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Development and Scaling of Sustainable Feeds for Resilient Aquatic Food Systems in Sub-Saharan Africa

A systems theory of change

In partnership with

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Development and Scaling of Sustainable Feeds for Resilient Aquatic Food Systems in Sub-Saharan Africa: A systems theory of change

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About Development and Scaling of Sustainable Feeds for Resilient Aquatic Food Systems in Sub-Saharan Africa (FASA)

WorldFish has partnered with the Norwegian Agency for Development Cooperation (Norad) on a 5-year project to develop low-cost and highly nutritious aquatic feeds based on novel ingredients. The project, known as Development and Scaling of Sustainable Feeds for Resilient Aquatic Food Systems in Sub-Saharan Africa (FASA), will run from 2022 to 2027 with Norad funding the initiative through a NOK 80 million (approximately USD 8 million) grant. The project aims to enable 5000 smallholder aquatic food producers in Kenya, Nigeria and Zambia to test and use these feeds and ingredients, which will increase their income, improve their nation's food security as well as reduce waste and pollution. An estimated 30 and 40 percent of aquatic food producers engaged in the project will be women and youths, respectively.

Acknowledgments

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List of abbreviations

ADB	African Development Bank
AKFEMA	Association of Kenya Feed Manufacturers
ARCN	Agriculture Research Council of Nigeria
BMU	beach management unit
BSF	black soldier fly
CAFAN	Catfish Farmers Association of Nigeria
CBN	Central Bank of Nigeria
CLD	causal loop diagram
CORAF	West and Central African Council for Agricultural Research and Development
NAFDAC	National Agency for Food and Drug Administration and Control
Fasa	Development and Scaling of Sustainable Feeds for Resilient Aquatic Food Systems in Sub-Saharan Africa
GHG	greenhouse gas
ICIPE	International Centre of Insect Physiology and Ecology
JKUAT	Jomo Kenyatta University of Agriculture and Technology
KAM	Kenya Association of Manufacturers
KEBS	Kenya Bureau of Standards
KEPSA	Kenya Private Sector Alliance
KMFRI	Kenya Marine and Fisheries Research Institute
MELIA	monitoring, evaluation, learning and impact assessment
MFI	microfinance institute
MFL	Ministry of Fisheries and Livestock
MOA	Ministry of Agriculture
NAFDAC	National Agency for Food and Drug Administration and Control
NARS	National Agriculture Research Systems
NGO	nongovernmental organization
Norad	Norwegian Agency for Development Cooperation
NRDC	Natural Resources Development College
SLU	Swedish University of Agricultural Sciences
SON	Standards Organization of Nigeria
SSA	Sub-Saharan Africa
TADAN	Tilapia Aquaculture Development Association of Nigeria
UE	University of Eldoret
VNM	value network map
ZABS	Zambian Bureau of Standards

Executive summary

Development and Scaling of Sustainable Feeds for Resilient Aquatic Food Systems in Sub-Saharan Africa (Fasa) is a 5-year project that runs from 2022 to 2027. Funded by the Norwegian Agency for Development Cooperation (Norad) at a cost of NOK 80 million, the project is being implemented by WorldFish in partnership with many organizations and partners: the International Centre of Insect Physiology and Ecology (ICIPE), the West and Central African Council for Agricultural Research and Development (CORAF), the Swedish University of Agricultural Sciences, Aller Aqua Zambia, the Natural Resources Development College (NRDC), and international consultants, as well as local feed millers and farmers organizations. The main objective of the project is to develop low-cost and highly nutritious aquatic feeds based on new and locally available ingredients in three countries: Zambia, Kenya and Nigeria. About 5000 smallholder aquatic food producers, both women and men, are expected to test and use these feeds and ingredients to increase their income, boost the target nation's food security, and reduce waste and pollution.

