A comparative study of aquaculture sector development in Egypt, Ghana and Nigeria:

Insights and lessons for Kenya

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3R Research Report

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List of Acronyms and abbreviations

GARFD	General Authority for Fisheries Resources Development
FFA	Fish Farm Associations
WRI	Water Research Institute
ARDEC	Aquaculture Research and Development Centre
MoFAD	Ministry of Fisheries and Aquaculture Development
FFEs	Fish Farming Estates
RAS	Recirculating Aquaculture System
NIOMR	Nigerian Institute for Oceanography & Marine Research
QC	Quality Control
GNADP	Ghana National Aquaculture Plan (2012-2016)
ECOWAS	Economic Community of West African Stat

1. Introduction

The 3R Kenya from Aid to Sustainable Trade project funded by the Embassy of the Kingdom of the Netherlands assesses evidence and lessons from its Food and Nutrition Security (FNS) and other related programmes that support competitive, market-oriented agriculture development in Kenya. The project focusses on three selected agri-food producing sectors that have potential for sustainable growth, trade and investments and can contribute to food and nutrition security (FNS) and socio-economic development in Kenya (horticulture, dairy and aquaculture). In this study, the focus is on the aquaculture sector.
A preparatory study - a so-called quick scan - was conducted to provide insights of the performance of the freshwater aquaculture sector in Kenya, with respect to the supply chain, institutional governance and innovation support system. The study has highlighted a number of challenges and existing opportunities, as well as weaknesses and threats to the sustainability and the growth of the sector (Obwanga et al., 2017).

The basic idea of this study is to explore ways to support a shift from subsistence to commercial aquaculture (See Box 1), in order to encourage sector development towards a more resilient, reliable, robust and market-oriented aquaculture sector. This comparative study based on experiences of successful transitions to commercial aquaculture in Africa is contributing with insights of successes and lessons learnt that may be also suitable for the Kenyan context. Therefore, three countries (Egypt, Nigeria and Ghana) with reliable production statistics and leading the production of either Nile tilapia or African catfish are compared.

1.1. Objectives

The main objectives of the comparative country study are; 1) to learn lessons from the experiences from the aquaculture sectors in Egypt, Ghana and Nigeria, and 2) to identify relevant factors that are influencing the development of the aquaculture sector in Kenya.

1.2. Methodology

The study was conducted in two stages. First, an extensive literature review was carried out to identify key factors that supported the transition towards a commercial sector in Egypt, Ghana and Nigeria. This involved an understanding of key strengths, weaknesses, opportunities and threats, as well as opportunities seized in those three countries. Second, findings of the literature review were presented and discussed in a stakeholder workshop held in Nairobi in March 2018 with aquaculture experts and various key agents of the Kenyan aquaculture value chain to discuss the study findings and to validate lessons learnt that are relevant for Kenya.

2. Comparative study and lessons learnt

In this section, the outcomes of the comparative study are presented. First, a basic comparison of tilapia and catfish production across the countries in 2015 is presented, followed by a comparison of strengths, weaknesses, opportunities and threats (SWOT analyses) across the three country (Egypt, Ghana and Nigeria).

2.1. Basic comparisons of the Tilapia and Catfish sectors and fish consumption across countries

First, an initial basic comparison of the Tilapia and Catfish sector production and fish consumption is conducted and presented in Table 1.

Table 1: Production of Tilapia and Catfish and fish consumption in Egypt, Nigeria and Ghana and Kenya in 2015.

Country	Production 2015	Top farmed fish species	Top production systems	Fish consumption
	Tonnes	(% of production)	(% of production)	kg/capita/year
Egypt	1 174 800	**Tilapia** (75.5%)	- Semi- & intensive earthen ponds (85%) - *Tanks and RAS developing*	15.0
Nigeria	316 700	**Catfish** (74%) *Tilapia (n.a.)*	- Intensive urban/peri-urban tanks-ponds; - *Intensive cages (started with high interest + investment)*	17.1
Ghana	46 250	**Tilapia** (95%) *Catfish (n.a.)*	- Intensive cages (90%)	25.0
Kenya	18 658	**Tilapia** (75%) Catfish (18%)	- Semi- & intensive ponds (70%) - *Intensive commercial tanks (started), & cages (interests)*	3.4

Second, similarities and differences have been identified in the comparative study of the countries Egypt, Ghana and Nigeria, from which lessons have been learnt. These are summarised in Table 2.

Table 2: Lessons learned from similarities and differences between Egypt, Nigeria and Ghana.

Policy & Strategy adaptation	The reliance on subsistence farming of Nile tilapia in earthen ponds is now overtaken by events and governments who have **shifted focus in policies and strategies aiming for commercialization of aquaculture.**
Private sector's role	From the three countries it is evident that **the private sector has played a key and leading role** to grow the aquaculture sector and make it successful. The private sector needs to invest in the sector and take it as a business enterprise.
Different approaches possible	The three countries have taken different approaches in aquaculture with **specific farming systems, farming models and use of different environments**.
Fisheries vs Aquaculture support	Except for Egypt, Nigeria and Ghana until recently gave little attention to aquaculture in their policies and strategies. **The policy has long been biased in favor of capture fisheries at the expense of aquaculture until catches started dwindling** and people realised **aquaculture was the solution to compensate for the declining supply from catch and to replace fish imports.**
Professional association's role	The role of professional associations lobbying for better working environment and for advocacy is well highlighted. However, when these associations are splintered, or lacking grass root membership, their effectiveness becomes irrelevant. **Effective professional aquaculture associations make the sector progress.** They are an integral component of the sector providing a linkage platform between farmers and other components of the supply chain like research, input suppliers, financial institutions, NGOs, etc.

2.2. SWOT-Analyses - Egypt, Ghana and Nigeria

The comparative country study has identified seven factors that play a crucial role in the development of commercial aquaculture in Egypt, Ghana and Nigeria: 1. Market demand, 2. Environment, 3. Infrastructure, 4. Technological capacity, 5. Investment, 6. Human resources and 7. Institutional system.

The seven identified factors are presented in a strengths – weaknesses – opportunities and threats (SWOT) framework that highlights the main findings per country. Whereas strengths refer to factors that can contribute to strengthening the commercialization of the sector, weaknesses refer to the factors that are hampering such developments, and are thus the weaknesses of the transition towards commercialization of the sector. Looking for future developments, the opportunities refer to potentials for developments, and threats to the factors that cause risks.

