Aquaculture value chain analysis in Zambia

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ACRONYMS

AfDB	African Development Bank
APDS	Aquaculture Parks Development Strategy
CEEC	Citizens Economic Empowerment Commission
CSO	Central Statistics Office of Zambia
DoF	Department of Fisheries
DRCR	Domestic Resource Cost Ratio
DRC	Democratic Republic of Congo
FAO	United Nations Food and Agriculture Organisation
FCR	Feed Conversion Ratio
EIB	European Investment Bank
EU	European Union
IAPRI	The Indaba Agricultural Policy and Research Institute
GIFT	Genetically Improved Farmed Tilapia
IFAD	International Fund for Agricultural Development
IGS	Intermediate goods and services
ILO	United Nations International Labour Organisation
LCA	Life Cycle Assessment
LCI	Life Cycle Inventory
LCIA	Life Cycle Impact Assessment
MoFL	Ministry of Fisheries and Livestock
NAqS	National Aquaculture Strategy
NAPD	National Aquaculture Development Plan
NARD	National Aquaculture Research and Development at Mwekera
NAS	National Aquaculture Strategy
NPC	Nominal Protection Coefficient
SADC	Southern Africa Development Community
t	Tonnes (1000 kg)
VCA	Value Chain Analysis
VCA4D	Value Chain Analysis for Development
VGGT	Voluntary Guidelines of the Governance of Tenure
WARMA	Water Resources Management Authority
ZAEDP	Zambia Aquaculture Enterprises Development Project
ZANACO	Zambia National Commercial Bank
ZEMA	Zambia Environmental Management Agency

EXECUTIVE SUMMARY

Context

This report provides an analysis of the aquaculture value chain in Zambia. The analysis is part of a larger project, funded by the European Commission's Directorate-General for International Cooperation and Development (DG DEVCO), entitled “Value Chain Analysis for Development” (VCA4D). The diagnosis of the aquaculture value chain intends to support the European Commission and the Government of the Republic of Zambia in structuring their policy dialogue around the strategic issues that presently hinder the sustainable development and growth of the aquaculture value chain in the country, and opportunities for its development.
Methodology

The assessment consisted of four analyses: functional, economic, social and environmental. All components of the analysis draw on multiple information sources, including primary and secondary data.

The functional analysis provides a general description of the value chain and forms the basis for the analyses in the economic, social, and environmental components. In this analysis, we distinguished between five types of fish farming systems, which are subsequently used in the other three analytical components, differentiated according to the level of intensity of their production, their annual output, the degree of commercialisation of their operations, and the type/technology of aquaculture system. These systems are: semi-subsistence pond smallholders (<400 kg fish/year), commercial pond smallholders (1-5 t/year), medium-scale pond farmers (20-200 t/year), large-scale pond farmers (<1500 t/year), and large-scale cage farmers (1500-4000 t/year). We defined project-specific classes of production volumes, as there is no official classification, but only anecdotal typologies used in government and other literature. Actors downstream in the value chain have been aggregated into three main groups (large wholesales/ importers, “City Ladies” or small retailers, and small wholesalers/ retailers/ butchers / supermarkets).

The economic analysis aimed to provide an answer to the following two framing questions: ‘What is the contribution of the value chain to economic growth?’ and ‘Is this economic growth inclusive?’ This is done through a financial analysis of each actor type (financial accounts, return on investment), as well as an assessment of the consolidated value chain (total value of production, global operating accounts). Secondly, it assesses the economic performance (contribution to economic growth in terms of total value added generated, and the sustainability/viability for the national economy within the international economy (Domestic Resource Cost Ratio, DRCR). Finally, it addresses inclusiveness of growth by examining income distribution (business income, wages), and employment creation and distribution. The analysis is partially conducted with the support of the Agri-Food Chain Analysis (AFA) software, developed by CIRAD.

The social analysis also provided evidence for the framing question ‘Is this economic growth inclusive?’ and aims to answer its primary question ‘Is the value chain socially sustainable?’ This is done through the development of a social profile, which follows six key domains and associated questions: Working Conditions, Land and Water Rights, Gender Equality, Food and Nutrition Security, Social Capital and Living conditions.

The environmental analysis aimed to answer the question ‘Is the value chain environmentally sustainable?’ and uses a Life Cycle Assessment (LCA) methodology in an attempt to do so. LCA consists of four phases, according to how the environmental analysis is organized, namely Goal and Scope definition, Life Cycle Inventory (LCI), Life Cycle Impact Assessment (LCIA) and

Interpretation. The scope of the LCA consists of three areas of protection: Human Health, Resources, and Ecosystem Quality, each associated with a set of environmental impact categories and corresponding indicators. The calculation of relevant environmental impacts in LCA is based on an exhaustive and quantitative inventory of all input and output fluxes over the entire life cycle of the studied system and is carried out using the software SimaPro.

Findings

The supply chain contributes in general to sustainable development in Zambia, yet various economic (trade, performance), social (gender, youth, access to enabling factors), environmental (impacts per unit of production) and technical (yields, management) challenges remain to be overcome.

Aquaculture production in Zambia has seen steady growth in recent years, according to official statistics growing from just over 10 000 t in 2011 to more than 30 000 t in 2016. The semi-subsistence smallholders mainly produce for home consumption, while larger and medium-scale farms, especially cage farms have been mainly responsible for this growth, achieving a higher level of productivity because of their use of high-quality seed, commercial feeds, good management practices and employment of farm labour. These farmers currently supply the majority of farmed fish in the country.

One key objective of the supply chain, besides socio-economic development, is the provision of sufficient and affordable fish to the Zambian population. There is limited data available on the consumption of farmed fish in Zambia, as fish consumption data is generally not disaggregated by source. Fish provides 55% of the animal protein consumed by Zambians and is an important direct source of protein and micronutrients; and often the only accessible and/or affordable source of animal protein for poor households in rural areas. The price of fresh fish has become the lowest among all animal-source foods in Zambia. Increasing annual farmed tilapia production by commercial enterprises in Zambia, and increasing imports (representing ~50% of available fish in the country), have resulted in an increase in supply per capita (from 5.6 kg per capita in 2006 to 14.5 kg in 2016). This is still significantly below the world's average of 19.2 kg/year, but well above the sub-Saharan average of 8.9 kg/year. Zambia's market is supplied by a large volume of imported wild capture fish from other African countries, and farmed tilapia, coming mainly from Asia (especially China), including alleged illegal imports. Markets differ across geographic locations, rural and urban localities, and wealth status of consumers.

Market dynamics are complex: semi-subsistence smallholder farmers sell a small portion of their harvest either at farm gate or at local markets. Mostly women retailers, called City Ladies, operate in wet markets and conduct mobile vending. Dedicated fish stores and butcheries, as well as supermarkets, other grocery stores, hotels and restaurants sell farmed fish. There is one large company that has taken on the role of wholesaler in the farmed fish value chain, featuring a vast distribution network throughout the country supplying, among others, to supermarkets, but some large-scale producers also operate their own outlets. Product differentiation is mainly based on size (small 100-200 g, medium 200-400 g, large 400-600 g) and product (fresh or whole frozen), although other types of product such as fillets are found in supermarkets, packaged and supplied by mainly one supplier. The large wholesalers, who create 27% of the value added receive 39% of the net operating surplus, distribute only 4% of the wages in the value chain. The situation is not inclusive when trading is included within the economic analysis. There is a concentration of wholesale activities, a very limited number of traders buy a large portion of the tilapia alluding to a monopolistic position in the value chain.

Major constraints for the value chain in Zambia include low availability of quality fingerlings, in particular in the northern parts of the country, inadequate extension services, low availability of good quality, affordable feed in particular for the smallholders, and severe lack of technical knowledge and business management skills among smallholder farmers (both the commercial and semi-subsistence). For the medium and large-scale companies, the main constraints relate to lengthy and costly licensing processes and competition with cheaper legal and (allegedly) illegal imports.

The value chain is economically sustainable, given that its activities create revenues for the actors who are partially or totally devoted to the activity. The net operating profits (including the value of self-consumption) range from 390 ZMW per year for the small-scale semi-subsistence pond farmer producing 170 kg to 5.3 million ZMW per year for the large-scale cage farmer producing 2 000 t of fish. Despite sufficiently high margins generated at the production level, prices in the chain (from 15 to 32 ZMW per kg for fresh fish) make farmed fish less competitive compared to imported farmed fish (11 ZMW/kg). This is measured by the Domestic Resource Cost Ratio, which is significantly greater than 1 (DRCR = 1.2).

Nevertheless, the total value added of the aquaculture value chain in Zambia was estimated at 692 million ZMW in 2016 (645 million ZMW of direct value added, plus 47 million ZMW of indirect value added). The total imports are estimated at 319 million ZMW (303 million ZMW of direct imports , plus 16 million ZMW of indirect imports). The contribution of the aquaculture value chain to Gross Domestic Product (GDP) was 0.32% in 2016 and to agricultural GDP 6.1%. The rate of integration into the economy (value added divided by value chain production) was 65%, which indicates a high level of integration.

The Government of Zambia does not provide direct subsidies to companies in this value chain, but the sector has benefited from several aquaculture support projects involving international and national public funds. The total taxes paid to the Zambian state by the actors in the value chain are estimated to amount to 80 million ZMW in direct taxes (the main portion consists of corporate taxes and import duties) and 4 million ZMW in indirect taxes.

The contribution to the balance of trade is negative as the country's imports are high and the exports are low. Imports of tilapia currently account for around 50% of the farmed fish consumed in Zambia. But, there is anecdotal evidence that suggests that exports of feed is beginning to happen to Malawi and Angola and there is also informal cross border trade of farmed fish to the Democratic Republic of Congo, including re-exports of imported frozen Chinese tilapia.
We estimate direct employment in the sector (including part-time employment and self-employment) to be around 20 000 jobs, of which the vast majority is at farm-level and unskilled labour.

The value chain is not socially sustainable nor is the economic growth it has created inclusive. There is a lack of support to smallholder farmers to shift from practicing semi-subsistence fish farming to farming as a business. This has enabled larger operators to dominate within the rather nascent, yet rapidly developing aquaculture value chain. The majority of smaller-scale fish farmers are only equipped to farm fish to improve their food and nutrition security and sell or barter within their locales. While some developments in the input market have occurred, lack of access to microfinance and extension services and vocational training by smaller-scale farmers means they will likely not benefit from this growth.

Larger fish farms employ mostly men as labourers due to the perception that carrying out fish farming activities requires physical strength. Men comprise the majority of fish producers in rural areas due to complex social/land tenure issues. Women tend to get involved in production by feeding fish or maintaining ponds and harvesting. Women are the main traders in both the aquaculture and capture fisheries value chains. Very little processing of farmed fish takes place by larger producers, other than gutting, scaling, and a small portion of farmed fish are filleted. Overall, it appears that youth are not well-integrated throughout the chain.

Certain well-managed systems in Zambia can be considered as environmentally sustainable, as compared with other global cultured tilapia systems. The overall contribution to impacts of the value chain is dominated by human and freshwater toxicity, according to normalised results. These impacts are explained mainly by the agricultural phase of feed production, especially in large cage systems. Feed provision is the main driver of most environmental impacts for all system types. The poorly managed systems (e.g. semi-subsistence ponds) are clearly environmentally unsustainable, while economically they presently generate small profits only because a value is put on the contribution to household food security.
The table below presents a comparative scoring of fish producer types.

Producer type	Yields (kg/ha)	Resilience	Economic performance	Social performance	Environmental performance *
Pond smallholders semi-subsistence	1900	★ Low: very sensitive to the quality and availability of inputs, including water	★ Very low profitability, little value added, few salaried jobs	★ Low input, low output system, yet important contribution to food and nutrition security and some income generation. Lack of women and youth involved.	★ Very low per t Very high per ha
Pond smallholders commercial	5 200	★★ Medium: flexible to varying quality and availability of inputs, thanks to management	★★ Good profitability, moderate value added, few salaried jobs	★★★ More intensive system, with apparent greater economic returns on investment.	★★★ Very high per t Low per ha
Medium-scale pond farmers	7 600	★★ Medium: flexible to varying quality and availability of inputs, thanks to management	★★ Medium profitability, moderate value added, few salaried jobs	★★ Contribution to local employment, potential to supply smallholders with better quality seed. Source of fish for larger markets/better-off households.	★★ High per t Low per ha

Producer type	Yields (kg/ha)	Resilience	Economic performance	Social performance	Environmental performance *
Large-scale pond farmers	16 000	★★★ High: very flexible to varying quality and availability of inputs. If integrated with livestock, close to self-sufficiency	★★ Medium profitability, high value added, medium salaried jobs	★★ Contribution to local employment, potential to supply smallholders with better quality seed. Source of fish for larger markets/better-off households.	★★ High per t Very low per ha
Large-scale cage farmers	880 000	★★ Medium: somehow sensitive to the quality of inputs (feed)	★★ Low profitability, very high value added, contribution to growth (fish, feed, seed), many salaried jobs, not viable in the international economy	★★ Contribution to local employment, potential to supply smallholders with better quality seed. Source of fish for larger markets/better-off households.	★★ High per tonne
Extensive ponds / stocked water bodies	<900	★★★ High: self-sufficient system, but very low output	★ Not studied but likely similar to smallholder semi-subsistence farmers	★★ Lack of available data, but likely provides a source of fish to rural smallholder for food and nutrition security and income	★ Very low per t Very high per ha
* Performance is here understood as the inverse of environmental impacts intensity. The lowest score per category is represented by one star, while the highest is three.					

The contribution of smallholders to the value chain performance is shaped by the following traits:

- Semi-subsistence systems are generally poorly managed, while small-scale commercial systems are managed to some extent or well-managed.
- Small and medium farms contribute 8% of the direct value added to the value chain and receive 20% of the net operating surplus. For the smallholder farmers, the share of the final price at farm gate is high as they sell directly to the final markets (this is also the case for medium and large farmers who sell more directly through their own shops and stores).
- Children do assist their parents carrying out many fish farming duties in rural areas. In rural areas, there is a major division of labour, whereby women exclusively carry out the domestic and caretaking duties, while men engage in tasks that are believed to require more physical strength. Women's access to or ownership of key aquaculture assets are limited, including land, which is due in part to residence norms. There is a total lack of

access to credit in rural areas for both women and men, especially to get involved in fish farming.
- Food crop production and incomes are increasing in rural areas, although there remains seasonal hunger during the rainy/cultivation period (December-March) for some. Piecework is the most common coping strategy during the "hungry" season. Child malnutrition (stunting) rates are still very high in Zambia, although have declined slightly over the past 5-10 years from 45.4% in 2007 to 40.1% in 2013-14. Rural farmed fish production is believed to play a significant role in providing enhanced nutrition to rural people (as farmed fish from larger farms is cost prohibitive for rural people and the urban poor).
- Women's groups, clubs, and farmer associations and cooperatives exist to help organize people and increase production, and women are very active both as members and leaders. However, group fish farming does not lead to productive results.
- Smallholder semi-subsistence systems have higher impacts, per produced t of whole fish, than any other system type due to their lower yields (largely associated to the type of management applied). Smallholder commercial systems, on the other hand, feature the best environmental performance among all systems, and thus a shift from semi-subsistence to commercial systems (small or medium), in terms of management, would considerably lower the negative impacts per t of fish (especially if small systems eventually contribute more to the national production, as it would be desired by the government).

Smallholders face many challenges to succeed in fish farming:
- High cost of feed as well as high costs and lack of access to good quality seed.
- Water access limitations in parts of the country.
- Poor roads and expensive transport, complicating access to inputs and markets.
- Larger-scale operations continue to grow and become the dominant player in the value chain, thus potentially excluding smallholders. Capital-intensive water-based systems could also exclude smallholders.
- Potential displacement of rural dwellers due to the expanding sector.
- Low access to labour-saving technologies by rural dwellers.
- Water pollution by aquaculture effluents.

The contribution of large producers to the value chain determined by their current characteristics:
- Large-scale systems are well-managed (feeding, fish reproduction and water).

- The large-scale cage farmers contribute 55% of the value added and receive 21% of the net operating surplus. Moreover, the latter distributes 78% of the wages in the value chain. The large players benefit from comfortable margins when they source through imports.

- Conditions for people working in formal employment in Zambia across sectors are generally good. Labour laws in Zambia are in line with international standards and larger farm managers/owners appear to respect them. Job safety practices at larger cage farms and feed mills and wholesale centres were evident during mission visits and there was no evidence of child labour on large farms.

- The new Lands Act of 1995 has a provision for the conversion of customary tenure into leasehold tenure, which has enabled large tracks of customary lands to be converted to state land, with displacement of people as a result. The Voluntary Guidelines of the Governance of Tenure (VGGT) are not well known or used by large-scale investors (in general) who displace people when they acquire land. It appears larger fish farms in Zambia (broadly) adhere to the VGGT. The Zambia Environmental Management Agency

(ZEMA) requires large farms to carry out an Environmental Impact Assessment (EIA) before operating.
- On larger farms, women are excluded from participating in most areas of production.
- The relationship between City Ladies and certain large operators is important as these female traders move a significant amount of fresh farmed fish daily. In rural settings, high levels of social capital exist, which can be regarded as both a positive and negative attribute.
- Large cage systems are more efficient than large pond systems, due to comparative feed conversion ratios (FCRs), and both systems are notably more environmentally efficient than poorly managed ones of all sizes (extensive, smallholder subsistence). Only large pond systems treat the polluted waters by means of constructed wetlands and other mechanisms.

Large producers also face certain challenges:
- There is price competition among large commercial players, who also need to compete with uncontrolled imports (including often lower-quality fish).
- Long and complicated licensing processes for medium/large-scale farms.
- Gender stereotypes and limited roles for youth in the value chain.
- Indirect environmental impacts due to commercial feed based on dedicated food crops.
- Water pollution by aquaculture effluents.

Recommendations

Both smallholders and large producers could contribute more and better to the sector, the economy and society in general, by overcoming these issues and limitations. Based on this assessment, several recommendations may be offered.

Innovations and strengthening aquaculture development policies and strategies

- Ensure that small-scale farmers can benefit from the recent innovations introduced by large-holders, for instance feed and seed efficiencies. However, this should not rely on linear developmental strategies that assume that progress achieved in the industrial sector automatically percolates to smallholders.
- Policy action should be tailored according to the type of aquaculture system and actors.
- Explore a more balanced development model of the sector, based on favouring the inclusiveness of smallholder extensive/semi-intensive aquaculture in order to satisfy the diversity of markets and consumers of farmed fish.
- Support developments and investments in hatcheries and nurseries, while promoting recognition of the value of larger seed, would likely improve access to seed by smallholders.
- Ensure that efforts to increase supply of microfinance to farmers is accompanied by efforts to strengthen technical knowledge on aquaculture and business skills, as without the two, farmers are highly likely to fail and become indebted.
- Linking rural smallholder farmers to output markets, via appropriate strategies (e.g., organization through cluster farming and aggregation or out-grower schemes) must be components of efforts to increase smallholders' access to inputs, microfinance, training, and the like.
- Clear gains can still be made among the small and medium farms. A focus on efficiency will not only be beneficial to economic performance, but will also have a positive impact on environmental performance.
- Before financing and promoting small-scale cage systems, test the feasibility of pro-poor cage farming with smallholder farmers (e.g. as an outgrower scheme with larger operators).

- There is need to design and test appropriate aquaculture-related labour-saving technologies with women, men, and youth.
- Test/promote integrated aquaculture agriculture systems and water management to enhance productivity of smallholders.
- For aquaculture to expand the main target needs to be on locations where access to water is not an issue as the additional costs for pumping of water are a major constraint for economic sustainability and profits. Either declare water-scarce areas as off-limits for year-round pond aquaculture or, after detail study of those areas, design appropriate technologies/systems designed to fit the circumstances.
- Fish farming as an individual business should be promoted and not as a group enterprise, which is closer to the widespread agricultural ways in Zambia.
- Diversify strategies for increasing fish availability in the country, by supporting the types of systems producing lower environmental impacts, namely well managed pond systems in water-abundant regions and large cage systems in new large water body locations (to prevent water pollution due to high concentration of cages in a few sites).
- Encourage the treatment of used waters with high organic loading.
- As more feed mills will begin targeting rural farmers to secure raw materials for increased production of feed, research testing alternative ingredients for use in fish feeds to avoid food/nutrition insecurity in rural (but also urban) areas is needed.
- Optimise feed formulations for increased digestibility and mechanic properties, thus generating less faeces and uneaten feed.
- Curbing fish imports (by border enforcement to reduce illegal imports and custom barriers to discourage legal imports of lower quality fish), while implementing policies that enable smallholders to compete (mainly to improve training and access to inputs and financing mechanisms), would even the competitive field, benefiting the entirety of the value chain. The immediate potential reduction in fish availability for the poor should be concurrently (and thoroughly) considered.
- Government should be careful to help expand the sector but not at the cost of rural people's lives and livelihoods by ensuring large-scale farms adopt and implement sound participatory processes when acquiring land or expanding production.

Capacity development

- Greater investments are needed in aquaculture training at all levels to ensure the current technical and vocational institutes have adequate personnel to teach, students receive enough practical experience, and rural farmers have access to such training as opposed to only that provided occasionally (if at all) by fisheries extension officers.
- Internship/apprenticeship programs with the private sector will help ground students' (and in particular youths') technical training and provide real-life vocational training experiences to ensure their skills development training is relevant to the private sector when seeking gainful employment.
- More effective extension services provided by the agricultural sector may be emulated for aquaculture, once or if the required critical mass is achieved. This would improve access by smallholders to both technical know-how and inputs.

Gender and youth

- Greater efforts are needed to bring women and youth more holistically into aquaculture production in rural areas and design/implement affirmative action-like policies that would ensure a large percentage of women are hired as labourers on larger farms. Adopting a gender transformative approach (e.g., engaging men, addressing harmful norms and power relations) would help ensure change is long lasting.

- Programs aiming to integrate more women into rural aquaculture activities must keep in mind women's significant role carrying out unpaid tasks so as to not inadvertently burden them with extra work while promoting aquaculture more generally.
- Engage local leaders and Government to improve women's and youth's access to land and water resources in rural areas for fish farming and other aquaculture-related value chain activities (e.g., production of key feed ingredients).
- Expanding the use of ICTs throughout the aquaculture value chain for enhanced site selection, investment, monitoring fish growth, health, and water quality, understanding market price differences and linking to wholesalers and retailers, and for knowledge-seeking reasons. How these could be used by rural youth and to provide paid-services opportunities for youth could be further explored.
- Greater understanding the aspirations of rural and urban youth to get involved in the aquaculture value chain is an important scoping activity to ensure various entry points for youth are relevant and enable their sustained participation.

Relevant issues requiring further in-depth analysis

- Precise understanding of the extent of rural people involved in fish farming throughout the country (e.g., population census of rural fish farmers, by sex and age), including their current levels of production and productivity.
- Design and testing of appropriate aquaculture technologies and approaches with rural farmers to increase productivity, improve water management, and access higher-quality inputs (better feed and seed).
- Precise understanding of the levels of fingerling production and sales in each district/province.
- Identification of successful innovative approaches to extension/outreach for rural farmers.
- Identification of novel and effective input (seed and feed) distribution systems for rural farmers.
- Identification of novel and effective microfinance options for rural farmers.
- Further research on the extent to which water-based systems displace or disrupt lives and livelihoods (e.g., fishing).
- Dedicated environmental assessment of agriculture providing feed inputs, and related research on suitable crops as alternative input feeds.
- Market and socio-economic studies for more detail understanding of informal trade, and the effects of imports, of initiatives by development aid institutions, and of the national demand for processed fish.

1 INTRODUCTION

This report provides an analysis of the aquaculture value chain in Zambia. The assessment is part of a larger project, funded by the European Commission's Directorate-General for International Cooperation and Development (DG DEVCO), entitled "Value Chain Analysis for Development" (VCA4D). The VCA4D project is part of the European Union's "Inclusive and Sustainable Value Chains and Food Fortification" Programme. The objective of this study is the description and analysis of the aquaculture value chain in Zambia, using the evidence-based, largely quantitative, toolkit developed/ compiled by DG DEVCO (methodological support for analysis and development of inclusive and sustainable value chains). This diagnosis of the aquaculture value chain is intended to support the European Commission and the Government of Zambia in structuring their policy dialogue around the strategic issues that presently hinder the sustainable development and growth of the aquaculture value chain in the country. It also highlights relevant issues and risks for the value chain, and areas for more in-depth analysis.

The Vision 2030 of the Zambian government aims for an efficient, competitive, sustainable and exports-oriented agriculture sector that ensures food security and increased income by 2030. The EU through its 11th EDF 2014-2020 National Indicative Programme is supporting the Zambian Government in these efforts with a view of ensuring higher and more sustainable income for rural households, improving food and nutrition security and improving environmental sustainability and climate change resilience. In this political context, an interest in the development of the emerging aquaculture sector is arising in Zambia.

The African Development Bank (AfDB) has started a 40 million USD project on the development of so-called "Aquaparks", following an approach supported by the FAO. The project is a pilot test of the viability and efficiency of such a business model in the context of Zambia. In addition, the European Investment Bank (EIB) is at an early stage of identifying a possible blending operation also in the field of aquaculture. The analysis of the aquaculture value chain in Zambia presented in this report, therefore, would be useful to help highlight potential technologies, models, and approaches of intervention as well as risks (and mitigation) in the aquaculture sector for the EUD to Zambia and the EIB for their project identification and approach.

This assessment was implemented over a period of one-year, between February 2017 and January 2018, and included two missions by the team of about two weeks each in duration (26 Feb - 6 Mar and 29 May – 9 Jun). The team who implemented this study consisted of the following members:

- Arie Pieter van Duijn, Wageningen Economic Research, the Netherlands, economic expert and team leader from February until April 2017
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- Steven Cole, WorldFish, Zambia, social expert
- Angel Avadí, CIRAD, France, environmental expert
- Charles Muwe Mungule, Muwe consultancy, Zambia, national expert

2 THE METHODOLOGY

2.1 DG DEVCO VCA methodology

The methodology used in the assessment aims at generating evidence, supported by a list of indicators measured quantitatively or based on expert assessments that together provide an answer to four framing questions:

1. What is the contribution of the value chain to economic growth?
2. Is this economic growth inclusive?
3. Is the value chain socially sustainable?
4. Is the value chain environmentally sustainable?

The analytical process comprised four components:
Functional analysis: provides a general mapping and description of the main actors, activities, and operations in the value chain, an overview of the products and product flows, the major production systems, a description of the main governance mechanisms in the chain, and a short description of (known) constraints. The functional analysis formed the basis for the analyses in the other three components. The analysis was mainly based on key informant interviews and structured questionnaires with both value chain actors and key experts, complemented with secondary data.

Economic analysis: firstly, consists of a financial analysis of each actor type (financial accounts, return on investment), as well as an assessment of the consolidated value chain (total value of production, global operating accounts). Secondly, it assesses the economic performance (contribution to economic growth in terms of direct and indirect value added generated, and the sustainability/viability for the national economy within the international economy (Domestic Resource Cost Ratio). Finally, it addresses inclusiveness of growth by examining income distribution (business income, wages), and employment creation and distribution. Data were derived from secondary data sources (articles, reports, statistics), key informant interviews, and structured questionnaires. The analysis was (partially) conducted with the support of the Agri-Food Chain Analysis (AFA) software, developed by CIRAD.

Social analysis: explores whether the aquaculture value chain is socially sustainable. It also contributes to discussion on whether economic growth in the value chain is socially inclusive. The social analysis drew on multiple information sources, including secondary data and field data from aquaculture producers at different scales, hatchery owners, processors, input suppliers, traders, and other government and non-government stakeholders. The social analysis followed the six domains and associated questions specified in the methodology and social analysis software: working conditions, land and water rights, gender equality, food and nutrition security, social capital and living conditions.

Environmental analysis: evaluates the environmental sustainability of the value chain. The analysis was conducted using Life Cycle Assessment (LCA). LCA consists of 4 phases, after which the environmental analysis was organised, namely Goal and scope, Life Cycle Inventory (LCI), Life Cycle Impact Assessment (LCIA) and Interpretation (EC-JRC 2010; ISO 2006). The scope of LCA focused on three areas of protection: Human health, Resources and Ecosystem quality, to which a set of environmental impact categories and corresponding indicators are associated. The calculation of relevant environmental impacts in LCA was based on an exhaustive and quantitative inventory of all input and output fluxes over the entire life cycle of the studied system, based mainly on field-collected primary data and complemented with secondary data (scientific and grey literature).

2.2 Scope of the Zambian aquaculture value chain analysis

The vast majority of aquaculture production in Zambia currently consists of tilapia species, namely *Oreochromis niloticus, O. andersonii, O. macrochir, O. tanganicae,* and *Coptodon rendalli*. In addition, there is some production of carps, clarias (African catfish, various species in the *Clariidae* family) and crocodiles. The major focus of the analysis presented in this report is on the production of tilapia, as it has been estimated to represent up to 99% of the total production in the country (DoF, pers. comm.). There is no particular geographical focus of the analysis, however in order to include the diversity of systems, scales, and levels of intensity, a number of specific provinces were targeted, which together make up the majority of production for each of those systems and scales. The larger producers of seed, feed, and fish are concentrated in specific areas in and around Lusaka and Siavonga, and thus, our interviews with larger producers were mostly focused in Southern and Lusaka Provinces. For smallholders, we attempted to include a larger geographical spread encompassing several other provinces. There seems to be some level of homogeneity among smallholders' production systems and behaviours.

2.3 Data collection

2.3.1 Primary data

Primary data were collected during two missions by the team in Zambia, and through follow up with key respondents after the second mission. The first mission took place from 26th of February until the 6th of March 2017 and the second from the 29th of May until the 9th of June 2017. Detailed work plans for the first and second missions are provided as Annex 1. The first mission was largely a scoping one, and took place mainly in and around Lusaka and in the Southern Province, where the larger producers are located. Courtesy calls were held with key government officials including the Permanent Secretary of MoFL, Senior DoF officers, and the European Union Delegation in Zambia. The first mission was also used for team preparatory meetings aimed at finalising the mission's work plan. A number of meetings were held with key individuals and institutions to gain insights and data appropriate for conducting the functional analysis, while laying the foundation for in-depth data collection relating to the economic, environmental and social analyses.
The second mission mainly focused on collecting detailed data through a survey developed to combine questions of the economic and environmental analysis in particular, while collection of data for social analysis was conducted using both a structured questionnaire and focus group discussions.

The second mission focussed more on smallholders and on investigating the purported progress in developing Aquaparks in the country. The team travelled to Northern, Copperbelt, and Northwestern Provinces (see map in Figure 1).

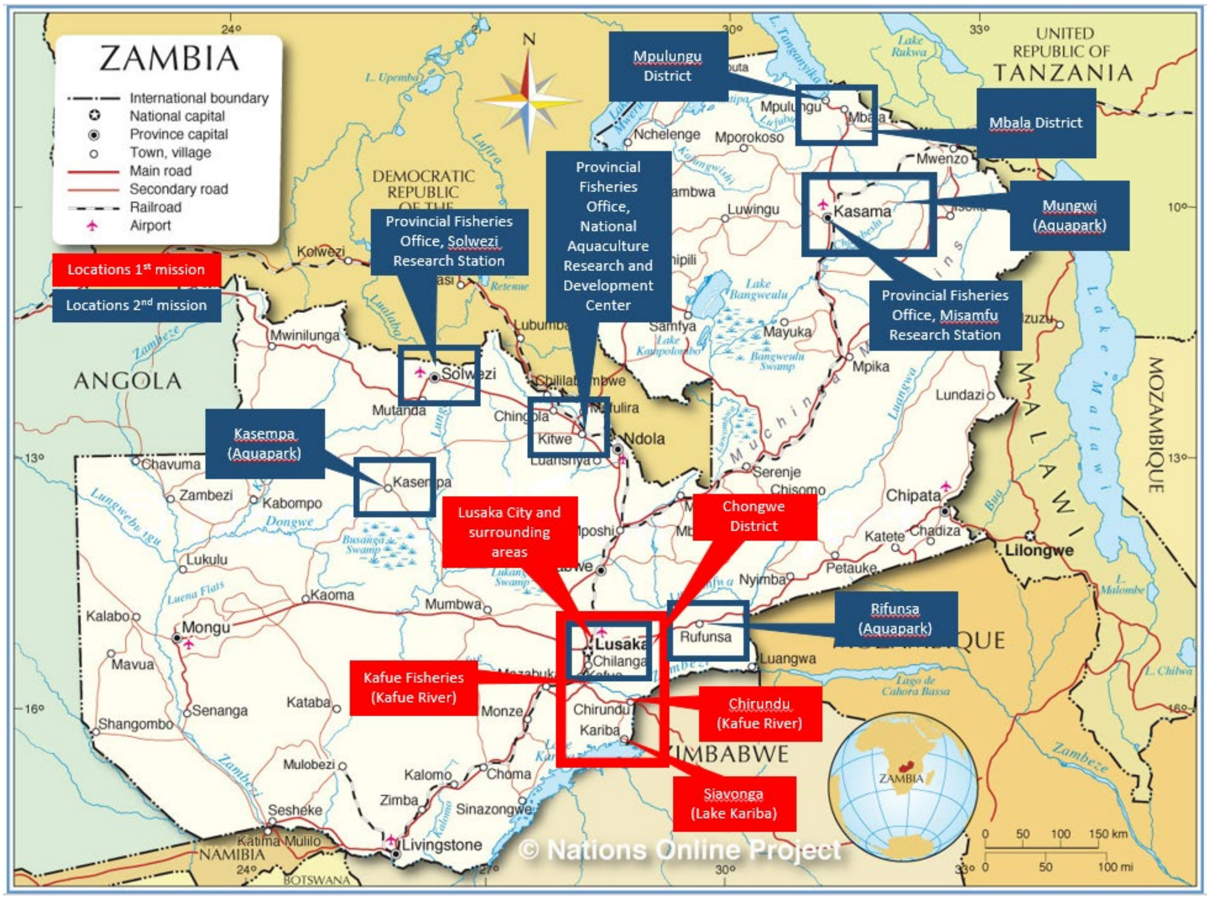

FIGURE 1. MAP OF FIELDWORK LOCATIONS

A total of 89 people were interviewed, covering a range of actors (see Table *1*). During some of the producers' interviews, and later via email, a representative dataset of primary economic and environmental data was obtained from over 20 producers of all types, as well as feed producers, and commercial and government seed producers.

	1st mission: 26 February – 6 March 2017			2nd mission: 29 May – 9 June 2017		
Stakeholder/ value chain node	**Men**	**Women**	**All**	**Men**	**Women**	**All**
Feed (pelleted)	2	0	2	0	2	2
Hatchery	4	1	5	0	3	3
Production						
Cage	2	1	3	0	1	1
Pond	5	1	6	21	1	22
Wholesale	1	4	5	1	0	1
Processing	3	0	3	1	0	1
Retail	3	0	3	1	1	2
Sub-total	**20**	**7**	**27**	**24**	**8**	**32**
Fisheries Administration	10	0	10	0	3	3
Fisheries Education Institutions	2	1	3	0	0	0
Commercial Banks	1	0	1	0	0	0
Other Financial institutions	2	1	3	0	0	0
Experts/ NGOs	5	0	5	0	0	4
TOTAL	**40**	**9**	**49**	**24**	**11**	**39**

TABLE 1. OVERVIEW OF KEY INFORMANT INTERVIEWS

2.3.2 Secondary data

Secondary data have been used extensively to model crops in the environmental analysis. Detailed (primary) data on the production of feed inputs (maize, soya, imported animal protein such as fishmeal) is beyond the scope of the study, and can benefit from the insights on another VCA4D study on the Zambian egg value chain (which may analyse as well maize and soya production). The social analysis also makes extensive use of the secondary literature and data. Aquaculture production and trade data were obtained from the Department of Fisheries.

3 Functional analysis

3.1 Overview of the sector

Located in the southern part of Africa, Zambia is a land-locked country with a total land area of 75 million hectares and a population of about 15.5 million (Central Statistics Office of Zambia (CSO), 2016). Out of its total land area, about 42 million hectares (58%) are suitable for agricultural production and generally receive favourable rainfall. The country has five main rivers and several major lakes and therefore has an abundant supply of water, which gives the country potential for engaging in aquaculture.

Traditionally, capture fisheries has made up the vast share of domestically produced fish in Zambia, however in recent years capture fisheries production has fluctuated, while aquaculture production has seen a steadily increasing trend (Figure 2). At the same time, fish imports have increased rapidly, accounting for 52% of total fish supply in 2016 (DoF, 2016). With capture fisheries production is likely to remain stagnant or even decline, and with the desire to curb imports of fish into the country, aquaculture production is becoming increasingly important to supply the Zambian population with fish for consumption.

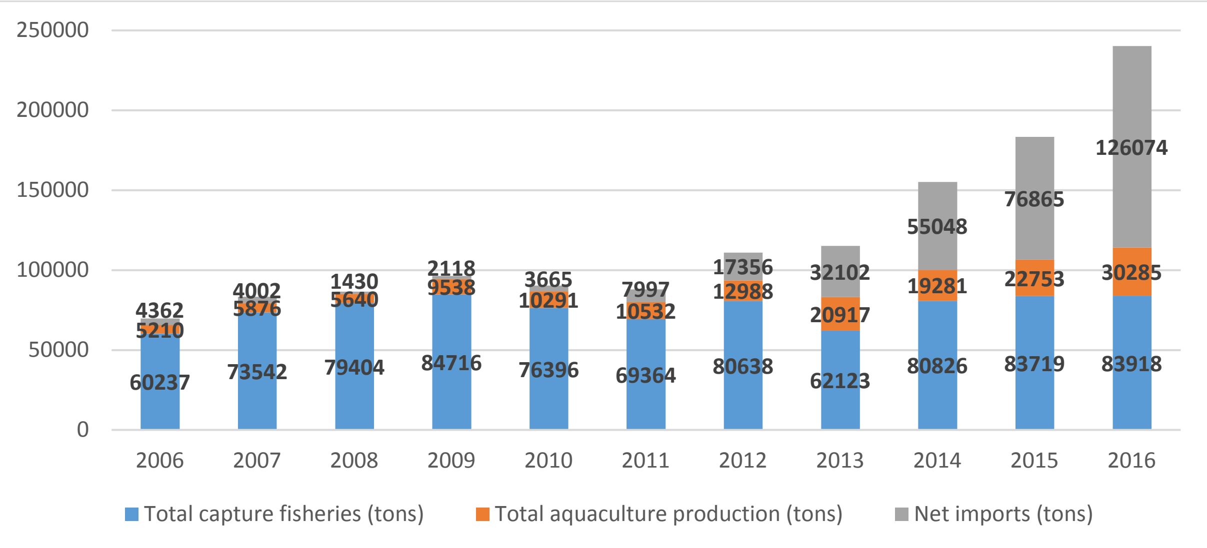

FIGURE 2: TOTAL SUPPLY OF FISH IN ZAMBIA IN T (2006-2016) SOURCE: DOF, 2016.

The recent growth in domestic aquaculture production (mainly tilapia) has now made Zambia the sixth-largest producer of farmed fish in Africa. Aquaculture production quadrupled in a decade to 30 285 t in 2016 (DoF 2016). Not only has the volume of production dramatically changed over the last decade, but also the composition of production. While extensive and small-scale systems now account for 26% of total production, this was 75% a decade ago. This is both due to rapid growth of the large-scale commercial sector, as well as a decline in production of the small-scale sector (DoF 2012 and 2015 quoted by WordFish, 2014). Presently, over three quarters of production comes from commercial aquaculture, particularly from cage culture on Lake Kariba and from large-scale pond-based enterprises (Table 2). Imports of farmed fish have been estimated at 28 000 t (both legal and illegal, see Section 3.2.1).

Type of operation	Estimated number of enterprises	Total volume (t)	Share in domestic production (%)	Share in total volume (%)
Extensive ponds / stocked water bodies	-	1705	5.4%	2.9%
Small-scale semi-subsistence pond farmers	11000	2 000	6.3%	3.4%
Small-scale commercial pond farmers	853	2 139	11.1%	5.9%
Medium-scale pond farmers	7	1000	3.2%	1.7%
Large-scale pond farmers	13	2 343	7.4%	3.9%
Large-scale cage farmers	12	21 089	66.7%	35.4%
Imported farmed fish	-	28 000	-	47.0%
Total sector		**58 276**		

Table 2: Overview of the farmed fish sector in Zambia by source (2016) Source: DoF, 2016 and authors' estimates.

3.2 Value chain mapping

3.2.1 Value chain actors

The farmed fish value chain in Zambia shows a dichotomy between, on one hand the extensive smallholder sector, supported by government-run services and little access to inputs and markets, and on the other hand a burgeoning commercial sector where a few pioneering lead firms have shaped the commercial value chain and dominate production (Kaminski et al., 2017). An overview of the aquaculture value chain in Zambia is presented in Figure 3. Economic inputs (financing mechanisms) are not indicated.