To understand the aquatic feed sector in Zambia, Kenya and Nigeria and to inform subsequent impact assessments of the Norad-Fasa project, the monitoring, evaluation, learning and impact assessment (MELIA) unit at WorldFish, together with implementing partners, organized 2-day workshops across the three countries. Using a participatory systems approach, the workshops brought together representatives of governments, nongovernmental organizations (NGOs), the private sector and farmers associations, as well as small-scale feed millers, fish aggregators, processors and smallholder fish farmers, to explore the potential socioeconomic impact of developing and scaling sustainable resilient feeds using local ingredients. The participatory systems approach is an emerging methodology that uses the lens of systems thinking to revolutionize impact assessment of projects by considering how they interplay with the environment that each project is embedded in. For the workshops, the systems approach was implemented in five steps:

1. mapping the problems within the aquatic feed sectors using causal loop diagrams (CLDs)
2. mapping the actors within the aquatic feed sector using value network maps (VNMs)
3. envisioning and developing a map of a systems theory of change (TOC)
4. developing a network change map
5. recasting the systems maps into conventional TOC diagrams and prioritizing points of assessments.

The results show that the problems in each country's aquatic feed sector are complex and intertwined with each other, so there are likely to be time delays between the project's activities and its intended outcomes. It is therefore important to differentiate between the short-term, mid-term and long-term impacts of Norad-Fasa. Accordingly, project leaders should make sure that different activities, such as training sessions, workshops, information sessions, demonstrations and farm trials, are synchronized so that follow-up evaluations are effective.

Introduction

The contribution of fish to human dietary protein has attracted attention for national governments in Sub-Saharan Africa (SSA) and their international development partners alike. Fish accounts for about 22% of all dietary protein in SSA, and about 200 million people are reported to consume fish (FAO 2016). With a growing population, coupled with urbanization, rising incomes, changes in lifestyles and a greater appreciation of the health benefits of fish consumption, the demand for fish in SSA is only expected to grow.

Amid this rising demand, however, fish production in aquaculture and growth in capture fisheries have remained slow in recent years. Many studies suggest that overfishing, poor fisheries management, and changes in water and land use are the main causes of this decline. To address the demand gap, aquaculture in SSA is expected to grow as much as 55% by 2030 (Falch 2014) and is already growing faster (10% per year) than in any other continent. Accordingly, many governments have shifted their attention toward expanding aquaculture. More than 20 countries have prioritized aquaculture expansion within their national agriculture development plans.

Despite the potential contribution of aquaculture and fisheries to the food security and livelihoods of aquaculture farmers in SSA, the growth of the sector faces challenges, especially relating to the lack of access to affordable nutrient-rich feeds and the low technical abilities of farmers and feed manufacturers to make high quality aquatic feeds (Brummett et al. 2008). The lack of quality, locally available feeds, the lack of appropriate technical innovations, and the limited knowledge on how to make feeds are the main problems to the transformation of the aquatic food system in SSA (Munguti et al. 2021). This has led to a reliance on imports of aquatic feed and ingredients and, in some cases, on informal feed millers, whose feed quality is inconsistent. And like other sectors, aquaculture is facing economic and environmental shocks that threaten the sustainability of the sector and the livelihoods of smallholders.

In an attempt to overcome the challenges facing the aquatic food system, Norad-Fasa is a collaborative project that aims to identify and increase the quality of local ingredients to help feed millers produce local, sustainable feeds that meet the nutrient requirements of local strains of tilapia and catfish in SSA, with a focus on Zambia, Kenya and Nigeria.

The aim of the project is to develop low-cost, highly nutritious aquatic feeds based on new and locally available ingredients in the three countries. About 5000 smallholder aquatic food producers, 30% of whom are women and 40% youths, are expected to test and use the new feeds and ingredients. The goal is to increase their income, boost each target nation's food security, and reduce waste and pollution.

The project expects to achieve three outcomes:

1. Enhance ability of at least two stakeholder groups in each of the three target countries to integrate best practices toward a more sustainable feed sector, and to learn about the nutrient requirements of multiple improved strains of tilapia and African catfish.
2. Improve the quality of at least 15 local ingredients through various processing techniques, and ensure that stakeholders in the three countries, including local millers and farmers, use the ingredients to produce nine new, cost-efficient feeds that will make aquaculture more productive and resilient.
3. Allow approximately 5000 farmers, who are either directly or indirectly linked to the project, to access, test and use new, locally available fish feeds and feed solutions using the knowledge and innovations developed by the project, with support from a range of strategic scaling partners and other stakeholders.