Strengths. Looking at the strengths across the three countries, it is shown that, among others, the demand for fish is overall high, which is enhanced by production located in short distances to urban markets and reliability of fish supply (low variability in supply), as well as adaptations to consumer interests and making use of new possibilities (e.g. road side markets) (Cai et al., 2009; Ozigbo et al., 2014). The environmental conditions seem to be favourable in all these countries, but they also instructs of how to choose production systems (e.g. levels and variability of water and temperature). For instance, the recirculating aquaculture systems (RAS) and Catfish experiences in Nigeria can be very valuable for Kenya, as well as use of brackish water to produce Tilapia in Egypt. Availability and short distances to feed-mills and hatcheries are valuable to aquaculture in these three countries, as well as cooperation between private and public sectors. Besides, it appears that the technologies have improved sufficiently (e.g. extrusion technology in feed production, cooling facilities and effective fingerlings production) (El-Sayed, 2007; Soliman and Yacout, 2016; Frimpong and Anane-Taabeah, 2017). It appears that while in Egypt, the public and private sectors have invested in the sector, in the other two countries, the fish farmers are foremost investing themselves, which favour large production units and/or cooperation through Fish Farm Estates (FFEs) (El-Sayed, 2017; Frimpong and Anane-Taabeah, 2017; Ozigbo et al., 2014). In all three countries, universities, NGOs, as well as private and public organizations are supporting the sector in ways that are valuable to job creation. In all three countries, a shift has taken place towards commercialization favourable to a licence system (e.g. Egypt). Still, in Ghana and Egypt the governments have intervened with governmental support and protection of the sectors (specifically fish markets) through bans on fish imports (Adewumi 2015; Atanda and Fagbenro 2017; El-Sayed, 2017; Frimpong and Anane-Taabeah, 2017). Table 3 provides an overview of strengths across the countries.

Table 3: Comparing strengths of aquaculture sectors in Egypt, Ghana and Nigeria

	Egypt (E.g. Ponyton, 2006; El-Sayed, 2007; NFDS, 2009; Soliman and Yacout, 2016; El-Sayed, 2017)	Ghana (E.g. Frimpong and Anane-Taabeah, 2017)	Nigeria (E.g. Ozigbo et al., 2014; Atanda and Fagbenro 2017)
Market demand	- High fish demand; - Simple but efficient fish market system; - Wholesale markets in major cities; - Short value chains; - Farmer access to supermarket chains; - Fish takes short time to reach market.	- High per capita fish consumption; - Existence of elaborate market structure in rural & urban markets; - Fish preferred whole reducing need for processing; - Low variability of supply of farmed fish; - Cordial agreements between farmers & traders.	- High fish demand; - Well established Catfish value chain; - FFEs close to urban markets; - High demand for inputs; - FFEs have led to rise of roadside markets (Bukas) which have increased fish demand; - Competitive markets for fish feeds led to improved fish feed quality.
Environment	- Conducive warm temperatures in parts of the year; - Successful use & focus on the Abbassa improved strain of Nile tilapia; - Successful use of brackish water in earthen ponds for intensive tilapia production; - Locally produced ingredients for feeds; - High number of hatcheries, majority of which are private sector owned; - Use of technologies to mitigate unfavourable weather.	- Stable weather all year round; - Successful focus & use of the Akosombo improved strain of the Nile tilapia; - Focus on cages in lakes and water reservoirs; - Cages easier to manage; - Production from cages takes shorter time to reach market size; - High number of hatcheries majority of which are private sector owned; - Whole year production of fingerlings possible.	- 70% land suitable for aquaculture; - Sector focuses on a hardy species (Catfish); - RAS system occupies less space & water; - Reliance on local fish feed ingredients; - High number of hatcheries, majority of which are private sector owned.
Infrastructure	- High number of feed mills with high production capacity; - Research, training & dissemination facilities by universities, demonstration units, research institutions available.	- Presence of high capacity feed mills; - Use of PPPs in managing research, training and extension facilities.	- High number of feed mills; - Success of FFEs influenced Government to improve infrastructure.
Technological capacity	- Rapidly expanding modern aquaculture; - Government supports research & extension; - Incorporation of extrusion technology in feed production; - Farmers have embraced quality feed; - Intensification in earthen ponds and intensive fish farms; - Collaborative research led to identification of better performing Abassa tilapia strain.	- Subsector has adopted a more productive & commercially oriented cage culture (accounts for about 95% or more of Tilapia production); - Incorporation of extrusion technology in feed production; - Large scale farmers have cooling facilities & are able to influence fish prices; - Collaborative research led to identification of better performing Akosombo tilapia strain.	- High quality fingerlings have reduced time taken for farmed fish to reach market/table size; - FFEs employ technicians who make management efficient; - Availability of large scale hatcheries; - Incorporation of extrusion technology in feed production; - Successful collaborative research; - Numerous institutions for research & training;

			- Governmental training of youth to make aquaculture growth sustainable.
Investment	- Some state owned & commercial banks provide credit to farmers; - High private sector investment, mostly in feed and seed industries; - High number of hatcheries & feed mills have reduced seed & feed prices.	- Expensive to start cage culture - but with quick returns; - Increase in hatcheries and fish feed mills; - Large scale producer investments make them able to transport products to urban areas; - High foreign investment in cage culture.	- Managerial efficiency of FFE model ensures profits; - FFEs contribute >80% of aquaculture production; - Successful FFEs have triggered growth of downstream industries, investors & support services; - Fish farmers have amassed enough economic & political mass power to influence growth of the sector; - Self-drive of attracting foreign investors; - 30% of new investments in aquaculture.
Human resources	- Important in job creation; - Aquaculture practiced by relatively young persons (average 43 years); - Relies on family labour that is relatively easy to manage; - GAFRD organises training & technology transfers for actors across the value chain; - Sector supported by research institutions, universities (> 10 universities) & technical colleges.	- Government supports capacity building of farmers, youths and staff; - NGOs & Universities support research; - Institutions like WRI, ARDEC, Public Universities & private laboratories support research, training, quality control & extension.	- Numerous institutions offer research and training in aquaculture e.g. NIOMR; - Use of technicians to manage FFEs more efficient & profitable; - Growth of FFEs has provided avenues for training of farmers & trip abroad for exposure.
Institutional system	- Sector a priority to Government; - GARFD has facilitated licensing for private hatcheries; - Policy push for sector privatization; - Strong presence of professional associations & Fish Farmers Associations (FFAs) distributed in major fish farming areas; - Law encourages foreign investment & sector modernization	- Policy shift to commercial aquaculture; - Ban on fish import; - Sector specific policy in place; - Sector specific Ministry MoFAD; - Incentives for foreign investment; - Active FFAs; - Government supports private sector.	- Policy shift to commercial aquaculture; - Government supports private sector; - Sector development programmes in place; - FFAs bridge between farmers & support services; strong PPPs; - Government imposed fish importation quotas to protect sector.