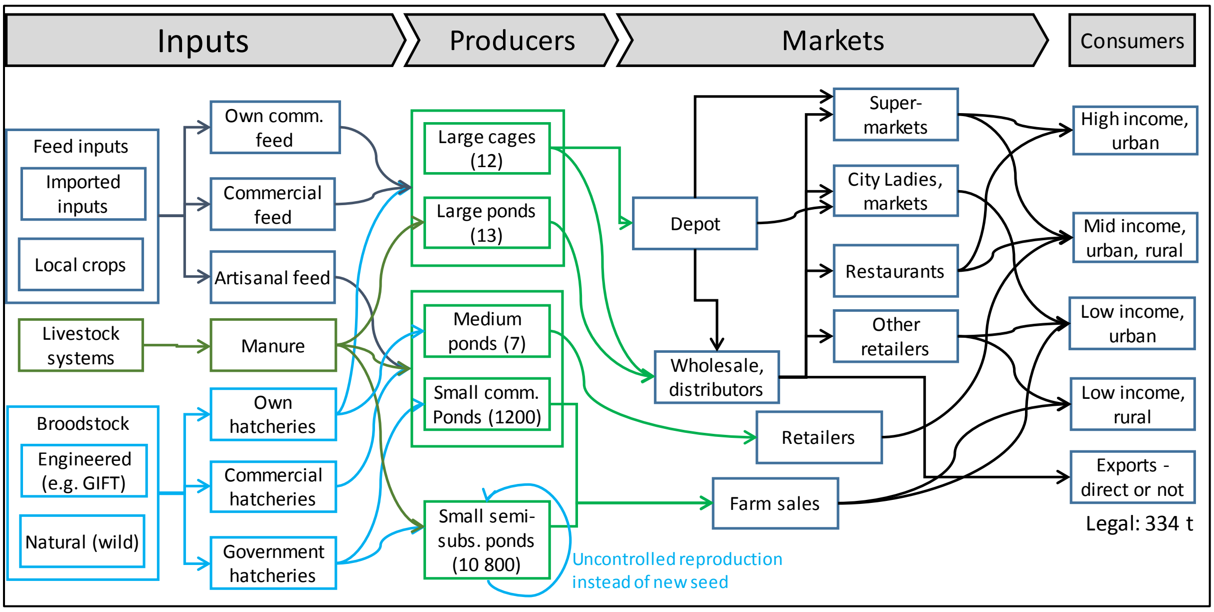

Figure 3. Value chain map featuring material inputs

We developed coherent typologies for feed and seed providers (Inputs), producers, and distribution channels (Markets). The different types of entities in each group interact in identifiable manners, thus establishing a verifiable number of combinations (anchored around the producers, as shown in Annex 2.

Producers

In the analysis, we distinguish between five types of fish farmers, who can be differentiated based on the level of intensity of their production, the degree of commercialisation of their operations, and the type of aquaculture system (Figure 4). We found no evidence of large land- or cage-based system producing any species other than *O. niloticus*, while medium-sized systems do indeed produce other species. Regarding the volume of production of each type, we defined classes[1] specific to this project. These five types are described below.

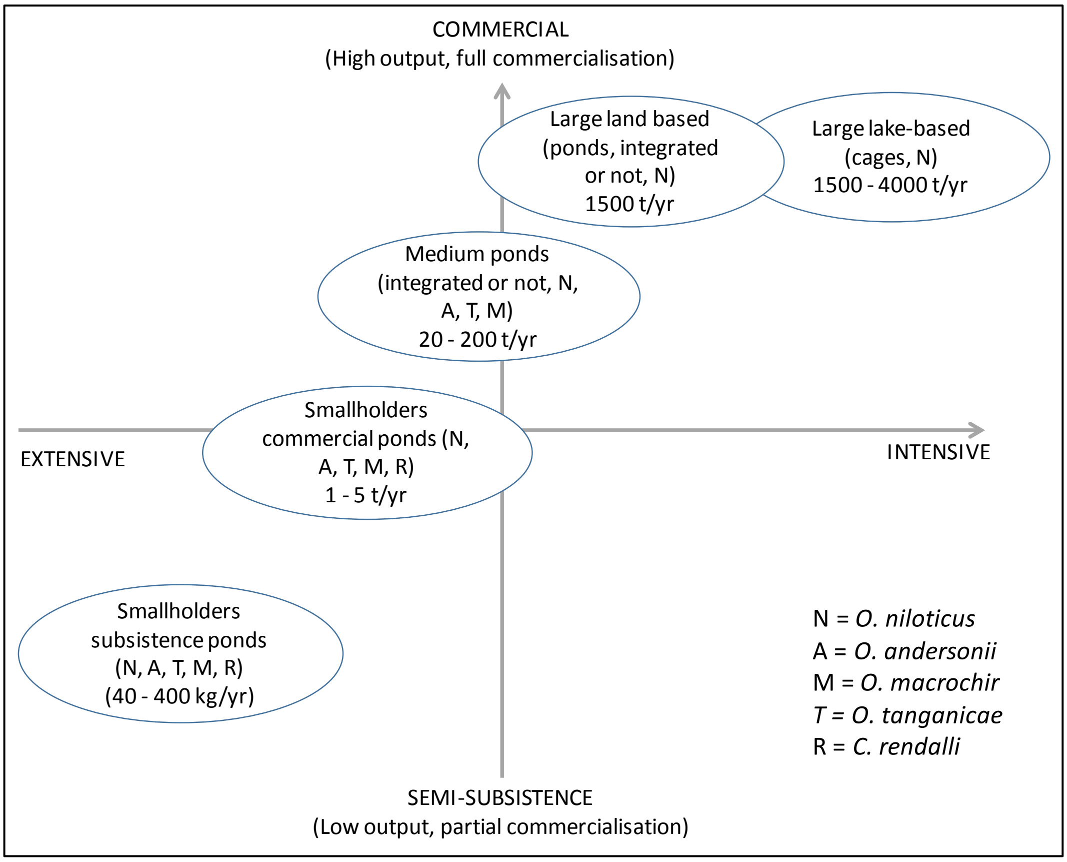

FIGURE 4. TYPOLOGY OF FISH FARMERS

Small-scale semi-subsistence pond farmers (~7% of production): These farmers conduct fish farming as a secondary/tertiary activity, employ very extensive systems of production, and the main use of fish is for home consumption although sales also provide some important cash income for household expenses. They produce between a few tens and a few hundred kg of fish per year. They also use fish as a barter item, exchanging for labour and as a gift to friends and relatives. These farmers usually operate only a few ponds. They tend to use recycled seed from within their locales, apply minimum management (including water management), do not use commercial feeds, employ a partial harvest strategy, and as a result, production intensity of these farms is low, and labour use on the farm is limited to family labour, when other activities require less attention (see also Kaminski et al. 2017). Yield of these farms is also low due to limited technical capacity among farmers and lack of use of (quality) feeds and poor-quality (often inbreed) seed. These farmers usually sell most of their fish at the pond side/farm gate or in a nearby local market. According to government statistics (DoF 2017) 11 853 of these farming systems exist (includes

[1] There is no official classification of fish farming systems in Zambia. There are anecdotal typologies used in government and other literature, but the existing official definitions were defined for agricultural entities, and are not adaptable to aquaculture.

“semi-subsistence” and “commercial”), but not necessarily all of them are currently in operation. They often are highly dependent on government/non-government organisations for support[2] (either technical or financial).

Small-scale commercial pond farmers (~7% of production): These farmers likely make up a small portion of the estimated 11 853 small-scale farmers and employ a higher level of intensity of production (semi-intensive), and in most cases possess a higher level of skill than the semi-subsistence smallholders. These farmers consider fish farming as a business (a profitable activity) and invest more in terms of inputs and labour. They usually use some commercial feeds, purchased seed from a hatchery, and have more assets (nets, wheelbarrows, etc.) and operate in clearer production cycles producing larger fish for urban markets. They likely have access to loans (if required). The majority of fish they produce is sold rather than consumed in the household. These farmers are generally better off than the semi-subsistence farmers, in terms of their level of education and their ability to invest in their fish farming business. These farmers generally have better market linkages, although they also sell at farm gate. Some farmers have their own outlets, or relationships with restaurants and institutional buyers. These farmers are likely to hire some labour for their activities.

Medium-scale pond farmers (~7 instances, 3% of production): These are the larger pond farmers who produce commercially 20 to 200 t/year. The owners and/or administrators are educated (formally or informally), have solid market linkages (including own selling points), engage in higher and more frequent investments than the smallholders, and rely on hired labour.

Large-scale pond farmers (~13 instances, 8% of production): These are the largest pond farmers, producing commercially more than 200 t/year, often around 1000 t/year. These professionally-run systems are often vertically integrated to some extent, be it with livestock production to benefit from manure for fertilisation of ponds, feed and/or seed production, and/or own complex distribution channels.

Large-scale cage farmers (~12 instances, including medium to large, 67% of production): These are large cage farmers, producing commercially between 1000 and 4 000 t/year, based in Lake Kariba. They are professionally run, integrating seed and, increasingly, feed production, and featuring their own complex distribution channels. It must be noted that cage operations are very capital intensive, and thus not currently successfully run by smallholders. The few existing smallholder examples (such as those on Lake Kariba) benefit from projects, grants, or other mechanisms by which their activities are partially or fully subsidised, and not economically self-sufficient in the long term.

Stocked water bodies (9% of production): no data was available, thus excluded from the analysis. The majority of smallholders are located in the northern parts of the country (Table 3). They are often highly scattered, which limits their access to feed, seed and extension services, with the latter currently almost exclusively provided by DoF officers.

Smaller (semi-subsistence) farmers use recycled (likely inbred) local species (some use *O. niloticus*), do not use commercial feeds, practice fish farming “by the way” (as a secondary or tertiary activity) for mostly food/nutrition purposes rather than as a commercial enterprise, do not keep records or

[2] Many smallholder-oriented projects have created a social dynamic of abandonment. This situation has been going on for some time in Africa (O. Mikolasek, pers. comm.). See also Harrison (1986) for a rich account that is still applicable today.

monitor their fish growth, and as a result, produce a lower-quality/small-sized fish that poorer, rural (in some cases poor urban) consumers can afford.

In contrast, large and medium-scale farms, especially cage-based ones, achieve a higher level of productivity given their use of high-quality seed (imported *O. niloticus* strains) and commercial feeds, as well as thanks to their good management practices including record keeping, tracking of their feed conversion ratio (FCR), harvesting all their fish at the end of each cycle (usually 2 full cycles per year) rather than partial harvests, and employing farm labour. As a result, they produce a higher-quality/bigger-sized fish that the urban (better off) market demands. These farmers currently supply the majority of farmed fish in the country. Smaller commercial farmers adopt similar production practices, albeit at a much smaller scale and tend to produce for local, rather than distant markets.

Province	Farmers	Ponds	Total area (m^2)	Ave pond size (m^2)	Total est. prod (t)
Copperbelt	1203	2 732	706 866	259	477
Northern	2 436	4 940	1 180 794	239	797
Muchinga	1573	2 265	44 055	19	30
Northwestern	2 915	4 538	990 075	218	668
Sub-total	**8 127**	**14 475**	**2 921 790**	**735**	**1972**
% of total in Zambia	**68%**	**70%**	**67%**		**67%**
Source: DoF (2015). Note: The provinces in this table were selected because they are considered "high potential zones", where plenty of sources of water and larger numbers of farmers exist. There are also a larger number of farmers in Eastern Province, however, access to sources of water is low in the province. Numbers for the year 2014 are presented for small-scale fish farmers, as the 2015 numbers were not available/complete. The overall number of farmers did not considerably change from 2014 to 2015 (10 416 to 11 853).					

Table 3. Number of smallholder fish farmers in selected provinces

Importers

Farmed fish in Zambia directly competes, mainly in urban centres, with farmed tilapia imported from Asia (primarily from China). Data on fish trade is considered unreliable, and is generally not disaggregated by type (farmed or wild). Figure 5 shows an overview of the trend of fish imports and its official origin including both captured and farmed fish. Several key informants have indicated the high degree of illegal imports of farmed fish, which allegedly comes in, disguised as wild marine fish from Namibia, thereby evading import duties, although this perspective is not fully shared by DoF officials. We have been unable to confirm or disprove this perspective.

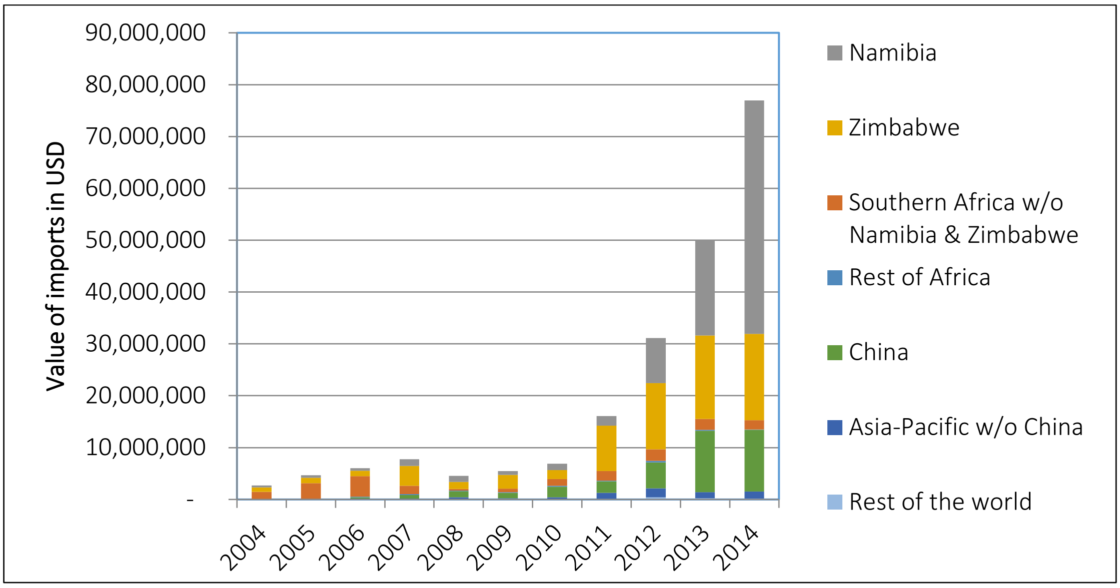

FIGURE 5. VALUE OF LEGALLY IMPORTED FISH INTO ZAMBIA BY ORIGIN (2004-2014)
SOURCE: DOF TRADE DATA 2004-2014.

According to one key informant, the reason for the low price of imported farmed fish is not necessarily the lower production costs in Asia, but the difference in the preferences of Asian, European and US versus Zambian consumers. Chinese (and other Asian) farmed tilapia production systems, are geared towards producing a larger size tilapia suitable for sharing and for filleting. Zambian consumers in contrast, prefer smaller sized tilapia, those suitable to prepare whole as a single serving. This means that the tilapia that is produced in Asia that does not reach the required size for the European, US, and Asian markets, can be sold into the Zambian market. As this is a "by-product"[3] of the produce targeted at other international markets, it can be sold relatively cheaply. While we have been unable to confirm whether this is the case, this seems like a plausible explanation of the low prices of legally imported tilapia (CIF price at entry 0.90 USD/kg (1.43 USD landed price) for whole round tilapia of 100-200 g and 1.27 USD/kg (1.89 USD/kg landed price) for whole round tilapia of 300-500 g). Illegally imported tilapia can be sold even cheaper as it avoids the duties (30%) that are paid on legal imports from outside the African free trade area.

The total amount of imports (both legal and illegal) is estimated at ~28 000 t in 2016 for the purposes of the present report.

Markets

Wholesalers: There is one major company that has taken on the role of wholesaler in the farmed fish value chain. This company, Capital Fisheries, is said to buy up to 70% of local supply and is also a major importer[4]. They have a distribution network throughout the country and are also the major supplier of supermarkets in the country. Some of the larger fish producers have wholesaling integrated into their operations and have set up depots in larger cities/towns in the country.

Retailers: Retail is performed by a variety of actors, including the so-called "City Ladies" who operate in wet markets and conduct mobile vending, dedicated fish stores, butcheries,

[3] The "dumping" of lower grade Chinese tilapia is not just a recent phenomenon in Zambia, but in other parts of Africa. It is rejected fish, often glazed during freezing/packaging, noticeably having very little taste, but made available at a cheaper price and/or of the "right" size affordable for poor urban consumers.

[4] The relative proportion of local sourcing vs. imports is said to have recently shifted, but Capital Fisheries have not confirmed this.

supermarkets, other grocery stores, hotels and restaurants. In addition, there are many institutional buyers (e.g. schools, public servants, clinics) who serve as the last intermediary to the final consumer. Both medium and smallholders also engage in farm gate sales.

Given that most large/medium-scale farms are vertically integrated, they tend to carry out much of the distribution and marketing/trading of their fish. Farms in and around Lusaka and in the Southern Region market their fish as "Kafue Bream" in the Lusaka and Copperbelt markets. Kasumbalesa (border town DRC/Zambia) is a growing/major market for these farmed fish produced by the large cage farms, whereby their depots sell fish to DRC traders who subsequently move the fish across the border into DRC for wider distribution and sales. Retail outlets operated or attached to the larger cage farms have expanded over the past years into outlying district capitals, together with Capital Fisheries. Large/medium-scale land-based pond operators outside the main zones of production transport and sell their fish in larger provincial markets. Trade within rural areas consists of farmers selling at their farm gates, and a smaller portion (who likely reside closer to district capitals) transporting their fish for sale in these urban centres.

Transformation

At present, there is only one major processing operation active in the country, Capital Fisheries. This company does some smoking, filleting, gutting and scaling, which is mainly sold to supermarkets and grocery stores. Larger farms such as Kafue Fisheries, Lake Harvest, and Yalelo also process a small portion of their output for sale, for example, in the large grocery store chains, but also at selected retail outlets in Lusaka (e.g., smoked catfish by Kafue Fisheries). The proportion of processed product in the Zambian market is still limited. World Bank has reported that about 5% of the fish that is handled by Capital Fisheries is smoked, filleted or gutted, while 45% is blast frozen, and 50% is sold fresh (on ice) (Krishnan & Peterburs, 2017).

Consumers

We distinguish between the urban and rural consumers, and between the medium to high and low-income consumers. We have already described how the market segmentation relates to the size of the fish being sold. In addition, we have described the products sold in supermarkets, generally out of reach for the low income urban consumers.
The consumption of fish varies greatly according to geographic location and wealth status. Fish consumption is generally higher in rural areas and low-income groups proportionally spend more on fish than on any other animal food source compared to high-income groups, though this differs when disaggregated by fish species (Hichaambwa, 2012; Longley et al., 2014). In absolute terms, fish consumption per capita is also higher in rural areas than in urban areas, in particular in provinces like Northern Province, Western Province, and Luapula Province where there are established capture fisheries (NFDS, 2016). Despite this relatively high consumption rate of fish in rural areas, these provinces still struggle with the highest malnutrition rates of the country (Longley et al. 2014; NFDS, 2016). Some rural areas can have high rates of fish consumption per capita with 13.9 kg/year reported in Chililabombwe and even up to 27.2 kg/year in Siavonga, though the bulk of this fish consists of small dried pelagic fish or small indigenous wetland species rather than larger tilapia (NFDS, 2016). This might have an implication on the productivity of smallholder farmers and motivation to farm since the supply of fish is largely met by capture fisheries and small fish species in these areas. Whilst in general the demand for the consumption of farmed fish in the country might be high, smallholder farmers struggle to reach these markets due to poor infrastructure, geographic proximity and an absence of cold chains.

Inputs

Commercial fish feed producers (4-5): Commercial fish feed producers are established animal feed producers, which in recent years have invested in the fish feed market. Based on interviews, it can be stated that these investments have either been financed by the poultry and other animal feed markets or represent a yet unrecovered cost account for companies (it has been mentioned that the fish producers "have not paid for the high investments of good extruders for floating pellets"). Fish producers very often complain about the quality of aquafeed (protein content, floatability, shelf life), to the extent that two large cage producers in Lake Kariba have or are about to launch commercial aquafeed mills in partnership with international feed companies. These will be the only aquaculture-specific feed mills in the country, so dedicated only to producing for the sector.

Government hatcheries (~8): Government-run hatcheries are part of the government's provincial and national research stations, and are often underfunded to the extent that they are currently unable to fulfil the growing demand for fingerlings by smallholders, and sell predominantly mixed-sex fingerlings. Selling price is commonly around 0.5 ZMW per fingerling (0.05 USD).

Commercial hatcheries (~10): An increasing number of private hatcheries have started up in recent years. Some are part of integrated operations, started with the main purpose of ensuring own supply of good quality fingerlings for grow-out, while others are standalone, only breeding and selling fingerlings. Broodstock is either homebred, by means of size selection over several generations, or imported, most often from Thailand (the Genetically Improved Farmed Tilapia, GIFT, *O. niloticus* strain). Standalone hatcheries purchase commercial feed and sell fingerlings to all types of producers. These hatcheries mainly sell sex-reversed fingerlings. Nonetheless, smallholders tend to rely on government-run hatcheries because they are located in closer proximity and because they often still have lower prices. Prices of fingerlings still vary greatly between commercial hatcheries and key informant interviews indicated a range from 0.3 to 2.5 ZMW per fingerling (0.03 – 0.25 USD)[5].

3.2.2 Geographical distribution

Figure 6 provides an overview of the geographical distribution of the different aquaculture systems and scales, as well as the main supply of fingerlings. Roughly speaking, the majority of smallholders are found in the northern provinces (Muchinga, Northern, Northwestern, and Copperbelt), while the largest producers are located in the central and southern areas of Zambia. However, some medium-scale producers are also found in the northern parts of the country. Fingerling production in the north is still mainly government-driven although some private hatcheries are found, in particular in Northern and Copperbelt Provinces. Northwestern Province at present has no fingerling supply[6] and larger and smaller, more commercially-oriented farmers therefore are dependent on distant suppliers.

[5] Siavonga-based hatcheries and Mpende Fisheries.

[6] A government hatchery exists in the area, but it is currently not in operation as it lost all broodstock during flooding last rainy season. A small private hatchery (IFAD -supported) is being set up but is not in operation yet.

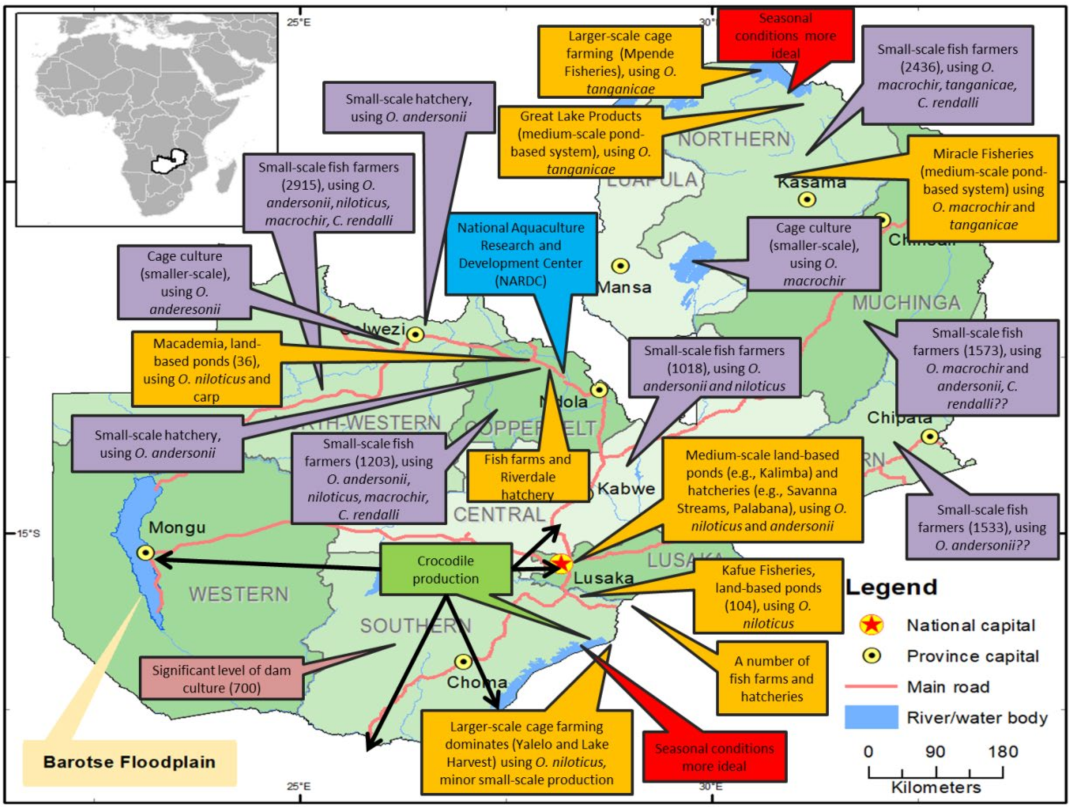

FIGURE 6. MAP OF DISTRIBUTION OF AQUACULTURE SYSTEMS AND SCALES

Source: DoF 2015, key informant interviews during assessment mission trips, and existing knowledge of team members.

3.2.3 Biomes/ water availability

Zambia is endowed with a large number of water sources, which makes it an ideal country to promote both land and water-based aquaculture (but also integrated aquaculture agriculture) systems. Large lakes exist in Luapula and Northern Provinces and the human-made lake (Lake Kariba) that was formed after the completion of Kariba Dam in the 1950s. More recently, Lakes Kariba, Bangweulu, and Tanganyika are being exploited for cage culture. A great number of wetlands are located throughout the country, which can be ideal for both pond culture and promotion of integrated aquaculture agriculture systems (e.g., fish/rice). There is no evidence that suggests that the latter have been promoted or piloted to date. Small dams/reservoirs created in drier provinces (e.g., Eastern and Southern Provinces) exist in large numbers, and are often stocked with fingerlings by government-run hatcheries as a means of increasing fish stocks in these water bodies. There is no evidence that indicates these dams/reservoirs are being used to explicitly cultivate fish (using commercial feeds or by fertilisation), but rather are left on their own to grow and provides a source of fish for nearby residents to harvest for food or local sales.

3.2.4 Material and economic flows

Material flows (Products)

As indicated above, aquaculture production in Zambia is dominated by the production of several tilapia species. The production of *O. niloticus*, an introduced strain, is only allowed in some parts of the country (south of the Itezhi-Tezhi dam in the Kafue River). In practice O. *niloticus* is found in other parts of the country as its banning is difficult to enforce. Government and some private hatcheries are now investing in the improvement of the local strains (O*. andersonii, O. macrochir, O. tanganicae,* and *C. rendalli*). In the urban market, these species are not easily distinguishable by all consumers and are all commonly sold as "Bream" or "Kafue Bream", although *O. macrochir and O. tanganicae* are rarely found in the Lusaka market and mainly sold/consumed in the north.

Product differentiation for the majority of farmed fish being sold is limited and mainly based on size (small 100-200 g, medium 200-400 g, large 400-600 g) and product (fresh or whole frozen), although other types of products such as fillets and otherwise processed fish are found in supermarkets, produced and supplied by mainly one supplier (Capital Fisheries). Imported tilapia is only sold frozen and has a lower price per kilogram. Size is becoming an interesting distinguishing feature: in Zambia, consumers seem to favour consuming one entire fish each, rather than sharing a larger fish. This results in medium to high income consumers favouring the 300-500 g size in particular. Smaller sizes are more popular in the low income consumer markets, as this allows consumers to buy a larger number of individual fish for the same price. Chinese tilapia is being imported in a range of sizes as well. This is also consistent with information from a key informant from the Zambian medium to large-scale fish producers who indicated that small-sized fish (100-200 g) is considered a by-product. The majority of farmed products are either sold fresh (on ice) or frozen. Products being sold in supermarkets include whole fresh, whole frozen, fillets, and gutted and scaled. We found also one example of fish being sold alive (especially to Chinese consumers) by a producer through one particular outlet in Copperbelt, a product form that may gain popularity.

Figure 7 provides a mapping of product flows and prices in the Zambian aquaculture value chain. The bulk of production originates from either large cage producers or imports.

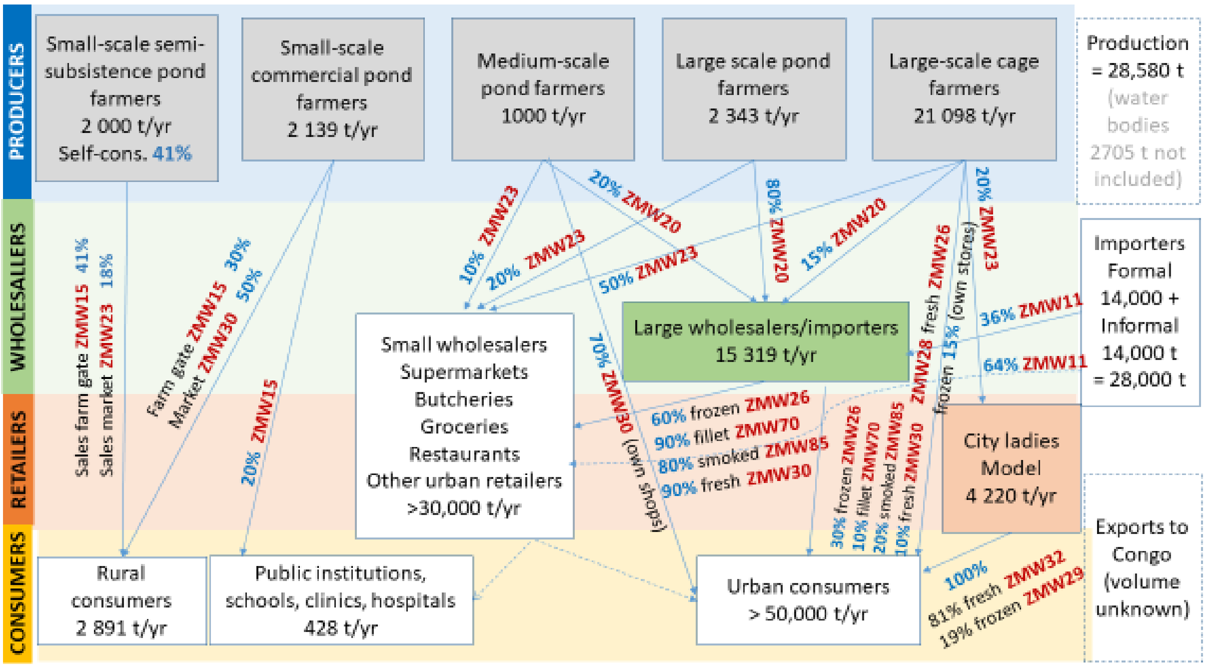

FIGURE 7. MAPPING OF THE MAIN ACTORS AND FLOWS IN THE VALUE CHAIN

Source: own data

The integrated wholesaler operations and one major individual wholesaler dominate the trade of farmed fish. Processing is also in the hands of mainly one agent. Further data is to be collected to confirm some of the product flows (in particular for other imports and fish from stocked water bodies). Aquaculture production is estimated at ~31 300 t in 2016 (~28 600 t excluding the output of stocked water bodies, for which we lack data).

3.3 Technical diagnosis

3.3.1 Performance (production)

Table 4 provides details for yields (kilograms of fish produced per hectare of pond area per year) and feed conversion ratios. Yield and FCR are not sufficient criteria to judge the productivity of a land-based producer, because key management aspects also contribute to it, such as feeding strategies and partially overlapping production cycles allowing for year-round harvests. Economies of scale definitely play a role in overall productivity, as it allows for buffers (feed, seed, storage) and financial flexibility.

Farm type	Yields (kg/ha)	Feed Conversion Ratio (kg/kg)
Pond smallholders semi-subsistence	1900	5.0
Pond smallholders commercial	5 200	2.0
Medium-scale pond farmers	7 600	2.0
Large-scale pond farmers	16 000	2.0
Large-scale cage farmers	880 000	1.6
Extensive ponds / stocked water bodies	<900	>5.0

Feed Conversion Ratio estimated from primary data, and validated against literature.

Table 4. Production performance indicators by farm type

Semi-subsistence smallholders use homemade feeds (mainly crop by-products, alone or in combination, but rarely pelleted mixes), recycled seed, sub-optimal water management and other management practices (e.g. fish density), and family labour. Their costs are therefore relatively low, but their yields are also low resulting in moderate net profits, if fish consumption at home is included. The average 100-200 m^2 pond produces around 10-30 kg per year, mostly using an extensive system and likely practicing partial harvesting. Lack of management is one of the key factors here, as fish farming for this group is carried out "by the way" (secondary but often tertiary activity). Lack of extension support and lack of training prevent these farmers from adopting better management practices.

Commercial smallholders with semi-intensive production have higher costs of production as they use commercial feeds and have higher levels of investment. While there are recent investments in this type of aquaculture, with numbers of new farmers rising, it appears these farmers do not necessarily have the skills to operate these fish farms at a profitable level. Their access to high-quality seed is often low, or seed has to be transported at great distances incurring major transport costs. Their level of expertise is still relatively low, which results in inefficient management practices. In addition, they have limited or no access to technical services except from government extension officers, who in turn have limited resources and skills to provide these services. The commercial smallholders, opposed to medium and large farmers, have no access to skilled aquaculture experts (from within or outside the country). While the recent surge in interest in (commercial smallholder) fish farming is encouraging, their lack of skills and access to good quality seed coupled with high levels of investment in establishment of ponds and their use of commercial feeds could threaten long-term growth in the sector.

3.3.2 Marketing, trade

Markets in the Zambian value chain differ across geographic locations, rural and urban localities, and wealth status of consumers. As indicated, the pond-based, semi-subsistence smallholder farmers produce mainly for household consumption and sell a small portion at farm gate to local consumers, some also barter fish. Studies show that around 40% of households consume all of their fish and do not sell to markets (Nsonga, 2015; Musuka and Musonda, 2013)[7]. Smallholders may use institutions such as churches and community meetings as communication channels to announce the harvest to sell directly from their farm. They may also sell door-to-door and go to nearby local markets to sell their fish. Smallholder commercial farmers may have linkages to local institutions such as schools. This has also been facilitated in some cases by the initiatives of the Citizens Economic Empowerment Commission (CEEC). Key informant interviews also show that some commercial small- and medium holders have their own outlets from which they sell fish.

All operators in large-scale commercial aquaculture (both pond and cage) mainly target urban areas as primary markets, for middle and upper-class consumers, but also lower-income consumers through the "City Ladies" who buy fish in depots and sell in wet markets[8]. Some large-scale producers also have their own ice production, freezing facilities and refrigerated trucks. Some actors operate with only one wholesale depot, others directly engage with a small number of retailers, and one producer distributes their produce to wholesale depots in five different provinces. Capital Fisheries is a major trader of wild, farmed and imported fish. They buy fish from the large producers, but also from small-to-medium-sized farms, and distribute fish through their extensive transport network, supplying several supermarket chains.

Farmed fish competes directly with capture fisheries and rapidly increasing fish imports. This drastic growth from 2011 does not seem to be slowing down and the fish sector as a whole in Zambia is being reshaped as consumers are introduced to different fish products such as horse mackerel (*Trachurus spp.*) from Namibia, which was barely on the market a decade ago. Figure 5 shows the importance of fish imports to national fish supply with the value of fish and total tonnes exponentially increasing in the last 6 years. Most of this imported fish is either horse mackerel from capture fisheries in Namibia or farmed tilapia from Zimbabwe and China. Without net imports the overall per capita consumption would have decreased by 3.9 kg/per capita in 2014, having clear implications for food and nutrition security in urban areas in the country.

3.3.3 Consumption

There is limited data available on the consumption of farmed fish in Zambia, as fish consumption data is generally not disaggregated by source. Fish provides 55% of the animal protein consumed by Zambians and is an important direct source of protein and micronutrients; and often the only accessible and/or affordable source of animal protein for poor households in rural areas (Longley et al., 2014; NFDS, 2016)[9]. Tilapia is a highly favoured food product for most Zambians (NFDS, 2016). The price of fresh fish has become the lowest among all animal-source foods in Zambia (Hichaambwa, 2012). However, due to an absence of cold chains, fresh fish might not be readily available in rural areas and small towns, and sun-dried and smoked tilapia (from capture fisheries) are still highly favoured, especially among poorer people who cannot freeze their fish (Hichaambwa 2012).

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7 These studies did not explore issues such as household food security, and their production numbers were based on recalls, not actual.

8 A "wet market" is a market selling fresh meat and produce, distinguished from dry markets which sell durable goods such as cloth and electronics.

9 Moreover, in the rural context (depending on the area) chicken, goats and pigs are often used to raise money during the "hungry" season. Chickens are also presented to guests and visitors, having thus strong cultural significance. Farmed fish and fish from capture fisheries (especially small indigenous species) thus becomes a very cheap source of protein/micronutrients as people can purchase small amounts ("heaps" or a given number of pieces) to feed their families. Slaughtering a pig, for instance, to do the same does not make economic sense and thus livestock tends to be eaten rarely and rather sold to subsequently purchase maize (or another staple food) in times of need. Sufficient maize supply is equated to food security in rural Zambia.

Figure 8 shows the official production, import and export data from 2004-2014 of capture and cultured fish in Zambia, which provides an indication of overall fish supply available to consumers in the country. The figure shows a rapidly growing population, erratic supply from capture fisheries, increasing aquaculture production, and imports, resulting in an overall increase in fish supply per capita.

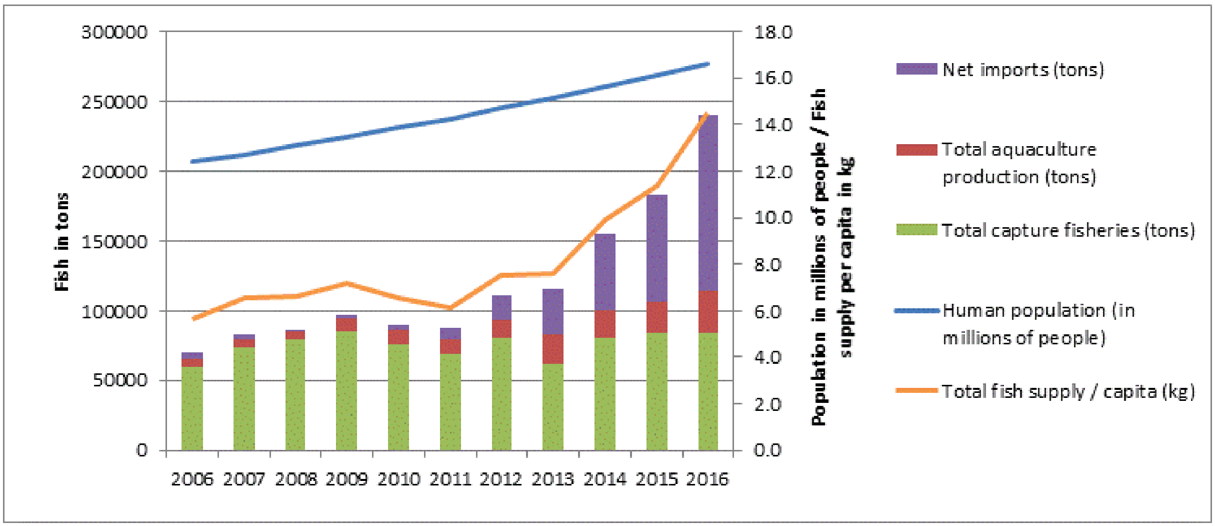

FIGURE 8. TOTAL FISH SUPPLY AND SUPPLY PER CAPITA (2006-2016)

Source: Authors' compilation based on DoF production data and World Bank population data (2006-2016).

The generation of an additional annual production of 13 690 t by commercial enterprises in Zambia and increasing imports have resulted in an increase in supply per capita, going from 5.6 kg per capita in 2006 to 14.5 kg in 2016. This is still significantly below the world's average of 19.2 kg/year, but well above the sub-Saharan average of 8.9 kg/year (FAO, 2016a). It should be noted that the share of imported fish in total fish available to Zambians, increased from 6 to 52% in the same period. It remains to be seen what effect the importation of fish will have on the competitiveness of the aquaculture sector. This is an issue that requires future research, not only in Zambia, but for sub-Saharan Africa as a whole. The share of domestically produced aquaculture in total fish supply increased from 7 to 13% in the 2006-2016 period, while the contribution of aquaculture to domestic fish production increased from 8 to 27%. This underscores the increasing importance of aquaculture, but also that its growth is unable to keep up with growing demand and influx of fish from abroad.

3.4 Enabling environment

The enabling environment of the value chain consists of the set of policies, rules, and regulations, including informal rules and cultural norms, infrastructure and services that support (or hinder) the aquaculture value chain, specifically:

- Policies: trade policy, land tenure and access, property rights, research and development, standards and regulations, taxes and tax management, labour policies, and SME policies
- Physical and business infrastructure: roads, market infrastructure, food safety infrastructure, and finance (availability, access and conditions)
- Services and coordination: extension, education, training and knowledge, business linkages and chain coordination, business development services, risk management options

The sections below describe some of our findings related to the enabling environment.

3.4.1 Government: policies and structure

The government of Zambia considers the aquaculture sector among the areas of the economy that have significant potential for contributing to accelerated sustainable socioeconomic development, and that is a suitable strategy for rural poverty reduction. In light of this, the Zambian government has decided to prioritise the development of its aquaculture subsector. This intention is clearly expressed in the country's **Seventh National Development Plan** (NDP) (2017 – 2021). In the NDP, the government aims at promoting fish production in general, although there is some bias towards promoting community-based resource management of capture fisheries. However, this includes increased investment in fish farming technologies, and strengthening fisheries training and research.

