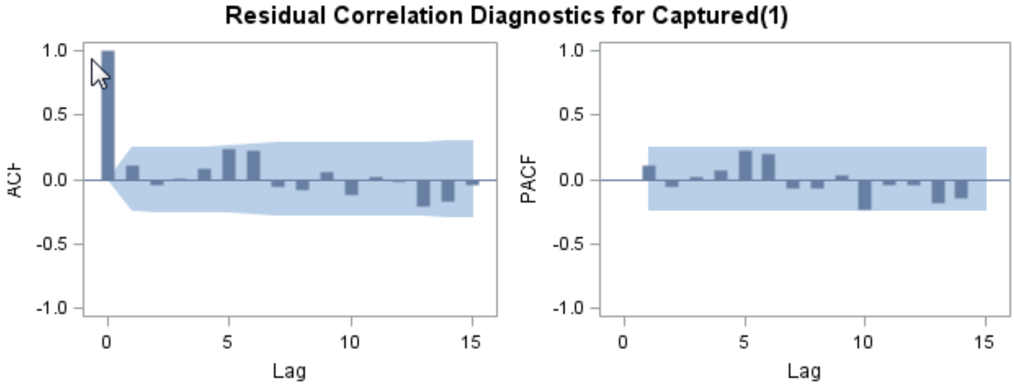
**AR 2 model with First difference –** Parameter estimates

**Conditional Least Squares Estimation**

| Parameter | Estimate | Standard Error | t Value | Approx Pr > \|t\| | Lag |
|---|---|---|---|---|---|
| MU | 2410.4 | 1494.2 | 1.61 | 0.1119 | 0 |
| AR1,1 | -0.31785 | 0.12412 | -2.56 | 0.0129 | 2 |

**MA 2 model with First difference**





Residuals can be seen to indicate white noise.

| Conditional Least Squares Estimation | | | | | |
|---|---|---|---|---|---|
| Parameter | Estimate | Standard Error | t Value | Approx Pr > \|t\| | Lag |
| MU | 2380.5 | 1421.7 | 1.67 | 0.0992 | 0 |
| MA1,1 | 0.28393 | 0.12655 | 2.24 | 0.0285 | 2 |

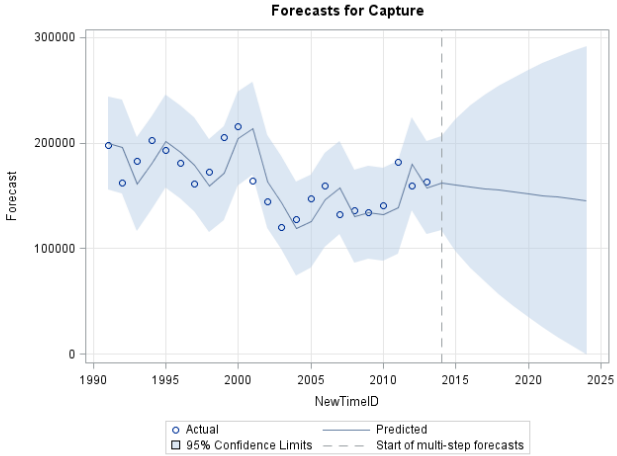
Parameter estimates

## Appendix 26: Captured– All simple forecasts - Data=1990-2013.

Forecasted results for captured fishery only using data from 1990 - SAS output & own work.

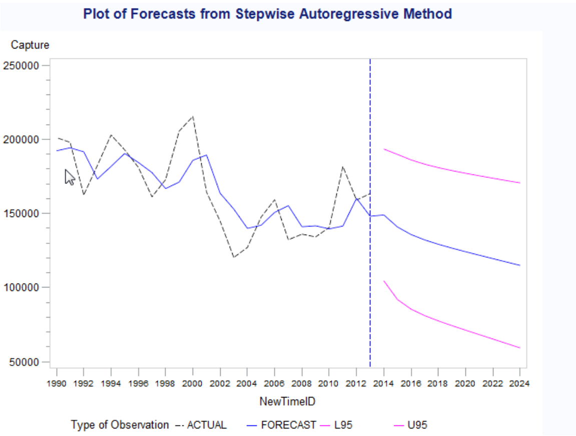
| **Forecasting captured fishing - Data from 1990** | MAPE | 2024 | Std. Dev. |
|---|---|---|---|
| Holt Winters | 11,1 | 113.284 | 27.896 |
| Exponential Smoothing | 18,2 | (67.205) | 57.073 |
| Stepwise Autoregressive | 9,2 | 114.950 | 28.380 |
| Random Walk | | 145.362 | 74.706 |

Using the ARIMA framework the optimal model was identified to be the Random Walk model, which only takes first difference of the data (or can be seen as an AR 1 with the coefficient of 1). No AR or MA parameters were required since from the ACF and PACF plots of the data series it could be seen that all spikes lied within the grey area (critical values) indicating no more modeling were needed. The forecasted values can be seen from the figure below. The model expects a small decreasing trend with an estimated value of captured output in 2024 of 145,362, which fits very well with the assumed trajectory of the sector. As can be seen from the plot the standard deviation is however extremely high (74,706 in 2024), why the model have been considered too inaccurate and therefore discarded.



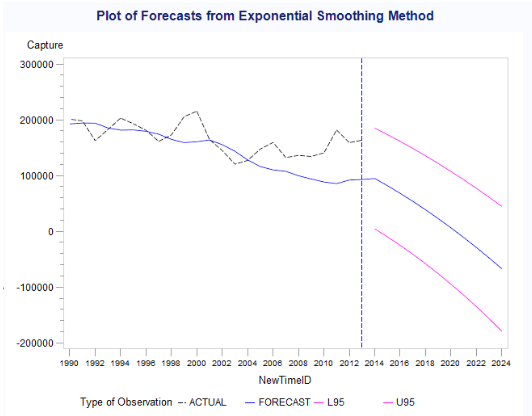

Forecasted capture fishery using a Random Walk model, data=1990-2013.