Weaknesses. In brief, looking at the weaknesses observed across the three countries (see Table 4), market factors disfavour commercialization such as: consumers demand for wild fish, fluctuating market prices, limited market outlets and information, long distances to markets, competing cheap Chinese tilapia, high prices, low trust, low or no exports, and illegal trade with neighbour countries (Frimpong and Anane-Taabeah, 2017). Scarcity of land and water, as well as seasonality and temperature variations, are the key environmental factors influencing fish farming, while poor policy instructions, harvests of fingerlings and seeds from wild ecosystems, as well as waste, are factors that damage environments if fish farms are not sufficiently monitored. The infrastructure is poor in all countries in terms of roads and electricity connectivity, as well as availability of cooling

facilities (El-Sayed, 2017; Frimpong and Anane-Taabeah, 2017; Atanda and Fagbenro, 2017). It is questioned whether private or public sectors should invest. Technological capacity suffers from inaccurate statistics and lack of national research catalogue, as well as low skills throughout the value chain (feed and seed, farm level as well as processing), and extension services are still low. As for investments, there are problems of uncertainties on land lease, high costs of land and inputs, high running costs in semi-intensive farms, scarce credit and loans. As for human resources there are weaknesses of low extension and highly distributed farmers, as well as understaffed governmental departments. Besides, processes are bureaucratic while there is weakness in quality control, law enforcements and performance of the FFAs (El-Sayed, 2017; Frimpong and Anane-Taabeah, 2017; Atanda and Fagbenro 2017).

Table 4: Comparing weaknesses of aquaculture sectors in Egypt, Ghana and Nigeria

	Egypt (E.g. El-Sayed; 2007; Nasser-Alla, 2008; El-Sayed, 2017)	**Ghana** (E.g. Asiedu et al., 2016; Frimpong and Anane-Taabeah, 2017)	**Nigeria** (E.g. Ozigbo et al., 2014; Adewumi, 2015; Atanda and Fagbenro 2017)
Market demand	- Lack of export market; - Consumers preference for wild fish; - Fluctuation in market prices; - Markets generally far from fish farms; - Limited market outlets; - Limited information on fish marketing.	- Farmed Tilapia is expensive; - Fish traders control prices; - Lack of trust by some traders; - Imported Chinese tilapia; - Lack of value addition.	- Value chain lacks export component; - Illegal fish trade with neighbours; - Fish traders control prices.
Environment	- Scarcity of land and water; - Limitations to use of second hand water; - Erratic policy limits cage culture; - Production dictated by seasonality; - Poor fish handling and waste disposal in fish markets.	- Most production focused on Lake Volta; - Sourcing fingerlings from the wild; - Fingerling production focuses on cage culture; - High sensitivity of Akosombo strain.	- Seasonality affects seed production; - Insufficient supply of fingerlings; - Underutilised high potential aquaculture land; - Reliance on unsustainable wild collected seed and imported brood-stock; - Imported brood-stock is subject to changes in tariffs, potential disease outbreaks.
Infra-structure	- Poor road infrastructure; - Lack of electricity connectivity; - Prohibitive laws on electrification of leased land lead to high fuel costs; - Limited cool storage facilities for fresh fish.	- Poor quality; - Lack of support industries/business.	- Poor infrastructure; - Lack of cooling facilities.
Technological capacity	- Inaccurate statistics; - Technical capacity still low in feed & seed production; - Fish processing industry still at infancy; - Poor extension services; - Capacity building along value chain still low.	- Lack of research agenda; - Fish processing basic; - High dependence on imported feed & fish feed ingredients; - Seed & feed quality still low; - Outdated and generic extension; - Lack of national research catalogue.	- Skills in feed & seed production still low; - Rudimentary technology in fish harvesting & processing; - Perception that imported feed is of superior quality; - Best quality feed is imported & expensive;

			- Implementation of research limited by most research being short-term & skewed towards production systems; - Low education among farmers.
Investment	- Uncertainties on land lease renewals; - High cost of land; - High running costs in semi-intensive farming; - Poor performance of the Egyptian pound; - High custom tariffs & taxes on inputs & equipment; - Scarce credit & loaning opportunities for fish farmers; - Poorly organised seed sector.	- High interest rates on loan; - Only 3% of farmers carry out cage culture; - Reliance on imported feed; - High cost of commercial feeds; - Focus on cage culture on Lake Volta unsustainable due to growing environmental concerns for pollution & social concerns like resource use conflicts.	- Lack of access to credit; - High cost of inputs; - Low investment in Tilapia farming.
Human resources	- Low funding for extension; - Low human resource to support extension in a wide geographic area.	- Underfunded & understaffed Governmental departments.	- Low number of extension officers vs a wide geographical distribution of farmers.
Institutional system	- Many FFAs inactive and irrelevant; - Weak law enforcement; - Weak control system for quality control, fish health, human safety in sector, & biosafety.	- Incentives favour large scale farmers; - Splintered FFAs; - Weak enforcement of acts & regulations; - GNADP objectives too ambitious given lack of finances for implementation within the time limits; - Cumbersome and bureaucratic requirements to start fish farming.	- Weak implementation of legal framework; - Irrelevant extension; - Policy & regulation biased to capture fisheries; - Sector underfunded by Government; - Overlap in administrations; - Changing policies by successive governments; - Bureaucracies in processes; - Ineffective extension.

Opportunities. Comparing the opportunities across countries (Table 5), it appears that markets can become more favourable to farmed fish by; improved labelling of products, increased exports to, for instance European Union and the ECOWAS market, as well as a shift to Catfish production and use of earthen fish ponds when appropriate (El-Sayed, 2017; Frimpong and Anane-Taabeah, 2017; Atanda and Fagbenro 2017). Although environmental factors restrict fish production, expansion of desert aquaculture and earthen fish pond production, more effective use of water, and growth of integrated aquaculture and agriculture production, are examples of possibilities that can help overcome these restrictions (El-Sayed, 2017). It also appears that the more important the sector gets, the more willing are different parties, including the government, to invest in infrastructure (Frimpong and Anane-Taabeah, 2017). With improved infrastructure, the possibilities get multiplied. Also advanced technological capacities and collaboration among stakeholders, can contribute to boost the sector. This certainly depends on investments in the sector, as well as human resources available to monitor and manage them. This again depends on the capacities of farm leasing control system, quality controls, legislation and regulations being enforced.