The **Ministry of Fisheries and Livestock (MoFL)** is in the lead for developing and implementing the policies regarding the aquaculture sector. Within the MoFL, the **Department of Fisheries**[10] has four units, of which two[11] are involved in aquaculture: Aquaculture Research and Aquaculture Extension (Figure 9). DoF's aquaculture governance structures extend nationally through provincial and district structures.

Research implemented by the DoF focuses on among others things:

- Use of local inputs for feed formulation: e.g., the National Aquaculture Research and Development (NARD) is developing feed using only locally available inputs; Use of lemon as source of vitamin C (funding from National Scientific and Technology Council).
- Improved commercial feed formulation: adapted for different species and broodstock, which are commercialised through the private sector.
- Improvement/selective breeding, e.g., *O. andersonii*, and increased production of improved fingerlings for sale (e.g., NARD & Misamfu), and sale of improved brood stock to farmers (plans by Misamfu).
- Development and introduction of improved methods for fish preservation techniques such as smoking, salting, and solar tents that aim at reducing time spent to preserve fish.

Government extension services focus on:

- Providing technical extension on a needs basis through provincial and district DoF offices
- Demo fish farms through lead farmers
- Organization of field days
- Teaching fish handling/hygiene.
- Linking of farmers to buyers

[10] *In addition, there is the Department of Livestock.*

[11] *The other two functional units of DoF relate to capture fisheries; Capture Fisheries Research, and Capture Fisheries Extension.*

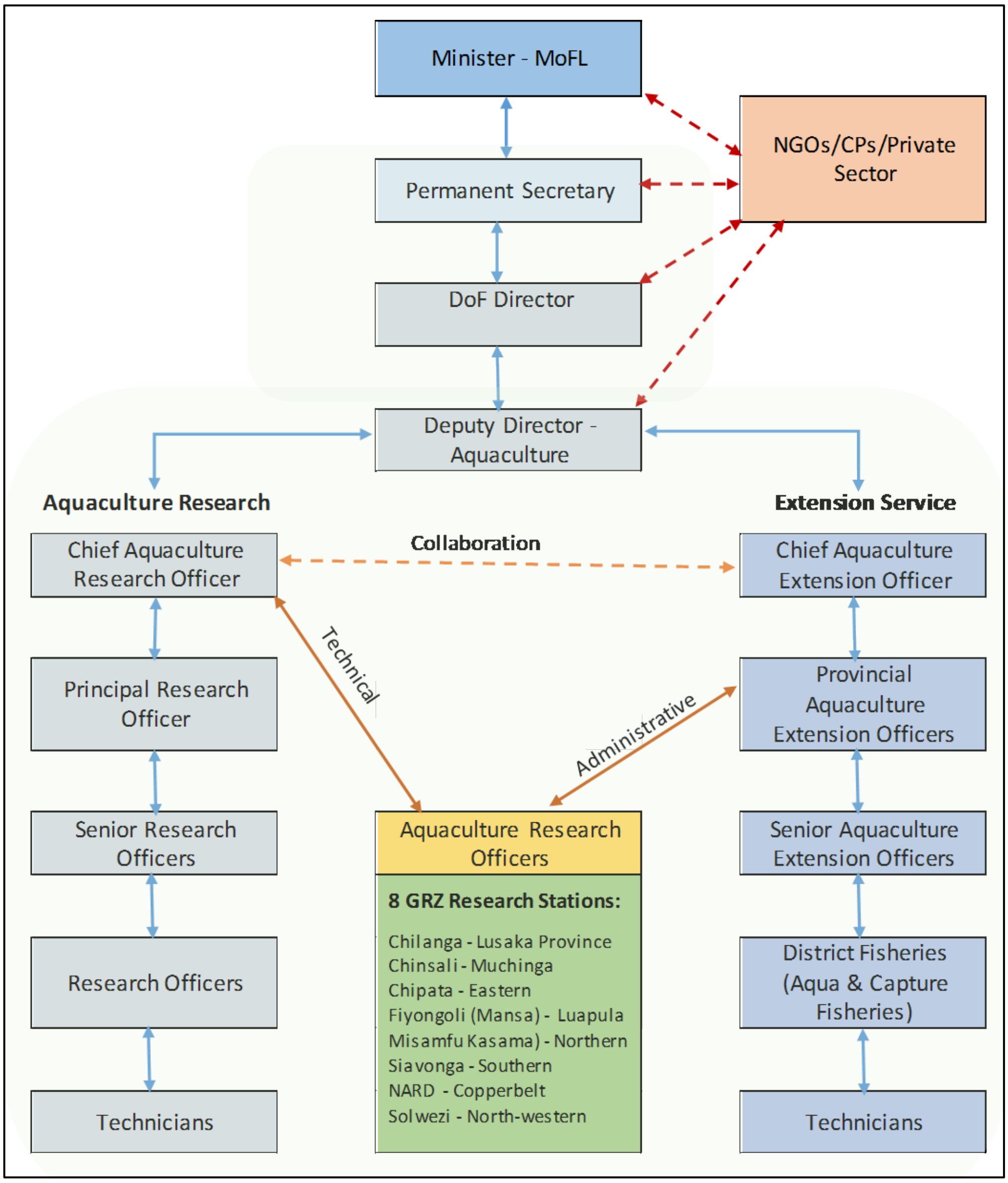

FIGURE 9. GOVERNMENT STRUCTURE SUPPORTING THE AQUACULTURE SECTOR IN ZAMBIA

Source: Authors' construction based on discussion with DoF Aquaculture Management.

The role of the DoF aquaculture research and extension is complemented by research and development organizations such as WorldFish and the United States Peace Corps who are currently operating[12] in different locations within Zambia. In addition, commercial fish and feed producers develop their own research relating to fish inputs, seed, production, and distribution.

Policy instruments include the **National Aquaculture Strategy (NAS)**, and the **National Aquaculture Development Plan (NAPD)**. The NAS is for the period 2014-2024 (updated with funding from FAO) and aims to effectively prioritise the aquaculture subsector and attract investment for its development. The NADP (2015-2020) provides an implementation framework for the NAS. The NAPD aims at improving the contribution of the aquaculture subsector to national socioeconomic development through enhanced national food and nutrition security, poverty reduction, national economic growth and improved balance of trade.

[12] *The US Peace Corps collect data, and are currently collaborating with WorldFish to test a decentralised seed distribution model, but in principle they aim to support DoF by stationing volunteers near fish farmers to develop their capacities to farm fish (and in some cases as a business). WorldFish is the only recognised body conducting aquaculture research in the country with DoF.*

Other rules and regulation that are relevant to the aquaculture sector include among others:

- Water permits: Users require water permits for water use, obtained from the Water Resources Management Authority (WARMA). There are requirements relating to water pollution control (effluent and wastewater) regulations.
- Land acquisition procedures for customary and state land: Customary tenure is practiced in areas regulated by traditional/local authorities and leasehold under state land. In Zambia, the President has the power to alienate land vested in him/her to any individual. Customary land acquisition processes could be more vexing as the possibility of getting embroiled in informal rules is high due to the nature of the process and the people involved. One is likely to deal with headmen, chiefs or their representatives, local authorities, and officials from the Ministry of Lands.
- Rules pertaining to company registration as provided by the Patents and Companies Registration Authority (PACRA).
- Taxation rules as provided for by the Zambia Revenue Authority (ZRA).
- Investment Certificate: The Zambia Development Agency facilitates acquisition of an investment certificate, which allows an investor to enjoy prescribed benefits. There are procedures and guidelines for issuing such an Investment Certificate.
- Environmental Impact Assessment (EIA): Aquaculture facilities require an EIA before setting up an aquaculture facility. The Zambia Environmental Management Agency (ZEMA) deals with environmental protection and pollution control, and some of the rules pertain to aquaculture facilities. Drugs are also covered under the Pesticides and Toxic Substances Regulations relating to environmental protection and pollution control.

Some recent governmental initiatives to support the sector include:

- Zero taxing of imports relating to aquaculture equipment.
- Permission to recruit 400 additional DoF officers most of whom will be fisheries assistants
- Setting up a fisheries and livestock research centre (in process).
- Promotion of training programs in fisheries and aquaculture conducted by existing institutions such as the Copperbelt University, Natural Resources Development College, and Kasaka Fisheries Training Institute.
- Measures to increase availability of fingerlings at government hatcheries (e.g., Mwekera and Misamfu).

The African Development Bank is providing MoFL a loan to implement the Z**ambia Aquaculture Enterprise Development Project (ZAEDP)**. ZAEDP aims at stimulating a viable and inclusive aquaculture subsector in Zambia to promote economic diversification, food security and sustainable employment generation, in line with the key priorities of the Government of Zambia (AfDB, 2016). The project will be executed in identified Aquaculture High Potential Zones across the country. One of the components of this project is the development of **Aquaculture Parks** in these zones (see also Section 3.2.5). So far, four pilot Aquaculture Parks are earmarked for development in Rufunsa in Lusaka Province (land-based); Chipepo in Southern Province (lake-based); Kasempa in Northwestern Province (land-based); and Mungwi in Northern Province (land-based). The project will be implemented over a period of five years, from 2017 to 2021. The Aquaparks are intended to create appropriate and sustainable employment opportunities through commercial and value addition activities (AfDB, 2016).

There is also collaboration at the regional level through the **Southern Africa Development Community (SADC) for the harmonization of eleven fish trading standards**, to promote intra-regional fish trade (SADC, 2017). For aquaculture, this includes standards of fresh fish, chilled fish, farmed tilapia (bream), quick-frozen fish fillets, and good aquaculture practices for bream (tilapia) farming. These standards and specifications, present an opportunity for Zambian manufacturers, traders and suppliers trading in fish and other fisheries products to export their products in the region and it is expected that this will enhance capacities for trade amongst small-scale processors and aquaculture producers as they present an opportunity for increased trade opportunities that even the smallholder commercial fish farmers can access (e.g. Kafue Women's Fish Processors Association, and a small woman-led enterprise, Lotuno Enterprises) (SADC, 2017).

3.4.2 Constraints in the enabling environment

Key informant interviews and secondary data have led to the identification of a number of constraints in the enabling environment that hamper the development of the aquaculture sector.

Policy and regulation

Policy framework: Despite the existence of the Fisheries Act 2011, the NAS and NAPD (see above), key informants indicate that the emphasis of the policy framework is on fish resource management and capture fisheries, while aquaculture is not adequately considered. There are also conflicting provisions in the existing legal framework, and actors signalled that there are weak institutional arrangements. The planned developments around the Aquaparks, presently lack conceptual clarity and a predictable framework for participation, long-term sustainability of operations, and role of the private sector. There is no consistent and clear categories of SMEs in the aquaculture subsector as stakeholders tend to use different definitional categorizations, which makes targeting them in policy-making challenging.

Coordination of efforts in the sector: Over time, many institutions have been involved in the promotion of aquaculture in Zambia, including Government, Non-governmental organisations, Universities, and research institutions. Initiatives have however not been well coordinated, resulting in less than desired outcomes.

Unregulated cross border trade:

- *Exports:* There is a high level of informal cross border trade with (among others) DRC, Malawi, and Tanzania, carried out by small informal fish traders that operate from border markets. There is limited oversight of these activities. There are also unregulated re-exports of imported fish, including Chinese tilapia (DoF, 2017). Due to these informal exports, there is a lack of data on real export volumes. This results in a lack of accurate data for policy making, and foregone revenues in export duties.
- *Imports:* As indicated in Section 3.2.1, there allegedly is a high degree of illegal/unreported import of farmed fish. According to key informants, possible methods of smuggling and tax evasion can be through undervaluing invoices, importers trading under multiple company names, tilapia being transported as Namibian horse mackerel with fraudulent SADC documents as this species of fish is exempt of duty, and destination fraud. We have estimated illegal imports of farmed fish at around 14 000 t for the purpose of our analysis. Both legal and illegal imports compete in price with domestically produced fish, putting pressure on the sector. In addition, the illegal imports evade import duties.

Lack of resources and capacity at the DoF: While the DoF implements research and extension for aquaculture, there are limitations in the degree to which this can be done effectively. The challenges are the following:

- Old and dilapidated research infrastructure
- Insufficient/late funding of research
- Experience of research staff: government structure leads to employment of new graduates without research experience, and limited ability to attract and maintain highly qualified personnel. This results in limited scope and depth of research undertaken.
- Limited ability to attract additional funding support for research.

- Human resources to provide adequate extension services (understaffing, in 2016 DoF's staffing level was 23.9% of full capacity)
- Means of transport to provide timely support to distant farmers (DoF staff share few vehicles)

Lack of infrastructure and institutions: a lack of general infrastructure such as roads, power, communication, are limiting the development of the aquaculture sector.
Data availability and reliability: Due to a lack of investment in R&D there is also limited data available on the aquaculture subsector, and the data that is available is considered of low quality. This includes key management data such as performance indicators and production figures. Collection of accurate and reliable data by the DoF officers is extremely challenging as they do not have adequate transport to conduct regular site visits/extension services, and therefore sometimes have to rely on unverified data volunteered by farmers.

Infrastructure, inputs and services

Limited access to finance: Unfavourable access to affordable finance for SMEs and smallholder farmers has made it difficult for them to engage in aquaculture profitably. There have been some initiatives directed at smallholder farmers, such as the Citizen Economic Empowerment Commission (CEEC), however these have had limited success in many cases where they have not been complemented with capacity building initiatives in aquaculture technical skills and entrepreneurship and business skills development.

Limited availability, affordability and quality of key inputs, in particular to smallholders*:*

- Feed: commercial fish feed is unaffordable to many (semi-subsistence) smallholders. They mainly resort to homemade feeds and garden and kitchen scraps, but lack the knowledge on how to formulate these feeds optimally. Efforts are being developed by organisations such as WorldFish to support the capacity development of smallholder farmers in this area, and the appropriate use of fertilisation.
- Seed: Availability and affordability of good quality fingerlings is poor for smallholder farmers. Semi-subsistence farmers only stock their ponds occasionally and rely on natural reproduction otherwise. This leads to in-breeding and low growth performance of fish. Some commercial smallholders face challenges in terms of availability of seed in nearby locations, which means they need to transport across long distances. This potentially negatively affects the quality of seed and means farmers incur additional transport costs.

Knowledge and skills

Small and medium-sized farmers have **limited technical knowledge on aquaculture production and pond management and entrepreneurial and business skills**. This in turn results in low performance of these farms, and limited profitability, which is a long-term threat for the development of the sector. This lack of knowledge and skills is the result of inadequate governmental extension due to the limitations highlighted above related to limited human capacity and lack of basic infrastructure, as well as a lack of private advisory services, and limited availability of institutions that offer aquaculture training courses.

There seems to be a vicious cycle of lack of technical experts in areas such as fish disease, fish genetics, fish nutrition, and production systems, which results in limited supply of aquaculture training and technical extension. In addition, institutions that do offer such trainings such as Copperbelt University, Natural Resources Development College, and Kasaka Fisheries Training Institute, face challenges such as inadequate facilities for practical trainings and training programs, which results in largely only theoretical trainings being provided, and limited linkages with the labour market that would ensure that trainings provided meet labour market demands.

Value chain linkages

Weak linkages between small and larger operations: The countries aquaculture subsector does not have well developed business linkages between smallholders and larger companies. This would have the potential of leveraging transfer of technical skills to smallholders, and improve smallholders' access to key inputs.

3.4.3 Recommendations on the enabling environment

To summarise, a number of potential intervention areas could improve the enabling environment, including:

- Tackling unregulated cross border trade (imports and exports)
- Establishing an Institute of Aquaculture Research not enshrouded in government structures but with greater autonomy to conduct appropriate research. This could also help to address the lack of coordination of efforts in the sector, and improve the generation of more and higher quality data on the sector
- Develop business models that improve linkages between smallholders and larger companies to address issues of access to inputs and facilitate transfer of technical knowledge
- Unfavourable access to affordable finance for SMEs and smallholder farmers
- Include the enhancement of business and entrepreneurial skills in capacity development efforts to support the transformation of (some) semi-subsistence smallholders into commercial small-scale farmers.

3.5 Value chain governance (coordination)

The concept of governance refers to the "*inter-firm relationships and institutional mechanisms through which non-market, or 'explicit', coordination of activities in the chain is achieved*" (Humphrey & Schmitz, 2004: 97). An analytical framework has been formulated (Gereffi et al., 2005) that yields forms of coordination based on a combination of three variables that can each take the value high and low. These variables are: (1) the complexity of the information and knowledge required to sustain a particular transaction; (2) the ability to codify and transmit this information between the parties; and (3) the capabilities of the suppliers to meet the requirements of the buyer. This results in five possible categories of coordination in individual nodes of the chain (Table 5):

1. Market: spot or repeated market-type inter-firm exchanges; both parties' costs of switching to new partners are low.
2. Modular: inter-firm relations involving more specialised suppliers who finance part of production on the part of the customer, but whose technology is sufficiently generic to allow its use by a broad customer base.
3. Relational: inter-firm relations involving multiple inter-dependencies, often underwritten by close social ties.
4. Captive: inter-firm relations involving one-way dependency of suppliers, high levels of supplier monitoring and high costs of switching for suppliers.
5. Hierarchy: classical vertical integration.

Governance type (analytical framework)	Complexity of transactions	Ability to codify transactions	Capabilities in supply-base	Degree of explicit coordination & power asymmetry
Market	Low	High	High	Low ↑
Modular	High	High	High	
Relational	High	Low	High	
Captive	High	High	Low	
Hierarchy	High	Low	Low	↓ High
Zambian aquaculture value chain				
Smallholders (farm gate / local market)	Low	High	High	Low
Smallholders (public institutions)	Low	High	High	Medium
Wet market retailers (city ladies)	Low	High	High	Low
Own retail outlets medium & large-scale farmers	Low	High	High	High
Wholesale Capital Fisheries	Low	High	High	Low
Imports	Low	High	High	Medium
Contract farming (emerging)	Low	High	High	Medium

Table 5. Types of governance applied to Zambian aquaculture value chain Source: Adapted from Gereffi et al. (2005).

There is limited complexity in the types of transactions taking place in the Zambian aquaculture value chain. We see several different types of governance emerge from the analysis of the Zambian aquaculture value chain:

3.5.1 Market

Smallholders often sell directly to consumers either at farm gate or in local markets. These are usually spot market type transactions, although in the case of farm gate marketing relational aspects play a role as the customers there are known to the farmers and are often contacted by phone or other means before harvesting starts.

3.5.2 Hierarchy

Several operations are integrated. Medium and large farms operate their own hatcheries, wholesale depots and retail outlets. With the establishing of Skretting (linked to Lake Harvest) and Aller-Aqua (linked to Yalelo) feed plants, the biggest farms in Zambia are essentially completely vertically integrated. Arguably, smaller semi-subsistence farms are also vertically integrated as they use recycled seed and market and sell their farmed fish within their immediate locales, whereas smaller commercial farms rely heavily on hatcheries, feed suppliers, and distributors of other aquaculture inputs (e.g., nets, liners, tools) and microfinance institutions to enable their systems to produce.

3.5.3 Relational

Capital Fisheries sources from many different suppliers. There are some **contractual relationships (either formal or informal)** between the company and the suppliers as Capital Fisheries acts as a secure buyer for a large volume produced by the medium and larger producers. WorldFish is testing a **decentralized seed distribution model** as a potential ”inclusive business model”. In this model, breeder farmers produce and supply fingerlings to clusters of farmers for grow-out, which enables better coordination and cooperation between farmers and creates local “production zones” that attract both input and output markets.

WorldFish is also testing the feasibility of a **contract farming or out-grower scheme** in which a private sector fish farm and hatchery contracts small-scale fish farmers to help them increase production by providing them with seed and feed on a loan basis, which can be recovered when the private sector company purchases fish after harvesting. While this binds farmers to a particular buyer through a credit dependence, the type of product they produce is still relatively standard, which makes this more a relational governance type, as when contracts are dissolved, farmers do not need to change their production process and can easily revert to selling to product through regular spot market transactions. However, there is potential for a captive relationship, if farmers become bound to specific buyers by debt.

3.5.4 Integrated models for input and service provision

Not technically value chain governance, but models that could enhance the functioning of the value chain in particular related to the supply of inputs and the provision of services are the Aquaparks and other cluster approaches.

As highlighted in Section 3.4.1, the **Aquapark** concept is now being developed as a possible model to enhance aquaculture development. This model consists of a cluster of enabling (meso) institutions and service providers established in close vicinity among each other and in identified “high potential areas” for aquaculture (Mushili & Musuka, 2015). These Aquaparks would provide technical extension services and access to inputs in “one-stop shops”, with an area of influence of several square km around its centre. Ideally, a public-private partnership would be put in place, with some incentives for private sector such as duty-free imports on equipment or consumables dedicated to the project, and in collaboration with international bodies and research institutes to provide relevant services. The Aquaparks could be a location for fingerling and feed production, as well as a site for training and research. For fingerling production the Aquaparks could serve as the breeding centre, while satellite farms provide nursing services. Preparations for implementation started a few years ago, but new funding from Africa Development Bank has now sparked renewed interest in development of the parks. It is unclear how the four sites to pilot the Aquapark concept were chosen and the level of private sector integration that will occur in practice.

A similar kind of effort was undertaken in Copperbelt Province, where FAO was implementing the “Zambian aqua-farmers project”, which was promoting a **cluster approach**. Farmers in clusters were monitored and advised on quality control measures to be put in place. A positive impact of the cluster approach was found (Mushili, 2015), however it is unclear how much of it has remained after the project ended.

4 Economic analysis

4.1 Introduction

The aim of the economic analysis is to provide answers to the following two key framing questions:

- What is the contribution of the aquaculture value chain to economic growth in Zambia?
- Is this economic growth inclusive?

To appropriately address the two key framing questions, the following steps were undertaken in line with the VCA4D methodology:

1. Undertaking the financial analysis of the key actors.
2. Assessing the overall effects on the national economy (contribution to economic growth in terms of generated direct and indirect value added).
3. Analysing the sustainability and viability of the chain within the international economy.
4. Assessing the inclusiveness of the chain economic growth, by examining income distribution (business income, wages), employment creation and distribution.

In the Zambian aquaculture case, the availability and quality of data on aquaculture in Zambia is relatively low and the sector is rapidly increasing, making it particularly difficult to develop an accurate estimation of production levels and other parameters. Existing secondary data has been validated with primary data from the two missions, complemented by sound expert knowledge where data gaps arose. Key areas where accurate data was limited, and some assumptions therefore had to be made, include imports, the flows of products through the different markets and the system of prices.

4.2 Value chain framing for the economic analysis

As indicated in the functional analysis (Section 3.1), the total aquaculture sector in Zambia had a volume of almost 59 000 t in 2016, including imports. The calculations of the contribution of the value chain to economic growth presented in the economic analysis are based on a level of total production of 28 580 t (excluding the water bodies production estimated at 1705 t) (see Table *2* for the composition). Tilapia is estimated to represent around 99% of the aquaculture production in Zambia. The economic analysis will therefore concentrate only on tilapia.

Official data on imports of fish is not disaggerated by source of fish (i.e. capture or farmed) and a level of imports of 28 000 t is used, with half of this considered to be formal imports, and the other half to be informal is assumed for the analysis. In the present report, these two are aggregated for the analysis as we did not manage to collect data on the imports and distribution of legally versus illegally imported fish. In the simplified mapping of the value chain, we assume that the imports supply for one third the large wholesalers and for two thirds the others traders.

As indicated in the functional analysis, there is a dichotomy in the value chain between the extensive smallholder sector and on the commercial sector (Kaminski et al., 2017). Smallholder farmers produce mostly for subsistence purposes and somewhat in isolation from the commercial value chain (Kaminski et al., 2017), as they mainly sell directly from their ponds or in local markets. In the present economic analysis, it is considered that flows from **small-scale producers** are as follows: self-consumption for semi-subsistence pond farmers (on average 41% of their production according to the team survey); sale to local public institutions, such as schools, clinics, hospitals, for commercial pond farmers (on average 20% of their production); both semi-subsistence and commercial farmers sell the rest of their production in the local rural markets. They can sell both at farm gate or at the local market in order to obtain a higher price. See flows distribution in percentages in Figure 10.

The team survey showed that **medium-scale pond farmers** are to be considered as an intermediate, independent category, as they integrate to a certain extent into the networks and markets of large-scale farms. They commercialise their fish with a variety of wholesalers/retailers and they sell directly in the urban markets. It appears that a few of them also sell part of their product to large-scale cage farmers that have developed their own outlets/depots. Some of the medium-scale farmers also had their own outlets nearby to sell their fish.

Medium-scale farms supply directly to urban suppliers and at a lower extent urban traders and large-wholesalers. It has been particularly difficult to estimate the product distribution flows of large-scale farmers across the various markets or actors. This is due to the fact that these actors differ both in terms of practices, volumes and commercial strategies. It was considered that large-scale farmers have a diversified commercialisation network: they supply to a large extent large wholesalers as Capital Fisheries (that resells fish under different forms, such as fresh, frozen, filleted, smoked); the "City Ladies"; all others traders (small wholesalers, supermarkets, butcheries, retailers) and direcly the urban consumers (with fresh and frozen fish). For clarity we again show the product flows and price structure in Figure 10.

Large-scale commercial farms, mostly target urban areas as primary markets for selling fish to the middle and upper classes. Across the different operators, the majority of production is transported and sold in Lusaka, either through company-owned retail outlets, or wholesale depots. Large scale farmers sell direct from their wholesale depots and retail outlets in key/strategic towns along the line of rail (those towns/cities from Lusaka up to Copperbelt Province), but also in other bigger towns throughout Zambia. Some large-scale producers have their own ice production, freezing facilities and refrigerated trucks. Some actors operate with only one wholesale depot, while others directly engage with a small number of retailers, and one company (Lake Harvest) distributes its produce through wholesale depots in five provinces. They sell also to "City Ladies" and other customers. Capital Fisheries is a major trader of wild, farmed and imported fish and buys fish from medium- and large-scale farms that do not engage in their own processing. As specified in the functional analysis, Capital Fisheries is one of the only large-scale processors in the value chain, and it also sells fresh, frozen and processed fish.

Fish prices depend on species, product form, and grade, as well as the location where the fish is sold. While on formal markets, depots and retail shops fish is mostly sold by weight the "City Ladies" in markets in Lusaka may buy fish (according to weight) and then resell by the piece (and this is how they make a profit). According to Kaminski et al. (2017), the majority of small-scale farmers (94%) stated that their farmed fish was sold at a higher price than fish from capture fisheries.

Farmed fish prices also fluctuate as fish imports are affected by volatile exchange markets, and fluctuations in total fish supply due to seasonality in capture fisheries. Generally, farmed fish from the medium/ large scale sector is categorized in three different grades: (1) fish that weighs more than 300 g and at the time of field research was sold for 24–27 ZMW (2.55 USD) per kg; (2) fish that weighs from 100 g to 250–300 g and is sold at 18 ZMW (1.80 USD) per kg; and (3) fish that weighs less than 100 g and is sold at about ZMW 8 ZMW (0.80 USD) per kg.

In the present economic analysis, the selected price system is coherent with the above. Prices used are per kg and are averages that do not distinguish the different grades of fresh fish. Prices range between 15 and 30 ZMW on rural markets; 23 ZMW from the medium and large farmers to intermediaries; between 28 and 32 ZMW for fresh tilapia on the urban markets; between 26-29 ZMW for frozen fish; 70 ZMW for fillets; and 85 ZMW for smoked fish. The price structure is also shown in Figure 10.

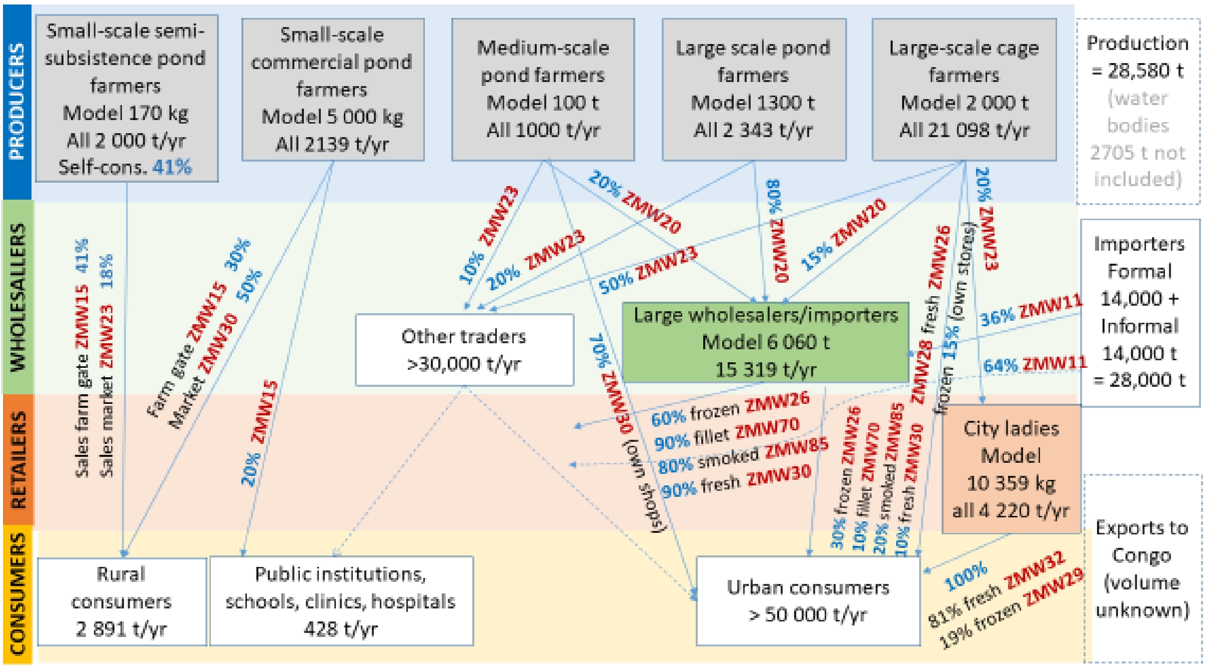

FIGURE 10. MAPPING OF THE MAIN DATA USED IN THE ECONOMIC ANALYSIS

Source: Authors

The "model" indications in Figure 10 are the basis for the calculations for each actor in the financial and economic analysis (for example the operating account of a small-scale semi-subsistence pound farmer will be computed for 170 kg per year on average and the value added will be calculated for 2 000 t when all farmers in this category are aggregated)[13].

4.3 Financial analysis of the viability for the individual actors

The financial analysis involves assessing the profitability of the key actors identified in the proposed typology. In this respect, the actor's operating account is the main basis of analysis and takes into account only flows involving market exchanges at actual market prices. However, given the difficulty in obtaining certain information pertaining to actors' operations, the financial analysis was complemented by proxy data as well as realistic estimates. For instance, details on actual capital and investments could not easily be obtained from the actors due to confidentiality concerns. Also, it was the large operators were unable to breakdown labour between permanent jobs and casual workers.

The financial analysis reported in Table 6 shows that all the categories of producers of farmed tilapia are economically sustainable (meaning they generate a profit and have a positive return on investments), despite differences in the levels of profitability and the fact that none of them receives subsidies. As mentioned, the operating accounts of the actors are based on surveys conducted by the experts that concerned 28 pond farmers, four cage farmers, six wholesalers and five retailers (see section 3). The details of the calculations for each actor are provided in Annex 3.

[13] As the medium-scale farmers are an intermediary category, it is possible that 100 t by year is over-estimated.

	Small-scale semi-subsistence pond farmer 170 kg	Small-scale commercial farmer 5 t	Medium-scale pond farmer 100 t	Large-scale pond farmer 1 300 t	Large-scale cage farmer 2 000 t
Sales	1 740	112 500	2 730 000	27 040 000	45 100 000
Self-consumption	1 050	0	0	0	0
Direct subsidies	0	0	0	0	0
OUTPUT	**2 790**	**112 500**	**2 730 000**	**27 040 000**	**45 100 000**
IGS	2 337	36 253	825 589	3 853 929	8 625 780
Wages	0	24 320	272 663	8 100 000	7 200 000
Financial charges	0	2 500	50 000	6 000 000	6 500 000
Taxes	0	3 375	85 900	1 304 466	3 077 644
Depreciation	64	4 430	615 745	*5 376 667	14 166 667
COSTS	**2 400**	**70 878**	**1 849 896**	**24 635 062**	**39 570 090**
Net operating profit	*390*	*41 622*	*880 104*	2 404 938	5 529 910
*Net added value***	*390*	*71 817*	*1 288 667*	17 809 404	22 307 554
Profit margin	*14.0%*	*37.0%*	*32.2%*	8.9%	12.3%

TABLE 6: ANNUAL OPERATING ACCOUNTS OF KEY PRODUCER TYPES (IN ZMW)

*Source: Computed from data collected in consultation with producers. Note: *we were unable to obtain data on establishment costs for the large scale ponds. We have estimated a value based on the medium ponds. **depreciation excluded*

4.3.1 Profitability for the different types of farmers

As shown in Table 6 the net operating profit margins vary according to the different producers. The analysis of net profits is relevant as it sheds light on cost structure and production efficiency. The lower the net operating profit margin, the less efficient the actor is in converting revenue into profit over a given period. The following sections describe indicators according to the five main types of farms. Figure 11 at the end of this section provides a graphical representation of the cost structure of these five types of farms.

Small-scale "semi-subsistence" pond farmers

These enterprises conduct fish farming as a secondary activity, employ very extensive systems of production with estimated annual production per enterprise averaging around 170 kg. Out of the total production, 41% is consumed by the family, while the remainder is sold to the local community to provide cash income for household expenses. Out of the fish sold, 30% is sold at farm gate price of about ZMW 15/kg while 70% of the fish is sold at the local market (largely rural market) at around ZMW 23/kg.

The cost structure of the small-scale semi-subsistence enterprise is indicated in Figure 11a and is largely composed of intermediate goods and services (97%) such as cost for fingerlings (although these costs are not incurred regularly as seed is often recycled for many years), ingredients for home-made fish feed, and transport for feed and fish from and to the local market. As this type of farmer does not use commercial feed, and other inputs, there is no component of imported intermediate goods and services and this farm type has no value addition apart from the net operating profit of ZMW 390.

The net profit is far below the country's nominal annual minimum wage of ZMW 8 400[14] for unskilled workers and even further below the annual living wage of between ZMW 20 520 and ZMW 30 840 for a single adult[15]. This figure should however be placed in context as the fish pond is just one of a smallholder household's many activities in their livelihood portfolio, and the fact that fish farming activities are to a large degree for the purpose of household nutrition.

Furthermore, the small-scale semi-subsistence pond farmers have no growth objective for the venture, and have low productivity and low average annual sales of around 1740 ZMW. This excludes the amount of fish consumed by the household, which when included brings the average value to 2 790 ZMW. Primarily, this kind of fish farmer practices low stocking density (of about one fish per square metre) and most of them let the fish breed in the ponds as a source of fingerlings. Low productivity can also be explained due to little or no use of commercial (more nutritious) feed, as well as limited knowledge on pond management.

Farmers improve their incomes when they are able to bring the fish to the market where they obtain a better price of 30 ZMW. From an economic point of view, beyond improving household income and providing a source of nutrition, fish farming also provides rural markets with relatively cheap fish, especially when fish is sold at a farm gate price of around 15 ZMW.

Small-scale commercial pond farmers

With some capital to invest, and more knowledge about appropriate pond management practices, the small-scale commercial farmers are able to run successful businesses. A small-scale commercial farmer's estimated average annual production is 5 000 kg, of which 2 500 kg is sold at farm gate price of ZMW 15/kg and another 2 500 kg sold at market price of ZMW 30/kg. Buyers include rural consumers (80%) and public institutions (20%) such as schools and hospitals or clinics. The sale to the public institutions is estimated to be at a farm gate price of ZMW 15/kg. The total sales of 5 000 kg yields sales amounting to ZMW 112 500.

The small-scale commercial pond enterprises' are, with a net profit margin of 37% substantially more profitable than the subsistence farmers. In fact, according to our data, this group of farmers has the highest profit margin among all farm categories. The estimated net earnings of ZMW 41 622 is well above the country's annual living wage of about ZMW 25 000 for a single adult. The operating cost structure as presented in Figure 11b shows that the largest share in costs is for labour, feed, and fingerlings.

The estimated value added in the chain resulting from a small-scale commercial pond enterprise is ZMW 71 817 and is generated by the value of net operating profit (41 622 ZMW), hired labour (24 320 ZMW), taxes (3 375 ZMW), and financial charges (2 500 ZMW). Given their size and the location of the market, these enterprises tend not to incur council levies. Depreciation amounts to ZMW 4 430 is also taken into account however is not include in the added value since there are no financial flows associated with this item in the value chain. The net earnings and profit margin suggest that fish farming at a small-scale pond level can be commercially viable and sustainable. However, from our field visits it did become clear that such small-scale businesses can only be successful with the required technical and business knowledge, linked with access to affordable finance. Examples of loans (e.g. CEEC loans) provided without this knowledge have shown that these kinds of business can also lead to failure and high levels of indebtedness.

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[14] Source: Koyi (2017). Minimum and Living Wages in Zambia: Some Analytical Considerations for Improving Workers' Conditions. Wage Indicator Foundation, Amsterdam.

[15] https://wageindicator.org/salary/living-wage/zambia-living-wage-series-january-2018

Medium-scale pond farmers

The estimated average annual production of a medium-scale pond enterprise is around 100 000 kg, giving total sales amounting to ZMW 2.7 million, of which 50 000 kg is sold at market price of 30 ZMW/kg giving ZMW 1 500 000 (EUR 124 481) in sales and the remaining 10 000 kg is sold at farm gate price of ZMW 23/kg, 20 000 at wholesale price of ZMW 20/ kg and 70 000 kg at market price of 30 ZMW/kg.

The estimated market distribution of medium scale production as indicated in Figure 10 shows that 70% of the produce is sold to the urban consumers, followed by 15 % to large-scale cage enterprises, 10% to large wholesalers, and the remainder (5%) to small wholesalers, supermarkets, butcheries, groceries, restaurants and other urban retailers.

The estimated net operating profits of ZMW 880 104, with a 32.2% profit margin, is an indication of the profitability and efficiency of this category of producers of farmed tilapia. These enterprises are run with technical knowhow and capacity to employ appropriate resources. Almost 45% of total expenses are for intermediate goods and services of which commercial feed and fingerlings are the largest cost components (Figure 11c). Other large expenses for medium scale farmers include depreciation (33%), and wages (15%). The estimated value added in the chain resulting from medium scale pond enterprise is ZMW 1.3 million and is composed of financial charges, taxes, wages, and net operating profit (Table 6). Like small-scale commercial farms, medium-scale farmers are profitable and sustainable businesses.

Large-scale pond farmers

The operating account for the large-scale pond enterprises estimates a production amounting to 1300 t[16] and corresponding to sales up to ZMW 27 million. In terms of market distribution, it is estimated that 24 960 t (80%) of farmed tilapia are sold to large wholesalers and 6 240 t (20%) to the small wholesalers, supermarkets, butchers, grocers, restaurants, and other urban retailers.

The net operating profit has been estimated at 2.4 million ZMW, with a profit margin of 8.9%[17]. Compared to medium-scale producers, labour forms a larger cost component for this type of producers. Among intermediate goods and services, the expenditure on commercial feed is the highest (3.0 million ZMW), followed by fingerlings (1.3 million ZMW) (Figure 11d). Some large-scale producers have integrated production operations with pigs and therefore have their own manure, which is included in the model at zero costs. This also reduces the costs for feeds as manure is used to stimulate the production of plankton on which the fish feed. Ultimately, a large-scale pond integrated system can offset a high degree of costs, therefore providing possibilities for high efficiency. The cost of fingerlings is relatively low as the enterprise integrates fingerling production into its main operations. This is a strategic decision aimed at ensuring to meet its needs of a continuous supply of high quality and affordable fingerlings. Currently, availability of fingerlings is a challenge at the national level both in terms of quality and quantity.

Other major costs for a large-scale pond enterprise include wages (8.1 million ZMW), financial charges (6 million ZMW) and depreciation (5.4 million). Value added amounts to ZMW 17.8 million of which 2.4 million is net operating profit (Table 6).

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[16] This is the size of the model we used for elaborating the account but many farms are smaller in this category.

[17] We have made some assumptions related to the size of capital depreciation as we did not have data on this item. This may have affected the profit margin.

In contrast to the small-scale and medium-scale operations, commercially oriented large-scale pond enterprises adopt a higher stocking density and provide feed supplements and pond fertilisation (resulting in an average feed convention ratio of around 1.6). At selling point, fish weights on average 350-450 g, although even bigger sizes are also found. When systems are highly integrated, a large-scale pond enterprise achieves productivity levels that are comparable to international standards.

Large-scale cage farmers

It is estimated that an enterprise produces an average of 2 000 t per year of fish distributed as follows: 40% (800 t) to the "City Ladies", 36% (720 t) to large wholesalers, and 24% (480 t) to small wholesalers, supermarkets, butchers, grocers, restaurants and other urban retailers (Figure 10). With a net profit margin of 12.3%, and a net profit margin of 5.5 million ZMW, a large-scale cage enterprise is profitable and economically sustainable.