Using a systems-based theory of change

Whereas Norad-Fasa has specific objectives and clear outcomes, understanding how change is likely to happen in the complex socioecological environment of SSA requires an in-depth contextual understanding of each system. One way that is popular to understand the impact of a project is relying on TOC diagrams and a logical framework to identify the indicators to track from baseline, midline and endline. One drawback of such an approach is the strong assumption that change is linear, even though extensive evidence shows that in socioecological systems, such as the food systems in developing countries, cause-and-effect relationships are non-linear (Leeuwis et al. 2021).

There are multiple pathways to achieve an outcome as well as feedbacks and time delays that are important to understand how change occurs from system interventions. In addition, relying too much on linear TOCs often fails to take into account how the project interacts with the wider environment it is embedded in. For instance, TOC diagrams have been criticized for failing to acknowledge other projects, programs and policies or the wider institutional setting where an intervention takes place (Wilkinson et al. 2021). Interventions in socioecological systems interact with the system elements as well as the different relationships that emerge or reemerge over time (Dentoni et al. 2023). Similarly, food systems interventions either influence or are influenced by multiple interacting issues at various levels of these systems, specifically among value chains, farming systems and households. As such, taking a simplistic linear perspective can lead to over or underestimating the impacts and difficulties of a project when differentiating its short-term and long-term effects.

Given these challenges, there is heightened need for impact assessment design approaches that account for time delays in aquatic food systems. Systems thinking and systems mapping provide a way to address these challenges by allowing participatory construction of systems-based TOCs that are context specific. The process of constructing such TOCs involves (i) understanding and visualizing the systems' current problems and issues, (ii) understanding how these problems are connected to existing actors and (iii) then collectively envisioning the potential contribution of the innovation to transform the systems. Combining these three steps will produce a systems TOC that describes how proposed interventions, enacted through envisioned reconfigurations of their value networks, tackle complex problems (Dentoni et al. 2021). That said, however, it is worth remarking that there are several benefits of traditional TOC diagrams, so the systems TOC approach does not try to substitute for these conventional TOCs and result frameworks of projects but rather to complement them in order to understand both the intended and unintended consequences of a project's interventions.

Developing a systems TOC map before or at the start of a project's activities is important to assess its impact for several reasons. Taking a systems approach allows us to capture all of a project's potential socioecological and economic impact while at the same time accounting for non-linearity, feedback loops and time delays. For the Norad-Fasa project, capturing this complexity also allows us to differentiate its short-term, mid-term and long-term impacts. In addition, because the deep knowledge about the possible impact of different activities lies with local stakeholders, a systems approach to an impact assessment gives us the opportunity to do it with the right people—both Norad-Fasa beneficiaries and key project stakeholders who are part of the systems in question. All together, this approach to understanding the project's impact helps develop competencies and processes of cross-scale stakeholder coordination to address complex problems, and it facilitates collective understanding of the problems at stake, cultivating a sense of project ownership among stakeholders from the start.

To understand the aquatic feed sector in the target countries and inform subsequent impact assessments of the Norad-Fasa project, the MELIA unit at WorldFish, together with implementing partners, organized 2-day workshops across the three countries between February and March 2023. In a participatory approach that considered gender and power dynamics, the workshops brought together representatives of governments, NGOs, the private sector, small-scale feed mills and farmers associations, as well as fish aggregators, processors and smallholder fish farmers. Together, they explored the potential socioecological and economic impact of using local ingredients to develop and scale sustainable feeds to make aquatic food systems more resilient.

Study objectives

The overarching objective of the project is to build a systems TOC to guide the assessment of the impact of the Norad-Fasa project on the aquatic food systems of Zambia, Kenya and Nigeria. With that in mind, this report addresses the following four objectives:

1. To collectively understand and visualize the problems surrounding fish feed.
2. To collectively understand and visualize the network of people that are entrenched in the problems and issues surrounding fish feed.
3. To explore the potential systemic impact of the project.
4. To identify points of impact assessment and make recommendations for the success of the project.