Table 5: Comparing opportunities of aquaculture sectors in Egypt, Ghana and Nigeria

	Egypt (E.g. El-Sayed; 2007; El-Sayed, 2017)	Ghana (E.g. Asiedu et al., 2016; Frimpong and Anane-Taabeah, 2017)	Nigeria (E.g Ozigbo et al., 2014; Adewumi, 2015; Atanda and Fagbenro 2017)
Market demand	- Value added on Tilapia & re-entry into export of Tilapia to EU market; - Future focus on niche products; - Campaigns to change negative consumer perception; - Embracing strategies to increase demand; - Better labeling to differentiate farmed & imported products.	- ECOWAS market; - Intensive production from earthen fishponds; - Preference of other fish species apart from Tilapia; - A shift to Catfish may prove to be more profitable; - Production trends indicate progress towards self-sufficiency in Tilapia production.	- Ever increasing fish demand; - Potential to produce Tilapia for export.
Environment	- Expansion/growth of desert aquaculture; - Growth of integrated aquaculture & agriculture; - Use of groundwater for farming to overcome future limitations of fresh and brackish waters.	- Intensive production from earthen fish ponds; - Most ponds producing below capacity; - Diversification into other unused water bodies & reservoirs.	- Steady growth of Tilapia farming; - Future aquaculture may explore intensive farming in earthen ponds and other water bodies.
Infra-structure	- Increased growth of the sector may drive government to improve infrastructure	- Improved infrastructure will reduce the cost of production; - Improved roads will open up access to areas with earthen pond aquaculture; - Private sector involved in improving of infrastructure like self-connection to electric main grid.	- FFEs are pulling government into developing roads & market infrastructures; - Government is engaging in PPPs in building & managing extension infrastructure
Techn. capacity	- Sector embracing cage culture, desert aquaculture & integrated aquaculture & agriculture; - Training of small scale hatcheries; - Development & provision of improved brood stock.	- Collaborative research has produced Akosombo strain.	- Exploring of niche marketing e.g. small sized for minced fish targeting the growing fast food industry.
Investment	- Bright future for investment in fish manufacture (demand to exceed 1.5 million tonnes by 2020); - Growth of super and hypermarket chains opening up for longer shelf life products, hence, opportunity for value addition.	- Future growth of the untapped pond aquaculture; - Opportunities to diversification into farming catfish in tanks and ponds.	- The urban and peri-urban aquaculture has an annual growth rate of 20%; - Financial institutions are ready to finance sector after exposure of sector potential.
Human resources	- Growth of sector to employ more people.	- Growth of cage culture create opportunity for improvement of extension packages.	- Frequent sending of staff abroad specifically Asia to learn best practices.

Institutional system	- Government consideration of duration of farm leases; - Change in legislation to check & guarantee on quality control; - Change of legislation to consider aquaculture as an agricultural crop.	- Other tertiary institutions apart from universities are becoming involved in aquaculture education to emphasise aquaculture extension.	- Government is intending to impose ban on fish feed imports.

Threats. Comparing the threats across Egypt, Ghana and Nigeria (Table 6), the market is vulnerable to fluctuation in fish market prices, cheap imports, illegal trade, and consumer perceptions that disadvantageous farmed fish can lead to hampered trade. Trade can be made even more unfavourable due to poor hygiene and quality control (El-Sayed, 2017; Frimpong and Anane-Taabeah, 2017; Atanda and Fagbenro 2017). Environmental conditions can be inconvenient when: freshwater is limited, competition for water is high, water is polluted, and fish is infected by parasites and disease outbreaks. Seasonality remains an everlasting factor, and no control of imports (e.g. brood stock in Nigeria) can lead to non-sustainability in production systems. Future will also have to deal with the challenges associated with infrastructure, technological capacity, investments, human resources and institutional system. Notably, devaluation of monetary unit in respective country will also impact the fish farm sector, and also, corrupt abuse of quotas will make it difficult to advance.

Table 6: Comparing threats of aquaculture sectors in Egypt, Ghana and Nigeria

	Egypt (Naziri, 2011; El-Sayed; 2007; El-sayed, 2017)	**Ghana** (Frimpong and Anane-Taabeah, 2017)	**Nigeria** (E.g. Ozigbo et al., 2014; Adewumi, 2015; Atanda and Fagbenro 2017)
Market demand	- Negative perception about farmed fish by consumers; - Poor hygiene and quality conditions in retail and wholesale markets; - Fluctuation in fish market prices; - Markets are generally far from farms.	- Cheap imports; - Consumer preference for wild fish; - Taste of oiliness, short shelf life major concerns for consumers - High tilapia price makes consumers prefer wild fish; - Huge gap between supply & demand drives illegal trade on banned imports	- Undocumented fish exports to neighbouring countries; - Poor handling of fish by traders.
Environment	- Limited freshwater resource; - Use of poor quality water for farming; - Poor product handling; - Competition for water by other sectors; - Lack of fingerling grading standard.	- Use of wild fingerlings; - Disease outbreaks; - Parasitic infections; - Theft; - Water pollution; - Lack of nursery component in seed production; - Environmental concerns may slow growth of cage culture on Lake Volta; - Lack of fingerling grading standard.	- Seasonality affects seed production; - Effect of unplanned FFEs on environment; - Competition over shared resources in urban areas - Imported brood stock not sustainable.
Infra-structure	- Poor infrastructure leads to losses; - Lack of cooling facilities affects fish hygiene and quality standards; - Undocumented hatcheries & feed mills which could be producing sub-standard products;	- Poor infrastructure increasing cost of production; - Poor infrastructure more acute in central and southern parts of the country with high earthen pond production potential; - Few hatcheries distributed in the Lake Volta region where most production comes from.	- Unplanned FFEs may lead to conflicts with dwellers in urban & peri-urban areas.