Of all the simple models the model that best fitted the data was found to be an AR model found through the Stepwise Autoregressive (linear) method, which projected a steeper decline in captured output relative to the Random Walk model. Its 2024 estimation ends at 114,950 with much lower standard deviation than was seen in the Random Walk model (28,380 in 2024). Although the model seems to fit the data rather well given the small number of observations, it has been found difficult to justify reasons for a decline in captured fishing output of this size.

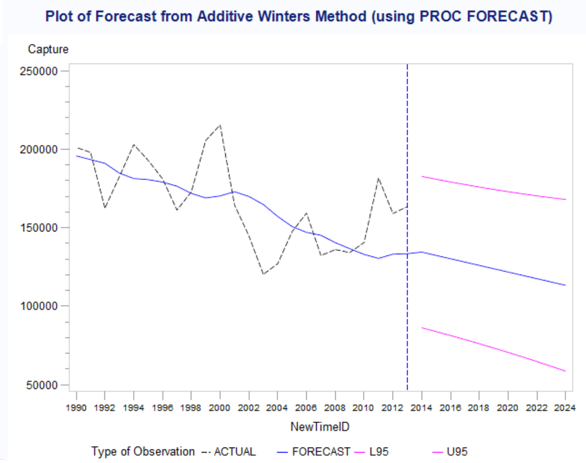



AR model with trend using the Stepwise Autoregressive Linear method with data from 1990-2013.

## Other models

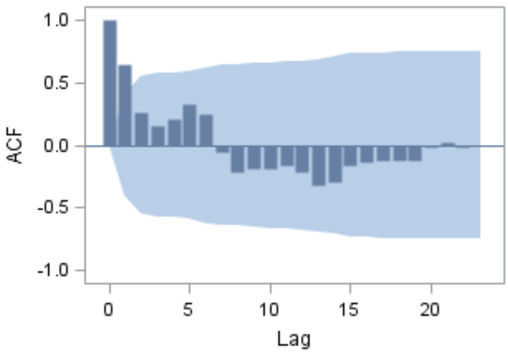


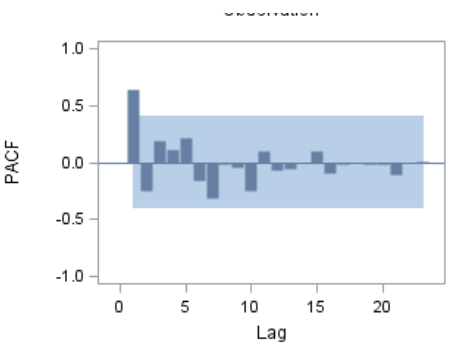

**Exponential Smoothing Quadratic**



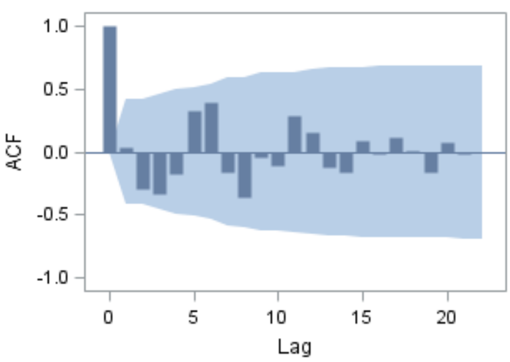

**Holt Winters Linear**

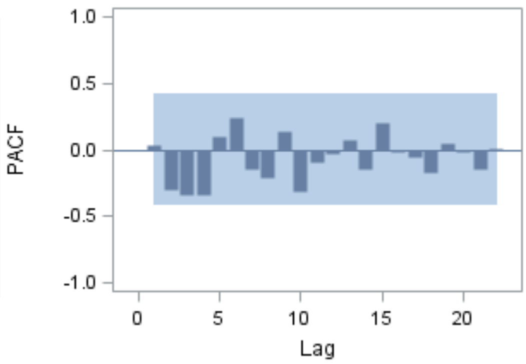
# Appendix 27: Captured Random Walk -Data=1990-2013.




ACP & PACF plot of the normal series data 1990-2013.




ACP & PACF plot of the data series after taking 1st difference.

# Appendix 28: Captured Constant Exponential Smoothing - Data=1950-2013.

**Parameters**

**Basic Forecasting**

**Parameter Estimates**

| Obs | _TYPE_ | NewTimeID | Captured |
|---|---|---|---|
| 1 | N | 2013 | 64 |
| 2 | NRESID | 2013 | 64 |
| 3 | DF | 2013 | 63 |
| 4 | WEIGHT | 2013 | 0.2 |
| 5 | S1 | 2013 | 155155.09 |
| 6 | SIGMA | 2013 | 26806.03 |
| 7 | CONSTANT | 2013 | 155155.09 |
| 8 | SST | 2013 | 2.8969E11 |
| 9 | SSE | 2013 | 4.5269E10 |
| 10 | MSE | 2013 | 718563262 |
| 11 | RMSE | 2013 | 26806.03 |
| 12 | MAPE | 2013 | 20.886036 |