Costs for intermediate goods and services amount to 8.6 million ZMW corresponding to 19% of total sales. As shown in Figure 11e, labour is the highest operating cost component, corresponding to 7.2 million ZMW, followed by commercial feed (2.9 million ZMW), fuel for transport and generators (3.3 million ZMW), and fingerlings (1.2 million ZMW). Depreciation on cages and other major capital items amounts to 14.2 million ZMW. The value added in the chain for a large-scale cage farm is estimated at 22.3 million ZMW. This is generated by the value of net operating profit (5.5 million ZMW), wages, financial charges, and taxes.

Like the medium-scale and large-scale pond operations, a large-scale cage farm is also involved in the production of fingerlings to be able to meet its requirement in terms of quality and quantity. By analysing the estimated levels of profitability and management and production practices, this kind of enterprise can be considered competitive, reaching a feed conversion ratio of about 1.5 to 1.6[18]. Due to intensive production and efficient management practices, as well as heavy reliance on commercially produced feed, a large cage enterprise can achieve a 80% survival rate or more at harvest, with fish reaching an average weight of 400-500 g over a 9-month cycle.

To ensure an effective distribution of its farmed fish, generally large-scale cage enterprises also establish depots in strategic locations (as Yalelo and Lake Harvest), and therefore part of their costs are trade expenses. From depots, they reach out different market segments and they sell fish with prices ranging between 23-24 ZMW for wholesale and above 26 ZMW for retail.

[18] This means that it takes 1.6 kg of feed to produce 1 kg of fish.

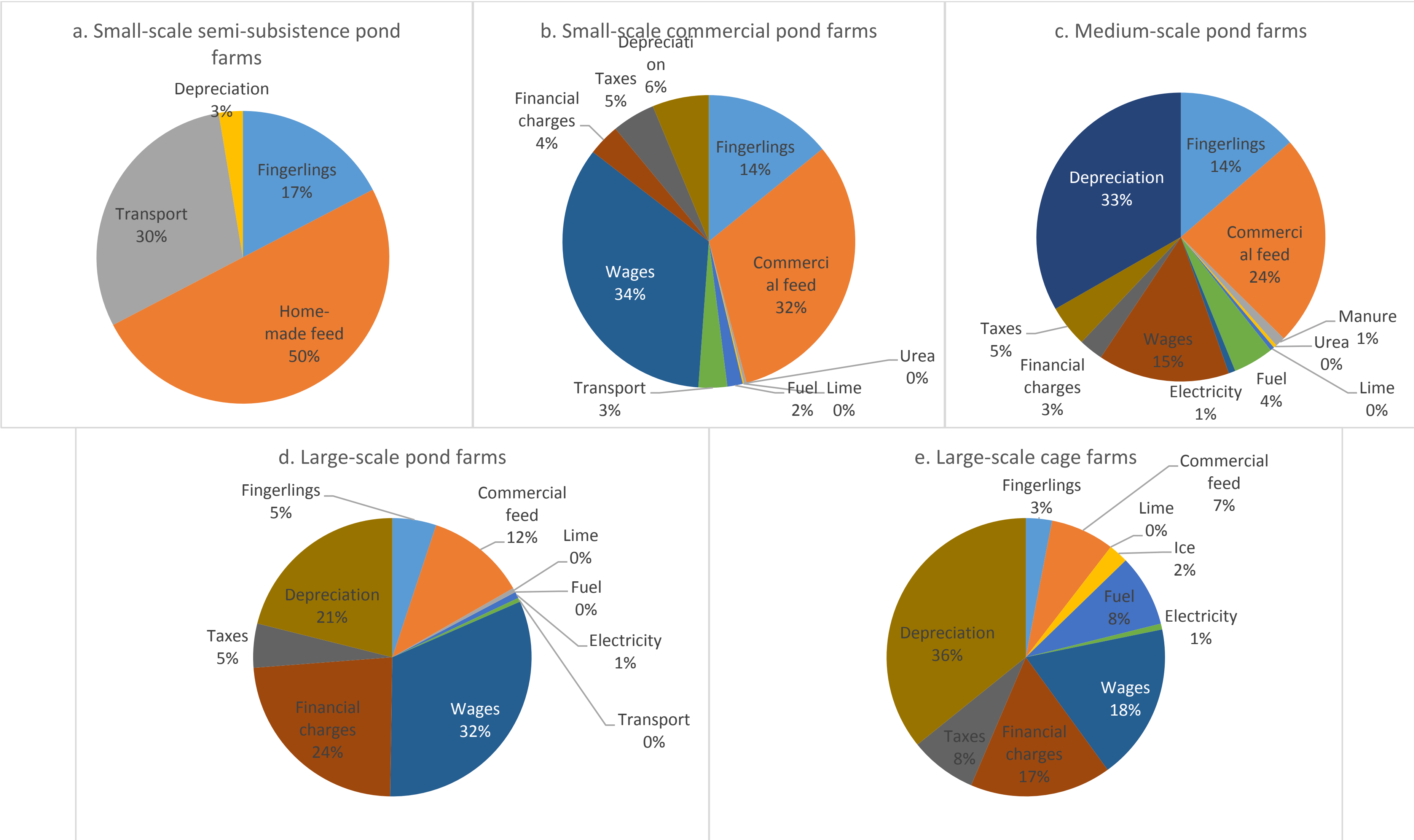

FIGURE 11: COST STRUCTURE OF FIVE TYPES OF FARMS (IN %)

4.3.2 Profitability for the main traders: "City Ladies" and wholesalers

There are several actors involved in the distribution of farmed fish at different levels. These include "City Ladies", small and large wholesalers, supermarkets, butchers, grocers, restaurants and other urban retailers. The following analysis is based on two main actors, namely the "City Ladies" and the large wholesalers. They are the actors whose core business is significantly connected with distribution and trade of farmed tilapia. Small wholesalers could be another interesting category to analyse, although, as they are highly fragmented, data available is not sufficient.

"City Ladies"

Out of the category of fish traders, in the present report the operating account was built around the reconstruction for "City ladies". This is the name given by the Zambian actors of the aquaculture value chain to women traders involved in the sale of farmed tilapia in urban areas (in particular Lusaka), in particular around Lusaka. They are primarily based in established township or suburb markets as well as in other designated trading areas.

	Quantity	Unit	Unit price (ZMW)	Total (ZMW)
OUTPUT				
Sales				
Fresh	*8 439*	*kg*	*32*	*270 048*
Frozen	*1 920*	*kg*	*29*	*55 680*
Self-consumption				0
Direct subsidies				0
Total output				**325 734**
EXPENSES				
Intermediate Goods and Services				
Tilapia	*10 359*	*kg*	*23*	*238 257*
Plastic bags	*500*	*packet*	*1.5*	*750*
Transport	*365*	*unit*	*50*	*18 250*
Ice	*500*	*unit*	*2.5*	*1 250*
Market fee	*365*	*day*	*5*	*1 825*
Wages				0
Financial charges				0
Taxes				0
Depreciation				30
Total expenses				**260 397**
PROFITABILITY RATIOS				
Net operating profit				*65 338*
Net added value				*65 338*
Profit margin				*20.1%*

TABLE 7: OPERATING ACCOUNT FOR AN AVERAGE CITY LADY (IN ZMW)

Source: Computed by authors from data collected in consultation with "city ladies"

The "City Ladies"[19] are supplied from two main primary sources, namely from large cage enterprises where she buys about 8 439 kg of fresh tilapia at wholesale price and also from large

[19] City Ladies occasionally source their farmed tilapia from small-scale commercial ponds located within the periurban areas, although this can be unreliable due to erratic supplies.

wholesalers where she buys 1920 kg of frozen tilapia annually. Hence, on average the "City Ladies" collect 40% of tilapia supplied by the large cage enterprises and 20% of frozen tilapia supplied by large wholesalers. She plays a critical role in the value chain at the distribution level as she is one key actor who retails the fish to the urban consumers at around 32 ZMW for the fresh and 29 ZMW for the frozen tilapia[20].

At an individual micro level, the estimated operating account of an average "City Lady" is as presented in Table 7. An average "City Lady" makes a net operating profit of 65 338 ZMW and has a profit margin of 20%. The operating account for this actor shows that she does not receive any direct subsidies. The cost structure has no wages, taxes, or financial charges and added value is therefore only composed of the net operating profits.

The highest cost for the "City Lady" is represented by tilapia purchases amounting to 91.5% of total expenses (238 257 ZMW), followed by transport costs for fish of 18 250 ZMW (7%), market fees (0.7%), ice (0.5%), plastic bags (0.3%) and depreciation (0.01%). A "City Lady" pays the market fee on a daily basis, and this corresponds to 5 ZMW. However, a "City Lady" that rents a market stand from another individual may end up paying an additional monthly rent of around 200 ZMW.

The value addition is only based on the net operating profit amounting to 65 366 ZMW. Based on the estimated operating account, the "City Lady" operation with a margin of 20% is profitable and sustainable. It is important to note that the "City Lady" operation yields net earnings well above the average annual living wage of between ZMW 20 520 and ZMW 30 840.

Large wholesalers

There is one large wholesaler/importer that plays an important role in the value chain as the operation deals with large volumes and differentiated tilapia products as shown in the operating account presented in Table 8 below. There are a number of other wholesalers and importers. From the domestic economy, a large wholesaler procures 5 500 t of fresh tilapia mainly from three different categories of suppliers: from large-scale cage farms (32% of his total supply), from large-scale pond farms (~8%) and from medium-scale pond farms (<1%). In addition to the local supply, a further 720 000 kg are imported (mainly from China) (58%).

The main outlets of the tilapia sold by the large wholesaler include small wholesalers, supermarkets, butchers, grocers, restaurants and other urban retailers who access a combination of frozen (75% of all the frozen fish sold by the wholesalers), fillet (90%), smoked (80%), and fresh (100%). Furthermore, some of the tilapia is sold directly to urban consumers: frozen (25%), fillet (10%), and smoked (20%). The operating account shows that the large wholesaler sells the tilapia using the following prices per kg: 26 ZMW for local frozen, and 21 ZMW for imported frozen, 30 ZMW for fresh, 70 ZMW for fillet, and 85 ZMW for smoked.

The overall volume of sales of a large wholesaler is estimated at around 180 million ZMW with net earnings amounting to 16.1 million ZMW. The operating accounts (Table 8) show that a large part of IGS is made up by the purchase of tilapia (97.5%), both local and imported. It is estimated that 1 kg of imported tilapia costs around 11 ZMW, compared to the local tilapia for which the wholesale price is around 21 ZMW/kg.

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[20] This could be considered as a high average price because many "City Ladies" buy and sell fish at lower prices from and to poor urban consumers.

This implies that in the local markets, there is direct competition between the locally produced and imported tilapia. Notwithstanding the general preference by consumers for locally produced tilapia products, low prices favour the sales of imported tilapia, especially among many consumers that do not recognised the difference between imported and locally produced tilapia[21].

	Quantity	Unit	Unit price (ZMW)	Value (ZMW)
OUTPUT				
Sales				
Frozen whole local	4 560 000	Kg	26	118 560 000
Frozen whole imported	720 000	Kg	21	15 120 000
Fresh	300 000	Kg	30	9 000 000
Fillets	240 000	Kg	70	16 800 000
Smoked	240 000	Kg	85	20 400 000
Direct subsidies				0
Total output				**179 880 000**
EXPENSES				
Intermediate Goods and Services				
Tilapia (imported)	*720 000*	*Kg*	*11*	*7 920 000*
Tilapia (local market)	*5 500 000*	*Kg*	*20*	*110 000 000*
Fuel	*48 000*	*L*	*12.03*	*577 440*
Ice	*1 760 000*	*Kg*	*1.36*	*2 400 000*
Wages	240	Fte	14 400	3 456 000
Financial charges				25 000 000
Taxes				
Duties imported fish				*1 980 000*
Corporate tax				*8 698 746*
Permits				*200 000*
Depreciation				
Freezers	*10*	*Unit*	*10 000*	*7 000*
Large trucks	*40*	*Unit*	*500 000*	*2 800 000*
Small trucks	*20*	*Unit*	*200 000*	*560 000*
Depots	*65*	*Unit*	*0*	*0*
Freezer containers	*30*	*Unit*	*60 000*	*126 000*
Total expenses				**163 725 186**
PROFITABILITY RATIOS				
Net operating profit				*16 154 814*
Net added value				*55 489 560*
Profit margin				*9.0%*

Table 8: Operating account for large wholesaler of tilapia.
Source: Computed by authors from data collected in the field. Note: this excludes the costs of the office and processing plant infrastructure. These are used also for other business.

[21] A number of actors have expressed concern over the influx of relatively cheap tilapia imports, and have requested the Government of the Republic of Zambia to intervene accordingly in order to augment the initiatives of local tilapia producers.

Figure 12 presents the cost structure for large wholesalers in percentage. The largest cost components include the purchase of local and imported tilapia (together 72%), financial charges (15%), and taxes and permits (7%).

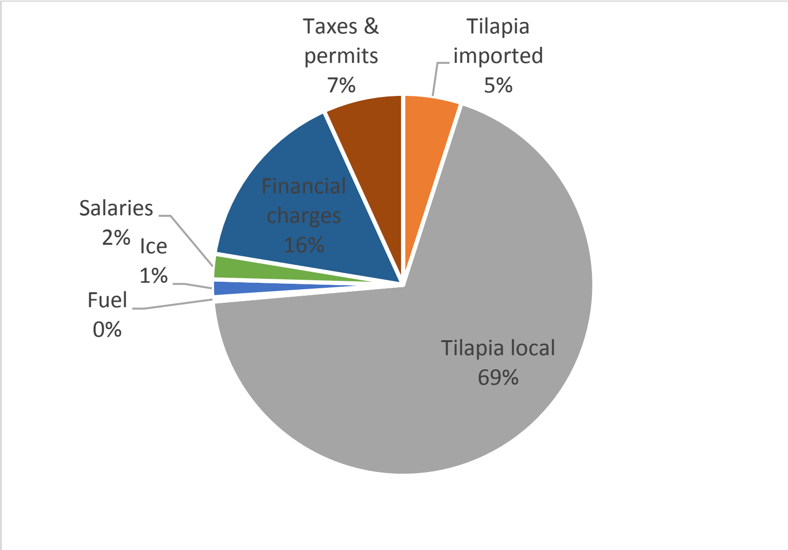

FIGURE 12: COST STRUCTURE FOR LARGE WHOLESALER

Added value amounts to 55 million ZMW, which is a combination of salaries (3.4 million ZMW), financial charges (25 million ZMW), taxes and permits (10.9 million ZMW) and net operating profits (16.1 million ZMW). Of all the actors in the chain, this account suggests that the large-scale wholesaler is the highest contributor to added value along the aquaculture value chain. However, it should also be noted that there is only one wholesaler of this size in the country.

The profit margin that is estimated for this actor is 9%. It plays an important distributive role within the aquaculture subsector, ensuring that both the locally produced and imported tilapia is available to consumers.

4.4 Analysis of the effects within the national economy

The macro-perspective analysis starting here is based on the operating accounts elaborated for the financial analysis; and the flows of products throughout the value chain as presented in Figure 10. The operating accounts and the representation of the channels could be improved through a process of in-depth collaboration with the private sector, resulting in new and more acurate simulations of the contribution of aquaculture to the country's economic growth. In the years to come, the sector is also expected to evolve, due to the impacts of current investments, therefore requiring monitoring and updates of the current figures.

Figure 13 shows the relative important of flows between actors in the value chain. It is clear that there are four main flows:

1) imports of fish/tilapia to large wholesalers (and probably other urban destinations),
2) sales of fresh tilapia from large cage farmers to wholesalers and urban retailers,
3) sales of frozen tilapia to large wholesalers and other types of distributors in the value chain and, to a lesser degree, urban consumers,
4) sales of fresh tilapia to "City Ladies" and urban consumers. The other flows represent the flows that are not as important.

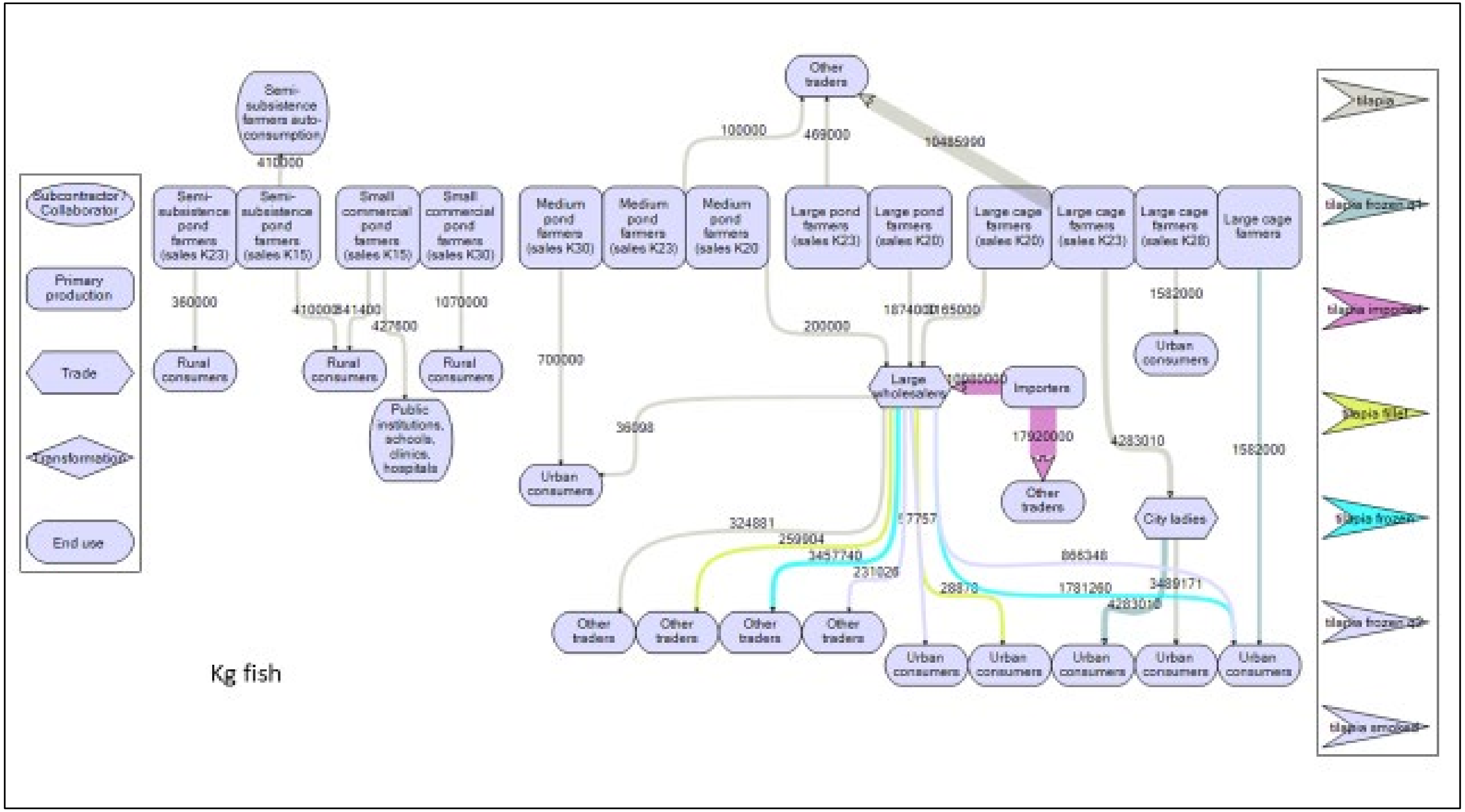

Figure 13: Relative importance of farmed fish flows between the main actors of the value chain. Source: AFA software based on authors' compilation of data.

The large wholesalers are at the core of the value chain; they are supplied by many types of farmers (except the small-scale farmers) and importers, and provide fresh and processed fish in many urban channels. Finally, there are two sub-systems with few relations between them: the rural system with the small-scale farmers selling fish directly to rural markets; the urban system with the big players and the urban traders and where the medium farmers are integrated.

4.4.1 Value chain consolidation and analysis of direct value added

Table 9 presents the operating account of the whole aquaculture value chain system in Zambia by merging the individual operating accounts of the main value chain actors. This global account allows calculating the direct value added generation and distribution.

Given data deficiency, the activities and associated value added of minor actors have not been taken into account in the calculation of the direct value added. This relates to the (legal and illegal) importers, the fragmented small and medium-scale wholesalers; the actors to whom fish is a minor input (supermarkets, butchers, grocers, restaurants); a part of urban retailers supplied by domestic or imported fish (all these fragmented actors are called ”others traders” in the previous figure, all their sales converge towards the urban markets). In this case, further data that would improve the knowledge on the actors’ activities, can in the future be integrated into the database created in the framework of this study, to increase the reliability and completeness of the analysis.

Therefore, the following calculation is likely to estimate the main part of the direct value added, while including and representing all the main actors in the value chain: all farmers, the large wholesalers (mainly represented by Capital Fisheries that buys, according to different estimations, between 40 and 70% of the national fish and between 30 and 60% of imported tilapia), the main retailers (“City Ladies”) selling on the urban markets.

Operation	Subsidy	Final output	Output in process	Input in process	Goods	Services	Salaries	Taxes	Financial costs	Depreciation	Net Operating Surplus	Value added
Semi-subsistence pond farmers	0	20 580 000	0	0	11 220 411	5 103 529	0	0	0	832 941	3 423 118	4 256 059
Small commercial pond farmers	0	48 135 000	0	0	14 546 484	962 550	10 404 096	1 443 825	1 069 500	2 109 054	17 599 493	32 625 968
Medium pond farmers	0	23 300 000	4 000 000	0	8 256 030	600 000	2 726 626	739 000	500 000	5 557 447	8 920 899	18 443 972
Large pond farmers	0	10 787 000	43 102 000	0	3 751 374	218 264	14 598 691	9 028 661	10 813 847	9 690 408	5 787 756	49 919 363
Large cage farmers	0	318 695 800	161 809 220	0	50 685 967	0	75 952 800	47 133 136	68 568 500	149 444 100	88 720 453	429 818 989
City ladies	0	134 674 800	0	98 509 230	826 916	8 300 167	0	0	0	12 404	27 026 080	27 038 484
Large wholesalers	0	216 442 700	0	129 478 100	3 574 938	0	4 158 471	22 009 030	12 032 610	4 202 992	40 986 460	83 389 563
Importers	0	197 120 000	110 880 000	0	308 000 000	0	0	0	0	0	0	0
Value chain	0	---------------	---------------	-----------------	400 862 120	15 184 510	107 840 684	80 353 652	92 984 457	171 849 346	192 464 259	645 492 397

Table 9: Operating account of the value chain computed with the support of the AFA software (ZMW)

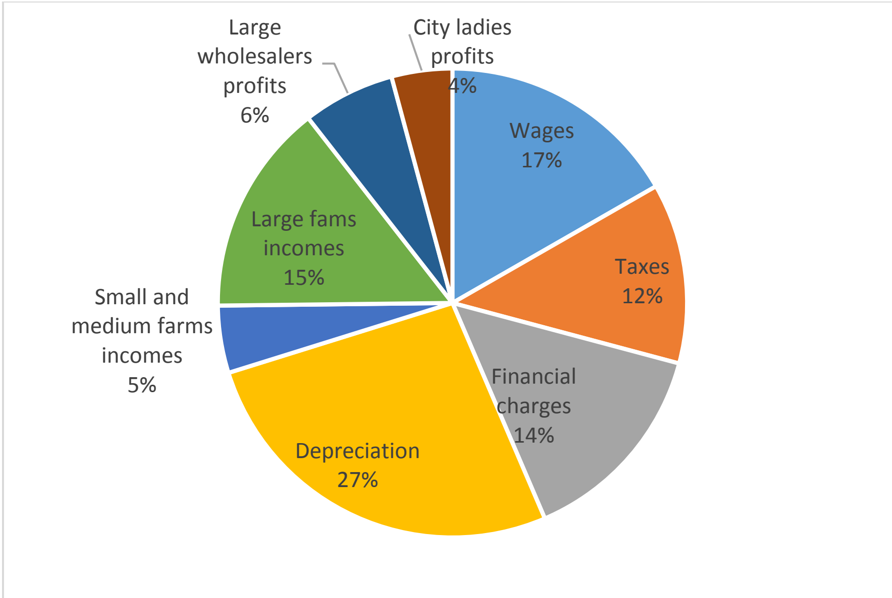

FIGURE 14: DIRECT VALUE ADDED DISTRIBUTION (COMPONENTS)

Table 9 indicates that the aquaculture value chain in Zambia generates about 645 million ZMW of direct value added per year (calculation based on 2016 flows). The main part is generated by the large-scale cage farmers (66%) and the large wholesalers (13%). The small and medium-scale farmers together represent 9% of the direct value added (Table 9 and Figure 15).

The main part of this direct value added comprises incomes and operating profits benefiting the actors involved in the value chain (57%), then to a lesser extent, by taxes (12% if taxes are paid), wages (17%) and financial charges (14%). This last figure corroborates that the value chain is emerging in Zambia and that actors are increasing their investments (Table 9). 21% of the net operating surplus of the value chain is benefiting the large wholesalers, 14% the "City Ladies" and the remainder (65%) the fish farmers, out of which 70% is going to the large scale cage farmers (Figure 15 middle), showing that inclusiveness could be improved in the value chain. The large-scale farmers together benefit from 49% of the net operating surplus of the value chain, while distributing 84% of the wages (Figure 15, right). This is explained by the labour-intensive activity of growing fish in cages and by the large volume of tilapia they produce.

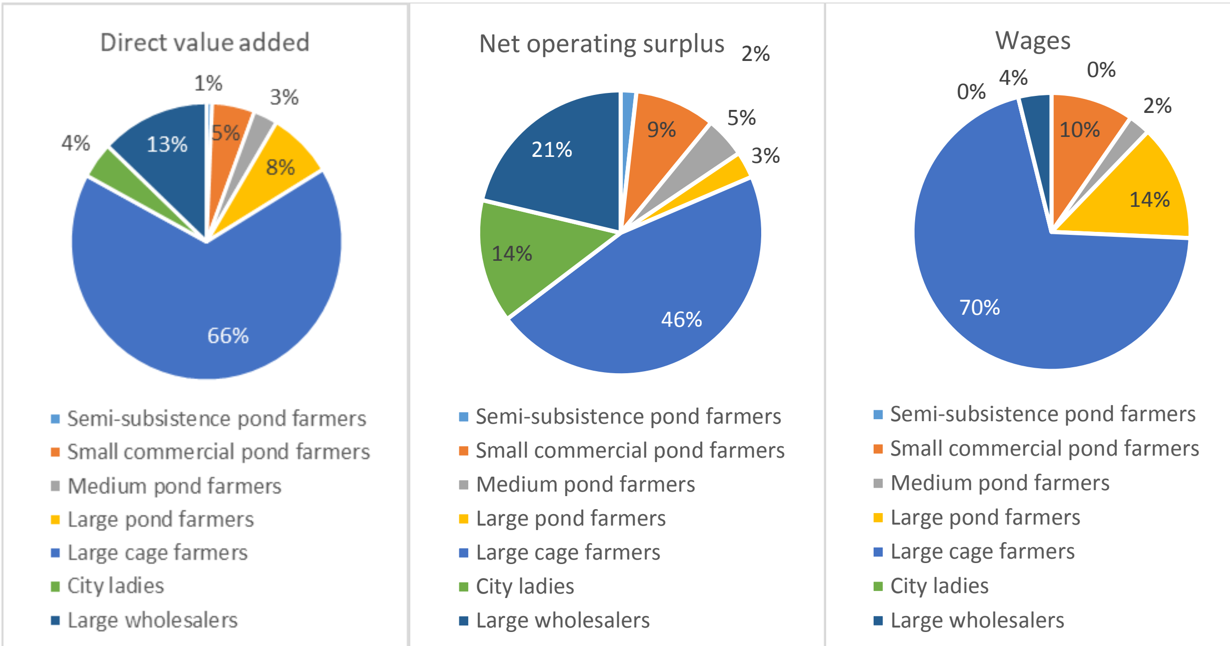

FIGURE 15: DIRECT VALUE ADDED, NET OPERATING SURPLUS AND WAGES DISTRIBUTION BETWEEN ACTORS

Source: own data

4.4.2 Computing growth generation

Growth is measured by the Gross Domestic Product (GDP), i.e. the total value added produced in the country. The measure of the contribution of the value chain to growth includes: i) direct value added generated by the actors (farmers, large wholesalers and "City Ladies"); and ii) indirect value added that results from activities induced by the use of intermediate goods and services (IGS) supplied to these direct actors by actors outside the value chain limits (producing feed, seed, fuel, etc.). The indirect value added is estimated through backward linkages computation.

Calculation of total value added and total imports

Table 9 indicates that the amount of IGS off-sector generated is 401 million ZMW for goods and 15 million ZMW for services, totalling 416 million ZMW, i.e. 43% of the value of final output. The main users of these IGS are importers and large-scale cage farmers.

The distribution of IGS is divided as follows: 74% corresponds to imported tilapia, 13% to feed either commercial feed or ingredients for homemade feed (mainly domestic good), 6% to (mainly imported) fuel and transportation costs (domestic services), 3% to fingerlings (although actual production from the large farmers is not known), 3% to ice (domestic good), 1.3% other IGS (electricity, market fees, plastic bag, lime, manure, urea) (Figure 16).

It should be noted that part of the 308 million of imported tilapia (64%) could be flowing towards actors which were not integrated in the calculation of the direct value added (other importers, small wholesalers, retailers). Therefore, it is likely that tilapia imports represent less of all IGS, albeit still represents the majority of IGS. Moreover, if this imported fish was to be partially replaced by domestic farming, the direct value generated by farmers in the national value chain would be much higher.

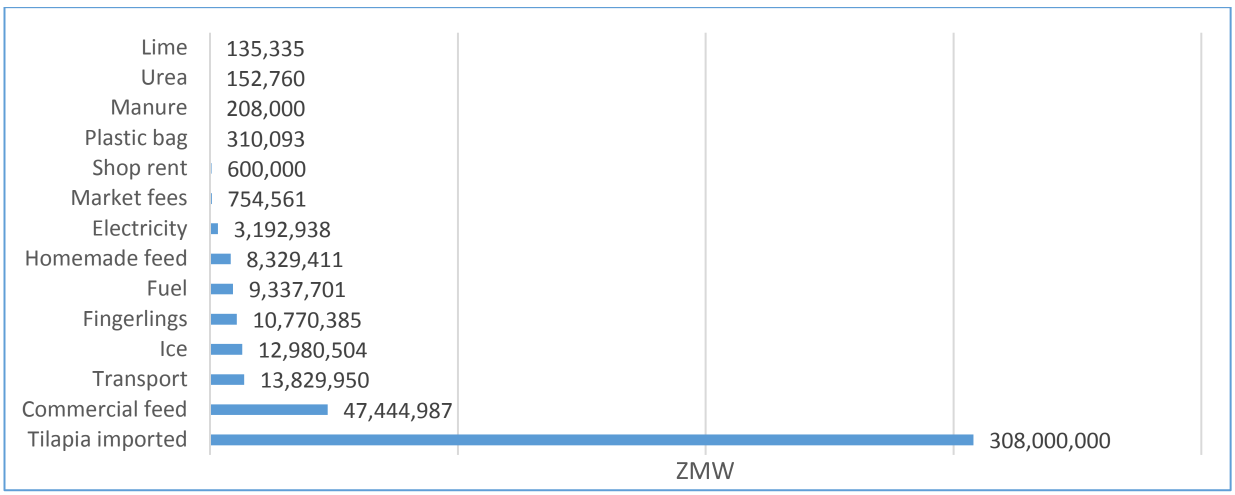

Figure 16: Intermediate goods and services in the aquaculture value chain of Zambia

Figure 17 shows the breakdown of the IGS in direct imports and indirect value added. We used data collected by surveys for valuing direct imports and the breakdown of fingerlings (surveys of one Government hatchery and two commercial hatcheries). The indirect value added (labour, taxes, financial charges, profits) generated by the other domestic goods and services is estimated, with the use of available secondary data.

AgriFood chain Analysis
Summary table of effects

Category	Item	IGS	Direct imports	Indirect VA	Labour	Taxes	Finance	Depreciation	Profit
Consommable	Commercial feed	47,444,987	0.20	0.40	0.30	0.10	0.10	0.20	0.30
Consommable	Fingerlings	10,770,385	0.00	0.70	0.40	0.10	0.10	0.10	0.30
Consommable	Fuel	9,337,701	0.90	0.00	0.00	0.00	0.00	0.00	0.00
Consommable	Homemade feed	8,329,411	0.00	0.70	0.50	0.00	0.00	0.00	0.50
Consommable	Ice	12,980,504	0.00	0.40	0.50	0.00	0.00	0.10	0.40
Consommable	Lime	135,335	0.00	0.50	0.40	0.10	0.00	0.10	0.40
Consommable	Manure	208,000	0.00	0.30	0.50	0.00	0.00	0.00	0.50
Consommable	Plastic bag	310,093	0.50	0.40	0.20	0.20	0.20	0.20	0.20
Consommable	Tilapia imported	308,000,000	0.90	0.00	0.00	0.00	0.00	0.00	0.00
Consommable	Urea	152,760	0.90	0.00	0.00	0.00	0.00	0.00	0.00
Consommable	Electricity	3,192,938	0.10	0.40	0.20	0.10	0.20	0.30	0.20
Service	Market fees	754,561	0.00	0.80	0.20	0.80	0.00	0.00	0.00
Service	Shop rent	600,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Service	Transport	13,829,950	0.50	0.50	0.50	0.10	0.10	0.20	0.10
		416,046,624							

	Direct effects	Indirect effects	Total effects
Imports	**302,619,728**	**0**	**302,619,728**
Labor	107,840,684	18,137,228	125,977,911
Tax	80,353,652	3,985,434	84,339,086
Finance	92,984,455	3,623,466	96,607,921
FBCF	171,849,342	6,866,468	178,715,809
CSE	192,464,259	13,977,361	206,441,620
Value added	**645,492,391**	**46,589,958**	**692,082,349**
IC Not Ventilated		66,836,940	66,836,940

Figure 17: Total effects (imports and value added)

To summarise, as shown in Figure 18, **the total value added of the aquaculture value chain in Zambia is estimated at 692 million ZMW** composed of 645 million ZMW of direct value added, plus 47 million ZMW of indirect value added.

As the information was insufficient to estimate the indirect imports by survey, the following ratio of the national economy of Zambia (2016) was used:

$$\frac{imports}{GDP} ratio = \frac{7.5\ billion\ USD}{21.7\ \text{billion USD}} = 34.7\%$$

This ratio was applied to the amount of indirect value added of 47 million ZMW and it is estimated that the **indirect imports are 16 million ZMW**. So, the **total imports are estimated at 319 million ZMW** composed of 303 million ZMW of direct imports, plus 16 million ZMW of indirect imports.

The remaining value is the domestic Intermediate Consumption (IC) that is not distributed, i.e. 67 million ZMW (Figure 18).

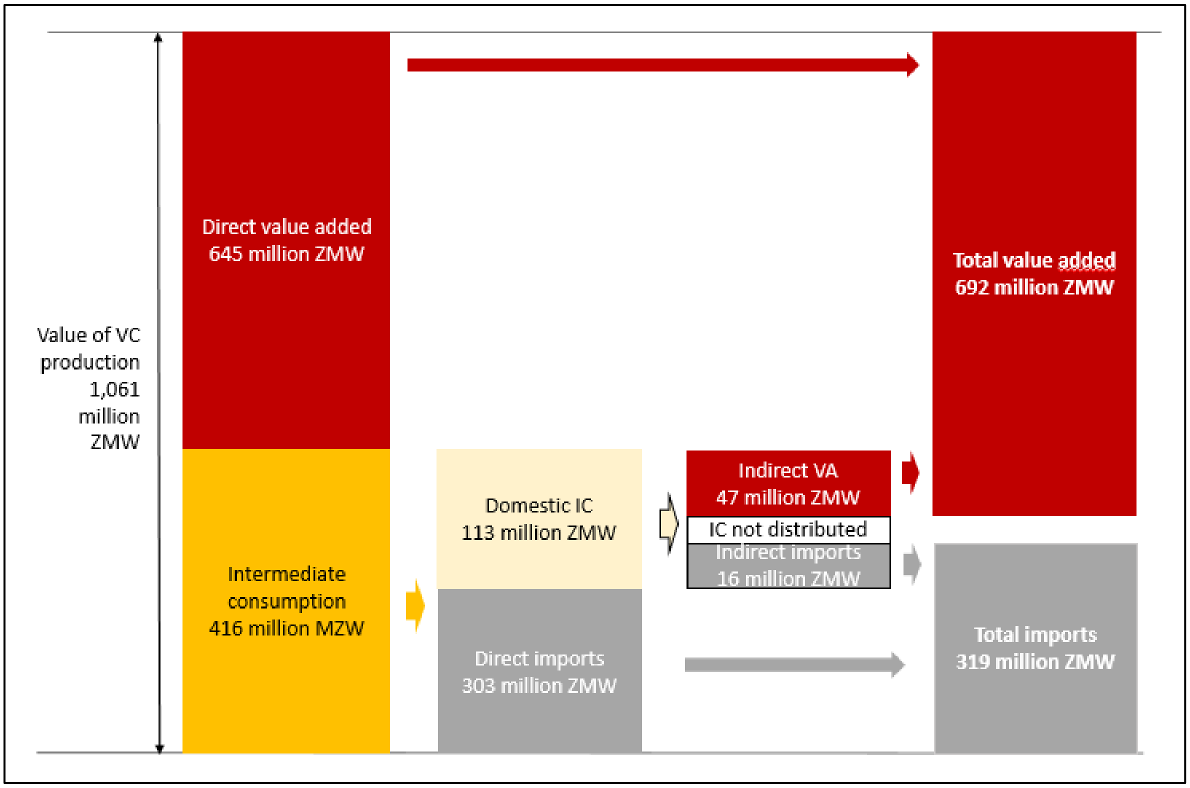

Figure 18: Total effects

NB: elements in Figure 18 are not proportional on purpose, to facilitate reading the values.

Contribution of the aquaculture value chain to the national and agricultural GDP

The contribution of the value chain to the GDP is calculated by dividing the total value added by the Zambian GDP. The GDP in 2016 was 21.7 billion USD or 215 481 million ZMW (with an average exchange rate in 2016 of 9.93 ZMW for 1 USD). Thus, **the contribution of the value chain to the GDP was 0.32% in 2016**.

$$\% \, contribution \, to \, GDP = \frac{692 \text{ million ZMW} * 100}{215\,481 \text{ million ZMW}} = 0.32\,\%$$

The agricultural GDP was ZMW 11 314 million in 2016 (5.25% national GDP), so **the contribution of the aquaculture value chain to the agricultural GDP was 6.1%**.

$$\% \, contribution \, to \, agricultural \, GDP = \frac{692 \text{ million ZMW} * 100}{11\,314 \text{ million ZMW}} = 6.1\%$$

The rate of integration into the economy (value added/value chain production) is 692 million ZMW out of 1061 million ZMW (**65%**). This rate has improved in the past years, as Zambia has developed its own feed production industry. Nevertheless, this could be further improved with the development of the aquaculture sector, also through a possible limitation of the rising fish/tilapia imports that are currently needed by traders to satisfy consumer' demand.

Discussion

It is to be noted that, for example, the NADP Document (Nov. 2016) is pessimistic on the effects of the aquaculture value chain within the national economy. The document suggests that upstream industries are poorly developed in Zambia (for example, there are very few or no producers of aquaculture machines or service providers in construction of nurseries and/or production infrastructure; there is limited production and utilisation of inputs like commercial feeds, fingerlings, inorganic fertilizers or animal health products from specialized producers). Downstream industries are quasi inexistent (the sector has not yet truly reached a development stage where the product is treated or processed after harvest; the producer is often both a consumer and a retailer). Under these circumstances, there is very limited revenue and employment generated in the chain. However, current trends in the development of the sector suggest that this scenario may be changing.

Such a recent development is the fact that two key inputs in the chain, feed and seed are now mainly supplied by domestic operators[22]. These two intermediate goods/inputs are key for a possible improvement of the productivity of farmers (in particular in terms of quality) and growth generation, as difficulties in accessing secure supplies of high quality feed and seed are often described as the biggest barrier to aquaculture development (see also Annex 4). Despite the recent developments in the fish feed sector, the quality of feed in Zambia is still considered to be low, resulting in high FCRs and negative impacts on water quality.

4.4.3 The contribution of the value chain to public finances

The Government of Zambia does not provide direct subsidies to companies in this value chain, but the sector has benefited from several aquaculture support projects involving international and national public funds (national counterpart). An analysis of project documents targeting aquaculture in Zambia in recent years, could provide a rough estimate of the public funding allocated to the value chain throughout the country.