Techn. capacity	- Farmers lack of knowledge on fish health & water variables; - Poor experience in fish breeding; - Poor storage and handling of fish feeds & ingredients; - 80% of feed is compressed & sinking pellets with poor FCRs; - High mortalities of seed during transportation; - Poor quality of finished feeds.	- Poor breeding techniques; - Lack of a research agenda; - Irrelevant extension to cage culture & lack of it for earthen pond farmers; - Lack of access by earthen pond farmers to knowledge on low cost and efficient production.	- Poor fish breeding techniques; - Sourcing of brooders from general fish markets; - Inadequate supply for low cost & good quality feed
Investment	- Poor performance of Egyptian pound affect fish feed & fish ingredient prices; - Dependence on imported fish feed ingredients; - Supply of poor quality feed & seed for farmers that take inputs on credit.	- Poor performance of the Ghanaian Cedi; - Most fish feed ingredients are imported; - Lack of start-up capital for earthen pond farmers; - Failure of some farmers to pay back loans to financial facilities.	- Low priority on potential of Tilapia farming; - High cost & reliance on imported feeds constraints growth of the sector.
Human resources	- Aquaculture extension is understaffed; - Fish markets handled mostly by unskilled persons mostly from poor backgrounds.	- Aquaculture extension is understaffed; - Unscrupulous ''experts'' offering extension services/advice; - Extension focussed on earthen pond farming, hence, irrelevant to cage culture.	- Aquaculture extension is understaffed; - Unscrupulous ''experts'' offering extension services/advice.
Institutional system	- Restrictive legislation on cage farming; - Laws restrictive of investment on leased land; - Coherent animal health control system lacking; - Regulation on use of veterinary drugs lacking; - Lack of quality control inspection; - Lack grassroots presence of FFAs .	- Weak regulations; - Lack of funding to the sector affects self confidence in research creating a void filled by donor community; - Lack grassroots presence of FFAs.	- Corrupt abuse of importation quotas; - Overlap of administrative roles between National & state governments; - Lack grassroots presence of FFAs.

Based on the SWOT analyses, a summary of key factors has been drawn. They are summarised in Table 7. It appears that market opportunities can increase substantially if production adapts to consumer preferences (e.g. a shift to Catfish production) and is located close by urban markets (Adewumi, 2015). Given that water is such a scarce resource for aquaculture, RAS and earthen ponds can serve as alternatives when groundwater reservoirs are not abundant. Infrastructure is a main barrier to future extension of fish farming, and private sector investments can provide opportunities and should be considered, but also governmental support to infrastructure is seen to be increasing along sector chain (El-Sayed, 2017; Frimpong and Anane-Taabeah, 2017; Adewumi, 2015; Atanda and Fagbenro 2017). When technology advances, it is obvious that increase in technological capacities is very much needed. Although most fish farms invest themselves in own production systems, public support, e.g. tax breaks and tax holidays, can encourage further investments (El-Sayed, 2017; Frimpong and Anane-Taabeah, 2017). Low human capacities in implementing policy and sector strategies, as well as governmental staff's knowledge of new technology, can create additional barriers for aquaculture developments. It is, however, shown that when the sector increases,

policies and regulations will follow-up intending to support catch of new opportunities and reduce new risks and potential damages.

Table 7: Summary of key factors in aquaculture development in Egypt, Ghana and Nigeria.

Key factors	Lessons learned from the comparative study
Market demand	• Identification and farming of species preferred by consumers (catfish vs tilapia: Nigeria) is important. • Production located close to peri-urban and urban markets to reduce transport costs and assure farmers of an ever ready market (Nigeria).

Environment	• Choice of farming environment and production system should take into account:
	  ○ Intensive production is achievable in earthen ponds (tilapia, Egypt).
	  ○ Tapping in abundant water reservoirs or lakes to practice cage culture (tilapia, Ghana).
	  ○ Entrepreneurs focusing on tanks and recirculating aquaculture systems (RAS) to produce catfish intensively in backyards on small land area in and near cities (Nigeria).
	• Choice of farmed species should take into account experiences in Nigeria:
	  ○ Focused on the Catfish, the most preferred fish for consumers, which is easy to farm due to its hardiness and ability to withstand high stocking densities that are common in RAS and tank systems.

Infrastructure	• Poor state of infrastructure increases costs of production (Egypt and Ghana). • Use of diesel run generators or installation of power increases fish production (Nigeria, Egypt). • Role of the private sector in driving infrastructure investment should be considered. • In Nigeria the growth of Fish Farming Estates (FFEs) has motivated the Government to fund and facilitate the development of roads to ease market accessibility; as well as to improve the accessibility to water and drainage. However, due to poor planning, FFEs have contributed to degrading environmental conditions and may be a source of conflict due to poor waste disposal.
Technological capacity	• Growth of commercial farming has led to demand for improved technical capacity in feed manufacturing and fingerling production in modern hatcheries (Ghana, Egypt and Nigeria). • Research has contributed to the production of the Akosombo (Ghana) and the Abbassa (Egypt) strains of tilapia and to the shortened time in fish production. • Improved technology shortens the cycle of fish production; hence, ensuring that farmers get maximum profits when using cages (Tilapia, Ghana) and tanks and RAS (Catfish, Nigeria) and intensive fish pond (Tilapia, Egypt). • Despite the vibrancy in feed and fingerling production the three countries still have problems with quality production of fingerlings and feeds.
Investment	• Incentives such as waivers on imported cages, tax breaks/tax holidays have worked to encourage investment in the sector for Ghana and Egypt. However, the incentives seem to favour large scale farmers at the expense of the small scale ones. • The Egyptian Government stimulated farmers to commercialize, which in turn resulted in the private sector investing in the aquaculture sector specifically in the feed and fingerling industry. • The private sector led industry in Nigeria has developed to a point when entrepreneurs who invested in FFEs have gained economic and political influence in the sector.
Human capacity	• Challenges of low human capacity to implement policy and sector strategies are noted as a key issue affecting the sectors in the three countries.

	• Also lack of sufficient technological capacity exists among the personnel working for the governments, specifically in extension services, and the labour forces in fish farms.
Institutional governance	• Policies have shifted in all three countries to support commercialization of aquaculture, and also to encourage the private sector to take a lead role in the sector. • In all three countries, Governments have formulated well-articulated policies and regulations, with the risk that weaknesses occur in the implementation phase, for instance, if not advocated by sufficient funding and human capital. • Professional associations; specifically the FFAs, play a significant role in the three countries for advocacy, and generally influencing a good environment for the sector development. The three countries have supported the presence and formation of the FFAs. However, without grass-root support the FFAs lack influence and become obsolete.