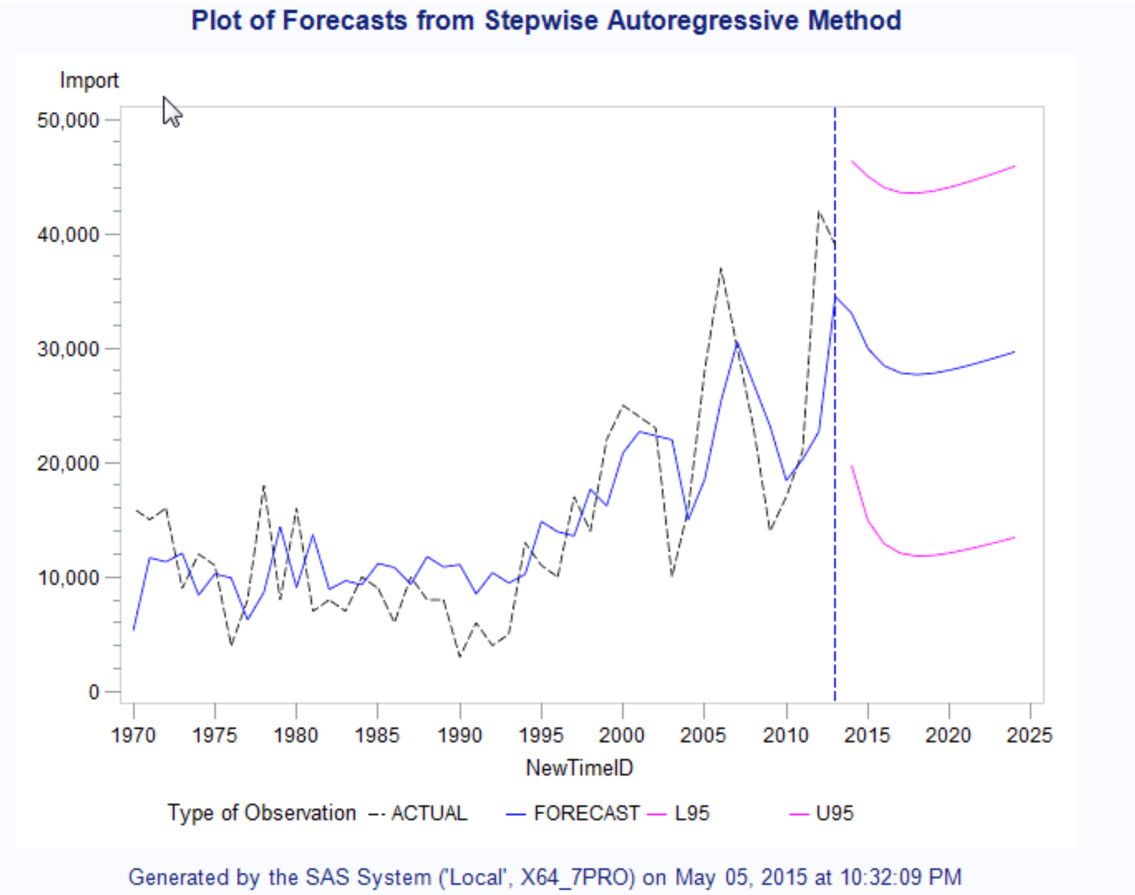
| Actual & forecasted capture production using the Constant Exponential Smoothing | | | |
|---|---|---|---|
| Year | Actual | Forecast | Residual |
| 1950 | 18000 | 22312,5 | -4312,5 |
| 1951 | 18000 | 21450 | -3450 |
| 1952 | 18000 | 20760 | -2760 |
| 1953 | 18700 | 20208 | -1508 |
| 1954 | 17600 | 19906,4 | -2306,4 |
| 1955 | 30100 | 19445,12 | 10654,88 |
| 1956 | 32600 | 21576,1 | 11023,904 |
| 1957 | 25500 | 23780,88 | 1719,1232 |
| 1958 | 22000 | 24124,7 | -2124,7014 |
| 1959 | 22600 | 23699,76 | -1099,7612 |
| 1960 | 12600 | 23479,81 | -10879,809 |
| 1961 | 13500 | 21303,85 | -7803,8471 |
| 1962 | 18400 | 19743,08 | -1343,0777 |
| 1963 | 20100 | 19474,46 | 625,53783 |
| 1964 | 20700 | 19599,57 | 1100,4303 |
| 1965 | 23400 | 19819,66 | 3580,3442 |
| 1966 | 27900 | 20535,72 | 7364,2754 |
| 1967 | 27300 | 22008,58 | 5291,4203 |
| 1968 | 28200 | 23066,86 | 5133,1362 |
| 1969 | 32000 | 24093,49 | 7906,509 |
| 1970 | 33700 | 25674,79 | 8025,2072 |
| 1971 | 28300 | 27279,83 | 1020,1658 |
| 1972 | 30000 | 27483,87 | 2516,1326 |
| 1973 | 29000 | 27987,09 | 1012,9061 |
| 1974 | 28581 | 28189,68 | 391,32487 |
| 1975 | 27341 | 28267,94 | -926,94011 |
| 1976 | 41001 | 28082,55 | 12918,448 |
| 1977 | 42739 | 30666,24 | 12072,758 |
| 1978 | 46344 | 33080,79 | 13263,207 |
| 1979 | 51685 | 35733,43 | 15951,565 |
| 1980 | 47739 | 38923,75 | 8815,2523 |
| 1981 | 57621 | 40686,8 | 16934,202 |