The total taxes paid to the Zambian state by the actors in the value chain are estimated to amount to 80 million ZMW in direct taxes and 4 million ZMW in indirect taxes. The direct taxes mainly consist of 35% profit tax (corporate taxes) for large scale farmers and wholesalers, council levies and import duties on legally imported fish (25% on the CFA price) by wholesalers and importers.

Estimates by the aquaculture sector association (ADAZ), estimate the shortfall in public finances due to illegal imports to be around 30 million ZMW. According to this document, imported tilapia should be expected to bring in 60 million ZMW to the public finances, but in reality, generates only half. Our economic analysis is even slightly higher and puts potential import taxes 77 million ZMW for a volume of 28 000 t on which all taxes would be paid (308 million ZMW * 25% = 77 million ZMW).

According to ADAZ, possible methods of smuggling and tax evasion can be through undervaluing invoices, importers trading under multiple company names, tilapia being transported as Namibian horse mackerel with fraudulent SADC documents as this kind of fish is exempt of duty, and destination fraud.

4.4.4 The contribution of the value chain to the balance of trade

[22] According to several sources, feed represents 60 to 70% of the production cost in fish farming. Our analysis may underestimate the needs of seed, but farmers increasingly have their own supply of fingerlings, and therefore seed is reducing in the intermediate consumption. Also, the competition inside the country has lowered the price of feed.

The contribution of the value chain to the balance of trade is highly negative. Zambia being a fish-consuming nation, fish imports far exceed exports. **Imports of tilapia currently account for around 50% of the farmed fish consumed in Zambia** (28 000 t out of 28 580 t except water bodies), while exports are limited (343 t of registered exports).

Some notable export destinations for Zambian capture fish and fish products registered by DoF are DR Congo, Angola, South Africa and China, while the import sources include Namibia, Malawi, Zimbabwe, Mozambique, China and Thailand (Fisheries Statistical Annual report, 2015). Some of Zambia's neighbouring countries also are large importers of fish, in particular Angola (143 389 t of fish imports in 2015), DR Congo (107 883 t), and Mozambique (52 352 t)[23], and could therefore potentially become recipients of Zambia's farmed fish in the future. According to DoF, farmers, buyers and traders have become increasingly aware of the large market potential in these two neighbouring countries.

Although **increasingly autonomous in the production of feed**, the country still needs to import fuel, urea, packaging and micro-ingredients such as fishmeal, premixes and vitamins. As a result, these imports are further widening the deficit in the trade balance of the value chain.

As noted above, **Zambia does not yet export feed to other countries**. Nevertheless, there is anecdotal evidence that suggests this is beginning to happen in Malawi and Angola. The competition inside the country has lowered the price of grower feed which may continue to drop according to World Fish (2017) and Desprez et Mikolasek (2017). The Zambian fish feed sector could potentially benefit the entire Southern region (Zambia, Zimbabwe, Mozambique, Malawi), especially where the potential of development for tilapia cage farming is high (Lake Kariba, Lake Malawi, Cahora Bassa), with positive impacts on the Zambian balance of trade.

4.5 Sustainability and viability of the value chain within the global economy

The Zambian aquaculture sector faces strong competition in the national market with domestic capture fish, imported capture fish, and imported farmed fish. As described in section 3.1.1 on value chain actors, imported tilapia is often smaller in size, and a "by-product" for those producing countries, hence sold at extremely low prices. Despite some degree of consumer' preference for locally grown tilapia, the higher price of this fish, and the inability of consumers to always immediately recognize the source of the product, can drive them towards imported fish. It has been suggested that the difference in cost price of locally produced fish, and legally imported fish (FOB price) is 5.3 ZMW per kg (for tilapia of 300-500 gr), implying that imported tilapia is 27% cheaper than locally produced fish. (See Annex 5 for a comparison). Legally and illegally imported tilapia of a smaller size (100-200 g) were priced at 13 and 11.5 ZMW per kg respectively, providing a price difference of 33% and 41% respectively with locally produced tilapia. Legal imports and smuggling therefore both put pressure on the price of locally produced fish, which negatively impacts the viability of local fish farmers.

The calculation of the coefficient of viability in the international economy

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[23] According to FAO Fisheries Statistics http://www.fao.org/fishery/statistics/global-commodities-production/query/en. Includes fish only, excludes crustaceans, molluscs and other aquatic invertebrate.

As the aquaculture value chain in Zambia competes with imports and the possibility of exports, it makes sense to measure the balance of the goods and services produced and consumed by the value chain using international prices (parity prices) to give an indication of the overall economic gain or loss of investing in aquaculture production for the national economy. For that, we use two standard coefficients: the Nominal Protection Coefficient (NPC) and the Domestic Resource Cost Ratio (DRCR).

Parity price is the price of the possible alternative obtained by importing from, or exporting to, the same geographical point and in the same form. As the analysis encompasses the value chain throughout the whole country, we use border prices as parity prices. The following calculation process eliminates transfers (taxes and financial flows) and values tradeable goods and services using international prices and using actual domestic market prices for other flows.

NPC = Value of VC total production at market prices ÷ value of VC production at parity prices

NPC = 1061 ÷ 560* = 1.9

*Given a parity price of 20 ZMW per kg: higher than the price of 11 ZMW per kg used for the financial analysis to take into account the difference of quality between imported fish and domestic farmed fish.

The production of the value chain is protected by the government by a tax on imports. But we know that part of the imports (estimated at around 50%) are illegal, these escape these taxes, reducing the actual protection of national producers. Also, the operating profits of wholesalers are higher than that they would be if all their supply would be from domestic farmed fish.

DRCR = no tradeable factors at actual domestic market price (without transfers) ÷ (value of VC total production at parity prices – tradeable inputs at parity prices)

DRCR = 374 ÷ (560 – 250) = 1.2

These results confirm the weak sustainability of the value chain within the international economy. Despite imported tilapia not being in theory a direct competitor to Zambian farmed tilapia (given its small size), productivity gains in the activities of the value chain actors are needed and should help reduce unit production costs and enable aquaculture products to be more competitive in the market with regard to capture fish and capture and aquaculture imports.

4.6 Growth inclusiveness

This part of the reports brings an economic perspective to reply to the framing question 'Is the economic growth of the Zambian aquaculture value chain inclusive?'. The social analysis will add to this from a social and qualitative perspective.

4.6.1 Income distribution across actors of the value chain

Figure 19: Share of direct value added, net operating surplus, and wages by VC actor shows a different depiction of the contribution to direct value added, net operating surplus, and wages. Small and medium farms contribute less to direct value added than their share of net operating surplus they receive (9% versus 16%), while this is the reverse for the large scale pond farmers (8% versus 3%) and large scale cage farmers (67% versus 46%) operating surplus. The value chain can be considered reasonably inclusive from the perspective of the small and medium farmers. The large scale farmers contribute high shares of wages, compared to their share of net operating surplus.

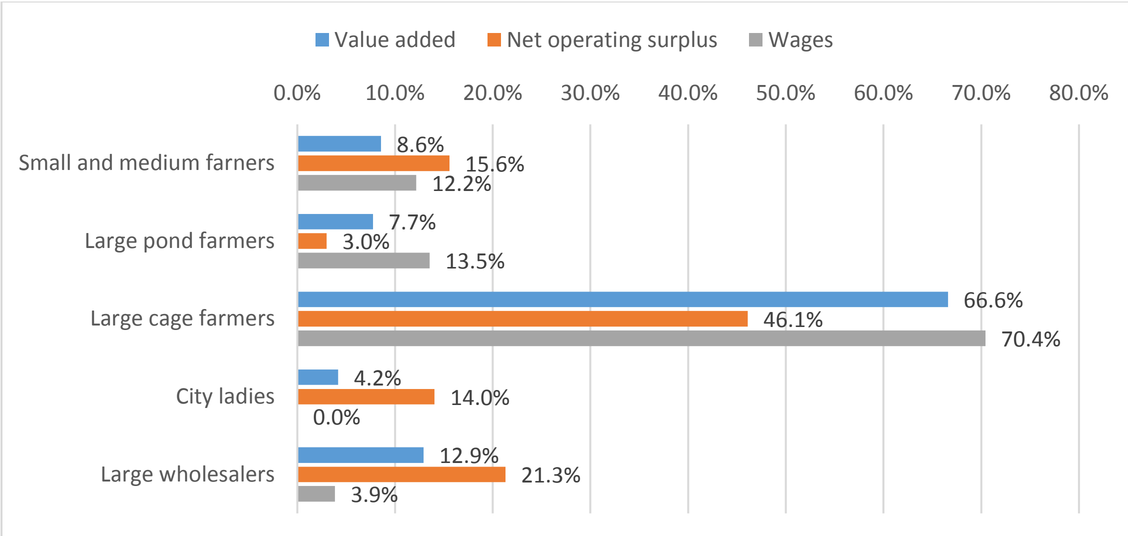

FIGURE 19: SHARE OF DIRECT VALUE ADDED, NET OPERATING SURPLUS, AND WAGES BY VC ACTOR

Similar to the small and medium farmers, retailers and large scale wholesalers also have a relatively large share of net operating surplus compared to their contribution to direct value added. Their contribution to wages is also limited. As is often the case, there is some degree of concentration at wholesale level; a limited number of traders buy a large share of the domestic farming production and imported tilapia.

4.6.2 Employment creation and distribution

A recent World Bank report (Krishnan and Peterburs, 2017) puts the contribution to employment in **13 471 jobs in the aquaculture value chain Zambia**, including micro-enterprises and self-employment, of which the majority, 11 490 jobs, is at production level, 1627 in feed production, 70 in processing, and 284 at hatchery level.

Our assessment of the value chain, seems to indicate that the number of jobs (including part-time jobs and self-employment) is higher than that (Table 10). We use the almost **12 000 registered farmers** in the country (see functional analysis) as a starting point and while it is known that more than one family member is usually involved in looking after the fish pond(s) we assume this generates 1 part-time job per farm. We further assume, based on our survey data that the majority of work on those farms is self-employment and (unpaid) family labour and that there is therefore very limited hired labour (apart from some occasional labour). For the medium and large-scale farms we have data on employment from some farms, which suggests that about **one person is employed for every 3 t produced on medium-scale farms and for every 5 t produced on large-scale farms,** including both unskilled and skilled labour such as accountants, management, drivers, mechanics and other positions. ther positions.

For feed production it has been estimated that for every 100 t of feed produced, one job is created (WorldFish, 2014). This means that by the end of 2017 (with an estimated size of the sector of 80 000 to 100 000 t) there could be **between 800 and 1000 jobs in the feed sector**.

Including the direct jobs and self-employed only, this would bring **total direct employment in the aquaculture sector to almost 20 000 jobs** (including self-employed and part-time (Table 10). Most of these jobs are unskilled.

In addition, there is some indirect employment related to the agricultural sector that supplies the feed producers. With a feed conversion ratio (FCR) of 1.7, every 10 000 t of fish will require 5 000 t of soya and 1500 t of maize (WorldFish, 2014). It has been estimated that in Zambia one labourer is able to produce 215 kg of maize (Li et al., 2012). For our calculations we take a slightly more conservative number of 250 kg per person, but this would mean that the production of 80 000 t of feed would require 52 000 t of crops, which would require 208 000 farm workers. While this could benefit thousands of farmers that supply the feed sector, it must be balanced with the food and nutrition security of rural populations who still depend on maize as their primary staple food.

	Specifics	Number of jobs (full-time and part-time)
Small-scale farmers (self-employed)	11 853 farms	11 850
Medium-scale farms (self-employed & wage labour)	1 job / 3 t * 1000 t	330
Large-scale farms (salaried labour)	1 job / 5 t * 23 432	4 700
Wholesale and import (salaried labour)	1 job / 25 t * 40 000	1600
Small-scale retail (self-employed)	1 job / 10 t * 4 220	420
Feed production (salaried labour)	1 job / 100 t * 80 000 t	800
Total direct jobs (including part-time and self-employed)		**19 700**
Agricultural for feed (self-employed & wage labour)	1 job / 250 kg of maize / soya * 52 000 t	280 000

TABLE 10: NUMBER OF JOBS IN THE AQUACULTURE SECTOR (INCLUDING PART-TIME AND SELF-EMPLOYED). SOURCE: OWN SURVEY AND SECONDARY DATA (WORLDFISH, 2014; LI ET AL., 2012).

4.6.3 Governance and innovation

The majority of transactions in the Zambian aquaculture value chain is of the spot market type, although some relationships exist. In this report we have therefore analysed these types of transactions only. There are however a number of alternative models that have been suggested and/or are being tested for further development of the aquaculture sector that would require a higher degree of coordination in the chain (listed in Section 3.5 on value chain governance). These in particular relate to developing strategies that benefit the poor by supporting the transformation of the small-scale semi-subsistence farmers into more commercially viable enterprises. The strategies can be grouped into three categories:

1) Strengthening value chain linkages establishing between the small-scale farmers and the commercial actors, so that smallholders can take advantage of distribution channels, and inputs developed by the large-scale commercial companies. This would require specific support for these farmers in the form of access to services, high quality inputs, and capacity

development both related to pond management and business literacy, and should therefore likely be linked to one of the two following strategies.

2) Developing cluster approaches with public-private partnerships that promote the access of smallholders to inputs, services, technical assistance and capacity development (such as the Aquaparks).
3) Developing other types of inclusive business models that provide smallholders with access to finance and / or inputs and / or a secure market, such as pro-poor microfinance mechanisms, decentralized seed distribution models, contract farming and out-grower schemes.

4.7 Conclusions of the economic analysis

To conclude, the economic analysis has demonstrated that the aquaculture value chain is sustainable from an economic point of view, given that its activities create revenues for the actors that are partially or fully dedicated to the activity.

Despite sufficient margins generated at the production level, prices are such that domestically farmed fish is uncompetitive compared to imported fish. Productivity gains and other efficiencies in production should reduce costs of production and increase competitiveness. This will depend to a large degree on improvements in management practices, as well as better quality seed and feed. Potential benefits from economies of scale have also been suggested, however this would require shifts in livelihood portfolios for smallholder farmers, as at present aquaculture is only one of many livelihood activities for these households.

The scope of the present study excludes an analysis of market dynamics and modes of operation. A complementary analysis on this topic could provide more clarity on market segmentation (rural vs urban areas, poor vs upper class consumers, low quality fish vs niche quality). While large-scale farmers and large wholesalers target consumers with a medium-to-high purchasing power and mainly urban (around 20% of the total population), small-scale farmers direct their sales towards rural customer. It is however not well understood to what degree this contributes to the food and nutrition security of low-income populations in the rural areas, apart from through self-consumption by farmers. This complementary study on the market dynamics could provide more insights into products, prices and consumers, and shed light on the degree to which further aquaculture development will depend on middle-class consumers. It would also help to understand the market channels and final customers for imported fish, and to what degree imported fish is really considered inter-changeable with locally produced fish. This knowledge would be important to ensure that strategies that develop the Zambian aquaculture sector do not negatively affect the affordability of fish to low-income consumers.

The typologies of farmers developed in this study, and the results related to their operations and economic performance, have shown that policy action should be tailored to specific types of actors. Smallholders will not automatically benefit from growth that happens in the large-scale commercial sub-sector. Additional and specific support is required, as well as alternative inclusive business models.

The recent development of commercial aquaculture in Zambia has resulted in an increase in production levels and in the impact of the sector at the level of macro-economic indicators (contribution to the economic growth, employment creation, public finances, etc.). Nevertheless, there are still concerns about the level competitiveness of the large-scale producers compared to Asian imports. Experiences from Egypt and Nigeria have shown that the sector grows where conditions support the emergence of small- and medium-scale aquaculture enterprises with a more commercial market-led orientation. A growth strategy that is inclusive of these small- and medium scale producers therefore seems important for the further development of the sector. At present, there is significant risk that the investments in the large scale sector could further marginalise small-scale farmers, since they may be unable to compete.

Small-scale farmers may need to develop a different niche among lower-income consumers. As shown in the social analysis, food security is still a major concern in Zambia and the increase in production of fish could be an important contributor to mitigate malnutrition. More effort needs to be made to make farmed fish more accessible to poorer populations, whether by introducing new species into the sector, decreasing the costs of production to produce cheaper fish, or for some farmers to generally produce smaller-sized fish that require less inputs.

5 Social analysis

5.1 Introduction

The social domain of the aquaculture value chain was analysed through many layers of people's life and livelihoods. The framework used elaborates an image of the main outcomes of the value chain activities in six basic domains, including working conditions, land and water rights, gender and social inclusion, food and nutrition, social capital, and living conditions. The methods employed for the social analysis of the Zambia aquaculture value chain assessment comprised the following: 1) semi-structured interviews with people from 7 aquaculture-focused institutions[24], 7 larger-scale fish farms[25], 2 feed companies[26] and 2 feed retail outlets[27], 3 fish retail outlets/wholesale centres[28], and 14 smallholder fish farmers[29]; 2) four focus group discussions with smallholder fish farmers and aquaculture-focused cooperatives[30]; 3) drawing on existing knowledge of the social expert; and 4) literature search and review. The use of the latter method aimed to fill gaps on wider, more provincial- or national-level or historical information the other tools were unable to collect. The data were analysed using content analysis. Findings are presented below and enabled the exploration of the two main research questions and those under each of the social domains of inquiry.

5.2 Findings on the core questions

<u>Research questions (RQ): Is the aquaculture value chain socially sustainable? Is the economic growth in the aquaculture value chain inclusive?</u>
In its current form, the aquaculture value chain is not socially sustainable and nor is the economic growth it has created inclusive[31]. There is a large gap between demand and supply of fish (wild and farmed) in the country (DoF 2017) and the implementation of the NADP that (among other things) was designed to support smallholder farmers to shift from practicing "subsistence" fish farming to farming as a business (GRZ & FAO, 2015) has been sub-optimal. These (lack of) developments have enabled larger input suppliers, farms, importers, and wholesalers and retailers to dominate their presence within the rather nascent, yet rapidly developing aquaculture value chain.

Recent growth in the sector primarily benefits larger operators supplying the gap for fish in the country given population growth and declined and/or stagnated production from the capture fisheries but will have some impact on job creation[32]. Given lack of access to seed (fingerlings), feed, extension support, vocational (or other types of) training, and microfinance (often featuring very large interest rates unaligned with the time constraints of aquaculture), the majority of smaller-scale fish farmers

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24 Department of Fisheries (national, provincial, and district levels including three (3) aquaculture research stations), WorldFish, United States Peace Corps, Siavonga Nutrition Group, International Fund for Agriculture Development (IFAD), World Bank, and Lake Tanganyika Development Project.
25 Lake Harvest, Yalelo, Benzo, Kafue Fisheries, Kalimba, Great Lake Products, and Macademia.
26 National Milling Corporation and Novatek.
27 Novatek and Olympic Milling.
28 Yalelo, Kachema Butchery, and Triple MBL.
29 6 women and 8 men.
30 2 women- and 2 men-focus groups.
31 See also Kaminski AM, Genschick S, Kefi SA and Kruijssen F. (2017). Commercial trends and upgrading in the aquaculture value chain in Zambia. Aquaculture.
32 For example, the largest operator directly employees around 350 people on their farm, albeit indirectly creates opportunities for especially fish traders to get involved in the supply chain.

are only equipped to farm fish to improve their food and nutrition security and sell or barter within their locales[33]. Their current level of production is estimated at 4 000 t (DoF 2017), which is equivalent to the total production of the largest cage farm in the country. Larger companies have expanded their retail outlets to the more rural districts (including the largest distributor of fish in the country—Capital Fisheries). The same is the case for feed mills, of which have grown in numbers and capacity over the past few years. Two new feed mills have or are about to start up in Siavonga (Lake Kariba). Few options for seed exist for smallholder farmers, while all larger farms visited integrate seed production into their overall systems. A few larger to smaller-sized hatcheries are near up and running in Northern (Mpulungu), Copperbelt (Kitwe), and Northwestern (Solwezi) Provinces[34], respectively. While these developments in the input market are promising for the overall sector, lack of access to microfinance by smaller-scale farmers means they will likely not benefit from this growth.

Moreover, larger fish farms employ mostly men as labourers due to the perception that carrying out fish farming activities requires physical strength. Men comprise the majority of fish producers in rural areas[35] due to complex social/land tenure issues. Women tend to get involved in production by feeding fish or maintaining ponds and harvesting. Women are the main traders in both the aquaculture and capture fisheries value chains. Very little processing of farmed fish takes place by larger producers, other than gutting, scaling, and a small portion of farmed fish are filleted. On the whole, it appears that youth are not well-integrated throughout the chain (WorldFish, 2014), an issue the ILO's YAPASA program is aiming to address[36]. However, a number of larger farms do employ youth as general workers, and youths comprise the upper management of the largest fish farm in Zambia.

5.3 Specific domains of inquiry

5.3.1 Working conditions

RQ: Are working conditions throughout the aquaculture value chain socially acceptable and sustainable?

Conditions for people working in formal employment in Zambia across sectors are generally good, although given inflation over the past few years[37], while improving, wages are arguably low for general labourers. Labour laws[38] in Zambia are in line with the eight fundamental ILO international labour conventions and the International Covenant on Economic, Social and Cultural Rights (ICESCR) and International Covenant on Civil and Political Rights (ICCPR). From discussions with larger farm managers/owners, it appears they respect these internationally-recognized standards and consider

33 Nonetheless, a recent World Bank report suggests that "[e]xpanding the Zambian aquaculture VC holds *potential* to promote job creation, particularly among smallholder fish farmers [with] the estimated number of jobs in the sector [at] approximately 13,000, which are primarily on-farm jobs and often low-skilled." (Krishnan and Peterburs 2017, emphasis ours).

34 Technical and/or financial support provided by WorldFish (Mpulungu) and through a matching grant under the IFAD aquaculture value chain development project (Kitwe and Solwezi).

35 For example, in Kasempa District (Northwestern Province) and Mpulungu District (Northern Province) around 40% of fish farmers are women and only 16% are women in Mbala District (Northern Province) according to the farmer registers of the offices of the Department of Fisheries visited during the second mission.

36 See http://www.ilo.org/addisababa/media-centre/pr/WCMS_497342/lang--en/index.htm

37 See https://tradingeconomics.com/zambia/inflation-cpi

38 Seehttp://lauraandpartners.com/index.php?view=article&id=77%3Azambia-labour-laws&format=pdf&option=com_content&Itemid=2

their hiring/employment conditions as "fair" or "very fair". One larger farm owner indicated they follow the contracts/rates suggested by the Zambia National Farmer Union (ZNFU). Casual labourers comprise some workers at larger farms given the need for seasonal labour (e.g., constructing ponds or harvesting). Such employment practices do not appear contrary to labour laws, although casualization[39] is illegal in Zambia[40]. Employees of some more rural-based, larger-scale farms live on site and are accommodated accordingly. One larger farm in existence since the early 1980s has built three schools and supports a recreation centre in the community nearby the farm. The largest fish farm in Zambia provides training for its employees and conducts regular inspections (both internally and independent) to ensure best practices and job safety. Job safety practices at larger farms and feed mills and wholesale centres were evident during mission visits[41].

All large farms visited during the two missions indicated their work force comprise mostly men as they believe farming fish requires a greater amount of physical strength that men possess. Some women are employed by these farms, but mostly processing/packaging fish or cooking for farm labourers. Youth are also employed by larger-scale farms. No larger-scale farms employee children; a practice that is very uncommon regardless of the sector in Zambia. However, children do assist their parents carrying out many fish farming duties (and other agricultural/non-agricultural tasks) in rural areas and can be found lingering around urban markets, selling small items, but rarely fish[42].

5.3.2 Land and water rights

<u>RQ: Are land and water rights socially acceptable and sustainable?</u>
The Lands Act of 1995[43] recognizes two land tenure systems in Zambia: state and customary. Arguably, the most significant aspect of the new Act is its provision for "the conversion of customary tenure into leasehold tenure" (see page 3). This has enabled large tracks of customary lands to be converted to state land for agricultural and non-agricultural (e.g., mining and tourism) development purposes[44]. In some cases, the land acquired displaces people either voluntarily or involuntarily and negatively affects people's lives and livelihoods. The process of converting customary land to state land is very time consuming and expensive for the majority of rural people (Cole 2012).

Pre- and post-colonial land and energy development projects have impacted people in many parts of Zambia, including when the Kariba Dam was built and subsequently (and involuntarily) displaced thousands of people before the lake was formed (Clark et al. 1995). Lake Kariba is now home to the largest cage farms in the country. Zambia has a Land Resettlement Programme that was only recently guided by a National Resettlement Policy[45]. Resettlement and compensation is in line with the African Union Convention for the Protection and Assistance of Internally Displaced Persons in Africa (Kampala Convention)[46]. To ensure transparency and good governance during the resettlement process,

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39 The act of engaging an employee on a casual basis for a job that is of a permanent nature.
40 See http://www.ilo.org/addisababa/countries-covered/zambia/WCMS_449885/lang--en/index.htm
41 For example, life jackets and floating feeding stations were being used at the two cage farms visited on Lake Kariba, mouth/nose guards and hard hats were being used in feed mills, and rubber boots and protective gloves at the fish wholesale centre, rubber boots and overalls at a number of larger pond-based farms.
42 Observation by the social expert who resides in Zambia.
43 See http://www.parliament.gov.zm/sites/default/files/documents/acts/Lands%20Act.pdf
44 See videos on the impacts of large-scale land acquisitions in Zambia at http://www.zla.org.zm/
45 See http://www.zla.org.zm/wp-content/uploads/2017/02/Final-National-Resettlement-Policy2.pdf
46 Seehttps://www.au.int/web/sites/default/files/newsevents/workingdocuments/32304-wd-au_convention_protection_idp_1_0.pdf

agreements and action plans are developed with affected persons. Plenty of examples exist, however, that highlight the imperfections implementing such processes including lack of genuine consultation and participation by affected rural people during the process[47].

According to Chu et al. (2015), the Voluntary Guidelines of the Governance of Tenure (VGGT)[48] are not well known or used by large-scale investors who displace people when they acquire land. Instead, investors site the World Bank's Operational Policy on Involuntary Resettlement and the InternationalFinance Corporation's (IFC's) Guidance Note 5. It appears larger fish farms in Zambia adhere to the VGGT. All the larger-scale farms visited during the two missions indicated they acquired their land through appropriate channels[49], either by purchasing it and obtaining a title deed or by following customary norms and practices to achieve the same result. A few larger farms indicated they had to remove people who were farming on their newly acquired land, and the people were compensated[50]. It is not clear whether current policies are equipped to deal with cage farming expansion on lakes and rivers throughout Zambia, although the Zambia Environmental Management Agency (ZEMA[51]) requires large farms to carry out an EIA before operating. One area of future research is to determine how these larger farms compete with local fishers (in the case of cage farming on lakes or rivers) and fish farmers who supply more local markets.

5.3.3 Gender and social inclusion

RQ: Is gender and social inclusion throughout the aquaculture value chain acknowledged, accepted, and enhanced?

The aquaculture value chain in Zambia accommodates existing gender norms and practices[52], regardless of the level of production. On larger farms, women are excluded from participating in most areas of production. Women carry out basic processing/packaging duties instead and are very active in the trading of farmed fish, especially in the capital city, Lusaka. Given that few large farms exist outside of the main zones of production, Lusaka and Siavonga (see map, Figure 6 above), fish that women trade in these areas most likely come from the capture fisheries or are imports (e.g., bought wholesale from Capital Fisheries and resold). Fish retail outlets in provincial/district capitals are growing in number, although it does not appear they are targeted by female traders for buying/reselling fish in smaller markets.

In rural areas, women's access to or ownership of key aquaculture assets are limited, including land. In patrilineal societies, a woman resides in her husband's village, and therefore, does not own the land she helps cultivate (Cole et al., 2015; Rajaratnam et al., 2015). This is believed to have a direct impact on women's decision-making powers (e.g., to get involved in fish farming, construct new ponds, how to spend income generated from fish farming). In matrilineal societies[53], a man resides in his wife's

47 Seehttp://www.plaas.org.za/sites/default/files/publications-pdf/PLAAS_ADC%20policy%20brief_Zambia_Web.pdf

48 See http://www.fao.org/docrep/016/i2801e/i2801e.pdf

49 This was not triangulated by speaking with local authorities or residents about the land acquired.

50 Given the strong customary land tenure norms/practices that exist in Zambia, it is unlikely that larger fish farm operators at current moment could move into an area and displace local people unless through corrupt practices.

51 See https://www.zema.org.zm/

52 A gender accommodating approach recognizes local social/gender norms and power relations when say hiring employees or introducing a particular agricultural project so to not disrupt the social fabric and ensure work or projects move along smoothly. Such an approach has failed to make significant gains in narrowing the gender gap. See Kantor (2013).

53 Residence patterns more recently are following those of patrilineal societies. See Cole (2012).

village for a period (sometime indefinitely), before shifting back to his natal village with his wife. Presumably, this means that women from matrilineal societies have more control over their land and have more decision-making powers. However, the qualitative data collected for this assessment suggest that women who get involved in fish farming in matrilineal societies are those who live in their husbands' villages, and not their own. It is forwarded here that men living in their wives' villages would not make the necessary investments as they cannot own the ponds they construct/manage in the long run. This needs to be scrutinised by future research. Most smallholder fish farmers (both women and men) interviewed indicated they independently generate income from various means, pool their monies, and jointly decide on how to spend it, while some indicated that the monies men generate is often controlled by them given they are the heads of households.

Generally, assets such as shovels, hoes, and wheelbarrows to construct/maintain ponds are owned by men. Rural farmers lack access to high-quality seed and commercial feed, nets for harvesting, as well as more lucrative output markets. Instead, they recycle their own seed or purchase from their neighbours, use extensive systems of production, drain their ponds to harvest or adopt a partial harvest strategy, and sell their fish locally.

Given a lack of financial and human resources, government-supported extension services are rarely provided or only when the client (farmer) can cover the costs of transport/materials. There are no non-government organisations in Zambia that are equipped to provide adequate aquaculture extension support in rural areas, other than WorldFish through its research efforts and Peace Corps volunteers through its Rural Aquaculture Program. Farm associations and cooperatives exist in rural areas, although mostly to secure farm inputs through the Farmer Input Support Programme[54] and to sell maize to the Food Reserve Agency[55]. They require fees to join and additional monies to get involved in activities, and thus, mostly better-off farmers comprise their members. A few cooperatives visited during mission two are involved in fish farming or seed production. It appears their involvement is the result of some government or non-government initiative, and therefore, lacks a strong business focus and can be characterised as less productive. Women seem to be very active in these groups and as leaders. Majority fish farmers interviewed have no understanding of aquaculture policies in the country, only that the Government plans to invest in aquaculture development in the near future.

There is a major division of labour in rural (also poor urban) areas, whereby women exclusively carry out the domestic and caretaking duties, while men engage in tasks that are believed to require more physical strength (e.g., ploughing, constructing ponds). However, a number of women interviewed stated they are active in pond construction and other physical activities. Few labour-saving technologies other than shovels or ploughs were identified during mission visits. Other than using draught power, most agriculture-based activities in rural areas are carried out using a hand hoe.

Focus on youth in Aquaculture in Zambia: Challenges and opportunities (source WorldFish, 2017)
A study carried out by WorldFish for the International Labour Organization (WorldFish/ILO Report 2014) argues that there are a number of entry points for youth to acquire decent work opportunities and contribute to food security outcomes through their participation in the aquaculture value chain

54 See http://www.pmrczambia.com/wp-content/uploads/2015/09/Farmer-Input-Support-Programme-Infographic.pdf
55 This is the strong opinion of the social expert based on many years of experience working in rural settings.

in Zambia given the country has both vast water resources and agricultural potential to develop the aquaculture sector. Entry points identified for youth included:

1. Aquaculture activities create employment opportunities for (youth) crop farmers, with every 10 000 tons per annum of fish produced requiring roughly 5,000 hectares worth of soy beans and 1,500 hectares worth of maize. This demand for feed ingredients could enable thousands of smallholder (youth) crop farmers opportunities to grow and sell these food crops to a number of aggregators and feed mills in the country[56].
2. Fish feed production for every 10 000 tons per annum of fish produced could create employment for approximately 100 (youth) workers in feed mills.
3. Production of fish during the grow-out period could create 600 to 900 (youth) jobs per every 10 000 tons of fish produced.
4. Fish distribution and sales at the retail level (including value addition) could create an unestimated large number of job opportunities for youth.

However, youth involvement in fish farming in rural areas remains questionable given land and water access remains a significant challenge (WorldFish/ILO Report, 2014). Male youth involvement in providing labour to construct ponds and carry out other physically-demanding tasks (e.g., harvesting) may be high in rural areas, but youth (and women) "…continue to be disadvantaged when it comes to accessing, controlling and owning land" in Zambia (Zambia Land Alliance 2015) [57], and especially female youth given relocation norms when young women marry and take up residence at their husbands' natal village. This matters, as the entry points identified above require youth to own or have access to agricultural land and water resources for fish farming and crop production. Lack of ownership of land also prohibits youth from accessing loans by using land as collateral (see Byamugisha and Ansu 2017) [58].

A recent World Bank report (Krishnan and Peterburs 2017) estimates that there are around 13 000 jobs in the aquaculture sector. Most of these jobs are on-farm and low-skilled, and therefore, smallholders provide the bulk of the jobs farming fish in rural areas and selling their products in local markets (usually at farm gate). Women comprise only 8% of the workforce in the aquaculture value chain. It is unknown what percentage of youth comprises the aquaculture value chain workforce. The report estimates that if per capita consumption of fish increases by 25%, this could create 22 000 jobs (including 8 600 new jobs) by 2022, with the vast majority continuing to be on-farm and low-skilled jobs that mostly rural smallholders would hold. Explicit attempts to bring in women and youth into the aquaculture value chain to ensure the distribution of jobs is more equitable will be critical. The WorldFish/ILO report (2014) provides some suggestions, yet the social context in Zambia (and especially in rural areas) is complex and requires further analysis to ensure entry points for youth (and women) are feasible and lead to gainful employment/jobs creation and direct benefits to youth and women.

While many of the jobs in the aquaculture value chain may be considered "low-skilled" and "on-farm", it is well known that technical and vocational skills of people in the broader Zambian labour force are low. The percentage of the working-age population in Zambia who indicated they had received skills training was only 15.1% in 2014 (CSO 2015). Only 10.6% of females indicated they received skills

[56] The food security implications of such sales needs to be researched before advocating such an entry point for youths to be integrated into the aquaculture value chain, with alternative crops being considered that do not compete with food security initiatives.

[57] See http://www.zla.org.zm/wp-content/uploads/2015/03/Press-statement-on-International-Womens-day-and-Youth-day.pdf

[58] See https://www.uneca.org/sites/default/files/uploaded-documents/LPI/CLPA_2017/Presentations/frank-byamugisha-and-yaw-ansu-clpa-2017-conference-paper.pdf

training, while 19.9% of males indicated they received skills training. Those aged 35-54 years were the highest percentage share (40.2%) who indicated they received skills training. The 15-24 year-olds accounted for 17.4% and the 25-34 year-olds accounted for 29.4%. Those trained on fisheries skills comprised only 0.3% of the total employed persons who received skills training. Of the 2,059 people trained on fisheries skills, 0.0% were female.

Zambia's National Youth Policy defines youth as a person aged 15 to 35 years (Ministry of Youth and Sport 2015). Youth unemployment was exceptionally high in 2014 at 10.5% (53.4% were male and 46.4% were female). Youth unemployment is a significant issue in Zambia as youth comprised 35.9% of the population in 2015, of which 52.2% were female and 47.8% were male (CSO 2016).

Given that youth constitute a major portion of the Zambian population, the Government revised the 2006 National Youth Policy in 2015 to ensure it was more responsive to the needs of youth in Zambia today (Ministry of Youth and Sport 2015). The goal of the policy is to "provide an enabling environment that promotes the rights and obligations of the youth and foster their participation in national development" (see Chapter 2). Target groups identified in the policy are rural youth (increased availability and access to goods/services and opportunities), female youth (promoting gender equality in all youth development sectors), youth in tertiary institutions and formal and informal employment (increased qualifications and opportunities), among others.

Two key thematic areas included in the National Youth Policy are "Youth Employment and Entrepreneurship Development" and "Education and Skills Development." Strategies to increase youth employment include facilitating the certification of skills gained outside the formal skills training sector and establishing a national apprenticeship and internship program to prepare youth for employment. Strategies to increase entrepreneurship development include promoting entrepreneurial education and skills training at all levels of education, facilitating the transition of informal enterprises into the formal economy, promoting the use of ICT for improved productivity, creativity, and innovation in youth enterprises, promoting the participation of youth entrepreneurs in national and international business linkage programs, and engaging the private sector on initiatives and linkages to promote youth enterprise development. Strategies to increase youth's access to education and skills development include incorporating ICT in education curricula, increasing their access to technical education, vocational and entrepreneurship training (TEVET) institutions, and increasing their access to skills development outside of mainstream education (e.g., workplace and distant learning skills development and adult literacy). All these strategies apply to increasing youth's aquaculture employment and entrepreneurship and education and skills development opportunities. In addition, the policy integrates the cross-cutting issue of gender to facilitate the equitable access to and control of economic resources and opportunities by female and male youth and promote equal rights and access to education and skills and development training.

Close to 300 training institutions are registered with the Technical Education, Vocational and Entrepreneurship Training Authority (TEVETA) (UNESCO 2016). Government-owned TEVET institutions comprised 32% of the total in 2013 (latest data). Private-run institutions comprised 28% of the total in 2013. Generally, students who enter TEVET institutions undertake 7 years of primary education and 5 years of secondary education. Training by TEVET institutions is offered at the following levels: trade test, craft, technician, and technologist/diploma. Gender disparities increase at higher level TEVET institutions, where the share of female students was only 8% (diploma level) in 2012 (UNESCO 2016). There are two main TEVET institutions that provide fisheries/aquaculture training (Natural Resources Development College (NRDC—diploma level) and Kasaka Fisheries Training Institute—certificate level). The 2018 Fisheries Science intake list for NRDC indicates that 41.7% of their intake is female (NRDC website, see here). And while there are other TEVET institutes that aspire to offer a certificate in general agriculture (of which fisheries/aquaculture is one component), such institutes have yet to implement the curriculum that was developed in 2016 to enable this to happen.

A recent review of the Education Policy in Zambia (UNESCO 2016: 24) highlights that "the principle challenge [the TEVET system faces moving forward in Zambia] is to improve access to high-quality, relevant programmes taught by qualified teachers." The report suggests that a number of issues need to be addressed to improve TEVET in Zambia [see Mwanza (2008) and UNESCO-UNEVOC (2010) for similar findings], including:

1. Limited (and inequitable) access to TEVET programs
2. Unpreparedness of young people for the world of work
3. Lack of financial support and funding
4. Need to improve quality and responsiveness to labour market requirements
5. Lack of quality trainers
6. Lack of quality training programs

5.3.4 Food and nutrition

RQ: Are food and nutrition conditions acceptable and secure?

While the vast majority of people interviewed indicated that 1) food crop production is increasing and 2) incomes are increasing given an increase in cash/food crop production, there still remains seasonal hunger[59] during the rainy/cultivation period (December-March) for some. Piecework[60] is the most common coping strategy during the "hungry" season. It is during this period that food prices (especially staple foods) increase significantly. Overall, food prices have increased over the past 5 years[61]. Most people interviewed indicated that fish production in their areas has actually declined[62]. Child malnutrition (stunting) rates are still very high in Zambia, although have declined slightly over the past 5-10 years from 45.4% in 2007 to 40.1% in 2013/14[63]. Considerable variation exists between the provinces. Zambia is a Scaling up Nutrition (SUN) focal country, and thus, in some districts throughout the country (14 total[64]) efforts to combat malnutrition (especially within the critical 1000 days period) have intensified.

Fish is one of the most-widely consumed sources of animal protein in Zambia, especially small fish from capture fisheries (Longley et al., 2014). According to Zhang et al. (2016) consumption of fish has declined from 42 g per capita per day (in 1966-1971) to 18 g/capita/day (in 2008-2013) in Zambia. For the most part, farmed fish from larger farms is cost-prohibitive for rural people and the urban poor (Marinda & Genschick, 2017). Local farmed fish production, while small in nature and lacks a business orientation, is believed to play a significant role in providing enhanced nutrition to many rural people. While prices of farmed fish in urban centres (wholesale and retail) range from around 20 to 35 ZMW based on current prices obtained in various parts of the country during the two missions, farmed fish in rural areas are cheaper (as low as 10 ZMW in some areas) given fewer costs associated with production (including hiring labour), transportation, and marketing, and presumably poor purchasing

[59] For a more nuanced understanding of hunger, see Cole & Tembo (2011).

[60] Casual labour carried out on other people's farms for cash or in-kind payment. See Cole & Hoon (2013).

[61] See also http://www.fews.net/sites/default/files/documents/reports/ZM_FSO_2016_10.pdf

[62] According to Department of Fisheries reports (2015 to 2017), estimated smallholder aquaculture production has increased from 2 954 t in 2014 to 4 138 t in 2016.