3. Determining factors and recommendations for Kenya

The core characteristics of Kenyan aquaculture include the focus on two main species: the Nile tilapia (Oreochromis niloticus) and the African catfish (Clarias gariepinus). Although there has been a blanket recommendation for production of these two species mostly in polyculture systems in earthen ponds, the main focus has always been on the Nile tilapia given its high consumer preference while the high potential of Catfish for intensification and consumption has been neglected. The Kenyan aquaculture industry suffers from poor fish breeding programmes. It is difficult to identify which strain farmers are growing due to poor record keeping in hatcheries and on-growing farms and lack of an inventory of fingerling distribution networks. It has also not been ascertained whether there are particular strains suited for particular regions and production systems. This needs to be streamlined for a better-performing aquaculture industry. It may not work to copy production systems that have been successful in the studied countries to the Kenyan context. The Kenyan aquaculture sector provides diverse opportunities which can be embraced.

Lessons learnt from the comparative country study of Egypt, Ghana and Nigeria have been discussed and validated by a platform of experts and stakeholders in roundtable discussions, to formulate recommendations suitable for the Kenyan aquaculture context (Koge et al. 2018). Their core recommendations are summarised in Figure 1 and explained further in the following.

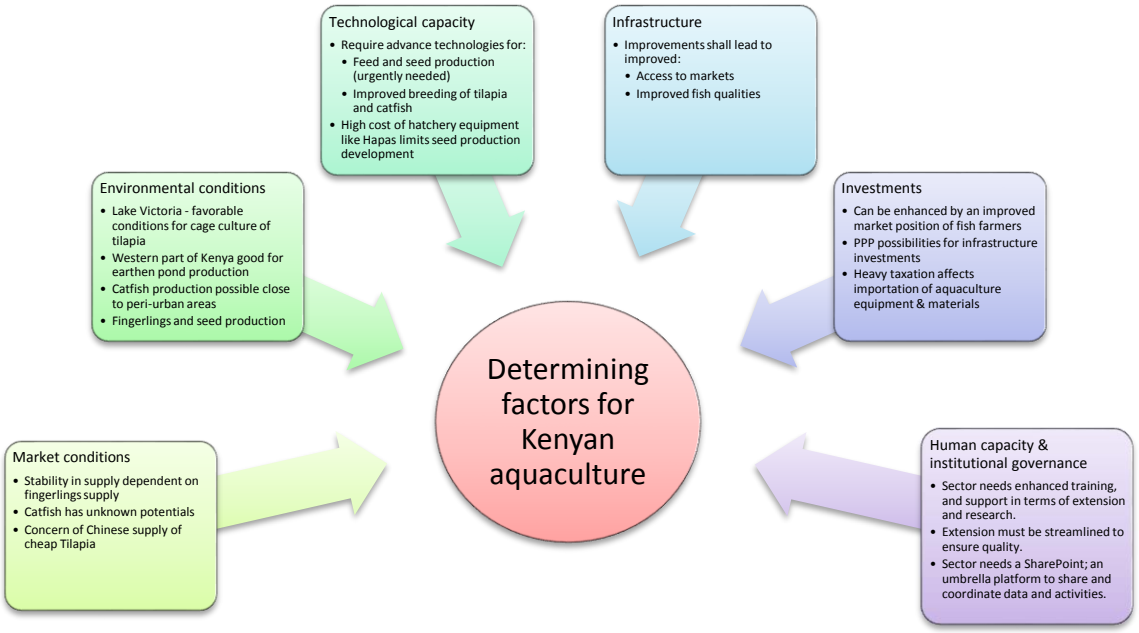

Figure 1: Summary of determining factors for Kenyan aquaculture across: market conditions, environmental conditions, technological capacity, infrastructure, investments as well as human capacity and institutional governance

Market demand. The debate on the existence or lack of fish market in Kenya is complex. While some people say there is no market, some stakeholders would say there is market but there has been failure to tap into it and sustain demand. The Kenyan Government has for a long time advocated for the farming of Tilapia due to its consumer preference. Unfortunately farmers have not been able to sustain the demand due to poor production technologies and low production volumes. Farmers should be empowered by training to sustain the market of fish. To increase the volumes of fish produced there is need to increase fingerling and feed production and to improve access to related production services. Fingerling demand in Kenya currently stands at more than 100 million fingerlings/year which cannot be supplied consistently by the available hatcheries (Obwanga and Lewo, 2017).

To meet the market demand for consumption fish, Tilapia is imported from China. This Tilapia is cheap and hence it is difficult for farmed Kenyan tilapia to compete with the Chinese imports. Ghana and Nigeria face the same problem and it is in fact worse in Ghana where farmed Tilapia is more expensive than the Chinese tilapia. Nevertheless in the two countries supply of fish still falls short of the demand and despite the bans and imposed quotas on fish imports, there is still opportunity to smuggle the fish into the countries. However, these challenges have not stopped the sector from growing in the two nations. There has always been a perception of low consumer preference for Catfish in Kenya, however the great market potential for value added Catfish products has scarcely been explored in the country.

The roundtable recommends to stimulate a shift in consumer preferences from harvested to cultivated fish to increase overall per capita fish consumption. Proactive campaigns and advertisements on traditional market days have worked in peri-urban areas like Kitengela and Kiambu close by Nairobi. Having a contact point in the counties and established fish collection centres for farmer groups have worked well in Kiambu County. In addition, fish farmers should receive technical support to increase supply, access market information and prompt updates on emerging issues in the industry through regular seminars and workshops in order to respond effectively to market demand.

Environment. Kenya has an abundant and diverse environment suitable for aquaculture production (Rothuis et al., 2011; Munguti et al., 2014a, b). Some of these environments have been explored while some remain untapped. Intensive earthen pond Tilapia and Catfish farming has potential in the Western parts of the country, close to Lake Victoria. This area has abundant water resources, good soils and suitable temperatures all year round.

In addition, cage culture has started to develop in Lake Victoria. The collaboration between the Government and other stakeholders has identified ideal sites for cage culture in Lake Victoria and motivated the sector to increase production. Opportunity for growth of the fingerling and seed industry has already been created. Also, there are many reservoirs in the country where cage culture has not been explored.

There is also opportunity to produce fish under RAS in small plots of lands which are close to urban areas specifically Nairobi. These can be taken up by counties close to the city like Kiambu, Muranga and Machakos. Embracing RAS production of fish close to major cities can be done by using Catfish which can withstand high stocking densities and can be carried out throughout the year without fear of low temperatures common in June and July. However caution needs to be taken with regard to availability of fingerlings as well as high quality feeds.

The roundtable recommends that care needs to be taken before exploring such environments due to their sensitivity and conflict of interests with other stakeholders who utilize them. Regulations should be put in place first to guide sustainable cage farming in open water systems.

The roundtable experts and stakeholders also propose identifying production systems that suit different counties based on characteristics that will include proximity to market, climatic conditions, easy access to abundant water resources, access to finance and proper infrastructure. These intensive systems should also take into account environmental sustainability and climate resilience.