| Actual & forecasted capture production using the Constant Exponential Smoothing | | | |
|---|---|---|---|
| Year | Actual | Forecast | Residual |
| 1982 | 81409 | 44073,64 | 37335,361 |
| 1983 | 98037 | 51540,71 | 46496,289 |
| 1984 | 90860 | 60839,97 | 30020,031 |
| 1985 | 105944 | 66843,97 | 39100,025 |
| 1986 | 119937 | 74663,98 | 45273,02 |
| 1987 | 131283 | 83718,58 | 47564,416 |
| 1988 | 138020 | 93231,47 | 44788,533 |
| 1989 | 145841 | 102189,2 | 43651,826 |
| 1990 | 201096 | 110919,5 | 90176,461 |
| 1991 | 197940 | 128954,8 | 68985,169 |
| 1992 | 162442 | 142751,9 | 19690,135 |
| 1993 | 182381 | 146689,9 | 35691,108 |
| 1994 | 202906 | 153828,1 | 49077,886 |
| 1995 | 192884,74 | 163643,7 | 29241,052 |
| 1996 | 181154,35 | 169491,9 | 11662,45 |
| 1997 | 161202,66 | 171824,4 | -10621,733 |
| 1998 | 172762,58 | 169700 | 3062,5394 |
| 1999 | 205549,39 | 170312,6 | 35236,834 |
| 2000 | 215359,91 | 177359,9 | 37999,992 |
| 2001 | 164411,32 | 184959,9 | -20548,594 |
| 2002 | 144783,33 | 180850,2 | -36066,865 |
| 2003 | 120316 | 173636,8 | -53320,826 |
| 2004 | 127065,07 | 162972,7 | -35907,587 |
| 2005 | 147511 | 155791,1 | -8280,1434 |
| 2006 | 159261 | 154135,1 | 5125,8853 |
| 2007 | 132264 | 155160,3 | -22896,292 |
| 2008 | 136029 | 150581 | -14552,033 |
| 2009 | 134183 | 147670,6 | -13487,627 |
| 2010 | 140572 | 144973,1 | -4401,1014 |
| 2011 | 181702 | 144092,9 | 37609,119 |
| 2012 | 159018 | 151614,7 | 7403,2951 |
| 2013 | 163394 | 153095,4 | 10298,636 |

| Forecasted capture production - using the Constant Exponential Smoothing method | | | | |
|---|---|---|---|---|
| Year | Forecast | L95 | Std Dev | U95 |
| 2014 | 155.155 | 97.602 | 29.365 | 212.709 |
| 2015 | 155.155 | 97.602 | 29.365 | 212.709 |
| 2016 | 155.155 | 97.602 | 29.365 | 212.709 |
| 2017 | 155.155 | 97.602 | 29.365 | 212.709 |
| 2018 | 155.155 | 97.602 | 29.365 | 212.709 |
| 2019 | 155.155 | 97.602 | 29.365 | 212.709 |
| 2020 | 155.155 | 97.602 | 29.365 | 212.709 |
| 2021 | 155.155 | 97.602 | 29.365 | 212.709 |
| 2022 | 155.155 | 97.602 | 29.365 | 212.709 |
| 2023 | 155.155 | 97.602 | 29.365 | 212.709 |
| 2024 | 155.155 | 97.602 | 29.365 | 212.709 |

# Appendix 29: Imported fish forecast – Data=1970-2013.

## Linear Stepwise Autoregressive model



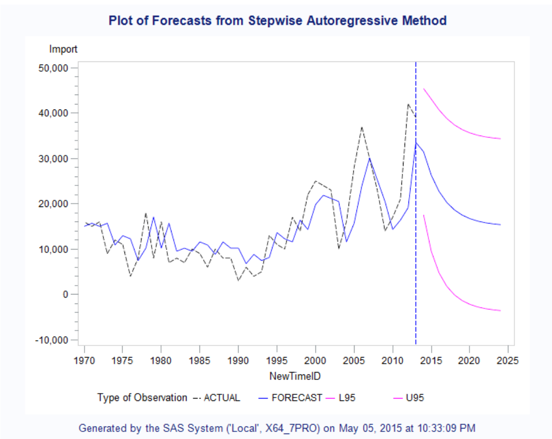

| Forecasted Imported Fish - using the Linear Stepwise Autoregressive | | | | |
|---|---|---|---|---|
| Year | Forecast | L95 | Std Dev | U95 |
| 2014 | 33.051 | 19.743 | 6.790 | 46.359 |
| 2015 | 29.963 | 14.922 | 7.674 | 45.004 |
| 2016 | 28.458 | 12.891 | 7.942 | 44.025 |
| 2017 | 27.827 | 12.068 | 8.041 | 43.587 |
| 2018 | 27.680 | 11.825 | 8.089 | 43.534 |
| 2019 | 27.800 | 11.879 | 8.123 | 43.721 |
| 2020 | 28.068 | 12.087 | 8.154 | 44.049 |
| 2021 | 28.418 | 12.378 | 8.184 | 44.457 |
| 2022 | 28.812 | 12.713 | 8.214 | 44.911 |
| 2023 | 29.232 | 13.072 | 8.245 | 45.392 |
| 2024 | 29.666 | 13.443 | 8.277 | 45.888 |

**Parameter Estimates**

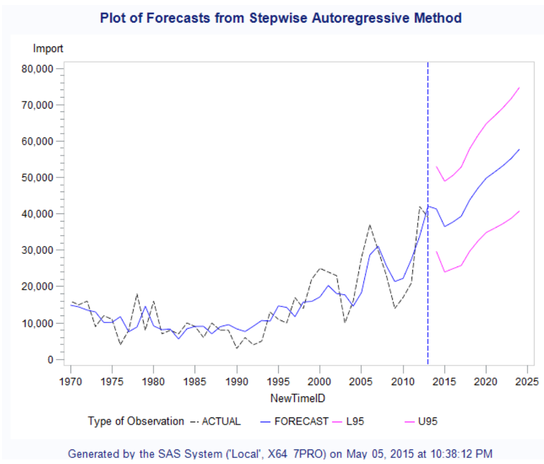
| Obs | _TYPE_ | NewTimeID | Import |
|---|---|---|---|
| 1 | N | 2013 | 44 |
| 2 | NRESID | 2013 | 44 |
| 3 | DF | 2013 | 41 |
| 4 | SIGMA | 2013 | 6372.0046 |
| 5 | CONSTANT | 2013 | 4861.5222 |
| 6 | LINEAR | 2013 | 450.59901 |
| 7 | AR1 | 2013 | 0.5528407 |
| 8 | AR2 | 2013 | . |
| 9 | AR3 | 2013 | . |
| 10 | AR4 | 2013 | . |
| 11 | SST | 2013 | 3.838E9 |
| 12 | SSE | 2013 | 1.6021E9 |
| 13 | MSE | 2013 | 39075494 |
| 14 | RMSE | 2013 | 6251.0395 |
| 15 | MAPE | 2013 | 44.956528 |

## *Other considered models imported fish*

- Both Holt Winters and the Exponential Smoothing models proved to be a terrible fit (both linear, constant and quadratic). All of them did not manage to capture the fluctuations.
- Both the Quadratic and Constant Stepwise Autoregressive method provided okay fits to the data and with acceptable MAPE and Std. dev., however their increasing or decreasing trajectories were found to extreme given the lack of knowledge on how the development of imported fish will be going forward.