[63] Zambia Demographic and Health Survey (DHS) reports (2009; 2015). See http://dhsprogram.com/Publications/Publication-Search.cfm?ctry_id=47&country=Zambia

[64] See http://scalingupnutrition.org/sun-countries/zambia/

power by most rural people. An important question to explore in the future if fish farming as a business increases in the rural areas, is whether this will impact supply/affordability of fish as costs of production will surely rise. Related, as more fish feed mills enter onto the market in Zambia or increase their production, it is believed that certain staple crops such as maize (perhaps cassava and rice bran) and secondary crops such as soy beans will be in greater demand, and thus, could impact on food and nutrition security in rural areas and increase staple food prices for the urban poor[65].

5.3.5 Social Capital

RQ: Is social capital enhanced and equitably distributed throughout the aquaculture value chain?
Given that most larger-scale fish farms (but also smallholder farmers) are vertically integrated, it is believed that notions of trust, reciprocity, solidarity, and group cohesion are not as vibrant as in other value chains where more horizontal relationships between actors define the value chain. These operators compete for the Lusaka market, some for the Copperbelt (Kitwe and Ndola) market, and a few for the Kasumbalesa (border town DRC/Zambia) market. Capital Fisheries no doubt adds a very interesting twist to the growing aquaculture sector story in Zambia. They have found a cheaper source of farmed fish (from China) that undercuts every local producer (perhaps besides the rural farmer using an extensive mono or polyculture and/or multitrophic system of production). This has created a political discourse that gets cited in the news and on the ground regularly (importing cheap fresh fish from China is "scandalous" and "criminal"—President Lungu[66]). With all this stated, the relationship between the notorious "City Ladies" and certain large operators is very important as these female traders move a significant amount of fresh farmed fish into the interior of Lusaka on a daily basis.

In rural settings, high levels of social capital exist, which can be regarded as both a positive and negative attribute of rural, closely-knit social networks (Portes & Landolt, 1996). Mechanisms exist to bring community members together to decide on important changes or projects to implement (e.g., building a school, fixing a bridge, lobbying for improved health care services). Knowledge (e.g., how to use new technologies) is shared mostly through "learning by doing" (demonstration plots or by gaining hands-on experience). Such "indigenous" knowledge it was found is well-respected by extension/non-government officers and other actors working in rural areas. Women's groups, clubs, and farmer associations and cooperatives exist to help organize people, pool resources or labour, build social cohesion, access government and non-government services, and increase production. However, this assessment unambiguously found that group fish farming does not lead to productive results. It may be a good channel for people to share knowledge and learn together, but not as a means of production, and especially not as a means of doing fish farming as a business.

5.3.6 Living Conditions

RQ: What are the standards of the health, education, and training infrastructure and services?

[65] This heightens the need to explore options for alternative feed ingredients as the sector grows, including alternatives to using fish meal (an ingredient that is predominantly imported, thus increasing the cost of feeds). See https://www.idrc.ca/en/project/integrating-insects-poultry-and-fish-feeds-kenya-and-uganda for information about a project in Kenya and Uganda exploring the use of black soldier flies as an alternative source of animal protein in fish and poultry feeds.

[66] See https://www.daily-mail.co.zm/fish-imports-must-end-says-lungu/

In general, primary education and health services are adequate in rural areas according to the small sample of people interviewed. Secondary schools are mostly located near or in towns, and thus, are expensive for rural children to attend given associated school fees and transport, accommodation, and food costs. Rural people live in houses made of mud or bricks that are grass thatched or roofed using iron sheets. Most have access to safe drinking water (from a borehole or well or protected spring), and use a pit latrine. Poor roads make linking rural people to input and output markets very difficult, especially inputs like seed and feed for fish farmers. Most hatcheries are located in a central place within a province (or not at all), and thus require major efforts to access, of which most fish farmers cannot afford to acquire without government or non-government assistance (the norm to date).

Very little training in aquaculture reaches the rural areas other than by government and non-government-supported extension officers. There are only three aquaculture training institutes in the country: Copperbelt University[67], Natural Resources Development College, and Kasaka Training Institute. None of these training institutes cater for rural farmers, but rather students who wish to improve their skills training for future employment within the public or private sector. During the first mission, the director of the biggest cage farm in Zambia indicated they will build a training institute on site as one means of improving people's (including young school-going children's) capacities and interests to farm fish.

Youth involvement in the aquaculture value chain seems low in rural areas, presumably given their lack of access to land while still residing with their parents (see Box above on youth focus). Given this demographic tends to be the ones who emigrate to urban centres seeking employment or educational opportunities[68], an important question to explore as the aquaculture sector grows is will their low participation continue?

<u>RQ: Do the aquaculture value chains contribute to improving health, education, and training infrastructure and services?</u>

Other than the farms located in more rural settings, very few aquaculture value chain activities (e.g., via direct or indirect employment) contribute to improving the living conditions of rural people. Own-production by rural people no doubt increases their consumption of fish and/or provides some source of cash (or barter opportunities) to purchase additional food or non-foodstuffs or pay for their children's school fees. However, low productivity given the use of poor seed and management practices and lack of access to commercial feed and extension services plagues the vast majority of rural fish farmers. For example, recent research by WorldFish and Department of Fisheries showed that rural fish farmers in Luwingu and Mbala Districts would produce (when the data are extrapolated) on average 1.2 and 0.65 t of fish per hectare, respectively, using a slightly intensive production systems (e.g., use of locally-produced improved feed and/or fertilization practices). This is relatively consistent with productivity numbers for smallholder farmers cited by others in Zambia (Musuka & Musonda, 2013; Nsonga, 2015). Nonetheless, it appeared from some focus group discussions that fish farming brings about a level of happiness as people enjoy spending time at their ponds watching the fish grow.

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[67] And recently the Department of Aquaculture/Fisheries at Copperbelt University shifted to Robert Makasa University in Muchinga Province.

[68] Based on interviews with rural farmers conducted during mission two.

5.3.7 Social profile score

The social analysis informed the scoring of the components under the domains of inquiry, resulting in a final score for each domain (lowest score = 1 "not at all" and highest score = 4 "high"). Table 11 and Table 11. Social profile score for each domain of inquiry
below present the scores for each domain, with working conditions, land and water rights, and social capital receiving scores of 2.88, 2.50, and 2.50, respectively. Gender equality, food and nutrition security, and living conditions domains received the lowest scores of 2.00 or below. A summary of the findings and recommendations as well as risks/mitigation are provided in Section 7.

Domain	Present profile	
	Score level	Count
1. WORKING CONDITIONS	Substantial	2.88
2. LAND & WATER RIGHTS	Substantial	2.50
3. GENDER EQUALITY	Moderate/Low	2.00
4. FOOD AND NUTRITION SECURITY	Moderate/Low	2.00
5. SOCIAL CAPITAL	Substantial	2.50
6. LIVING CONDITIONS	Moderate/Low	1.96

TABLE 11. SOCIAL PROFILE SCORE FOR EACH DOMAIN OF INQUIRY

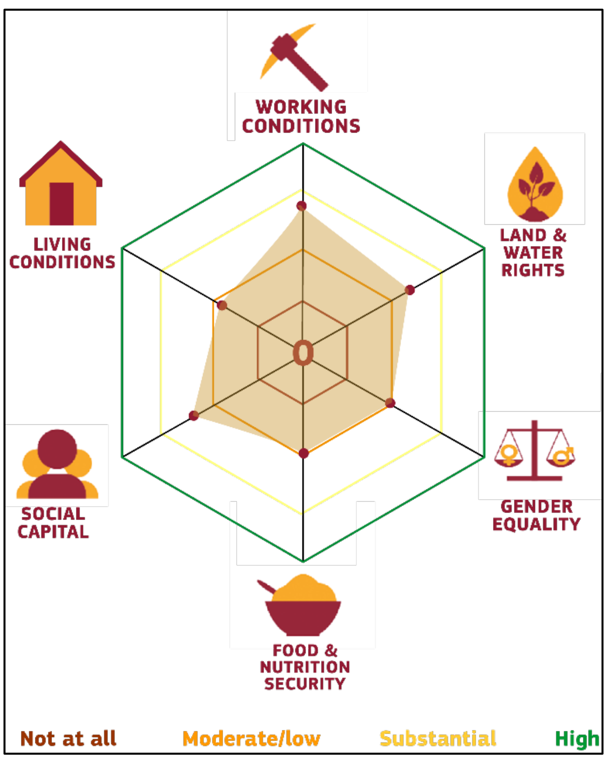

FIGURE 20. SOCIAL PROFILE

6 Environmental analysis

6.1 Introduction (goal and scope)

The LCA of the Zambian aquaculture value chain aims at determining the potential impacts of its current functioning on the three common areas of protection addressed by LCA: human health, ecosystems and resources. To estimate these impacts, we constructed LCIs representing the various types of systems on each link of the value chain (e.g. feed, seed and fish producers). To do so, we collected primary and secondary data for the most representative system types, as defined by the actor typologies (Annex 2, Figure 4). The LCIA methods recommended by the ILCD 2011 Midpoint+ v1.09 method (EC-JRC 2012) and the EC's Product Environmental Footprint (PEF) initiative (EC 2013) were retained (Table 12). The updated list of methods presented in the recent Product Environmental Footprint Category Rules Guidance (Version 6.2 - June 2017) was not followed because the newest choices are not available yet in SimaPro (Annex 6). This list of midpoint indicators was complemented with ReCiPe (2.2 Endpoint World H/A (Hierarchy/Average)) endpoint indicators[69]. ReCiPe was chosen because it features endpoint indicators on the three LCA areas of protection, based on many relevant impact categories (Huijbregts et al. 2016). The hierarchical (H) perspective was chosen because it is based on the most common policy principles with regards to time frame and other issues and is thus often encountered in scientific models (Goedkoop et al. 2013).

[69] Endpoint indicators are dimensionless. In ReCiPe are expressed simply in "points" (Pt). Endpoint indicators express a) the relative contribution of an impact category to the cumulative impacts of the product system on an Area of Protection, and b) the cumulative environmental performance (impacts) of the product system. Endpoints only make sense in comparative contexts.

Impact Category	Impact Assessment Model	Impact Category indicators	Source
Climate Change	Bern model - Global Warming Potentials (GWP) over a 100-year time horizon	kg CO_2 equivalent	Intergovernmental Panel on Climate Change, 2007
Ozone Depletion	EDIP model based on the ODPs of the World Meteorological Organization (WMO) over an infinite time horizon	kg CFC-11 equivalent	WMO, 1999
Ecotoxicity for aquatic fresh water	USEtox model	CTUe (Comparative Toxic Unit for ecosystems)	Rosenbaum et al., 2008
Human Toxicity - cancer effects	USEtox model	CTUh (Comparative Toxic Unit for humans)	Rosenbaum et al., 2008
Human Toxicity – non-cancer effects	USEtox model	CTUh (Comparative Toxic Unit for humans)	Rosenbaum et al., 2008
Particulate Matter/Respiratory Inorganics	RiskPoll model	kg $PM_{2,5}$ equivalent	Humbert, 2009
Ionising Radiation – human health effects	Human Health effect model	kg U^{235} equivalent (to air)	Dreicer et al., 1995
Photochemical Ozone Formation	LOTOS-EUROS model	kg NMVOC equivalent	Van Zelm et al., 2008 as applied in ReCiPe
Acidification	Accumulated Exceedance model	mol H+ eq	Seppälä et al.,2006; Posch et al., 2008
Eutrophication – terrestrial	Accumulated Exceedance model	mol N eq	Seppälä et al.,2006; Posch et al., 2008
Eutrophication – aquatic	EUTREND model	fresh water: kg P equivalent marine: kg N equivalent	Struijs et al., 2009 as implemented in ReCiPe
Resource Depletion – water	Swiss Ecoscarcity model	m^3 water use related to local scarcity of water	Frischknecht et al., 2008
Resource Depletion – mineral, fossil	CML2002 model kg	kg antimony (Sb) equivalent	van Oers et al., 2002
Land Transformation	Soil Organic Matter (SOM) model	kg (deficit)	Milà i Canals et al., 2007

Table 12. PEF and ILCD-recommended impact categories and impact assessment models

Intended outcomes of the assessment include:

- Absolute impact assessment of the whole Zambian aquaculture value chain (tilapia only): 1 t fish

- Absolute impact assessment of the whole sector, on the basis of the total number of systems of each type (estimated from DoF statistics and expert opinions, including DoF field officers): n t fish
- Comparative impact assessments of existing production types, per t fish:
    - Cages vs. ponds, large producers
    - Pond systems: large vs. medium vs. small commercial
    - Pond systems: small commercial vs. semi-subsistence

6.1.1 System boundaries

We modelled LCIs for aquafeed producers, hatcheries, and fish producers, on the basis of primary data. Due to resource and scope constraints we used secondary data for upstream (i.e. crop and other inputs to aquafeeds) and downstream (i.e. distribution) processes. Nonetheless, we modelled the transportation of fish, based on distances and transportation means, associated with the investigated distribution strategies adopted by the various producer types. The final transportation to households and home storage by consumers is generally very challenging to model, and its assessment is not part of the goals of the study, which focuses mainly on the production and distribution. Moreover, in Zambia it is common to consume fish shortly after its purchase. The system boundaries are presented in Figure 21. The scope of the analysis can be described as gate-to-gate.

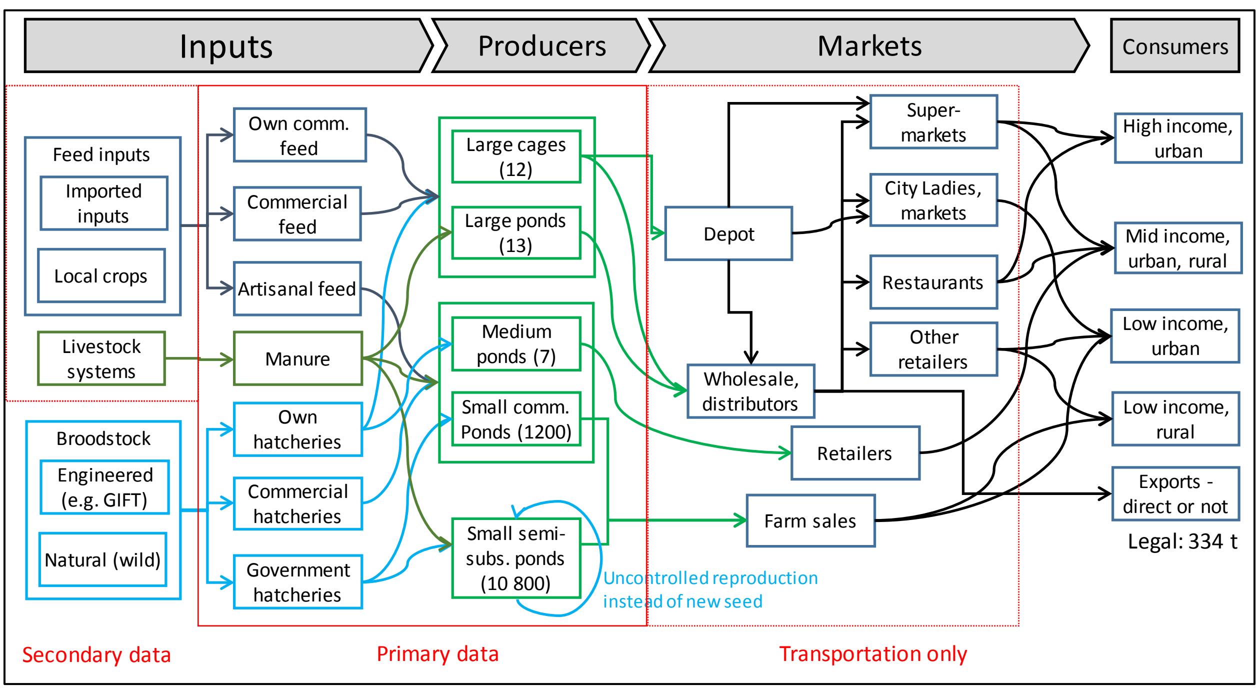

FIGURE 21. LCA SYSTEM BOUNDARIES

6.1.2 Functional unit

Functional units retained include 1 t of whole fish at farm gate and 1 t of whole fish at a retailer (to account for transportation in distribution). These functional units allow for the comparison of production systems and distribution strategies.

6.1.3 Allocation

Tilapia is mainly distributed and sold whole, thus no allocation was necessary. Regarding the inputs to aquafeeds, processes using mass allocation were preferred.

6.2 Life Cycle Inventory

The following LCIs based on primary data, collected in the field by the current four team members (and the former team leader):

- Producers
  - Large cage systems: 2 key players in Southern Province (Lake Kariba).
  - Large pond systems: 2 key players in Lusaka (Kafue River) and Northern (Lake Tanganyika) Provinces. The second system is actually a very extensive one, featuring low output.
  - Medium pond systems: 3 key players in Copperbelt, Southern and Lusaka Provinces.
  - Smallholder's commercial pond systems: 4 key players in Northern and Copperbelt Provinces.
  - Smallholder's semi-subsistence pond systems: 9 representative players in Northern and Copperbelt Provinces.
- Feed producers
  - Commercial feed mills: 1 key player based in Lusaka but featuring national distribution (a second national producer declined to provide data, as they have recently shut down its aquafeed production division).
- Seed producers
  - Government hatcheries: 2 government hatcheries associated with research stations, in Northern and Copperbelt Provinces.
  - Commercial hatcheries: 1 commercial hatchery in the Lusaka Province.
  - Vertically integrated hatcheries: 4 producers featuring integrated hatcheries.

Regarding feed production, a major constraint for aquaculture (together with seed and water management), a second key commercial feed producer has just discontinued its production and is currently investing in feed R&D. Moreover, the two large cage producers in Lake Kariba are building their own feed plants (in cooperation with international feed companies), while the large pond-based producer in Kafue produces part of its own supplementary feed.

Inventories for feed inputs were not constructed, but proxies (when data on specific inputs and processes is not available, proxy data derived from previous studies is commonly used) available in SimaPro were used instead[70]:

- For Zambian maize production, which is mainly rain fed and produced by smallholders, with yield of 2.2 t/ha and a national production of 2.8 million t/y; a dataset for South African maize from the Agrifootprint[71] database was retained.
- For Zambian soya bean production, which is mainly irrigated and produced by large commercial farms, with yield of ~2 t/ha and a national production of 260 kt/y; a dataset for international soya from the ecoinvent 3 database was retained.
- For animal-based protein sources, a dataset on meat by-product meal and another on Peruvian fishmeal (the most traded fishmeal in the world, preferred by commercial aquafeed producers) from the Agribalyse[72] database were retained.
- For transportation of aquaculture inputs (non-refrigerated) and outputs (refrigerated in the case of large producers), we used ecoinvent 3 processes (EURO3).

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[70] These proxies for maize and soya bean will be replaced by Zambia-specific datasets, once they are available from the VCA4D project on Zambian Maize/Soya.

[71] http://www.agri-footprint.com/

[72] https://simapro.com/products/agribalyse-agricultural-database/

We obtained only average feed compositions (Table 13) because the exact composition of feeds is treated as an industrial secret by feed producers. These compositions are compatible with previously published ones in LCA literature.

Item	Average feed, 32% protein	Average feed, 18% protein	Process name
Maize	28%	38%	• Maize, at farm/ZA Mass
Imported Animal and Plant Protein	20% (fish 10%, broiler 5%, swine 5%)	10% (broiler 5%, swine 5%)	• Fish meal with waste water treatment, Peru, at feed plant/FR S • Transformed animal proteins, from broiler, animal feed, at retailer gate/FR U • Transformed animal proteins, from pig, animal feed, at retailer gate/FR U
Soya Cake	49%	49%	• Soybean meal {GLO}| market for | Alloc Def, U
Minerals, Vitamins, Amino Acids	3%	3%	• Vitamin, animal feed, at retailer gate/FR U

TABLE 13. SIMPLIFIED COMPOSITION OF COMMERCIAL TILAPIA FEEDS CONSUMED IN ZAMBIA. OTHER CALCULATION DATA AND ASSUMPTIONS USED TO CONSTRUCT THE LCIS ARE PRESENTED IN TABLE 14. MOREOVER, DETAILED CAGE MATERIALS DATA WAS OBTAINED FROM (VÁZQUES-OLIVARES 2003).

1.5	m	mean depth of ponds
26.4	kg	mean weight of a 100 m2 fishing net
0.51	ZMW/kWh	price for industrial kWh from ZAMCO
2.5	g	mean individual weight of fingerlings at seeding
32	MJ/L	LHV gasoline
39	MJ/L	LHV diesel

TABLE 14. SUPPORTING ASSUMPTIONS AND DATA

Moreover, direct emissions to the aquatic environment due to fish production, namely N and P in mortalities, faeces and uneaten feed, were calculated using a mass balance that considers the fish body composition and the composition of feeds (Table 15).This mass balance approach (Cho and Kaushik 1990) is commonly used in aquaculture LCAs, of both land- and water-based systems (Avadí et al. 2015; Mungkung et al. 2013). No evidence was found of the generalised use of homemade feeds, other than maize bran, rapeseed press cake and other by-products used directly in some pond systems (especially by smallholders).

For tilapia feed with 18% protein, used in fertilised pond systems, FCR: 2.0					
N faeces	8.34		P faeces	5.63	
N uneaten	11.52		P uneaten	3.52	
N dead fish	2.18		P dead fish	0.72	
N solid	19.86		P solid	9.15	
N dissolved	13.83		P dissolved	0.61	
Total N emission	**33.69**	**kg/t fish**	**Total P emission**	**9.77**	**kg/t fish**

For average tilapia feed with ~32% protein, used in cage systems, FCR: 1.8					
N faeces	13.34		P faeces	4.61	
N uneaten	18.43		P uneaten	2.88	
N dead fish	2.18		P dead fish	0.72	
N solid	31.78		P solid	7.49	
N dissolved	36.47		P dissolved	(0.92)	
Total N emission	**68.25**	**kg/t fish**	**Total P emission**	**6.57**	**kg/t fish**

For maize bran* with ~11% protein, used in extensive pond systems, FCR: 5					
N faeces	12.51		P faeces	4.64	
N uneaten	17.28		P uneaten	2.90	
N dead fish	2.18		P dead fish	0.72	
N solid	29.79		P solid	7.54	
N dissolved	32.70		P dissolved	(0.87)	
Total N emission	**62.49**	**kg/t fish**	**Total P emission**	**6.67**	**kg/t fish**
*Maize bran is used here as an example of supplemental feeding, ideally coupled with good pond management (water and fertilisation)					

TABLE 15. N AND P EMISSIONS PER T OF COMMERCIALLY-FED FARMED TILAPIA

Direct emissions from agricultural production were calculated using the collection of methods retained by each background database they were taken from (Table 16). The ongoing PEF initiative does not suggest a selection of models.

Abridged life cycle inventories of sample aquaculture systems in Zambia modelled for the assessment are presented in Table 17.

Substance	Compartment	Source/mechanism	AGRIBALYSE (Koch and Salou 2015)	ecoinvent v2/v3 (Nemecek and Kagi 2007; Nemecek and Schnetzer 2012)	World Food LCA database (Nemecek et al. 2015)	Agrifootprint (Blonk Agri-footprint BV 2014)
Nitrate (NO3)	Groundwater	Mineral fertiliser/leaching	Annual crops: ARVALIS (COMIFER 2001; Tailleur et al. 2012); Prairies: DEAC (Cariolle 2002); Tropical: IPCC (2006) tier 1	Europe: SALCA-Nitrate (Richner et al. 2011) Overseas: SQCB (Faist Emmenegger et al. 2009)	SQCB (Faist Emmenegger et al. 2009)	IPCC (2006) tier 2
Nitrate (NO3)	Groundwater	Manure: buildings, yard, storage, spreading/ leaching	Basset-Mens et al. (2007)			-
Nitrogen oxide (NO)	Air	Mineral fertiliser	EMEP/EEA (2009) tier 1 for emission factors		EEA (2013)	-
Nitrogen oxide (NO)	Air	Manure: buildings, yard, storage, spreading	CORPEN (1999a-1999b-2001-2003-2006) for N-excretions + EMEP/EEA (2009) tier 2 for emission factors			-
Ammonia (NH3)	Air	Mineral fertiliser	EMEP/CORINAIR (2006)	EMEP/EEA (2009) tier 2. For Switzerland: Agrammon tier 3 (Agrammon Group 2009a,b)	EMEP/EEA (2013)	IPCC (2006) tier 2
Ammonia (NH3)	Air	Manure: buildings, yard, storage, spreading	CORPEN (1999a-1999b-2001-2003-2006) for N-excretions + EMEP/EEA (2009) tier 2 for emission factors			IPCC (2006) tier ?

Substance	Compartment	Source/mechanism	AGRIBALYSE (Koch and Salou 2015)	ecoinvent v2/v3 (Nemecek and Kagi 2007; Nemecek and Schnetzer 2012)	World Food LCA database (Nemecek et al. 2015)	Agrifootprint (Blonk Agri-footprint BV 2014)
Nitrous oxide (N2O)	Air	Mineral fertiliser	IPCC (2006) tier 1	IPCC (2006) tier 1	IPCC (2006) tier 1	IPCC (2006) tier 2
Nitrous oxide (N2O)	Air	Manure: buildings, yard, storage, spreading	CORPEN (1999a-1999b-2001-2003-2006) for N-excretions + IPCC (2006) tier 2 for emission factors	IPCC (2006) tier 2	IPCC (2006) tier 2	IPCC (2006) tier ?
Phosphate, phosphorus (P)	Surface water, groundwater	Fertiliser/ erosion, leaching, runoff	SALCA-P (Prasuhn 2006)	SALCA-P (Prasuhn 2006)	SALCA-P (Prasuhn 2006), SQCB (Faist Emmenegger et al. 2009)	CFs from (Struijs et al. 2010)
Soil erosion			RUSLE 2 (Foster 2005)		SALCA-P (Prasuhn 2006), SQCB (Faist Emmenegger et al. 2009)	-
Heavy metals (Cd, Cr, Cu, Hg, Ni, Pb, Zn)	Soil, surface water, groundwater	Fertilisation/ leaching, runoff, accumulation	SALCA-Heavy Metals (Freiermuth 2006) partially modified (SOGREAH 2007)	SALCA-Heavy Metals (Freiermuth 2006)	SALCA-Heavy Metals (Freiermuth 2006)	SALCA-Heavy Metals (Freiermuth 2006)
LUC	Air		ecoinvent v2 (Frischknecht et al 2007)	ecoinvent v2 (Frischknecht et al 2007)	Blonk LUC (van Zeist 2016)	Blonk LUC (van Zeist 2016), based on PAS 2050-1
Methane (CH4)	Air	Rice, enteric, manure management	IPCC (2006) tier 1 or 2	IPCC (2006) tier 2	IPCC (2006) tier 2	IPCC (2006) tier ?
Water use	Water	Irrigation		ecoinvent v3 (Lévová et al 2012)	ecoinvent v3 (Lévová et al 2012)	Blue water footprint

Substance	Compartment	Source/mechanism	AGRIBALYSE (Koch and Salou 2015)	ecoinvent v2/v3 (Nemecek and Kagi 2007; Nemecek and Schnetzer 2012)	World Food LCA database (Nemecek et al. 2015)	Agrifootprint (Blonk Agri-footprint BV 2014)
						(Mekonnen & Hoekstra, 2010)
Pesticides	Soil	-	ecoinvent v2 (Nemecek and Kägi, 2007)	ecoinvent v2 (Nemecek and Kägi, 2007)	ecoinvent v2 (Nemecek and Kägi, 2007)	ecoinvent v2 (Nemecek and Kägi, 2007)

Table 16. Abridged life cycle inventories of sample aquaculture systems in Zambia, per year of operation

Inventory item	Unit	Large cage systems (12)		Large pond systems (13)		Medium pond systems (7)		SH pond commercial systems (1200)	SH pond semi-subsistence systems (10 800)	Government hatcheries (8)	Commercial hatcheries (10)
		LC1	LC2	LP1 **	LP2	MP1	MP2	4 farms	9 farms	GH1	CH1
Key parameters											
Feed conversion ratio (FCR)	ratio	1.5	1.6	5.0	2.0	2.0	2.0	2.0	5.0	N/A	N/A
Stocking density	fish/m2 or m3	67	~60	1.2	7.5	4	5	4-5	1-2	N/A	N/A
Outputs											
Fish production	kg	7 200 000	1 500 000	4 000	1 300 000	157 500	64 000	3 580	189	N/A	N/A
Fingerling production	u	60 000 000	13 500 000	-	4 000 000	-	700 000	-	-	129 000	2 496 000
Inputs											
Fingerling consumption	u	43 200 000	9 000 000	-	6 000 000	840 000	400 000	7 209	2 079	N/A	N/A
Commercial feed consumption	kg	10 440 000	2 465 000	-	3 050 000	120 000	129 000	2 177	67	6 000	4 880
Electricity consumption	kWh	1 440 000	300 000	64 200	151 060	23 529	31 373	-	-	11 765	
Fuels consumption	L	49 067	48 000	1 200	250	6 462	-	100	15	160	3 900
Transportation (inputs, outputs)***	tkm	3 528 000	793 000	-	304 500	3 735	27 230	1 117	72	45	-
Land occupation (ponds)	m2	60 000	13 500	44 466	807 000	210 000	83 300	6 853	1 014	14 619	1 700
Water occupation (cages)	m2	22 134	21 653	N/A							
Manure consumption (ponds)	kg	-	-	-	300 000	96 000	-	2 075	1 770	4 500	-
Chemical fertiliser consumption (ponds)	kg	1 080	243	-	-	-	1 499	50	40	-	-
Lime consumption (ponds)	kg	6 000	1 350	7 115	160 000	21 000	8 000	131	25	5 000	-
Nylon (nets: ponds and cages)*	kg	17 778	17 139	52	130	78	104	143	65	104	104
HDPE (cages)*	kg	92 177	90 173	N/A							
Polyestyrene (cages)*	kg	25 123	24 577								
Steel (cages)*	kg	139 327	136 298								

* Net and cage materials are not expressed on an annual basis, but on total weight per system. Nets have a lifespan of 2 years, cages of 10 years. Ponds have a lifetime of 10-15 years. Requiring regular maintenance (bank consolidation, silt removal, etc)

** The LP1 system is rather atypical, as it is a very extensive pond system with natural reproduction and very low output. The company is currently carrying out a native tilapia genetic quality improvement project, involving a hatchery sub-system with an expected output of 150 000 to 500 000 fingerlings per year (over the next 3 years), with the aim of intensifying and

*** Fish transportation by large cage and pond producers is made in refrigerated trucks.

Values in parenthesis represent the population size of each system type

6.3 Life Cycle Impact Assessment

The impact assessment of all concerned processes was calculated using SimaPro 8.3, a commonly-used software that enables comparisons and uncertainty management.

6.3.1 Absolute and relative impact assessment of the Zambian aquaculture value chain (tilapia only)

The endpoint impacts per t fish produced are presented in Figure 21 per type of system and for the "average" tilapia. These endpoint indicators represent the sum of all normalised (i.e. expressed in a common unit regarding their contribution to overall impacts) impact categories. The average produced tilapia in Zambia is determined on the basis of the relative contribution to total annual production of the different types of systems (~31 300 t[73] in 2016, further subdivided from the classes used in the DoF annual report 2017), namely:

- Large cages 67%
- Large ponds 8%
- Medium ponds 3%
- Small commercial 7%
- Small semi-subsistence ponds 7%
- Stocked water bodies 9%

Figure 21 suggests that environmental impacts are correlated with management, as the less managed systems feature the higher impacts. Moreover, it seems paradoxical that smaller systems, in principle expected to face higher resource constraints because of lack of economies of scale, feature lower impacts. Such apparent paradox is analysed below.

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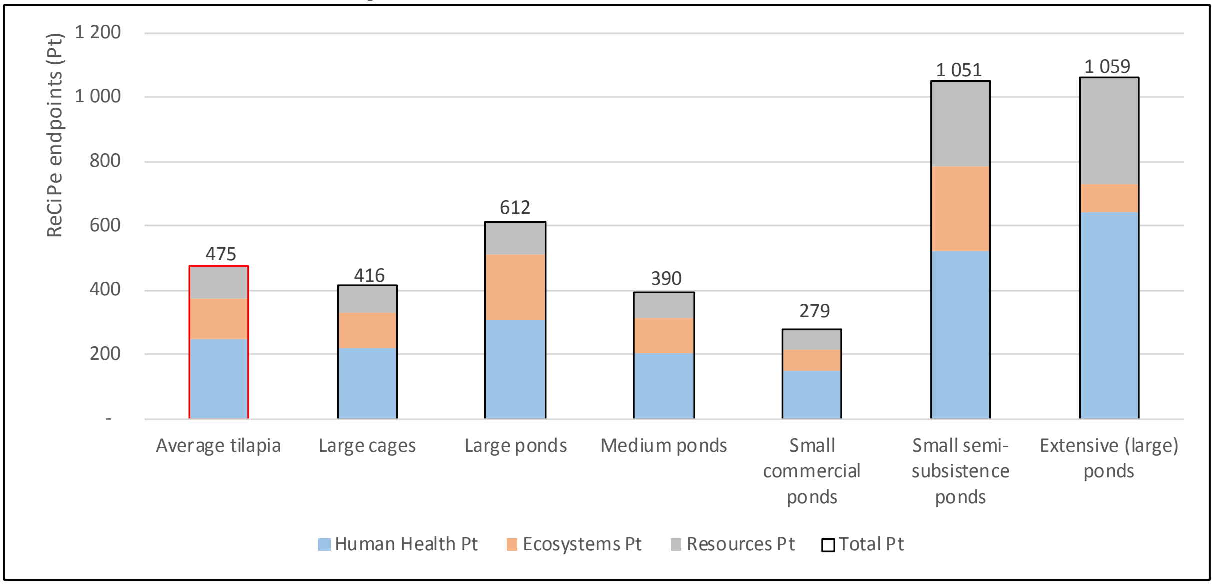
[73] The 60 000 t presented in Figure 7 refers to all farmed fish available to consumers in 2016, including imports (~28 000 t). The ~20 000 t presented in Figure 8 correspond to farmed fish produced in the year 2014.

a) Per 1 t of whole fish at farm gate



b) Per 1 ha of water body occupied (land-based systems only)

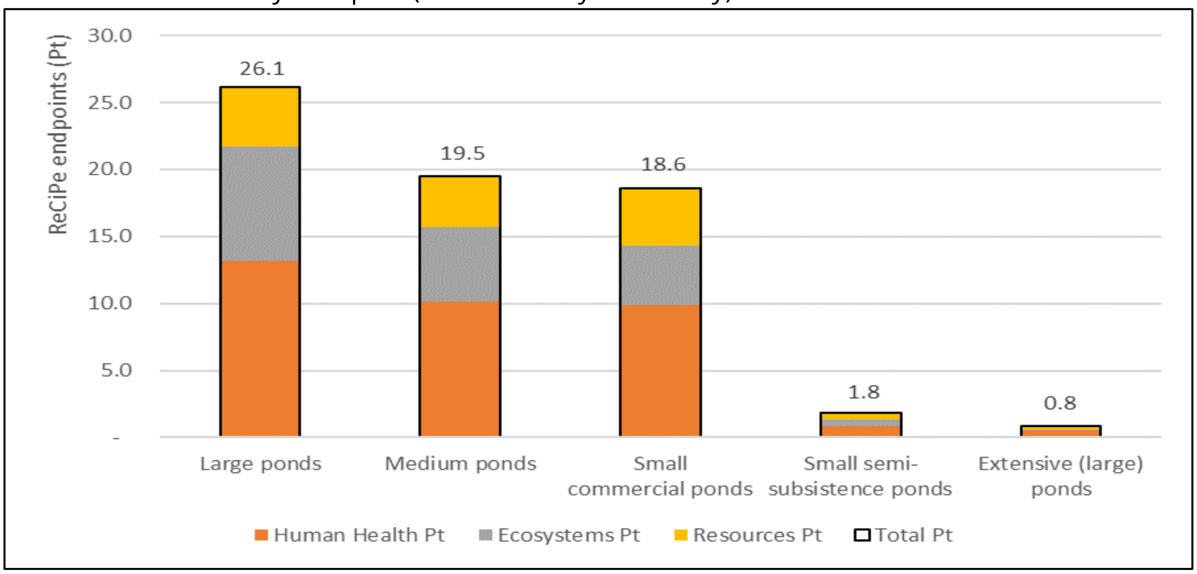


FIGURE 22. RELATIVE ENDPOINT IMPACTS OF PRODUCING TILAPIA, PER SYSTEM TYPE, PER AREA OF PROTECTION

For system comparison across all system types, the use of 1 t of fish as functional unit is relevant, but land-based systems may also be compared on the basis of area used. As expected, the intensity of environmental impacts is correlated with the yield of land-based systems, and thus with their stocking density.

Midpoint impacts are presented in full in Annex 6, and a selection of them in Figure 23. In this report, we privilege endpoint indicators, which, in our opinion, better convey the relative contribution of impacts to the AoP and the relative environmental performance of the various system types.

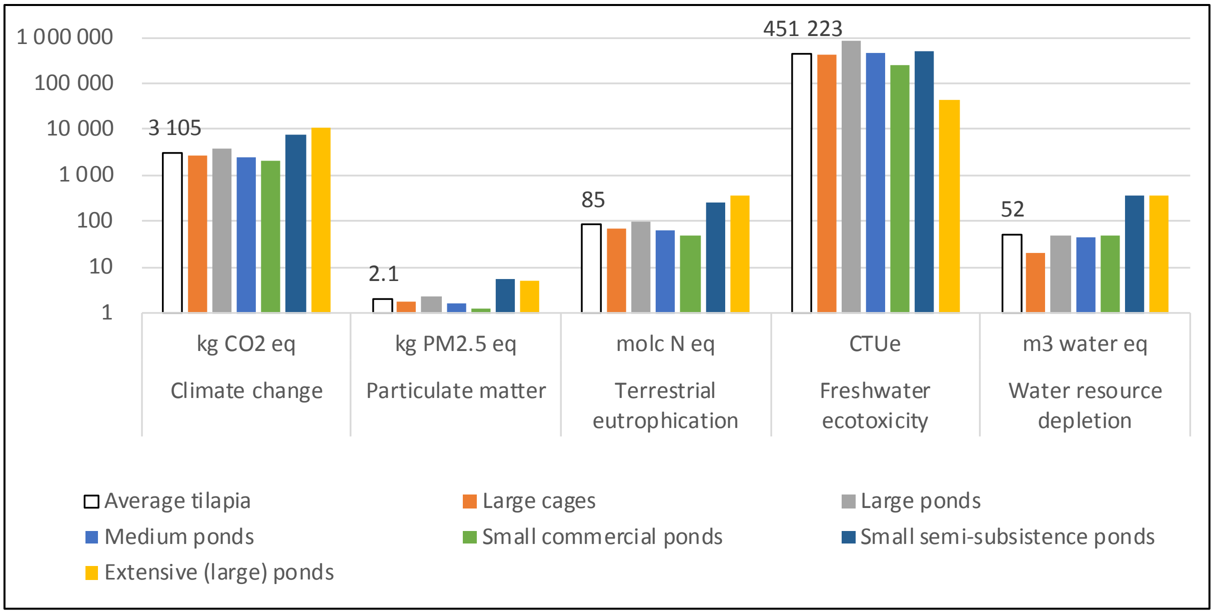


FIGURE 23. RELATIVE MIDPOINT IMPACTS OF PRODUCING 1 T OF TILAPIA, PER SYSTEM TYPE, PER SELECTED IMPACT CATEGORIES

From Figure 21 and 22 it can be noticed the relative environmental cost of producing 1 t of tilapia under various system types, being small and medium commercial pond systems and large lake-based cage systems more environmentally efficient than large extensive systems and barely managed small pond systems. A more interesting question for an absolute assessment is the relative contribution to impacts of each type of system, based on their total national output. Those relative contributions are presented in Figure 24. It is noticeable that, due to the sheer volume of their output, large cage systems are the main contributors to the impacts of the average produced tonne. Large cage systems are not the most efficient ones, due to their high feed demand.