Further, the roundtable experts and stakeholders suggest product diversification through value addition for Catfish, which could open up opportunities for urban markets, as a high future potential.

Technological capacity. There is need for more investment by the private sector in high technologies of fingerling and feed production in the country. Feed and seed are the two critical inputs that require advanced technology for the aquaculture sector to grow. Unfortunately, Kenya has not yet fully embraced advanced technology in fingerling and feed production to develop the sector to levels comparable with countries like Nigeria, Ghana and Egypt. Countable fish feed production companies, and most animal feed producing companies, focus mostly on poultry and dairy animal feeds. On the one hand, production of extruded feeds remains a challenge and at the moment only two animal feed companies (Unga Holdings Ltd and Sigma Feeds Ltd) have the technology to produce floating fish feed. Therefore, most of the fish feed produced for Tilapia, for instance, is in form of sinking pellets, as floating feed is not available. On the other hand, poor technologies in Tilapia and Catfish fingerling production has compromised the growth of the sector for a long time.

The private sector needs incentives to encourage production of the two critical inputs: fingerlings and feed. Some equipment and material for fingerling production like hapa nets still fall within the tax brackets of items used in the capture fisheries, which is a disadvantage to fingerling producers.

Infrastructure. Poor infrastructure remains a big challenge in Kenya just like in Nigeria, Ghana and Egypt. Fish being a perishable commodity and suitable production sites often located at a distance from markets, there is need for the Government of Kenya to improve the transport network and to develop cooling facilities to encourage farming and to reduce post-harvest losses.

The roundtable recommends developments of the market infrastructure like cold rooms, and handling and testing facilities for quality assurance of the farmed products. The Government of Kenya could explore private-public-partnerships (PPPs) in infrastructure development and benefit from what has worked in Ghana and Nigeria.

Investment. The investment environment for the Kenyan aquaculture sector can be improved through the farmers striving for an improved market position to obtain improved access to inputs, credit and higher product prices.

Human capacity. The aquaculture sector still suffers from acute shortage of human capacities in extension, research and training and there is an urgent need to develop these extensively. The existing extension services suffer from unscrupulous extension personnel that have invaded the sector, which need to be streamlined and upgraded by appropriate quality control measures.

There is, on the one hand, need for capacity training along the value chain; for instance, training of farmers through transfer of skills from farmer to farmer or from updated and relevant extension providers. On the other hand, trainees at any entry level of aquaculture sector should attend job training as part of their curricula (field attachment only is not enough), while best aquaculture practices across the value chain should be considered to be obligatory.

The roundtable recommends relevant and practical research that investigates needs of the sector. This can be achieved by linking research to industry so as to ensure relevance. A national central platform for data on research findings for all aquaculture stakeholders should be developed.

Institutional governance. Despite the private sector playing the lead role in the Kenyan aquaculture sector, their influence on sector development is yet to be felt. Although the Government plays the facilitator and regulator role, the sector is yet to benefit from the Government's commitment to the sector. The Government needs to create a conducive context for the different actors of the supply chain to increase possibilities to become active participants in the sector. Notably, devolution has created confusion about roles and levels of policy implementation, and there is need for a clear framework which will identify roles.

There is no registered umbrella platform for all aquaculture stakeholders in the form of a formal association that brings together all aquaculture stakeholders on one platform or a stakeholder platform database. While the Aqua-Roundtable attempts to bring on board all actors in the aquaculture sector, the Aqua-Roundtable is not a registered entity and therefore its role in lobbying and advocacy is minimal.

The roundtable recommends that enhanced facilitation by the Government of Kenya could contribute to strengthen capacity of fish farmers by means of useful extension. Since the Government of Kenya may not have enough money to handle extension, it needs to identify innovative approaches to support. Moreover, collaborative research between the private sector and the public sector could bring about new important insights. For instance, the feed industries are ready to fund research within their premises but they lack equipment which the public institutions may have or can provide in a PPP construction.

The roundtable also informs that the restructuring of the State Department of Fisheries and Blue Economy (SDFBE) and the creation of the Kenya Fisheries Service (KFS) provide

opportunities for membership of representatives for an aquaculture stakeholders platform. Such quick registration will create immediate opportunities for advocacy at the highest level. Enhanced sector growth driven policies and a better articulated National Aquaculture Policy could benefit the county level by means of a trickledown effect.

4. Discussion and concluding remarks

The main objectives of this study are; 1) to learn lessons from a comparative study of experiences made in leading aquaculture producing countries in Africa; Egypt, Ghana and Nigeria, and 2) to identify relevant factors that are influencing the development of the aquaculture sector in Kenya. The comparative study has been discussed in a stakeholder-expert roundtable meeting, and core recommendations have been formulated. The question is – what are the most restricting factors for the aquaculture to grow in Kenya? This study has addressed two locations as particularly relevant to future growth of aquaculture, namely Lake Victoria and Nairobi. While Lake Victoria provides opportunities to overcome environmental restricting factors, such as provision of abundant water resources, good soils and suitable temperatures all year round, Nairobi contributes with potentials for future demand. Thus, while Lake Victoria can deal with the environmental restricting factors, Nairobi can deal with the restricting factors of low demand of farmed fish. These are factors at the very different ends of the value chain. Thus, what restricting factors must be addressed first?

Before discussing the most urgent factors, it is useful to consider the core factors needed to undergo transitions from less to more sustainability. Geels (2011) has developed theories that can help us conceptualize societal transition towards sustainability. In this view, transitions are non-linear processes that result from the interplay of developments at different levels, including: 1) regime level – which are the established practices and interactions based on capital, skills and urgencies, and 2) niche levels – which are experimental space, for instance, in small market niches with special demands and willingness to explore new innovations. Rauschmayer et al (2015) added another level below the niche-level to explain that the core dynamics of change is fully dependent upon individuals with motivation and capacities for influencing others (knowledge broker) and assess the extents to which transition actually is going in directions of more sustainability (evaluator) (Figure 2).