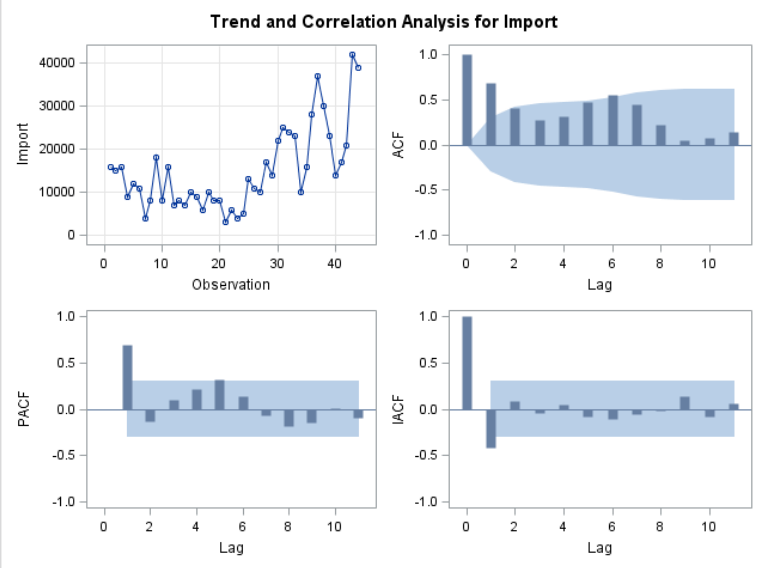



Stepwise Autoregressive Constant

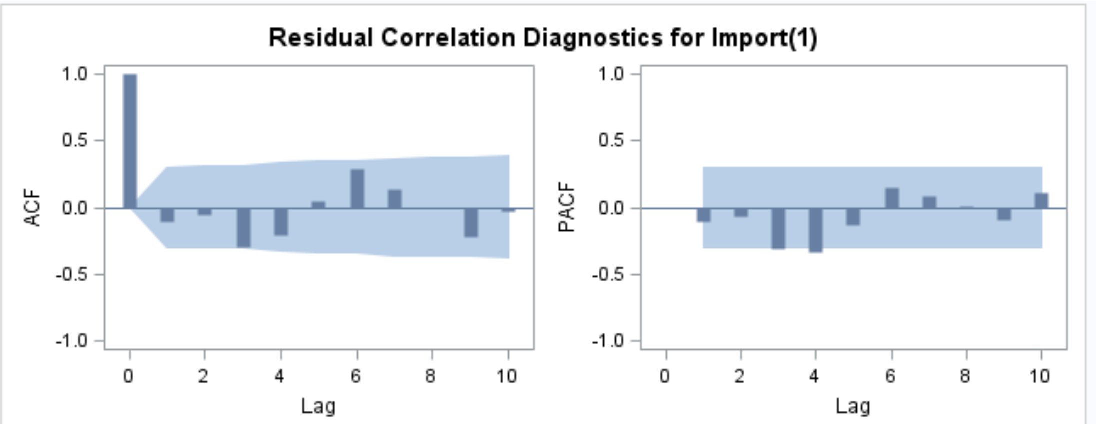



Stepwise Autoregressive Quadratic

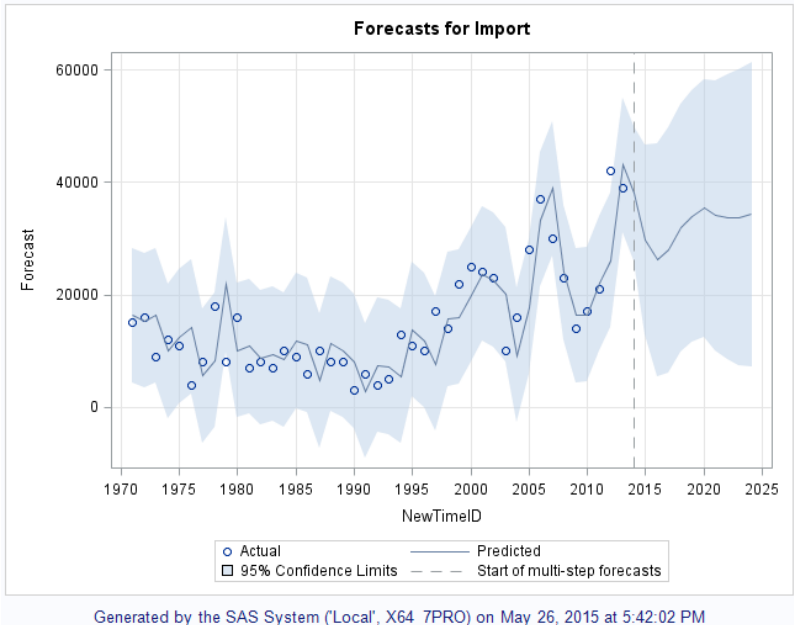
- **ARIMA:** Several models were tried out. First the imported fish series can be seen to be non-stationary from the ACF & PACF plots below, why first difference was taken.