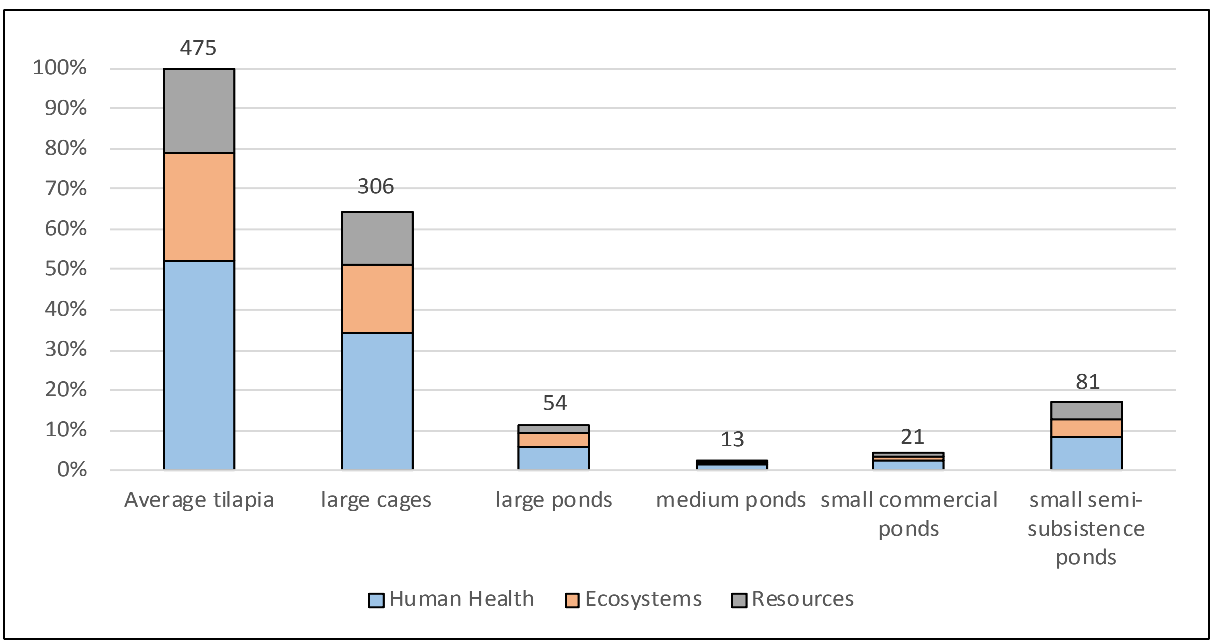


FIGURE 24. RELATIVE CONTRIBUTION OF EACH SYSTEM TYPE TO 1 T OF AVERAGE TILAPIA

Specific comparisons between system types allow for the following statements (see detailed results in Annex 7). Moreover, a contribution analysis (to impacts) highlights and explains differences in performance (Figure 25):

- Among large producers, cages have lower overall impacts than ponds, despite large feed demand of the former, due to the higher FCR of the latter. Larger resource demands of pond systems (land occupation, pumping, direct emissions due to manure use) do not seem determinant to impacts.
- Among pond systems, large systems feature higher impacts than well managed medium and small commercial ones, while small semi-subsistence and extensive systems have very high impacts per produced t of fish in relation to other pond system types. The reasons are multiple, and include economies of scale, feeding efficiency and other management-derived performance aspects, as well as the extent of extensification. The extent of extensification (as represented by the stocking density and FCR) seems to play an important role in determining environmental performance, for instance punishing large pond systems and pure extensive systems (such as stocked water bodies).

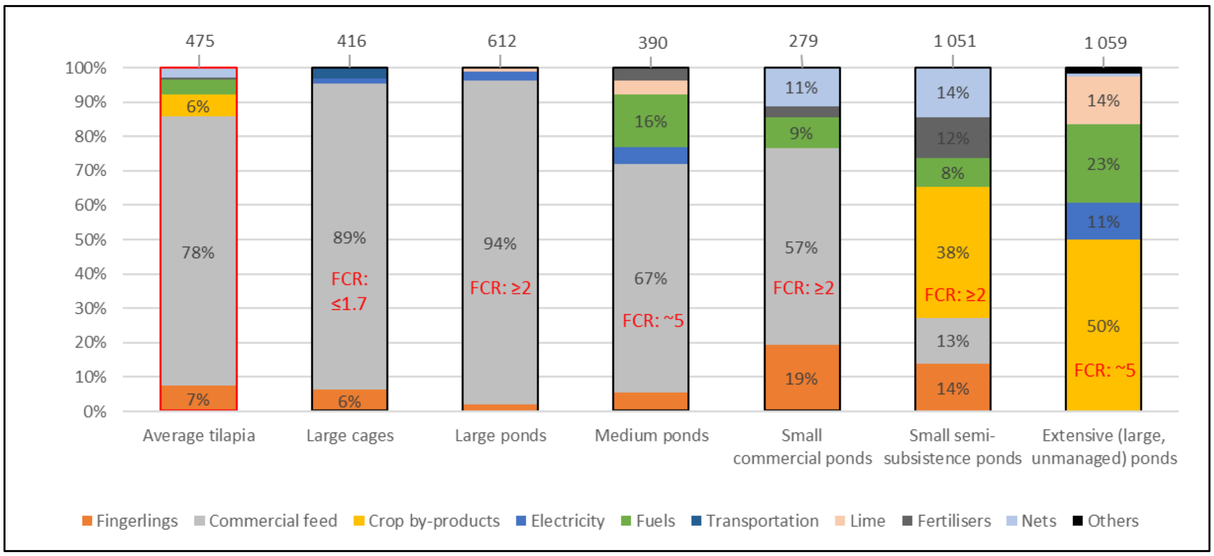


FIGURE 25. CONTRIBUTION ANALYSIS PER SYSTEM TYPE FOR THE PRODUCTION OF 1 T OF TILAPIA

Selected midpoint impacts for the whole sector in 2016 (~28 600 t, excluding output of stocked water bodies, for which we do not have data) are presented in Figure 26. 89 000 t of CO_2-equivalents were emitted, 1.5 million m^3 of freshwater consumed and the equivalent to 234 t of phosphorus were released in rivers and lakes. These figures may look alarming, but in comparison with other food production sectors (fisheries, agriculture, and livestock) are undoubtedly very minor. Ways to reduce emissions and resource consumption should be found, such as providing the means for small subsistence pond systems to "graduate" into commercial. Such a shift may reduce certain overall impact associated to smallholder subsistence systems (which are high per produced t of fish, due to low yield), but further and more detailed studies would have to be conducted to determine the impact associated to increased resource consumption (water, feed).

Transportation of inputs and products plays a minor role in the environmental performance of all systems, but this is limited by the way transportation was modelled, using European background transportation processes, which may not represent the performance of transportation means in Zambia.

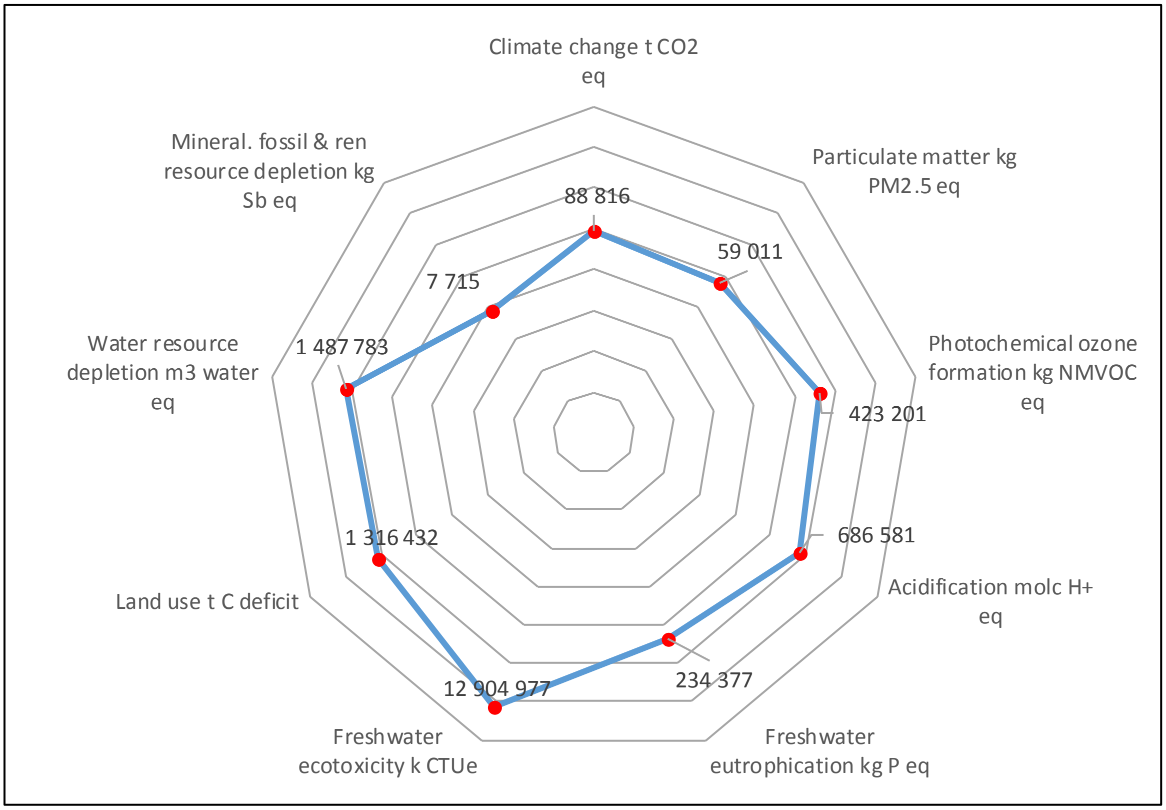


FIGURE 26. MIDPOINT IMPACTS OF TOTAL TILAPIA PRODUCTION IN ZAMBIA IN 2016 (~28 600 T), FOR SELECTED IMPACT CATEGORIES

6.3.2 Sensitivity and variability analyses

Due to data constraints, mainly the reduced number of samples and the unavailability of sensitivity data for foreground flows (feed consumption, energy use), sensitivity and variability analyses were not conducted.

6.3.3 Comparison with previous studies

Results of this assessment were compared with those of tilapia LCA studies in low/middle-income tropical countries, namely Cameroon (Efole Ewoukem et al. 2012), Peru (Avadí et al. 2015) and Indonesia (Pelletier and Tyedmers 2010). The Cameroonian systems are smallholder, pond-based, without commercial feed use, often integrated with animal husbandry. The Peruvian systems are medium scale, ranging from semi-intensive (lake-based) to super-intensive (land-based), and consuming both homemade artisanal feeds and commercial feeds. The Indonesian systems are intensive lake and pond-based, consuming commercial feed. A comparison of midpoint results from the Zambian systems with results of these studies is presented in Table 18. To enable comparison, midpoint impacts of the Zambian systems were recalculated using ReCiPe and CML, because the reference studies did not use ILCD but those other methods.

		Climate change	Eutrophi-cation	Acidifi-cation	Non-renewable energy use	Land use	Water use
		kg CO_2-eq	kg PO_4-eq	kg SO_2-eq	MJ	m^2/yr	m^3
Cameroon small scale systems, no commercial feed	Integrated pig-and-fish system	5 100	908	22	17 100	4 369	16 900
	Wheat bran as fish feed	1 600	318	7	4 000	3 672	20 000
	Pig manure and crop by-products	800	401	3	1 800	2 820	5 100
	Pig and chicken manure	600	157	3	1 700	1 973	23 700
Peru medium scale systems	Semi-intensive, homemade feed	1 745	51	18	26 422	14 256	3 973
	Intensive, commercial feed	3 563	36	36	40 579	2 808	1 444
Indonesia intensive systems	Lake-based	1 520	48	20	18 200		
	Pond-based	2 100	46	24	26 500		
Zambia: this study	Large cage systems	3 670	57	13	26 208	2 927	152
	Large pond systems (pig-integrated)	5 206	57	19	32 733	4 868	1 939
	Large pond systems (extensive)	10 878	81	64	103 610	5 238	21 923
	Medium pond systems	3 364	52	14	23 320	2 770	3 523
	SH pond commercial systems	2 521	50	10	20 536	1 681	6 157
	SH pond semi-subsistence systems	8 696	71	52	85 813	4 660	13 263

Table 17. Comparison of midpoint results from several tilapia studies, per t of fish produced

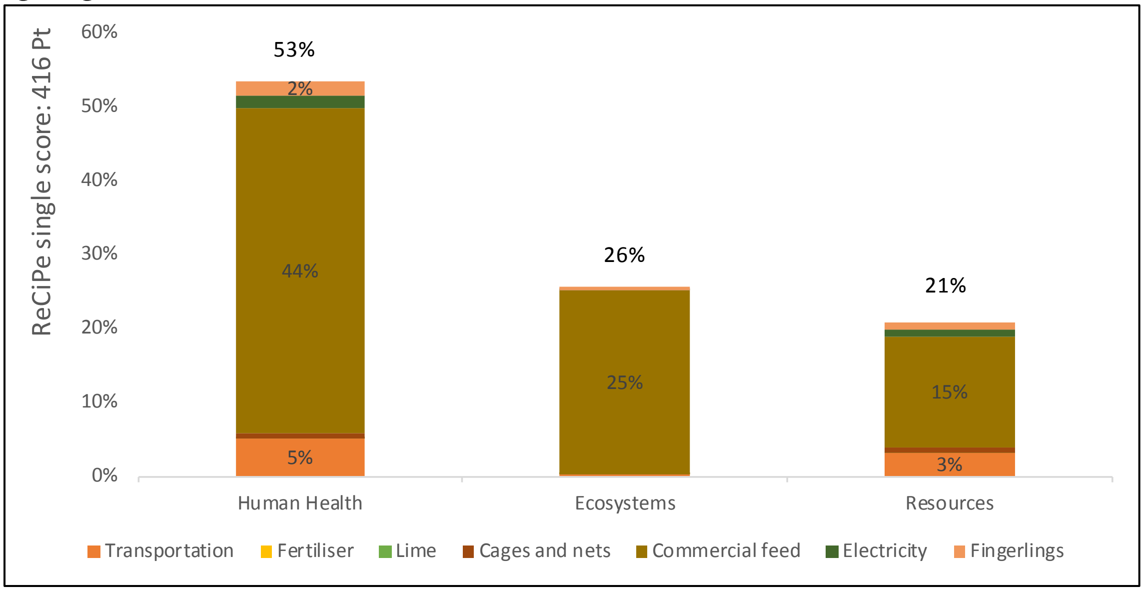
In the Cameroonian farms the bulk of impacts is due to feed and manure inputs, while in the Peruvian and Indonesian ones the main driver of impacts is feed (>50%), as it is for the Zambian systems (Figure 25). Systems across countries with similar positions in the extensive-intensive continuum feature impacts within the same orders of magnitude. The smallholder semi-subsistence ponds feature particularly higher impacts per produced tonne, which is a direct consequence of these poorly-managed, very low yield systems.

6.4 Summary of the core questions (interpretation)

The overall contribution to impacts of the value chain is dominated by human and freshwater toxicity, according to normalised results (not shown). These impacts are explained mainly by the agricultural phase of feed production, especially in large cage systems. Feed provision is the main driver of most environmental impacts for all system types. Extensive and undermanaged systems feature higher impacts than intensive and/or well managed ones, but the overall environmental performance of the value chain is determined by the dominant production of large cage systems, which feature relatively low impacts.

Figure 27 presents the relative contribution of both commercial and semi-subsistence feed to overall impacts per area of protection of two extreme systems: large cages and small subsistence ponds. As often found in the literature, feed provision is the dominant contributor to environmental impacts in aquaculture systems of all types.

a) Large cages



b) Small semi-subsistence pond systems

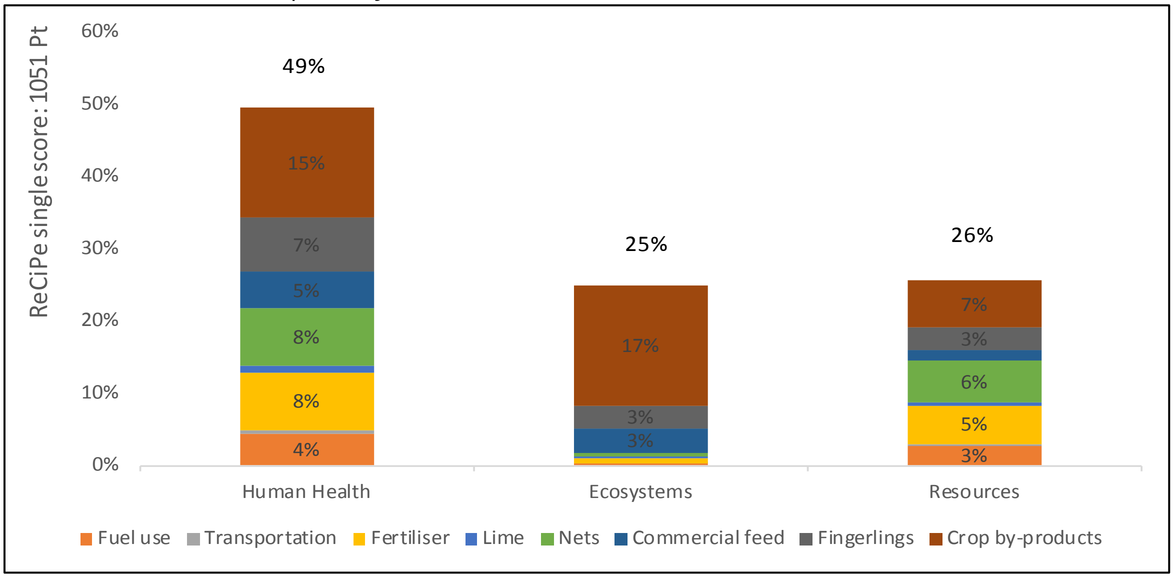


FIGURE 27. DETAILED CONTRIBUTION ANALYSIS OF TWO TYPES OF FISH PRODUCTION SYSTEMS, PER AREA OF PROTECTION

6.4.1 CQ4.1: What is the potential impact of the value chain on human health?

The impacts on human health from small systems are mainly due to the provision of feed by agricultural by-products, while from large systems are due to the provision of commercial feed. These impacts mainly correspond to climate change, particulate matter formation and toxicity, due to fuel use and emissions associated with agricultural activities.

6.4.2 CQ4.2: What is the potential impact of the value chain on ecosystem quality?

Ecosystem quality is negatively affected by the activities of the value chain, mainly regarding soil and water degradation driven by agricultural activities (feed) and to a lesser extent water use (both consumption and pollution of water). Large producers are either next to main rivers or in lakes, where water availability is not a problem, but potential impacts on water quality may increase as more producers get established. In the other hand, extensive systems (waterbodies, dams) can improve underground water reserves and fish stocks.

6.4.3 CQ4.3: What is the potential impact of the value chain on resources depletion?

For small pond systems, the main contributor to resource depletion is the provision of nets, followed by the consumption of fuels and other resources during agricultural activities. For large cage systems, the provision of feeds dominates all areas of protection, being driven by agricultural inputs in the case of resource depletion. The water resource is a key limiting factor for aquaculture in Zambia. Occasionally, access to water is so limited that farmers producing fish at the smallholder level need to prioritise irrigation of their crops rather than refilling their fish ponds. Fish production in situations where water is not amply available adds additional stress on the resource.

7 Conclusions and recommendations

7.1 Framing questions

7.1.1 What is the contribution of the value chain to economic growth? Is this economic growth inclusive? Is the value chain socially sustainable?

The financial analysis demonstrated that the aquaculture value chain is sustainable from an economic point of view, given that its activities create revenues for the actors who are partially or totally devoted to the activity. However, from a socially sustainable and inclusive perspective, smallholder farmers' lack of access to microfinance, key inputs (seed and feed), extension services and vocational training opportunities, and to more vibrant output markets prohibits them from moving from a more subsistence production system to one that enhances their productivity and sustainably increases their incomes. As a result, larger operators have dominated their presence within the aquaculture value chain over the past 5-10 years.

Domestically farmed fish is less competitive compared to imported farmed fish (11 ZMW/kg). Access to key aquaculture assets by rural women and men fish farmers is poor and access to microfinance for aquaculture investments is non-existent in rural areas. The current production systems employed by most rural people enable them to access fish for food and nutrition security purposes and to generate small amounts of income. Farmed tilapia produced for urban markets is cost-prohibitive for poor consumers.

Nevertheless, the total value added of the aquaculture value chain in Zambia was estimated in 2016 at 692 million ZMW. The total imports are estimated at 319 million ZMW, and imports of tilapia currently account for around 50% of the farmed fish consumed in Zambia. Imports no doubt help fill fish supply gaps and provide additional fish for human consumption, yet the (alleged) illegal importation of fish is controversial and may stunt aquaculture development efforts moving forward. As such imports comprise a significant amount of lower grade/sized tilapia from China, how this negatively impacts output market dynamics for poorer smallholder fish farmers appears significant.

The contribution of the value chain to the Gross Domestic Product (GDP) was 0.32% in 2016 and the contribution of the aquaculture value chain to the agricultural GDP was 6.1%. The total taxes paid to the Zambian state by the actors in the value chain are estimated to amount to 80 million ZMW in direct taxes (the main portion consists in corporate taxes and import duties) and 4 million ZMW in indirect taxes. The contribution to the balance of trade is negative as the country imports are high and the exports are low.

We estimate direct employment in the sector (including part-time employment and self-employment) to be around 20 000 jobs, of which the vast majority is at farm-level and unskilled labour. The recent WorldBank report (Krishnan and Peterburs 2017) estimates that women comprise only 8% of the workforce in the aquaculture value chain. The social analysis carried out for this assessment confirmed that women are excluded from employment opportunities on larger farmers and make up a smaller percentage of rural fish farmers in the country.

Small and medium farms contribute less to direct value added than their share of net operating surplus they receive (9% contributed to value added, versus 16% share in operating surplus), while this is the reverse for the large scale pond farmers (8% versus 3%) and large scale cage farmers (67%

versus 46%) operating surplus. The value chain can be considered reasonably inclusive from the perspective of the small and medium farmers. The large scale farmers contribute high shares of wages, compared to their share of net operating surplus. While their contribution to the value chain is significant, women's lack of participation as employees on these larger-scale cage farms means the production node of the value chain is especially unequal in creating gainful employment for women.

Large wholesalers who create 13% of the value added receive 21% of the net operating surplus and distribute only 4% of the wages in the value chain. There is a concentration of wholesale activities, a very limited number of traders buy a large share of the tilapia.

The effects of policies that relate to restricting imports (either by increasing taxes and duties or through quality requirements, are difficult to predict. However, we can speculate about the possible positive and negative effects. When protective measures are introduced on farmed fish imports, the aquaculture sector would have a reprieve of competition and is therefore potentially able to develop itself further to become more competitive. We examined available official trade data, including the categories that products are declared as when imported. According to these data, Zambia imported 55 000 t of fish in 2014, out of which about 10 000 t was imported as fresh, chilled or frozen whole tilapia or fillets from China, Hong Kong and India. Based on these figures, applying higher tariffs or quality standards would therefore affect about 18% of the fish officially supplied to Zambians through imports, and 6% of total fish supply. It can be argued that this would have some but limited effect on fish prices for domestic consumers. As allegedly illegal imports are already an issue in the aquaculture sector, it is likely that policies that would restrict imports lead to increases in illicit imports of farmed fish.

Labour conditions on the relatively small number of larger farms are generally good, with efforts to comply with local and international labour laws and standards being the norm. No larger farms employ children, although children do assist their parents carrying out fish farming tasks in rural areas. While land and water rights issues (including involuntary displacement of rural people by large companies) seems to be a concern in other sectors (e.g., mining and tourism), no evidence of such occurring in the aquaculture sector was found by the social analysis.

Food crop production and incomes are increasing in rural areas over the past five years, yet seasonal hunger still exists for some during the rainy/cultivation period (December to March). This is of great concern as rural farmers become targeted by new and existing feed mills for food crops as main ingredients in fish feeds. Child malnutrition rates are still unacceptably high in Zambia, only declining slightly over the past 5-10 years. Living conditions (housing, access to health services and primary education) for rural people appear adequate, albeit could be better. Social capital throughout the aquaculture value chain seems low, while in rural areas fish farmers often come together to learn about fish farming and are often organized into groups by outsiders to achieve this goal. Nonetheless, extension support and training opportunities are few and usually occur only when donor-supported projects (sometime through government funds) facilitate. Group fish farming seems to be highly problematic as a means of production.

7.1.2 Is the value chain environmentally sustainable?

Smallholder semi-subsistence systems have the higher impacts per produced t of fish due to low yields. Smallholder commercial systems, on the other hand, feature the best environmental performance among all systems, and thus a shift from semi-subsistence to commercial systems (small or medium), in terms of management, would considerably lower the mean impacts per t of fish (especially if small systems eventually contribute more to the national production). Large cage systems are more efficient than large pond systems, due to comparative FCRs, and both systems are notably more environmentally-efficient than poorly-managed ones of all sizes (extensive, smallholder subsistence). Only large pond systems treat the polluted waters by means of constructed wetlands and other mechanisms, but smallholder systems dispose part of the polluted water without treatment. Finally, no anthropogenic system is ever truly sustainable, but the environmental performance of certain well-managed systems in Zambia can be considered as acceptable and contributing directly or indirectly to the well-being of Zambian families, while poorly managed ones are clearly unsustainable both environmentally and economically, and only marginally from a social standpoint.

7.1.3 Sustainability comparison of Zambian fish farming systems

Producer type	Yields (kg/ha)	Resilience	Economic performance	Social performance	Environmental performance *
Pond smallholders semi-subsistence	1900	★ Low: very sensitive to the quality and availability of inputs, including water	★ Very low profitability, little value added, few salaried jobs	★ Low input, low output system, yet important contribution to food and nutrition security and some income generation. Lack of women and youth involved.	★ Very low per t Very high per ha
Pond smallholders commercial	5 200	★★ Medium: flexible to varying quality and availability of inputs, thanks to management	★★ Good profitability, moderate value added, few salaried jobs	★★★ More intensive system, with apparent greater economic returns on investment.	★★★ Very high per t Low per ha
Medium-scale pond farmers	7 600	★★ Medium: flexible to varying quality and availability of inputs, thanks to management	★★ Medium profitability, moderate value added, few salaried jobs	★★ Contribution to local employment, potential to supply smallholders with better quality seed. Source of fish for larger markets/better-off households.	★★ High per t Low per ha

Producer type	Yields (kg/ha)	Resilience	Economic performance	Social performance	Environmental performance *
Large-scale pond farmers	16 000	★★★ High: very flexible to varying quality and availability of inputs. If integrated with livestock, close to self-sufficiency	★★ Medium profitability, high value added, medium salaried jobs	★★ Contribution to local employment, potential to supply smallholders with better quality seed. Source of fish for larger markets/better-off households.	★★ High per t Very low per ha
Large-scale cage farmers	880 000	★★ Medium: somehow sensitive to the quality of inputs (feed)	★★ Low profitability, very high value added, contribution to growth (fish, feed, seed), many salaried jobs, not viable in the international economy	★★ Contribution to local employment, potential to supply smallholders with better quality seed. Source of fish for larger markets/better-off households.	★★ High per tonne
Extensive ponds / stocked water bodies	<900	★★★ High: self-sufficient system, but very low output	★ Not studied but likely similar to smallholder semi-subsistence farmers	★★ Lack of available data, but likely provides a source of fish to rural smallholder for food and nutrition security and income	★ Very low per t Very high per ha

* Performance is here understood as the inverse of environmental impacts intensity.
The lowest score per category is represented by one star, while the highest is three.

7.1.4 Key recommendations

Innovations and strengthening aquaculture development policies and strategies

- Ensure that small-scale farmers can benefit from the recent innovations introduced by large-holders, for instance feed and seed efficiencies. However, this should not rely on linear developmental strategies that assume that progress achieved in the industrial sector automatically percolates to smallholders.
- Policy action should be tailored according to the type of aquaculture system and actors.

- Explore a more balanced development model of the sector, based on favouring the inclusiveness of smallholder extensive/semi-intensive aquaculture in order to satisfy the diversity of markets and consumers of farmed fish.
- Support developments and investments in hatcheries and nurseries, while promoting recognition of the value of larger seed, would likely improve access to seed by smallholders.
- Ensure that efforts to increase supply of microfinance to farmers is accompanied by efforts to strengthen technical knowledge on aquaculture *and* business skills, as without the two, farmers are highly likely to fail and become indebted.
- Linking rural smallholder farmers to output markets, via appropriate strategies (e.g., organization through cluster farming and aggregation or out-grower schemes) must be components of efforts to increase smallholders' access to inputs, microfinance, training, and the like.
- Clear gains can still be made among the small and medium farms. A focus on efficiency will not only be beneficial to economic performance, but will also have a positive impact on environmental performance.
- Before financing and promoting small-scale cage systems, test the feasibility of pro-poor cage farming with smallholder farmers (e.g. as an out-grower scheme with larger operators).
- There is need to design and test appropriate aquaculture-related labour-saving technologies with women, men, and youth.
- Test/promote integrated aquaculture agriculture systems and water management to enhance productivity of smallholders.
- For aquaculture to expand the main target needs to be on locations where access to water is not an issue as the additional costs for pumping of water are a major constraint for economic sustainability and profits. Either declare water-scarce areas as off-limits for year-round pond aquaculture or, after detail study of those areas, design appropriate technologies/systems designed to fit the circumstances.
- Fish farming as an individual business should be promoted and not as a group enterprise, which is closer to the widespread agricultural ways in Zambia.
- Diversify strategies for increasing fish availability in the country, by supporting the types of systems producing lower environmental impacts, namely well managed pond systems in water-abundant regions and large cage systems in new large water body locations (to prevent water pollution due to high concentration of cages in a few sites).
- Encourage the treatment of used waters with high organic loading.
- As more feed mills will begin targeting rural farmers to secure raw materials for increased production of feed, research testing alternative ingredients for use in fish feeds to avoid food/nutrition insecurity in rural (but also urban) areas is needed.
- Optimise feed formulations for increased digestibility and mechanic properties, thus generating less faeces and uneaten feed.
- Curbing fish imports (by border enforcement to reduce illegal imports and custom barriers to discourage legal imports of lower quality fish), while implementing policies that enable smallholders to compete (mainly to improve training and access to inputs and financing mechanisms), would even the competitive field, benefiting the entirety of the value chain. The immediate potential reduction in fish availability for the poor should be concurrently (and thoroughly) considered.
- Government should be careful to help expand the sector but not at the cost of rural people's lives and livelihoods by ensuring large-scale farms adopt and implement sound participatory processes when acquiring land or expanding production.

Capacity development

- Greater investments are needed in aquaculture training at all levels to ensure the current technical and vocational institutes have adequate personnel to teach, students receive enough practical experience, and rural farmers have access to such training as opposed to only that provided occasionally (if at all) by fisheries extension officers.
- Internship/apprenticeship programs with the private sector will help ground students' (and in particular youths') technical training and provide real-life vocational training experiences to ensure their skills development training is relevant to the private sector when seeking gainful employment.
- More effective extension services provided by the agricultural sector may be emulated for aquaculture, once or if the required critical mass is achieved. This would improve access by smallholders to both technical know-how and inputs.

Gender and youth

- Greater efforts are needed to bring women and youth more holistically into aquaculture production in rural areas and design/implement affirmative action-like policies that would ensure a large percentage of women are hired as labourers on larger farms. Adopting a gender transformative approach (e.g., engaging men, addressing harmful norms and power relations) would help ensure change is long lasting.
- Programs aiming to integrate more women into rural aquaculture activities must keep in mind women's significant role carrying out unpaid tasks so as to not inadvertently burden them with extra work while promoting aquaculture more generally.
- Engage local leaders and Government to improve women's and youth's access to land and water resources in rural areas for fish farming and other aquaculture-related value chain activities (e.g., production of key feed ingredients).
- Expanding the use of ICTs throughout the aquaculture value chain for enhanced site selection, investment, monitoring fish growth, health, and water quality, understanding market price differences and linking to wholesalers and retailers, and for knowledge-seeking reasons. How these could be used by rural youth and to provide paid-services opportunities for youth could be further explored.
- Greater understanding the aspirations of rural and urban youth to get involved in the aquaculture value chain is an important scoping activity to ensure various entry points for youth are relevant and enable their sustained participation.

7.2 Major issues/risks

Risk/issue	Possible mitigation
Economic	
Competition: Larger commercial players are competing among each other driving prices down, and both small and large-scale farmers compete with cheap farmed fish imports (both legal and illegal). This could lead to exclusion of smaller-scale farmers and hinder further growth of the sector.	Curb illegal imports, implement policies that enable smallholders to compete, mainly training and access to inputs and financing mechanisms.

Risk/issue	Possible mitigation
High costs of feed: the high price of feeds is seen as a constraint to farmers' businesses. The cash investment into feed during a production cycle is a major risk for farmers, and many smallholders are unable to secure sufficient funds to purchase commercial feeds.	A number of additional commercial players are presently entering the market, which may lower prices. Alternative options for smallholders are also being developed by the government and organisations such as WorldFish to provide farmers with access to better quality home-made feeds. Both can be further promoted. In addition, testing/promoting integrated aquaculture agriculture systems and water management for enhanced productivity.
High costs and lack of access to good quality seed: Seed prices are relatively high (compared to other countries). The development of a private hatchery and nursery sector is still in its infancy and clear gains can still be made here. At present there are no price differences between fingerlings of different sizes and seed is sold at very small sizes, which means that risk of mortalities is still high and that the grow-out period increases, thus augmenting the costs of feed, likely increasing total production costs.	Develop nursery systems and promote recognition of the value of larger seed. Support developments and investments in hatcheries and nurseries.
Poor roads and expensive transport: In some parts of Zambia there are issues of poor road networks. This affects the speed, quality and costs of transport, which in particular increases the mortality among fingerlings being transported and cost of feeds.	Capital Fisheries has a distribution network that effectively reaches most parts of the country, which shows it is possible. Moreover, the more effective extension services provided by the agricultural sector may be emulated for aquaculture, once or if the required critical mass is achieved.
Uncontrolled imports: It has been estimated that at present Zambia loses 30 million ZMW (about 3 million EUR) in import duties because of fish being imported disguised as another product, although detection has been limited.	Reinforcing border controls and physical checks of fish imports may reduce illegal fish imports.
Imported fish of poor quality: Glazing of frozen fish is a common practice, and high levels of glazing are used (both reported and unreported). This results in poor quality and artificially lower prices for imported fish.	Impose custom barriers (e.g. regulations on glazing) and/or taxes on imported tilapia to guarantee the same or higher selling price than that produced domestically.
Long and complicated licensing processes for medium/ large-scale farms: The large-scale sector requires several types of licenses and permits such as the Environmental Impact Assessment and clearance by ZEMA. This process is considered too lengthy, costly and not transparent and key informants consider it	Expedite licensing process (yet retaining EIA).

Risk/issue	Possible mitigation
to hinder the development of the large-scale sector[74].	
Lack of water: Some parts of the country have insufficient water during specific periods of the year. This means that the production cycle is significantly shortened and therefore having multiple production cycles becomes impossible, fish are unable to grow to full capacity, and fish conserved in ponds does not survive.	For aquaculture to expand the main target needs to be on locations where access to water is not an issue as the additional costs for pumping of water are a major constraint for economic sustainability and profits. Either declare water-scarce areas as off-limits for year-round pond aquaculture or, after detail study of those areas, design appropriate technologies/systems designed to fit the circumstances.
Social	
Larger-scale operations continue to grow and become the dominant player in the value chain. Smallholder/rural farmers could get excluded from the sector given their lack of access to microfinance, inputs, skills, output markets, among other things.	Improve access to microfinance for rural/smaller-scale farmers, especially rural women and youth. Increase and improve extension services and vocational training opportunities (see below). Link rural farmers to output markets.
Gender stereotypes are adhered to and promoted in the value chain, which especially discriminate against women. **Limited roles for youth in the value chain**. Their poor representation as rural fish farmers is due in part to complex social/land issues.	Target women and youth to bring them (more holistically) into aquaculture production. Design/implement affirmative action-like policies that would ensure X percentage of women is hired as labourers on larger farms. Adopt more gender transformative approaches (e.g., engaging men, addressing harmful norms and power relations) to ensure change is long lasting.
Rural people (potentially smallholder fish farmers) could be displaced off their lands as the sector grows. **Capital intensive water-based systems** could exclude smallholder farmers lacking the required initial and working capitals.	Mandatory participatory processes instituted by larger-scale operators when entering the market/expanding. Government should be careful to help expand the sector but protect rural people's lives and livelihoods. Test feasibility of pro-poor cage farming with smallholder farmers (e.g., as an outgrower scheme with larger operators).
Few rural people have access to **labour-saving technologies** to reduce drudgery when	Design and test appropriate aquaculture-related labour-saving technologies with women, men,

74 The process can be long and expensive and thus deters some farms from moving forward or getting involved or the like. Yes, it generates income for government, but ultimately the process ensures farms have thought about the environmental issues that could occur when setting up their systems. The process completely excludes smaller-sized commercial farms from setting up their operations, but likely this only matters as they try to expand and government sees their production system as viable and generating profits.

Risk/issue	Possible mitigation
farming fish. Women rely on mostly their hands to carry out unpaid (domestic) work.	and youth. Programs aiming to integrate more women into rural aquaculture activities must keep in mind women's significant role in unpaid tasks to avoid burdening them with extra work.
With **increased domestic production of commercial aquaculture feed**, certain staple and secondary crops will be in greater demand, and thus, could impact on staple food prices and food and nutrition security among the rural and urban poor. Feeds, once exported, could considerably exacerbate this issue.	Encourage feed mills to experiment with using alternative ingredients to avoid food/nutrition insecurity.
Group fish farming does not lead to productive results.	Avoid promoting fish farming as group enterprises but rather as an individual business.
The level of **vocational and other types of aquaculture training is low** in Zambia, especially for rural farmers. As the sector continues to grow, it runs a risk of not having adequately-trained personnel or farmers who can help meet growing demands.	Greater investments in aquaculture training at all levels to ensure the current institutes have adequate personnel to teach, students receive enough practical experience, and rural farmers have access to such training.
Environmental	
Water pollution by aquaculture effluents.	Establish mandatory wastewater treatment (for instance by means of settling ponds or constructed wetlands) for medium to large operations. Encourage the reuse of pond water and silt for irrigation and fertilisation of crops near pond systems of all sizes.
Indirect environmental impacts due to commercial feed based on dedicated crops which exert themselves impacts on the environment.	Promote the development of agricultural by-product-based feeds, both homemade and commercial.

7.3 Relevant issues requiring further in-depth analysis

- Precise understanding of the extent of rural people involved in fish farming throughout the country (e.g., population census of rural fish farmers, by sex and age), including their current levels of production and productivity.
- Design and testing of appropriate aquaculture technologies and approaches with rural farmers to increase productivity, improve water management, and access higher-quality inputs (better feed and seed).
- Precise understanding of the levels of fingerling production and sales in each district/province.
- Identification of successful innovative approaches to extension/outreach for rural farmers.
- Identification of novel and effective input (seed and feed) distribution systems for rural farmers.
- Identification of novel and effective microfinance options for rural farmers.

- Further research on the extent to which water-based systems displace or disrupt lives and livelihoods (e.g., fishing).
- Dedicated environmental assessment of agriculture providing feed inputs, and related research on suitable crops as alternative input feeds.

7.4 Observations/ recommendations regarding the methodology

The framing question for the environmental analysis, "Is the value chain environmentally sustainable?", is incorrect in the sense that no anthropogenic system is ever sustainable, as it will always consume natural resources and produce emissions. It should be reformulated to convey a comparative meaning, as LCA is essentially a tool for relative comparisons among systems, types of system, scenarios, etc. Concerning the social analysis, the social profile tool was helpful and enabled a relatively straightforward analysis of really complex issues. Time is always a constraint with such assessments, and therefore, the social analysis and the use of profile tool are particularly relevant for social scientists who have worked in the country under study for a significant time and can hit the ground running. The mobility component under living conditions needs to be better brainstormed for possible lines of inquiry, and later contextualized to fit the specific country context.