The remainder of the report is as follows. In section 2, we present the context of SSA, briefly highlighting the major challenges facing the aquatic food systems of focus. Next, the report presents the methodology, focusing on how the systems thinking and systems mapping methodology worked for the workshops. The report then presents findings from Zambia, Kenya and Nigeria. While doing so, we provide visual diagrams and explain the systems TOC for each country. Finally, we provide points of impact assessment along the project's timeline before making recommendations for project leaders and other Norad-Fasa stakeholders, and then conclude with some final remarks.

1. The context of Sub-Saharan Africa

Despite the expectation and increasing attention on aquaculture, fish feed, which is one of the major constraints in aquaculture, remains very expensive and not always of good quality. Feed accounts for about 60%–75% of the total cost of fish production in many SSA countries, and studies suggest that further growth in the aquatic food system will require making more quality fish feeds available. Until recently, the majority of smallholder fish farmers produced feed from their farms. In 2005, about 70% of aquafeed in Nigeria was farm-made (Fagbenro and Adebayo 2005) and in Kenya, before compounded feeds became available, most used locally available feedstuffs such as cornmeal or rice bran to feed their fish, or reared their fish in ponds with manure with or without supplemental feeds (Liti 2006).

However, although many smallholder fish farmers in SSA still use their own feeds, the quick expansion of aquaculture has led to feed shortages and reliance on imported ingredients. In Zambia, for instance, almost all micro-ingredients in feeds, such as fishmeal, premixes and vitamins, are imported (Genschick et al. 2017; Kaminski et al. 2018). Because of this gap in the aquafeed supply, informal small-scale feed millers have emerged and often produce feeds of inconsistent quality, while formal large-scale aquafeed manufacturers often monopolize prices (Hecht 2007).

Sections 1.1–1.3 that follow outline the context of Zambia, Kenya and Nigeria, focusing on aquaculture and aquafeed.

1.1. Zambia

Zambia's fisheries sector plays a significant role in the country's economy, providing an avenue to improve nutrition, increase incomes and create jobs. Fish makes up over half of the country's animal protein intake, and demand is rising. The fisheries sector has the potential to produce 150,000 t of fish annually, but it currently produces only about 100,000 t, of which 87% comes from capture fisheries (MOA and MFL 2016). The country is one of the biggest aquaculture producers in SSA, producing about 8500 t of fish per year. Certain indigenous tilapia species are farmed throughout the country, but most of the production is dominated by non-native tilapia species (*Oreochromis niloticus*). Given Zambia's abundant water resources, aquaculture is one of the main ways to diversify to economy.

According to Kaminski et al. (2017), Zambia's overall aquaculture production yield almost doubled between 2004 and 2014. However, there is still a gap between demand and local supply (from both the stagnating capture fisheries and the growing aquatic food system) that amounts to 70,000 t annually. In 2015, Zambia imported 77,199 t of fish, which increased to 126,345 t the following year (DOF 2017). FAO (2023) estimates there are more than 6000 smallholder fish farmers and over 13,000 fishponds in Zambia. There are several reasons preventing the country from producing more fish. There are not enough quality fingerlings and affordable feeds available, extension services are inadequate, and farmers do not have the technical knowledge and business management skills they need (European Commission 2018).

Over the past few years, the aquafeed sector has seen tremendous improvements, as new feed mills have emerged and established mills have started to develop lines to manufacture aquafeed (Genschick et al. 2017). However, although these large-scale feed companies sometimes sell to small-scale farms, most of their feeds go to large tilapia cage farms because smallholder farms buy less and are often sparsely distributed throughout remote areas of Eastern, North-Western, Northern, Lusaka and Luapula provinces.

WorldFish's Zambian office is implementing the Norad-Fasa project in partnership with Aller Aqua Zambia, the NRDC, Department of Fisheries, smallholder farmer associations and local feed millers.