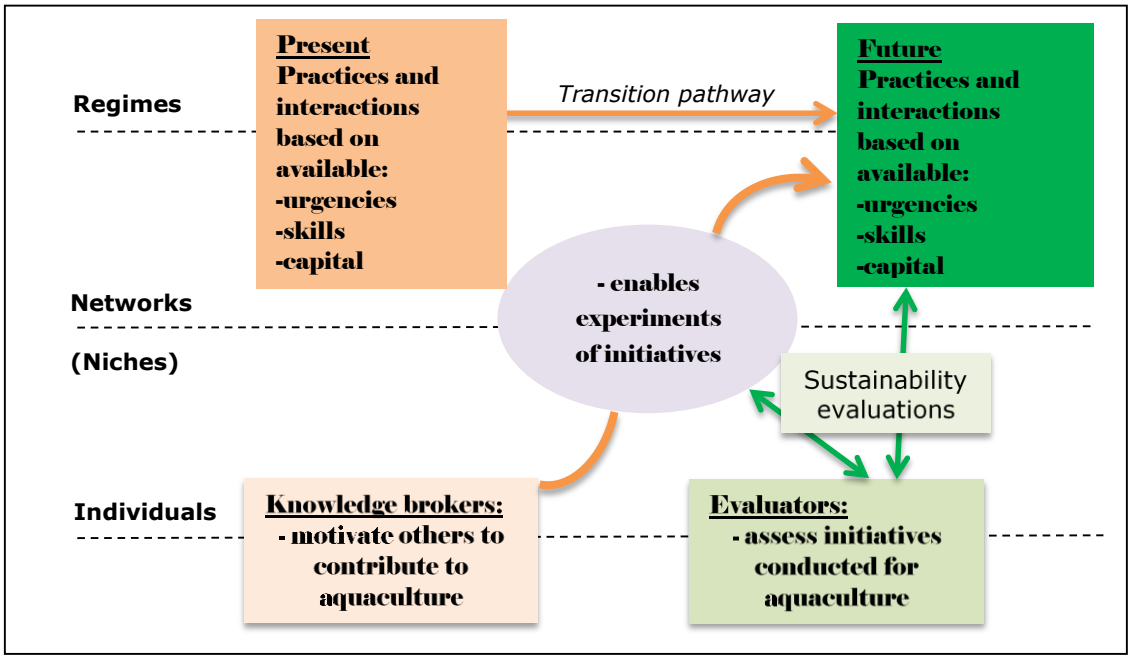

Figure 2: Critical factors of sustainable transition pathways; including levels of regimes, networks and individuals, and associated practices and interactions based on urgencies, skills and capital, experiments of initiatives, as well as knowledge brokers motivating change and evaluators judging on levels of sustainability

In Table 8, the insights of the transition theory introduced in Figure 2 are applied to the aquaculture sector in Kenya, by first addressing transition factors at regime level referring to capital, skills and urgencies, and then judging for each factor the issues of relevance in Lake Victoria and Nairobi, separately. While capital refers to the core materials needed throughout a value chain, the skills address human resource factors, knowledge and institutional factors, while urgencies refer to presence of willingness to invest in people and capital, as well willingness of consumers to actually pay sufficiently for the products made available.

Table 8: Transition and restricting factors applied to the aquaculture sector in Kenya.

Transition factors			Restricting factors	
Capital (value-chain factors)	**Skills (human resource & institutional factors)**	**Urgencies (willingness to invest/pay)**	**Lake Victoria**	**Nairobi**
Environmental thresholds & resource base	Sustainability and climate change	Global and local; concerns the whole society and future generations	Expansion of production systems must be regulated to avoid degrading natural capital (impacts of aquaculture)	Scarce resource availability, e.g. water shortage etc. can be dealt with by e.g. RAS.
Inputs (fingerlings, feed, seed)	Fish farmers need technical support and facilitation of knowledge sharing	Willingness to invest in capital by foremost private actors.	Stable supply – urgent to ensure Low variability in outputs	Stable supply - urgent to ensure Low variability in outputs
Production system (RAS,			Investments in intensive earthen	Investments in RAS in small

earthen ponds, cages)	Governmental support must be qualified Choices depends on skills of all capital factors, skills and urgencies	Willingness to invest in farm knowledge and human resources.	pond Tilapia and Catfish farming are expanding.	cages an under used potential, as well as information to potential fish farmers needed.
Outputs (Tilapia and Catfish)			Effectiveness of Tilapia production is high, so both Tilapia and Catfish are attractive to future.	Potential future high competition with cheap Chinese Tilapia – Catfish is a future potential
Transport & processing (cooling systems)		Willingness to invest in infrastructure, also a responsibility for government (PPP)	An urgent problem of distance to consumers (cooling and transport time)	Distance to market is shorter, but storing facilities needed
Market place	Consumers need accountable information of new products to change consumer behaviours	Consumer demand – attractiveness of product-price relations to consumers.	The distance to large cities is limiting possibilities for matching supply with demand.	Distance to potential new markets & consumers not a problem, consumers need more information.

One of the most restricting factors in both Lake Victoria and Nairobi are marked with red in Table 8. In both locations, solving the shortage of fingerling and feed supplies will increase the ability to produce with low variability of supply over time, which is highly urgent (low variability is a main strength in Ghana).

In the region of Lake Victoria, the distance to markets is a main restricting factor. Proximity to markets from the lake region is large in terms of urban centers like Nairobi, which consumes a lot of fish harvested from Lake Victoria, as well as to urban centers close by cities like Kisumu and Kakamega. Investments in cooling and infrastructure are particularly urgent to ensure that supply meets demand. While investments in production systems are already taking place at Lake Victoria, investments in production systems are more urgent in the region of Nairobi. Here extending opportunities for urban markets can be obtained by complementing Tilapia production systems with Catfish production. Increased investments in production systems, such as RAS and cages, as well as in assisting fish farm industry to access market information, technical support and updates on emerging demands, can enhance further possibilities for aquaculture farmers to increase stable supplies.

Besides, to enhance skills factors, it is advised that:

- Taking into account environmental sustainability and climate resilience should be made obligatory when promoting more intensive production systems;
- Accompanying growth of cage culture in lakes with appropriate regulations of open water systems is needed to guide sustainable cage farming;
- Linking research to industry will ensure relevance of research to sector needs.
- Implementing appropriate sector growth driven policies can improve sector investment contexts.
- Conducting innovative campaign designs can lead to considerable increase in per capita fish consumption.

This study is the second in a row of multiple studies covered by the project 3R Kenya. Whereas the earlier Quick scan (Obwanga et al., 2017) was conducted in advance of this study, it will be followed by a household study based on interviews of around 300 fish farmers in Kenya, as well as a qualitative analyses for further investigating the factors addressed in this study by means of in-depth interviews of value chain stakeholders.

In the qualitative analyses, the different aspects of the transition pathways will be investigated further, including the roles of capital, skills and urgencies, as well as levels of experiments and motivations by knowledge brokers, as well as sustainability assessments.

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