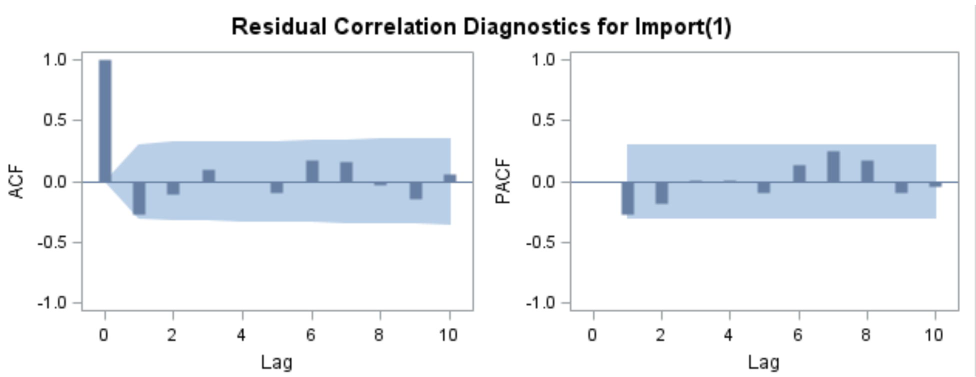

– After taken first difference two spikes can be seen from the imported fish series' PACF in plot at lag 3 and 4, and one borderline spike at the ACF plot indicating either an AR 3 & 4 (or one of them) model or an AR 3,4 & MA 3 (using the borderline spike from the ACF plot and also taking the negative sign of the spike into account).



– Both an AR 3,4 and an AR 3,4 with a MA 3 part fitted the data quite well with similar AIC ratios (see chart below).




– Looking at the residuals (not the series) for the ACF and PACF plots (see below) from the AR 3,4 it can be seen that the residuals can also be assumed to be white noise with all lying within the graded area (critical values).




– Several other models were also tested also with various combination of AR and MA parts, however the best fit and the one with the lowest std. dev. relative to only using models, which the initial ACF and PACF plot of the data series indicated (after taking first difference).

- The AR 3,4 model does capture the data quite well, however it had a higher std. dev. relative to the AR 1 model chosen through the Stepwise Autoregressive method why it was not chosen.
- An AR 1 model without first difference was also tried similar to the one chosen through the Stepwise Autoregressive method, which resulted in an estimated AR coefficient of 0.80696. Although this model also fitted the data well it still had higher std. dev. than the AR 1 model found through the Stepwise Autoregressive model, which also estimated a different AR 1 coefficient of 0.55.

## Appendix 30: Exported fish forecast – Data=1970-2013.

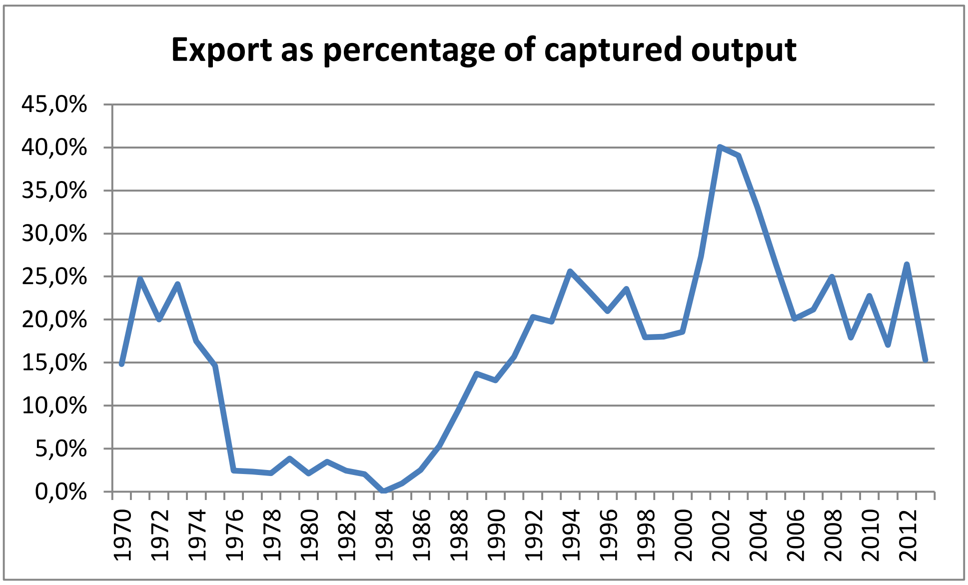



Figure XX: Export of fish as % of captured fish – FAO Food Balance Sheet, KNBS, 2014 & 2015 and own work.

## Appendix 31: Forecasted values for import, export, stock variations and fish used as feed.

### *Forecast assumptions*

#### *Stock variations*

These were only present in five out of the 14 years data was available for with varying signs and no clear pattern. Stock variations have never constituted more than 5.9% of total fish output. It has because of these characteristics been found reasonable to assume no stock variations will be present in the forecasted years.

### *Fish output used as feed*

No proper model was found to estimate Fish output used as feed. The output used as feed has only twice slightly exceeded 5% of total fish output in Kenya and this was back in 2000 and 2002 and since 2003 the data has been fairly stable. An average of the past 10 observations (2004-2013) have been found to be the most optimal method to use for forecasting (median gave almost the same, slightly lower).