1.2. Kenya

Fisheries play a critical role in Kenya, with commercial fishing estimated at 150,000–300,000 t. In 2019, total fisheries production was valued at KES 237 million (KNBS 2020). The country is the fourth-largest producer of freshwater fish in

Africa (Chia 2020). Nile tilapia accounts for 75% of aquaculture production, followed by African catfish at 18% (Opiyo et al. 2018). The aquatic food system has evolved to play an important part in the Kenyan food system, employing about 20,000 people. The domestic demand for fish is 500,000 t annually and, according to Nyandat and Owiti (2013), the country can farm more fish. More than 1.14 million ha of land is potentially available to produce over 11 million metric tons per year. It is estimated that the production of farmed fish in Kenya would need to reach 150,000 t by 2030 in order to meet the growing demand of the rising population.

Fish farming is practiced mostly in Central, Nyanza and Western provinces, parts of the Rift Valley and the coastal provinces (Nyonje et al. 2011). More than 90% of Kenyan farmers practice semi-intensive fish farming, while only 3% use an intensive system because of the high cost of electricity and the lack of inexpensive quality feeds (Opiyo et al. 2018). The country's agriculture and fisheries sectors produce most of the raw materials needed to make local fish feeds, but there are few large-scale feed mills (KMFRI 2017).

Despite the critical role and growing interest in promoting aquaculture in Kenya, multiple factors prevent it from realizing its full potential, including few extension services, a lack of quality and affordable feeds and a lack of market information (KMFRI 2017). Currently, the Kenya Marine and Fisheries Research Institute (KMFRI) considers that the quality of most fish feeds that small-scale feed millers and fish farmers produce is inadequate. There is a significant need for training and communication around local ingredients and feeds, appropriate feed formulation techniques and processing technologies, and access to up-to-date market information (Munguti et al. 2021b). In Kenya, the ICIPE is implementing the Norad-Fasa project in partnership with the KMFRI, Kamuthanga Fish Farm, Machakos and Victory Farms Ltd from the private sector, the University of Eldoret (UE), Jabali Fish Farm (Jabali Fisheries Traders), beach management units (BMUs), county governments and the Kenya Bureau of Standards (KEBS).

1.3. Nigeria

In Nigeria, aquaculture plays a significant role in both the society and economy. Over 40% of the protein sources consumed in Nigeria comes from fish. The country is the largest aquaculture producing nation in SSA and is ranked second in all of Africa, after Egypt. By 2012, the aquatic food system in Nigeria had grown 500% (FAO 2012) because of the need to narrow the gap between production and demand for fish. The country is currently producing around 260,000 t of farmed fish annually (FAO 2020), and the government has recently set a target of producing 2.5 million metric tons of fish from aquaculture. African catfish remains the dominant fish species among farmers in Nigeria, followed by tilapia (Hasan and New 2013).

Although aquaculture continues to attract interest among Nigerians, the country imports approximately 70% of its aquafeed annually (Udo and Umanah 2017). This is despite there being many local feed factories across Nigeria, as well as farmers who produce their own feed. Yet, the quality of feed is inconsistent. They do not use proper methods to make the feeds, the quality of the ingredients is low (protein, lipids, minerals, vitamins, fiber, energy and digestibility of nutrients), and the manufacturing processes and storage methods are inadequate (Udo and Umanah 2017).

Aquaculture thrives in most parts of Nigeria, but the most active regions are South West, South, South East and North Central. About 70% of fish farmers are smallholders who are located in rural areas. The Norad-Fasa project will concentrate on the 23 states distributed across the regions of South West (Ekiti, Lagos, Ondo and Oyo), South South (Akwa Ibom, Delta and River), South East (Abia, Ebonyi and Imo), North West (Kaduna, Kano, Sokoto and Zamfara), North Central (Benue, Nasarawa, Niger and Plateau, as well as the Federal Capital Territory) and North East (Adamawa, Borno, Taraba and Yobe). CORAF is leading the implementation of the project.