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Annexes

Annex 1: Locations visited and respondents interviewed during the two missions

First Mission: 26 February to 7 March 2017

Date	Place	Main Activity	People met
Sun 26 Feb	Lusaka	• Arrival of three team members at Lusaka airport. • Team meeting	
Mon 27 Feb	Lusaka	• Meeting with Department of Fisheries (DoF) • Meeting with WorldFish	**DoF**: (1) Dr. Harris Phiri (Deputy Director Capture Fisheries); (2) John Mwango (Deputy Director Aquaculture); (3) Mulenga Musonda (Chief Aquaculture Officer); and (4) Kondwani Gondwe (Senior Planner – Policy Planning and Information Department). **WorldFish**: (1) Sloans K. Chimatiro (Acting Country Director); (2) Sven Genschick; and (3) Olek Kaminski.
Tue 28 Feb	Lusaka	• Meeting with Peace Corps • Meeting with the EU Delegation to Zambia and COMESA • Meeting with Permanent Secretary of the Ministry of Fisheries and Livestock (MFL) • Travel to Siavonga	**Peace Corps**: (1) Cleopher Bweupe (Senior Project Manager – Rural Aquaculture Program); and (2) Donald Namushi (Aquaculture Training Specialist). **EU Delegation**: (1) Matteo Sirtori (Head of Economics Agriculture and Regional Sections); and (2) Friedrich Mahler (Agriculture and Rural Development Advisor). **MFL**: (1) Dr. David Shamulenge; (2) John Mwango (Deputy Director Aquaculture); and (3) Kondwani Gondwe (Senior Planner – Policy Planning and Information Department).
Wed 1 Mar	Siavonga	• Morning: team discussion • Meeting with the Siavonga Nutrition Group (SNG) • Meeting with the Buyantanshi women's group.	**SNG**: Musaka Muntondo (coordinator). **Buyantanshi women's group**: (1) Beauty Mwelwa- (chairlady) (2) Jessica Mwanza- (member) (3) Mary Namutowe- (member) and (4) Regina Namutowe- (member).
Thu 2 Mar	Siavonga	• Meeting with Kariba Harvest LTD (part of Lake Harvest) at Lake Kariba. • Meeting with Yalelo LTD at Lake Kariba.	**Kariba Harvest LTD/ Lake Harvest (large-scale cage)**: (1) Dr. Chris Chiwenda (CEO); and (2) Yvonne Mwanza (Lake ops. Manager). **Yalelo LTD (large-scale cage)**: with (1) Andre Zwaga (GM), (2) Marc Verkuyl (Lake ops. Manager); and (3) Adam Taylor (Owner).
Fri 3 Mar	Kafue and Chirundu	• Travel to Chirundu • Meeting with Benzo fisheries (Stephen Cocker's farm) in Chirundu • Travel to Kafue • Meeting with Kafue Fisheries LTD in Kafue • Travel to Lusaka	**Benzo Fisheries (medium-scale ponds)**: (1) Tom (Administrator); and (2) Coluber Muchelenga (Senior supervisor) **Kafue Fisheries LTD (medium-scale ponds)**: Speedy Holden (CEO)
Sat 4 Mar	Chongwe	• Travel to Chongwe • Meeting with Peace Corps volunteer	**Peace Corps**: (1) Daniel Bevington (Peace Corps volunteer); and (2) Donald Namushi (Aquaculture Training Specialist). **Small scale pond farmer**: Olipa Phiri (owner)

Date	Place	Main Activity	People met
		• Meeting with fish farmer • Visit supermarket (PicknPay Garden City).	
Sun 5 Mar	Lusaka	• Meeting at Kalimba Farms • Visit Yalelo Chelstone Fresh and various fish stalls at City Market. • Team meeting	**Kalimba Farms (incl. fish and crocodile farm, mediun-scale ponds)**: Emanuele Cayron-Thomas (owner).
Mon 6 Mar	Lusaka	• Visit Yalelo Depot and various city ladies, fish stalls in the traditional markets and small formal retail stores. • Meeting with National Milling • Meeting with Novatek Animal Feeds • EU Delegation debriefing • Team meeting	**Yalelo Depot**: (1) Adam Taylor (Owner); (2) Nathan Kanchebele (Sale team leader / dispatch supervisor); (3) Mutale Mubanga (Sales & Customer Service Manager); and Rachel Chkole (restaurant owner). **Fresh Foods Butchery & Restaurant**: (1) Muyunda Musole (owner); and (2) Inambao Musole (owner). **National Milling (feeds)**: (1) Dr. Anthony Chackao (CEO); (2) Sven Pihlblad (GM). **Novatek Animal Feeds**: Walter Roodt (GM). **EUD** (1) Matteo Sirtori (Head of Economics Agriculture and Regional Sections); and (2) Friedrich Mahler (Agriculture and Rural Development Advisor).
Tue 7 Mar	Chongwe	• Visit Chongwe District Fisheries and Livestock Office. • Meeting with commercial smallholder fish farmer • Meeting with commercial smallholder fish farmer • Drop off Arie and Angel at Lusaka airport.	**Chongwe District Fisheries and Livestock Office**: (1) Mwaka Nyirongo (Senior Fisheries Officer – Department of Fisheries); (2) Dr. Francis Mwanza (District Fisheries and Livestock Coordinator); (3) Musanda Lunkuntwe (District Fisheries Officer); and (4) Edna Sakaza (District Fisheries Assistant). **Smallholder pond farmer**: Colonel (ret.) John Msoni (owner). **Smallholder pond farmer**: General (ret.) Maiko Mbao (owner).

Second Mission: 31 May – 9 June 2017

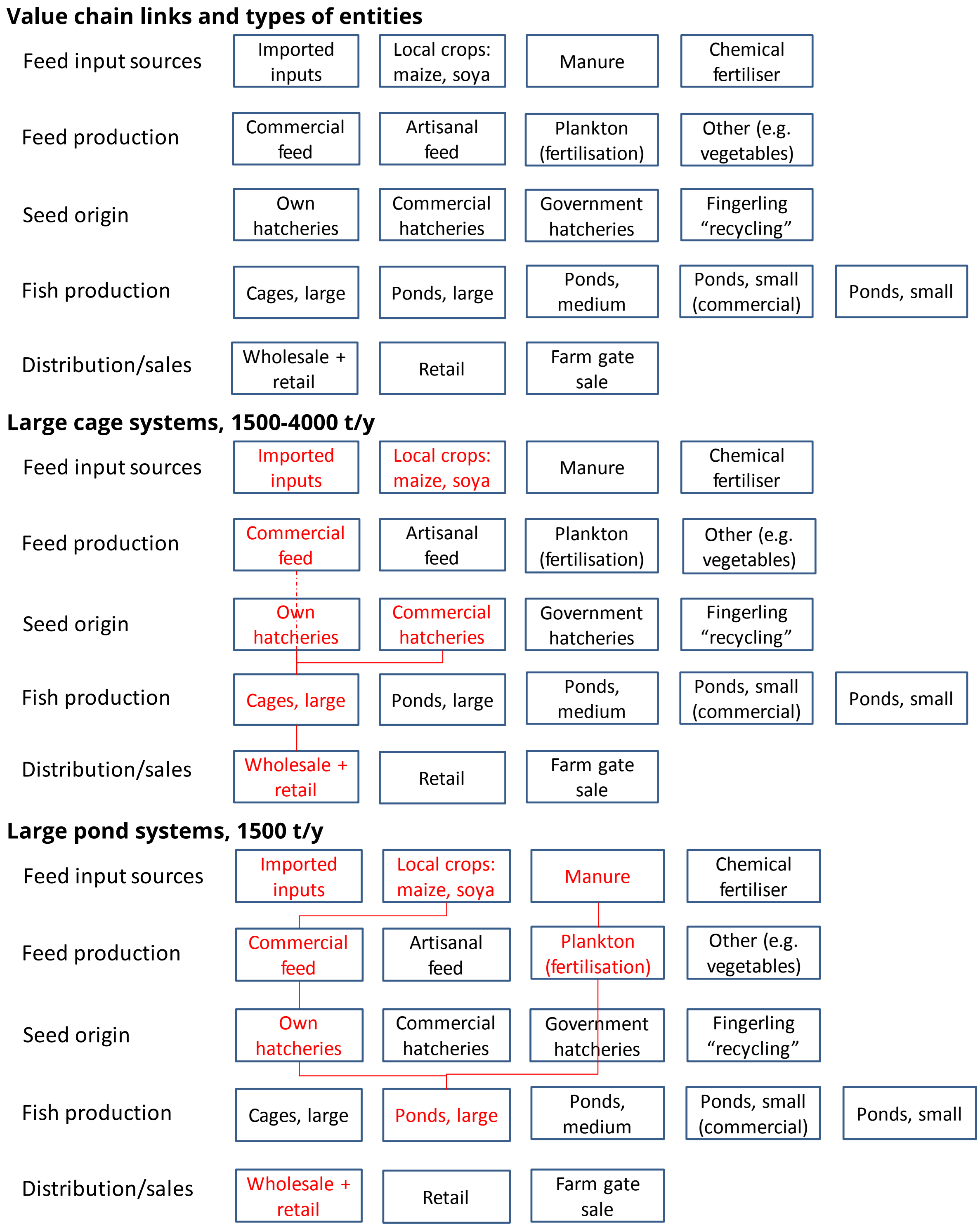
Date	**Place**	**Main Activity**	**People met**
Mon 29 May	Lusaka (EUD Office)	Meeting (partly video conference) with EIB, EUD Delegation, and VCA4D PMU	**EUD** Matteo Sirtori, Friedrich Mahler **EIB** Francois-Xavier Parant, Daniel Themen, Alessandra Borrello **PMU** Marie-Helene Dabat, Olimpia Orlandoni, Sara Jones
Tue 30 May	Lusaka	• Meeting with WB-IFC • Meeting with AfDB • Meeting with IFAD	**WB-IFC** Henry Sichembe **AfDB** Lewis Bangwe **IFAD** Dick Siame, Elemson Muyanga
Wed 31 May	Serenje, Northern	• Pick up Froukje from airport • Travel to Serenje	-
Thu 1 Jun	Kasama, Northern	• Travel to Kasama • Visit Provincial Fisheries Office • Site visits within Kasama • Misamfu Research Station • Kasakalambwe Multipurpose Cooperative • Melima Farm (PJT Farm) • Travel to Mpulungu	**DoF**: Provincial Fisheries Coordinator - Joseph Chiti, Provincial Fisheries Officer - Ramus Kayumu, District Fisheries Officer - Nelson Siwale **Kasakalambwe Cooperative:** Coop Secretary – Felix Mulenga **Misamfu:** Aquaculture Research Station Officer – Mr. Toloka Khosa

Date	Place	Main Activity	People met
			Melima Farm (medium-scale ponds): Owner/Manager – Enock Simute; Supervisor – Kennedy Simuchenje
Fri 2 Jun	Mpulungu/ Mbala, Northern	• Visited new breeding program being set up at Great Lake Products • Visit to Lake Tanganyika Development Project • Visit to CEEC cages • Meetings with smallholder farmers • Travel to Kasama	**GLP (medium-scale ponds):** GLP Director – Salim Sarham; Researcher – Mr François; WorldFish researcher – Dr Mary Lundeba; WorldFish researcher – Mr Mulenga **LTDP** Peter Mutale Kangwa and Robert Haloba **Small-scale pond farmers:** (1) Mr Joseph Simuchenje (CEEC supported farmer); (2) Mr Gilbert Sinjela - Headman Chisitu/ Fish Farmer (in Chief Sonkolo Area); (3) Mr Chonya Simuwala - Chisitu Village; (4) Mr. Winford Sichula (Chisutu village), (5) Mr. Willen Sichula / Ms. Esther Nakalundi (Chisutu village); Mr. Kennedy (Mbala); Mrs. Neli (Mbala)
Sat 3 Jun		Travel to Copperbelt Province	
Sun 4 Jun	Kitwe, Copperbelt	• Meet with Kitwe District officer • Visited smallholder farms in and around Kitwe • Visit Bream Source Fisheries farm • Visit Twatasha Cooperative • Visit National Aquaculture Research and Development Centre (NARDC) - Mwekera	**DoF:** Kitwe District Fisheries Officer – Mr Malambo **Bream Source Fisheries (small-scale ponds group)**: Patrick Fwalanga **Twatasha Cooperative (small-scale ponds):** Mr Avito Kamuchele **Small-scale pond farmers:** (1) Mr Kangwa Musanga (commercial smallholder and owner of retail outlet), (2) Mr Gordon Chiwila, Fish Farming Cooperative; (3) Mr. Nick Chungu (individual farmer and cooperative member) **NARDC:** Provincial Fisheries Officer – Mrs Zyangani Chirambo; Acting NARDC Director – Mrs Patience Chungu; NARDC Research Officer – Mrs Beenzu Mutaka Langi; NARDC Hatchery Manager – Mr Chad Kancheya
Mon 5 Jun	Kitwe, Copperbelt	• Meet with District officer • Meet with Macadamia Fisheries (medium scale farm) • Meet with tropical fish exporter • Meet with Kitwe Novatek Agent • Meet with wholesaler/retailer agents	**DoF:** Kitwe District Fisheries Officer – Mr Malambo **Tropical Fish Exporter**: Mr John Buckland; Mrs Michele Buckland **Macadamia Fisheries (medium-scale ponds)**: Mr Lindsey Rodgers **Retail/ wholesale:** (1) Triple MBL (Yalelo fish)– Eric Sing'andu; (2) Lake Harvest retail (no name) **Novatek agent (feeds)** no name
Tue 6 Jun	Solwezi	• Travel to Solwezi (Steve & Muwe) • Travel to Lusaka (Angel & Froukje) • Depart to France (Angel)	
Tue 6 Jun (Steve & Muwe)		• Meet with DoF in Solwezi and held brief meeting.	**DoF:** Provincial Fisheries Officer – Mr Atherton Jere

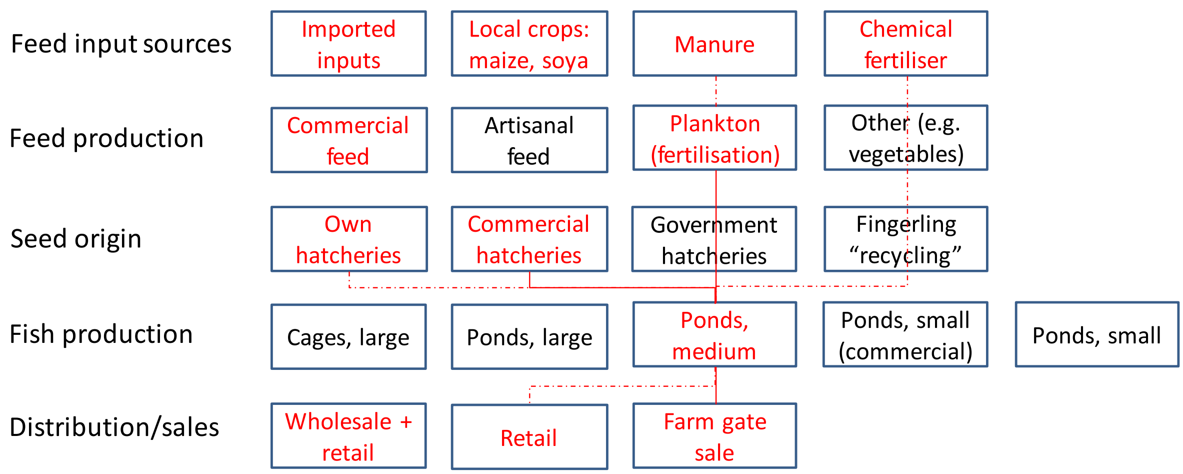
Date	Place	Main Activity	People met
		• Courtesy Call with Provincial Livestock Coordinator • Visit GRZ Hatchery, Solwezi Research Station (DoF) • Visit smallholders farms	**Provincial Livestock Coordinator**: Mr Martin Situmbeko **DoF:** Provincial Fisheries Officer – Mr Atherton Jere; Research Officer – Mr Mupeta Mwape **Small-scale pond farmers:** (1) Shikenu Farming Group Fingerlings Project (SAAP funded) – Mr Brighton Muchima (Chairperson); (2) Mrs Chilemo (Farmer)
Wed 7 June (Steve & Muwe)	Solwezi/ Mutanda/ Kasempa, Northwestern	• Olympic Milling (retail outlet) • Travel to Mutanda and Kasempa • Visit river-based cages (Mutanda) • Meet with Kasempa district officer • Visit one of the Aquapark cluster locations (Kasempa) • Meet with cooperative smallholder fish farmers in Mpungu area (Kilondo Village) • Travel to Lusaka (Thursday)	**Olympic Milling (feeds)** Martha Chikwenda **Cages** Tink Limited – Mrs Donia Tink **DoF** Kasempa DoF Officer – Mr Joseph Chilembo **Lwamabembe Cooperative:** Mr Newton Musukw; Mrs Trina Mbelenga (secretary); Mr Kabesha Shadreck Farmers
Wed 7 Jun (Froukje)	Rufunsa	▪ Travel to Rufunsa ▪ Palabana (hatchery and contract farming model) ▪ Visit Yapasa farm (ILO/ FAO project) ▪ Meet with Rufunsa District officer ▪ Visiti Rufunsa Aquapark site ▪ Meet with smallholder farmers	**Palabana hatchery** Mr. Sammy Willey **DoF** Rufunsa district officer - Ms. Lumbo **Small-scale pond farmers** (1) YAPASA farmer - Mr. Francis, Rufunsa: (2) Mr. Aiden Longu, (3) Mr. Adamson G. Sakala
Thu 8 Jun (Froukje)	Rufunsa/ Lusaka	• Visit smallholder farmers • Travel to Lusaka • Visit to Capital Fisheries Ltd. • Team meeting	**Small-scale pond farmers** (1) Mr. Mate, (2) Mr. Godfrey Pusanga, (3) Mr. Felix Mwansa **Capital Fisheries (import and wholesale):** Director - Mr Gavin Thomas, General Manager - Mr Tim Kenny
Fri 9 Jun	Lusaka	• Debrief EUD • Debrief with Ministry of Fisheries and Livestock • Froukje departs to the Netherlands	**EUD** Matteo Sirtori, Friedrich Mahler **DoF** John Mwango, Dr. Phiri, Robert Lubilo, Sharon

Annex 2: Typology of value chain actors and common interactions among value chain links and types

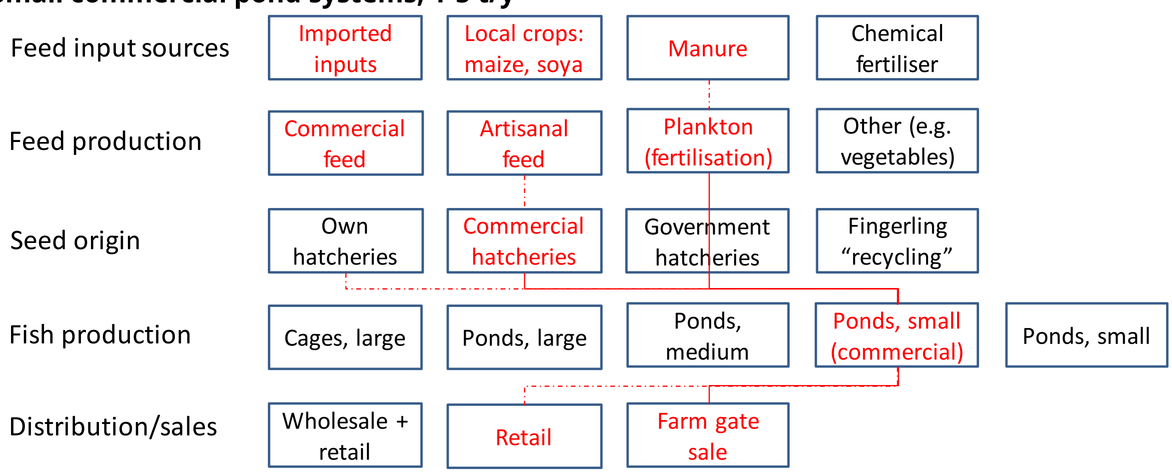
Continuous lines represent established, common links, discontinuous lines represent emergent links.



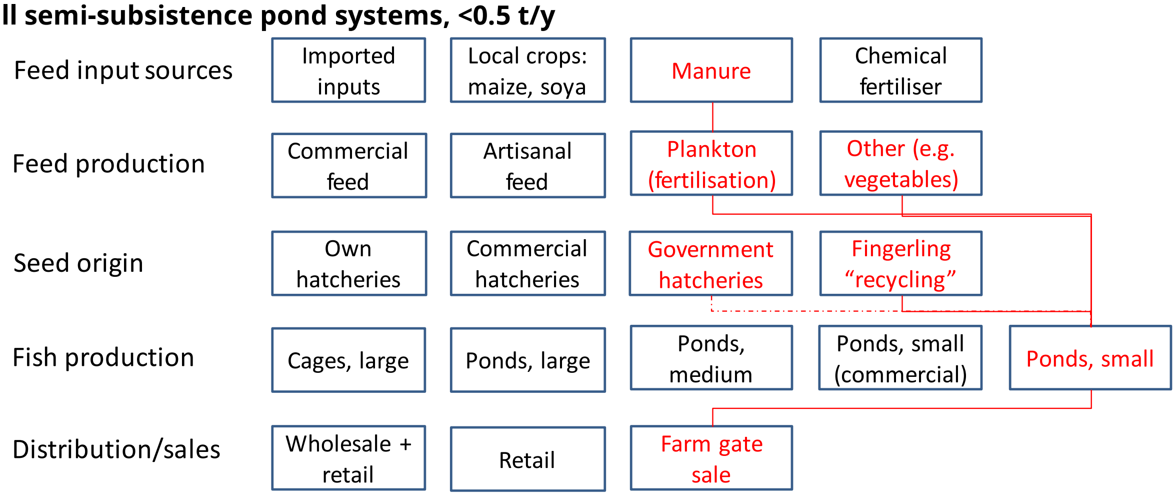
Medium pond systems, 20-200 t/y



Small commercial pond systems, 1-5 t/y



Small semi-subsistence pond systems, <0.5 t/y



Annex 3: Details of financial accounts

Note: In each case these accounts are averages of several interviewed actors. This is done to protect respondents' confidentiality.

Small-scale semi-subsistence pond farmer (170 kg)	Quantity	Unit	Unit price (ZMW)	Value (ZMW)
OUTPUT				
Sales				
Tilapia (farm gate)	*70*	*kg*	*15*	*1 050*
Tilapia (local market)	*30*	*kg*	*23*	*690*
Self-consumption	70	kg	15	1 050
Direct subsidies				0
Total output				**2 790**
EXPENSES				
Intermediate goods and services				
Ingredients for home-made feed	*1 000*	*kg*	*1.20*	*1 200*
Fingerlings	*833*	*unit*	*0.5*	*417*
Transport feed	*6*	*bags*	*120.00*	*720*
Wages				0
Financial charges				0
Taxes				0
Land rental				0
Depreciation				
Shovels	2	unit	75	19
Hoses	2	unit	45	45
Total expenses				**2 400**
Profitability ratios				
Net operating profit				390
Added value*				390
Profit margin				14.0%

*Added value is the sum of wages, financial charges, taxes, and net profits

Small-scale commercial pond farmer (5 t)	Quantity	Unit	Unit price (ZMW)	Value (ZMW)
OUTPUT				
Sales				
Tilapia (farm gate)	*2 500*	*kg*	*15*	*37 500*
Tilapia (local market)	*2 500*	*kg*	*30*	*75 000*
Self-consumption	0	kg	0	0
Direct subsidies				0
Total output				**112 500**
EXPENSES				
Intermediate Goods and Services				
Fuel	*100*	*l*	*12.03*	*1 203*
Fertilizer: urea	*50*	*kg*	*4*	*200*
Fingerlings	*20 000*	*unit*	*0.5*	*10 000*
Commercial feed	*3 000*	*kg*	*7.50*	*22 500*
Lime	*100*	*kg*	*1.0*	*100*
Transport fish	*30*	*Trip*	*50.00*	*1 500*
Transport feed	*1*	*Trip*	*750.00*	*750*
Transport manure	*0*	*Bags*	*0.00*	*0*
Wages				
Salaries	*2*	*fte*	*8 400*	*16 800*
Casual labour	*16*	*day*	*23.50*	*7 520*
Financial charges	1	unit	2 500	2 500
Taxes	1	unit	3 375	3 375
Land rental				0
Depreciation				
Net	*2*	*Unit*	*900*	*900*
Fencing	*1*	*Unit*	*7 500*	*1 500*
Shovel	*3*	*Unit*	*80*	*60*
Pick	*4*	*Unit*	*70*	*93*
Wheelbarrow	*2*	*Unit*	*500*	*500*
Drum	*2*	*Unit*	*210*	*210*
Pump	*1*	*Unit*	*3 500*	*1 167*
Total expenses				**70 878**
PROFITABILITY RATIOS				
Net operating profit				41 622
Total added value				71 817
Profit margin				37.0%

Medium-scale pond farmer (100 t)	Quantity	Unit	Unit price (ZMW)	Value (ZMW)
OUTPUT				
Sales				
Tilapia (farm gate)	*10 000*	*kg*	*23*	*230 000*
Tilapia (local market)	*70 000*	*kg*	*30*	*2 100 000*
Tilapia (wholesale)	*20 000*	*kg*	20	*400 000*
Self-consumption				0
Direct subsidies				0
Total output				**2 730 000**
EXPENSES				
Intermediate Goods and Services				
Fuel	*6 462*	*l*	*13.00*	*84 006*
Fertilizer: urea	*1 680*	*kg*	*4.00*	*6 720*
Fingerlings	*840 000*	*unit*	*0.30*	*252 000*
Commercial feed	*90 000*	*kg*	*4.89*	*439 800*
Lime	*21 000*	*kg*	*0.4*	*8 400*
Fertilizer: chicken manure	*5 200*	*kg*	*4*	*20 800*
Electricity	*23 529*	*kWh*	*0.54*	*13 863*
Wages				
Salaries	*16*	*fte*	*9 000*	*144 000*
Casual labour	*5 475*	*day*	*23.50*	*128 663*
Financial charges	1	unit	50 000	50 000
Taxes				
Value added tax	*1*	*unit*	*81 900*	*81 900*
Council levy	*1*	*unit*	*4 000*	*4 000*
Land rental				0
Depreciation				
Net	*6*	*Roll*	*900*	*2 700*
Plastic crate	*50*	*Unit*	*91*	*1 517*
Pump	*2*	*Unit*	*120 000*	*16 000*
Bush cutter	*5*	*Unit*	*7 000*	*7 000*
Feeder	*10*	*Unit*	*1 600*	*3 200*
Generator	*1*	*Unit*	*12 800*	*2 560*
Aerator	*35*	*Unit*	*2 500*	*17 500*
Motorbike	*1*	*Unit*	*18 000*	*3 600*
Boat	*1*	*Unit*	*5 000*	*1 000*
Farm purchase	*1*	*Unit*	*5 000 000*	*500 000*
Shop equipment	*1*	*Unit*	*6 680*	*668*
Shop rental	*1*	*Unit*	*60 000*	*60 000*
Total expenses				**1 849 896**
PROFITABILITY RATIOS				
Net operating profit				880 104
Total added value				1 288 667
Profit margin				32.2%

Large-scale pond farmer (1300 t)	Quantity	Unit	Unit price (ZMW)	Value (ZMW)
OUTPUT				
Sales				
Tilapia (wholesale)	*1 040 000*	*kg*	*20*	*20 800 0000*
Tilapia (retail)	*260 000*	*kg*	*24*	*6 240 000*
Self-consumption				0
Direct subsidies				0
Total output				**27 040 000**
EXPENSES				
Intermediate Goods and Services				
Fuel for generator	*250*	*l*	*12.03*	*3 008*
Fuel for transport	*10 920*	*l*	*11.09*	*121 103*
Fingerlings	*3 466 667*	*unit*	*0.30*	*1 040 000*
Commercial feed	*485 333*	*kg*	*4.89*	*2 371 662*
Lime	*320 000*	*kg*	*0.40*	*128 000*
Fertilizer: manure (own)	*300 000*	*kg*	*0*	*0*
Transport fish	*1*	*unit*	*121 103*	*121 103*
Electricity	*350 000*	*kWh*	*0.54*	*190 157*
Salaries	*270*	*fte*	*30 000*	*8 100 000*
Financial charges				6 000 000
Taxes				
Value added tax				*1 294 966*
Council levy				*6 500*
Water permit				*3 000*
Land rental				0
Depreciation				
Net	*100*	*unit*	*500*	*25 000*
Generator	*2*	*unit*	*120 000*	*16 000*
Pump	*8*	*unit*	*50 000*	*26 667*
Aerator	*100*	*unit*	*5 000*	*100 000*
Truck	*1*	*unit*	*1 000 000*	*200 000*
Motorbike	*2*	*unit*	*18 000*	*9 000*
Pond establishment				*5 000 000*
Total expenses				**24 635 062**
PROFITABILITY RATIOS				
Net operating profit				2 404 938
Total added value				17 809 404
Profit margin				8.9%

Large-scale cage farmer (2 000 t)	Quantity	Unit	Unit price (ZMW)	Value (ZMW)
OUTPUT				
Sales				
Tilapia (wholesale)	*300 000*	*kg*	*20*	*6 000 000*
Tilapia (retail)	*1 700 000*	*kg*	*23*	*39 100 000*
Self-consumption				0
Direct subsidies				0
Total output				**45 100 000**
EXPENSES				
Intermediate Goods and Services				
Fuel for generators	*48 000*	*l*	*11.25*	*540 000*
Fuel for transport	*250 000*	*l*	*11.09*	*2 772 500*
Fingerlings	*4 000 000*	*unit*	*0.30*	*1 200 000*
Commercial feed	*600 000*	*kg*	*4.89*	*2 934 000*
Lime	*2 000*	*kg*	*0.40*	*800*
Ice	*668 000*	*kg*	*1.36*	*908 480*
Electricity	*500 000*	*kWh*	*0.54*	*271 157*
Salaries	240	fte	30 000	7 200 000
Financial charges				6 500 000
Taxes				
Value added tax				*2 977 644*
Council levy				*100 000*
Water permit				*0*
Land rental				0
Depreciation				
Fixed assets				*11 944 444*
Other assets				*2 222 222*
Total expenses				**39 570 090**
PROFITABILITY RATIOS				
Net operating profit				5 529 910
Total added value				22 307 554
Profit margin				12.3%

Annex 4: Seed and feed

Feed supply (source WorldFish, 2017)
Fish feed sector is developing in Zambia with, at least, four factories producing good quality fish feed. The growth of the commercial sector has started to stimulate the development of the feed sector. Numerous existing feed mills, such as Savanna Streams, Farm Feeds, Olympic Milling, Tiger Feeds, and Novatek Animal Feeds, invested in the development of aquafeeds over the last 5 years and started diversifying their product portfolio to satisfy the requirements and needs of large-scale commercial fish farms. These companies produced around 30 000 t of feed in 2015. Novatek Animal Feeds, for example, produces about 600–800 t of feed per month with four different product lines (fry mash, juvenile crumble, starter pellets and grower pellets), none of which existed on the Zambian market before 2015. In anticipation of future aquaculture production expansion, large-scale commercial operators ventured into partnerships with feed mills to better control supply, quality and prices of feeds.

To date, however, almost all micro-ingredients, such as fishmeal, premixes and vitamins, are still being imported, which is keeping the price of commercial feeds relatively high in Zambia. This may be a contributing factor as to why feed companies have yet to distribute aquafeeds to small-scale farmers around the country where there is little demand for expensive feed products. Feed companies such as Novatek Animal Feeds have retail outlets all over the country and express the desire to distribute the product to small-scale farmers, though there is still not sufficient demand from the sector. Additionally, many small-scale farmers also do not know how to use commercial feeds, and this hinders their demand. This is expected to change, however, with the investment of two large, foreign owned feed companies in Zambia in 2017. Aller Aqua has partnered with Yalelo, Skretting and Lake Harvest to build two feed factories in Siavonga, and this is expected to radically reshape the feed sector by the end of 2017 and provide an additional 75 000 t of aquafeed to the country. These large-scale producers have also partnered with the international feed giants to secure a consistent source of cage feed for their own production and the feed companies in turn have seen an opportunity to expand the feed supply chain in the region. The Aller Aqua factory is expected to be the largest fish feed factory in Africa.

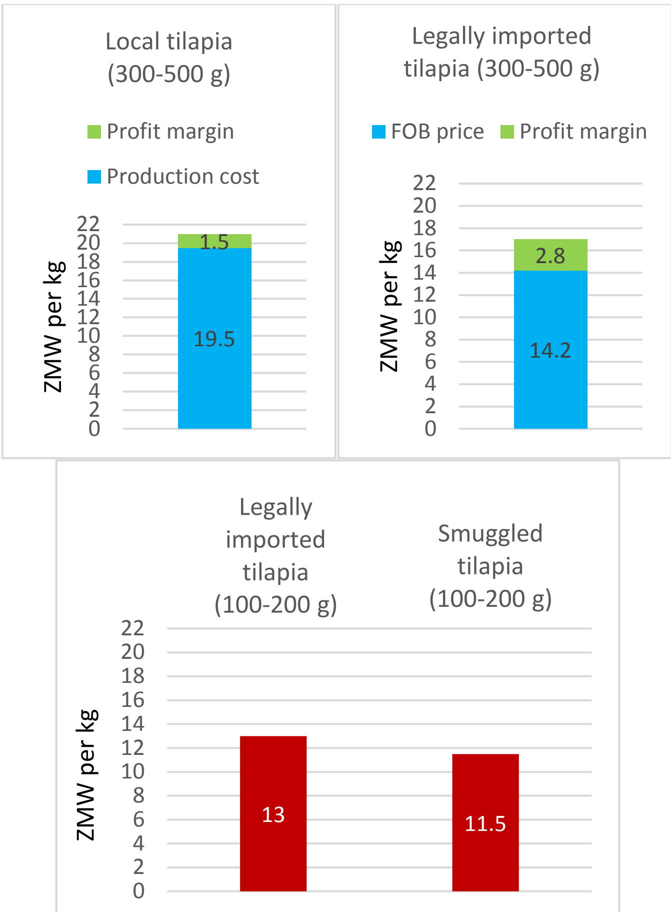
Seed supply (source WorldFish, 2017)
The fish seed supply sector in Zambia is also experiencing major changes. In the past, there were only 9 state hatcheries that supplied the entire aquaculture sector with mixed-sex tilapia fingerlings. Today, the growth of commercial aquaculture has seen large-scale aquaculture producers develop their own hatcheries that produce mixed-sex and male sex-reversed fingerlings for grow-out purposes. Through on-site hatchery production (a form of vertical integration), some largescale producers have more control over costs, quality and continuity in supply by producing their own seed. This is a major trend for commercial operators in Zambia. The core business of a commercial operator is thus defined by the production of fry and fingerlings, either for their own grow-out or for selling to small- to medium-sized farmers, with most companies favouring the former, while only four operators have found niches in the latter. Palabana Fisheries has, for instance, begun supplying tilapia fingerlings (mostly *O. niloticus*) to small-scale farmers located in close proximity to the company through out-grower schemes that attempt to stimulate the small-scale sector. This out-grower scheme was tested and funded by the Swedish International Development Cooperation (SIDA) together with the FAO and International Labour Organization (ILO).

There are six operating state-run hatcheries in the country that produce fingerlings primarily for small-scale aquaculture and stocking in small local water bodies. These hatcheries, however, only produced about 516 000 fingerlings in 2015 (mostly *O. macrochir*, *C. rendalli* and *O. andersonii*), which cannot possibly meet the fingerling demand of over 12 000 registered farmers around the country. To put this into context, Kafue Fisheries, one of the largest commercial land based pond farms in Zambia, produces more than 2 million fingerlings every year. Most private hatcheries, so far, only supply for their own grow-out operations, and almost all of them are located in either Southern Province or in major cities such as Lusaka, Kitwe and Ndola. This means that most small-scale farmers in the country do not have access to fingerlings from private hatcheries and are largely dependent on state-run hatcheries that do not have the capacity to supply all registered small-scale farmers.

The state-run hatchery, Misamfu Aquaculture Research Station in Northern Province produced 1 062 314 fingerlings between 2005 and 2015—only half of what one large company such as Yalelo can produce in a year. Of these fingerlings, 54% were part of government-run programs to restock small water bodies and dams in the province over a 10- year period. The other 46% were distributed to small-scale farmers, 59% of which were bought by development organizations (e.g. World Vision, Caritas, Self Help Africa) for distribution in donor-driven, small-scale aquaculture projects.

The DoF distributed the remaining fingerlings to small-scale farmers in the province over the same period. The small-scale sector in Zambia has for decades been dependent on state-run hatcheries and extension services for inputs, which has so far resulted in little sustained growth.

Annex 5: Cost and pricing structure of local and imported tilapia



Source: ADAZ, 2014

Annex 6: List of PEF recommended models at midpoint with indicator, unit and source

In red text: the differences compared to the 2013 PEF guide

Impact category	Indicator	Unit	Recommended default LCIA method	Source of CFs
Climate change	Radiative forcing as Global Warming Potential (GWP100)	kg $CO_{2\ eq}$	Baseline model of 100 years of the IPCC (based on IPCC 2013)	EC-JRC, 2017[75]
Ozone depletion	Ozone Depletion Potential (ODP)	kg CFC-11eq	Steady-state ODPs 1999 as in WMO assessment	EC-JRC, 2012
Human toxicity, cancer effects*	Comparative Toxic Unit for humans (CTU_h)	CTUh	USEtox model (Rosenbaum et al, 2008)	EC-JRC, 2012
Human toxicity, non-cancer effects*	Comparative Toxic Unit for humans (CTU_h)	CTUh	USEtox model (Rosenbaum et al, 2008)	EC-JRC, 2012
Particulate matter/ Respiratory inorganics	Impact on human health	Deaths/kgPM2.5$_{emitted}$	UNEP recommended model (Fantke et al 2016)	EC-JRC, 2017
Ionising radiation, human health	Human exposure efficiency relative to U^{235}	kBq U^{235}	Human health effect model as developed by Dreicer et al. 1995 (Frischknecht et al, 2000)	EC-JRC, 2012
Photochemical ozone formation	Tropospheric ozone concentration increase	kg NMVOCeq	LOTOS-EUROS (Van Zelm et al, 2008) as applied in ReCiPe	EC-JRC, 2012
Acidification	Accumulated Exceedance (AE)	mol H+ eq	Accumulated Exceedance (Seppälä et al. 2006, Posch et al, 2008)	EC-JRC, 2012
Eutrophication, terrestrial	Accumulated Exceedance (AE)	mol N eq	Accumulated Exceedance (Seppälä et al. 2006, Posch et al, 2008)	EC-JRC, 2012
Eutrophication, aquatic freshwater	Fraction of nutrients reaching freshwater end compartment (P)	fresh water: kg P equivalent	EUTREND model (Struijs et al, 2009b) as implemented in ReCiPe	EC-JRC, 2012
Eutrophication, aquatic marine	Fraction of nutrients reaching marine end compartment (N)	fresh water: kg N equivalent	EUTREND model (Struijs et al, 2009b) as implemented in ReCiPe	EC-JRC, 2012
Ecotoxicity (freshwater)*	Comparative Toxic Unit for ecosystems (CTU_e)	CTUe	USEtox model, (Rosenbaum et al, 2008)	EC-JRC, 2012
Land use	Soil quality index[76]	dimensionless	Soil quality index based on LANCA	EC-JRC, 2017[77] Bos et al. 2016
	Biotic production	kg biotic production/(m^2*a)[78]	LANCA (Beck et al. 2010)	EC-JRC, 2017 Bos et al. 2016
	Erosion resistance	kg soil/(m^2*a)	LANCA (Beck et al. 2010)	EC-JRC, 2017

75 Forthcoming document on the update of the recommended Impact Assessment methods for the EF.
76 This index is the result of the aggregation, performed by JRC, of the 4 indicators provided by LANCA model as indicators for land use
77 Forthcoming document on the update of the recommended Impact Assessment methods and factors for the EF
78 This refers to occupation. In case of transformation the LANCA indicators are without the year (a)

Impact category	Indicator	Unit	Recommended default LCIA method	Source of CFs
				Bos et al. 2016
	Mechanical filtration	m^3 water/(m^2*a)	LANCA (Beck et al. 2010)	EC-JRC, 2017 Bos et al. 2016
	Groundwater replenishment	m3 groundwater/ (m2*a)	LANCA (Beck et al. 2010)	EC-JRC, 2017 Bos et al. 2016
Water use	User deprivation potential (deprivation-weighted water consumption)	m^3 world eq. deprived	Available WAter REmaining (AWARE) Boulay et al., 2016	WULCA 2016
Biotic production	Abiotic resource depletion (ADP ultimate reserves)	kg Sb-eq	CML 2002 (Guinée et al., 2002) and van Oers et al. 2002.	CFs from CML-IA method v. 4.8 (2016)[79].
	Abiotic resource depletion – fossil fuels (ADP-fossil)[80]	MJ	CML 2002 (Guinée et al., 2002) and van Oers et al. 2002	CML-IA method v. 4.8 (2016)

[79] The CFs are taken from the CML-IA website: www.universiteitleiden.nl/en/research/research-output/science/cml-ia-characterisation-factors.

[80] In the ILCD flow list, and for the current recommendation, Uranium is included in the list of energy carriers, and it is measured in MJ.

Annex 7: Midpoint impacts of the Zambian tilapia aquaculture systems

Absolute impacts per t of produced tilapia

Impact category	Unit	Average tilapia	large cages	large ponds	extensive ponds	medium ponds	small commercial ponds	small semi-subsistence ponds
Climate change	kg CO2 eq	3 105	2 660	3 648	10 794	2 451	1 984	7 705
Ozone depletion	kg CFC-11 eq	2.65E-04	2.51E-04	2.82E-04	8.48E-04	1.88E-04	1.42E-04	5.00E-04
Human toxicity. non-cancer effects	CTUh	9.21E-04	6.98E-04	4.77E-04	7.70E-03	6.45E-04	6.78E-04	3.79E-03
Human toxicity. cancer effects	CTUh	1.04E-04	9.39E-05	1.03E-04	3.52E-04	8.36E-05	6.57E-05	2.31E-04
Particulate matter	kg PM2.5 eq	2.1	1.7	2.3	5.1	1.6	1.3	5.5
Ionizing radiation HH	kBq U235 eq	167	148	192	767	123	95	379
Ionizing radiation E (interim)	CTUe	1.22E-03	1.02E-03	1.58E-03	6.81E-03	9.60E-04	7.15E-04	3.12E-03
Photochemical ozone formation	kg NMVOC eq	14.8	13.6	16.1	50.8	11.0	8.6	30.1
Acidification	molc H+ eq	24	19	27	94	20	14	76
Terrestrial eutrophication	molc N eq	85	69	99	351	66	49	251
Freshwater eutrophication	kg P eq	8	7	11	9	10	10	11
Marine eutrophication	kg N eq	75	81	54	118	46	43	74
Freshwater ecotoxicity	CTUe	451 223	414 693	830 183	44 301	464 159	257 381	491 611
Land use	kg C deficit	46 029	43 893	68 374	59 509	39 456	24 169	59 035
Water resource depletion	m3 water eq	52	21	48	356	44	48	357
Mineral. fossil & ren resource depletion	kg Sb eq	0.27	0.27	0.34	0.28	0.21	0.15	0.30