## *Forecasted values*

| **Forecasted import, export, stock variations and fish used as feed** | Import | Stock variation | Export | Used as Feed |
|---|---|---|---|---|
| Year | Tons | Tons | Tons | Tons |
| 2006 | 37,000 | (9,000) | 32,000 | 7,000 |
| 2007 | 30,000 | (8,000) | 28,000 | 4,000 |
| 2008 | 23,000 | 7,000 | 34,000 | 5,000 |
| 2009 | 14,000 | 6,000 | 24,000 | 2,000 |
| 2010 | 17,000 | 4,000 | 32,000 | 1,000 |
| 2011 | 21,000 | - | 31,000 | 4,000 |
| 2012 | 42,000 | - | 42,000 | - |
| 2013 | 39,000 | - | 25,000 | - |
| 2014 | 33,051 | - | 37,213 | 2,900 |
| 2015 | 29,963 | - | 37,213 | 2,900 |
| 2016 | 28,458 | - | 37,213 | 2,900 |
| 2017 | 27,827 | - | 37,213 | 2,900 |
| 2018 | 27,680 | - | 37,213 | 2,900 |
| 2019 | 27,800 | - | 37,213 | 2,900 |
| 2020 | 28,068 | - | 37,213 | 2,900 |
| 2021 | 28,418 | - | 37,213 | 2,900 |
| 2022 | 28,812 | - | 37,213 | 2,900 |
| 2023 | 29,232 | - | 37,213 | 2,900 |
| 2024 | 29,666 | - | 37,213 | 2,900 |

- For the Optimal case scenario from year 2016-2024 imported fish are only forecasted as 50% of the values seen above because of the ban of imported tilapia that is expected.

# Appendix 32: Price elasticity

### *Details on data issues*

Several attempts were made to retrieve fish prices from the State Department of Fisheries in Kenya, even making an Agricultural Economist from KARI (Kenya Agricultural Research Institute) making the request, who normally gets special treatment. However they were only able to supply data from 2013 and 2015, and told, which is not enough to perform the analysis. The State Department of Fisheries kept saying they had severe troubles finding the data, and considering the Kenyan culture or normally not admitting if you don't have the answer this has been perceived as they did not have the data.

### *Equation examples*

- $\ln(Y_i) = \alpha + \beta_1 * \ln(X_i) \ldots + u_i$
- **Price elasticity:** $\ln(\text{fish consumption per capita})_i = 0.172 + 0.395 * \ln(\text{whitefish price real}) + u_i$
- **Inverse price elasticity:** $\ln(\text{whitefish price real})_i = 0.025 + 2.030 * \ln(\text{fish consumption per capita}) + u_i$
- **Cross price elasticity (meat):** $\ln(\text{meat consumption per capita})_i = 0.699 + 0.266 * \ln(\text{whitefish price real}) + u_i$

## *Forecasting output*

**Africa Price elasticity: Y=Fish_cap , X=whitefish_price**

**Linear Regression Results**

The REG Procedure
Model: Linear_Regression_Model
Dependent Variable: Fish_cap

| | |
|---|---|
| Number of Observations Read | 21 |
| Number of Observations Used | 21 |

| Analysis of Variance | | | | | |
|---|---|---|---|---|---|
| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
| Model | 1 | 0.04555 | 0.04555 | 77.17 | <.0001 |
| Error | 19 | 0.01121 | 0.00059023 | | |
| Corrected Total | 20 | 0.05676 | | | |

| | | | |
|---|---|---|---|
| Root MSE | 0.02429 | R-Square | 0.8024 |
| Dependent Mean | 0.92301 | Adj R-Sq | 0.7920 |
| Coeff Var | 2.63210 | | |

| Parameter Estimates | | | | | | | |
|---|---|---|---|---|---|---|---|
| Variable | DF | Parameter Estimate | Standard Error | t Value | Pr > \|t\| | 95% Confidence Limits | |
| Intercept | 1 | 0.17231 | 0.08562 | 2.01 | 0.0586 | -0.00689 | 0.35151 |
| Whitefish_price | 1 | 0.39520 | 0.04499 | 8.78 | <.0001 | 0.30104 | 0.48936 |

Generated by the SAS System ('Local', X64_7PRO) on May 17, 2015 at 1:51:53 PM

**Africa inverse price elasticity: Y= whitefish_price , X= Fish_cap**

## Linear Regression Results

The REG Procedure
Model: Linear_Regression_Model
Dependent Variable: Whitefish_price

| | |
|---|---|
| Number of Observations Read | 21 |
| Number of Observations Used | 21 |

| Analysis of Variance | | | | | |
|---|---|---|---|---|---|
| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
| Model | 1 | 0.23403 | 0.23403 | 77.17 | <.0001 |
| Error | 19 | 0.05762 | 0.00303 | | |
| Corrected Total | 20 | 0.29165 | | | |

| | | | |
|---|---|---|---|
| Root MSE | 0.05507 | R-Square | 0.8024 |
| Dependent Mean | 1.89955 | Adj R-Sq | 0.7920 |
| Coeff Var | 2.89901 | | |

| Parameter Estimates | | | | | |
|---|---|---|---|---|---|
| Variable | DF | Parameter Estimate | Standard Error | t Value | Pr > \|t\| |
| Intercept | 1 | 0.02540 | 0.21368 | 0.12 | 0.9066 |
| Fish_cap | 1 | 2.03047 | 0.23113 | 8.78 | <.0001 |

Generated by the SAS System ('Local', X64_7PRO) on May 17, 2015 at 2:54:28 PM

**World Price elasticity: Y=Fish_cap , X=fish_price**

## Linear Regression Results

The REG Procedure
Model: Linear_Regression_Model
Dependent Variable: Fish_cap

| | |
|---|---|
| Number of Observations Read | 21 |
| Number of Observations Used | 21 |

| Analysis of Variance | | | | | |
|---|---|---|---|---|---|
| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
| Model | 1 | 0.02614 | 0.02614 | 22.83 | 0.0001 |
| Error | 19 | 0.02175 | 0.00114 | | |
| Corrected Total | 20 | 0.04788 | | | |

| | | | |
|---|---|---|---|
| Root MSE | 0.03383 | R-Square | 0.5458 |
| Dependent Mean | 1.19659 | Adj R-Sq | 0.5219 |
| Coeff Var | 2.82734 | | |

| Parameter Estimates | | | | | |
|---|---|---|---|---|---|
| Variable | DF | Parameter Estimate | Standard Error | t Value | Pr > \|t\| |
| Intercept | 1 | -0.34488 | 0.32267 | -1.07 | 0.2985 |
| Fish_price | 1 | 0.75817 | 0.15866 | 4.78 | 0.0001 |