Section 3 details the tools and approaches used in the workshops to contextualize and identify potential points for assessing the socioeconomic and ecological impact along the project's timeline.

2. Methods and approach

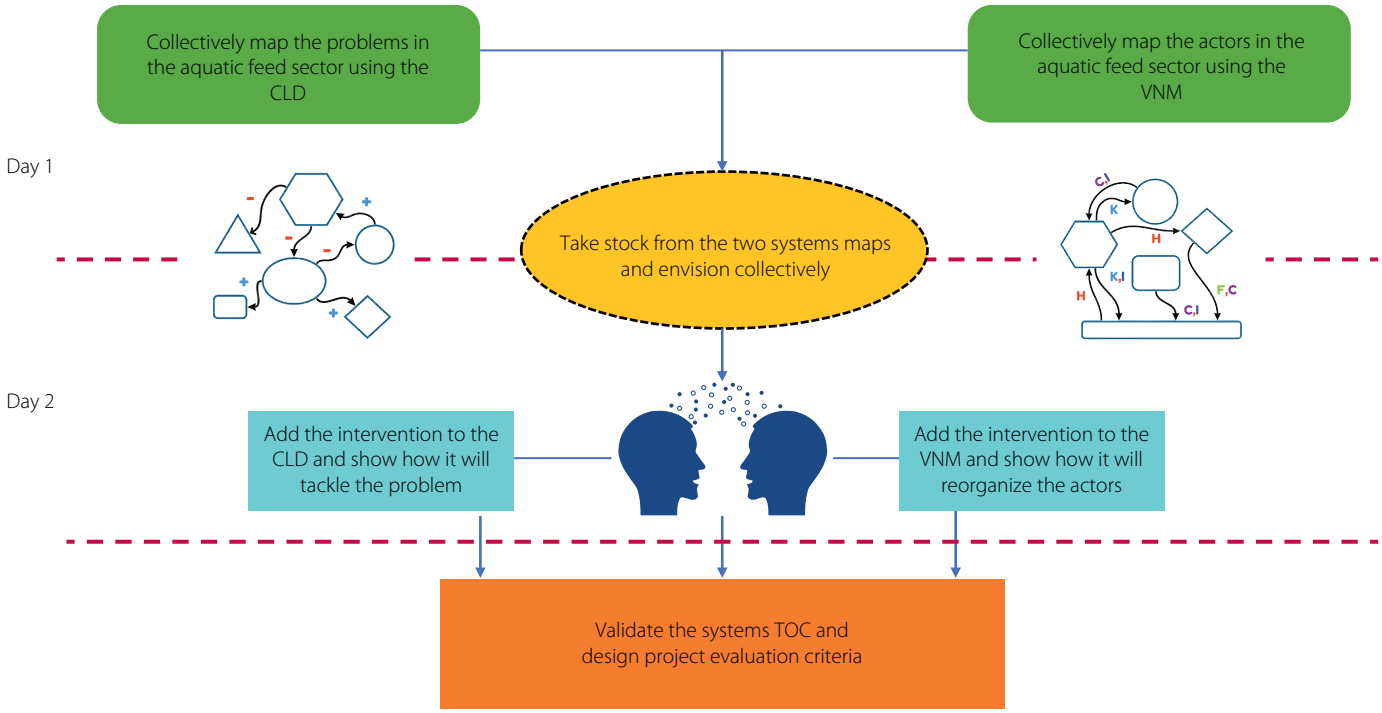
2.1. Systems thinking and mapping to understand change in aquatic food systems

To explore the potential socioeconomic and socioecological impact of the Norad-Fasa project, the workshop used systems thinking and systems mapping as its methodologies. In food systems, systems thinking is a way of making sense of the complexity of the system by looking at the interactions among multiple interdependent social and ecological agents (Meadows 2008; Williams et al. 2017; Dentoni et al. 2023). Systems mapping involves a set of stakeholders, working together, co-creating visual depictions of a complex system, including its entangled set of relationships and feedback loops, using their knowledge and previous experiences of the system (Dentoni et al. 2023). Systems thinking and mapping is a participatory approach where people in socioecological systems collectively map challenges and their related network of actors and then collectively envision change by considering project interventions, activities and relationships among interdependent social, economic and ecological actors (Williams et al. 2017). This creates a space to collectively understand, map and envision opportunities to address challenges (Dentoni et al. 2023).