Generated by the SAS System ('Local', X64_7PRO) on May 17, 2015 at 3:42:56 PM

**World inverse price elasticity: Y= fish_price , X= Fish_cap**

## Linear Regression Results

The REG Procedure
Model: Linear_Regression_Model
Dependent Variable: Fish_price

| | |
|---|---|
| Number of Observations Read | 21 |
| Number of Observations Used | 21 |

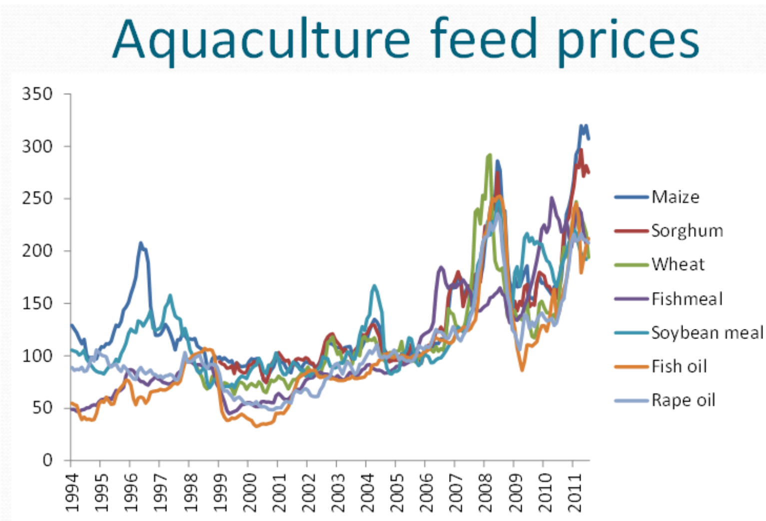
| Analysis of Variance | | | | | |
|---|---|---|---|---|---|
| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
| Model | 1 | 0.02482 | 0.02482 | 22.83 | 0.0001 |
| Error | 19 | 0.02065 | 0.00109 | | |
| Corrected Total | 20 | 0.04547 | | | |

| | | | |
|---|---|---|---|
| Root MSE | 0.03297 | R-Square | 0.5458 |
| Dependent Mean | 2.03314 | Adj R-Sq | 0.5219 |
| Coeff Var | 1.62149 | | |

| Parameter Estimates | | | | | |
|---|---|---|---|---|---|
| Variable | DF | Parameter Estimate | Standard Error | t Value | Pr > \|t\| |
| Intercept | 1 | 1.17169 | 0.18042 | 6.49 | <.0001 |
| Fish_cap | 1 | 0.71993 | 0.15066 | 4.78 | 0.0001 |

Generated by the SAS System ('Local', X64_7PRO) on May 17, 2015 at 3:43:47 PM

**Global aquaculture feed input prices: Reproduction from FAO et al., 2011 page 48.**



# Appendix 33: PoU Sensitivity

| PoU with sensitivity of MDER (using Base) | MDER - 5% | MDER - 3% | MDER - 1% | **Base** | MDER +1% | MDER + 3% | MDER + 5% |
|---|---|---|---|---|---|---|---|
| 2015 | 18.11% | 20.20% | 22.44% | **23.62%** | 24.83% | 27.35% | 29.98% |
| 2016 | 17.62% | 19.62% | 21.78% | **22.92%** | 24.09% | 26.52% | 29.08% |
| 2017 | 17.27% | 19.16% | 21.23% | **22.32%** | 23.45% | 25.84% | 28.36% |
| 2018 | 16.79% | 18.65% | 20.69% | **21.77%** | 22.89% | 25.24% | 27.74% |
| 2019 | 16.25% | 18.10% | 20.13% | **21.21%** | 22.33% | 24.68% | 27.18% |
| 2020 | 15.65% | 17.48% | 19.49% | **20.56%** | 21.67% | 24.00% | 26.48% |
| 2021 | 15.12% | 16.93% | 18.91% | **19.96%** | 21.06% | 23.36% | 25.80% |
| 2022 | 14.75% | 16.46% | 18.35% | **19.36%** | 20.42% | 22.67% | 25.09% |
| 2023 | 14.23% | 15.88% | 17.73% | **18.72%** | 19.75% | 21.96% | 24.33% |
| 2024 | 13.70% | 15.33% | 17.14% | **18.12%** | 19.14% | 21.31% | 23.65% |

| PoU with sensitivity of CV (using Base) | CV -15% | CV -10% | CV -5% | **Base** | CV +5% | CV +10% | CV +15% |
|---|---|---|---|---|---|---|---|
| 2015 | 18.95% | 20.57% | 22.12% | **23.62%** | 25.05% | 26.41% | 27.72% |
| 2016 | 18.28% | 19.88% | 21.43% | **22.92%** | 24.35% | 25.72% | 27.03% |
| 2017 | 17.82% | 19.35% | 20.86% | **22.32%** | 23.73% | 25.10% | 26.41% |
| 2018 | 17.28% | 18.81% | 20.31% | **21.77%** | 23.18% | 24.54% | 25.86% |
| 2019 | 16.73% | 18.26% | 19.76% | **21.21%** | 22.62% | 23.99% | 25.30% |
| 2020 | 16.10% | 17.62% | 19.11% | **20.56%** | 21.97% | 23.33% | 24.65% |
| 2021 | 15.52% | 17.03% | 18.51% | **19.96%** | 21.37% | 22.73% | 24.04% |
| 2022 | 15.10% | 16.54% | 17.96% | **19.36%** | 20.74% | 22.07% | 23.37% |
| 2023 | 14.51% | 15.92% | 17.33% | **18.72%** | 20.08% | 21.41% | 22.71% |
| 2024 | 13.94% | 15.34% | 16.74% | **18.12%** | 19.48% | 20.80% | 22.09% |