To assess the impact of a project, systems thinking develops a systems-based TOC where a diverse set of actors in a system use various thinking tools to map out the specific problems, actors and their relationships and the potential impact of an intervention or project (Williams et al. 2017). To understand and visualize the interconnectedness of the focal problems surrounding fish feeds in Zambia, Kenya and Nigeria, we used CLDs, which are a graphical visualization of the interactions between causes and effects of the multiple elements of a complex problem (Sterman 2000). They are a simply way to understand the interconnectedness of multiple issues across multiple scales, such as in a fish farm, a fish farming community, the fish feed industry and aquatic food systems as a whole. Using CLDs allows us to collectively understand and visualize the specific issues that constitute the main problems in the feed sector, and how these are causally related to each other. To understand the specific actors that influence or are affected by the problem within and surrounding the feed sector, we used the value network map (VNM) tool. In this context, a VNM helps understand when, how and with whom people can help solve challenges (Dentoni et al. 2023).

For the Norad-Fasa project, using systems thinking to build a contextualized systems-based TOC for each country entailed organizing a workshop to bring together diverse actors from the aquatic feed sector in each country. They included feed millers, fish farmers, and insect and crop farmers as well as representatives from farmers associations, NGOs, certification authorities, research institutes, extension departments and implementing partners. In total, 26 participants attended the workshops in Zambia, 25 in Kenya and 25 in Nigeria.

In each of the workshops, to help ensure equal participation, the participants were divided into three groups according to their organization, sex, age and their role in the feed system. Using a CLD, each group first explored the main challenge facing their aquatic feed sector and mapped the actors involved using a VNM. Next, the groups looked at the socioeconomic and ecological potential of Norad-Fasa in solving the challenges, focusing on improving the availability, access and affordability of fish feed. This was done by (i) co-creating a CLD that plugged in the intervention activities to see what changes the project is likely to make with respect to the challenges, and (ii) plugging the project's partners into the VNM by showing how the relationships among actors will develop and identifying other potential partners to bring onboard to achieve the desired change. Figure 1 outlines the structure of the workshops.



Source: adapted from Dentoni et al. 2023.

Figure 1. Structure of the 2-day workshop.

2.1.1. Understanding problems in aquatic feed systems

In each country, the workshops were held over 2 days: February 14–15 in Zambia, March 14–15 in Kenya and March 22–23 in Nigeria. The first day was dedicated to introductions, an overview of the project and a presentation on the need for a systems TOC that would guide the next steps in the design of a robust impact assessment for Norad-Fasa. Across the three workshops, the key message was the need to complement linear thinking tools with other non-linear tools to design impact evaluation studies—a move away from the simplistic cause-effect analogy. This is fundamental because system challenges are complex, interconnected and dynamic, with feedback dynamics and time delays. In addition, it was stressed that observed impacts are often a culmination of the interaction of multiple actions from actors within and outside systems boundaries, whether planned or unplanned. As such, attributing impact to a specific intervention or project is often elusive and problematic. The presentations zoomed in on the need to understand the entire system in relation to the impact of developing and scaling fish feeds using local ingredients.

The facilitators demonstrated the steps for mapping problems and issues in the aquatic seed sectors using a CLD. Arrows were used on the map to represent the causal relationships, with either a plus (+) or minus (-) sign. For example, in a mathematical sense, a plus sign from A→B would denote that A increases B, while a minus sign from A→C would denote that A reduces C (Dentoni et al. 2023). The mapping process involved writing the names of variables (referred to as problems or issues in the system) on sticky notes or drawn circles on flip charts and creating directional links that connected the variables.

A facilitator demonstrating how to map problems in the aquatic feed sector using a CLD.

After the facilitator's presentation and demonstrations, the participants could go to three separate roundtables for group activities. They were expected to collaboratively map the challenges in their aquatic feed sector using the CLD. Where necessary, the facilitators were always there to provide guidance. Each group activity lasted 2.5 hours after which 30 minutes of presentation and collective reflection were done in plenary.

In the second session, participants collectively mapped and visualized the ecosystem of actors in their aquatic feed sector and their relationships. This session was important to understand the connections and relationships among actors who directly or indirectly influence the problem in question or are influenced by it.

The facilitators started this session by giving a brief presentation on why it is important to understand the relationships among actors in the systems since most of the problems and issues are always tied to the ecosystem of actors (Dentoni et al. 2023). Participants were asked to focus on the broader systems and to reflect on how different actors are related to each other in terms of sharing resources. Demonstrations on how to build a VNM were done in plenary after which the participants proceeded to their groups for the group activity. There, they mapped the network of actors in the aquatic feed sectors, paying particular attention to the shared resources. After mapping the networks, each group could select a member to present their VNM in plenary, and members from other groups were allowed to ask questions for clarification and give their contributions.

Photo credit: Elizabeth Akuwa/WorldFish

Various representatives mapping the issues and problems affecting Nigeria's feed sector.

Photo credit: Timothy Manyise/WorldFish

A participant presenting the existing networks in Kenya's aquatic feed sector.

2.1.2. Understanding the potential impact of the project

At the beginning of the second day of the workshop, it was important to dedicate the first 1.5 hours for the participants to understand the Norad-Fasa project—its objective, planned activities and the implementation plan in each country. The project leader and/or the implementing partner of each country gave a detailed presentation to the participants, focusing on the project's goals and activities, and the roles and contributions of each partner.

The purpose of the presentation was to tell the participants how the project can potentially address the problems identified during the first day of the workshop, and to present the expected outcomes and the partners. The aim of the

Photo credit: Agnes Chileya/WorldFish

The project leader explaining the project's activities and partners to participants on February 15, 2023, in Zambia.

presentation was to ensure that the participants had a clear understanding of Norad-Fasa, paving the way for them to collectively envision how the project can help tackle the problems.

In Kenya, for instance, one of the project's components focuses on enhancing the capacity of stakeholders to make use of locally valuable feed ingredients such as insects, specifically black soldier flies (BSFs). Using BSFs is expected to reduce imports of costly ingredients, which would lower the cost of fish feeds and increase access to low-cost nutritious fish feeds.

After the presentation of the Norad-Fasa project, the facilitator showed participants how to use CLDs to map ways in which the project can address the problems. This was followed by a demonstration of the mapping process on flip charts. Overall, participants were expected to map both the intended and unintended consequences of the project.

After presenting and demonstrating the systemic change mapping, the participants moved into their respective groups to map the potential impact of the Norad-Fasa intervention activities. After the mapping activity, the groups were given an opportunity to present their maps in plenary. All participants were able to ask questions and make contributions to improve the co-created CLD.

The final session of the workshops always started with a presentation on how to map the reconfigurations of actors and their resources in

A participant showing how Norad-Fasa can address the problems in Nigeria's feed sector.

the feed system during the course of the project. This involved mapping the actors in the presence of the project and envisioning how to organize the resources and which actors to bring onboard to help address the problems. This session required the input of project leaders and implementing partners to explain how they will work with other actors in the system along the project's timeline. As such, each group was given a project partner to help clarify the roles and responsibilities of Norad-Fasa's partners.

After mapping the network change, the participants presented their maps in the plenary. Participants from other groups were able to ask questions and get clarification on the networks. This was also necessary to have a shared understanding of which

Participants collectively envisioning and mapping how the project can tackle problems in Zambia's feed sector.

Participants mapping how the project will help existing networks and resources in Kenya's feed sector.

stakeholders were expected to contribute, and in what way, in order to achieve specific outcomes.

The process of analyzing the maps proceeded step by step and involved several feedback sessions with key stakeholders and participants. The preliminary maps for Zambia, Kenya and Nigeria (36 in total) were synthesized and merged into 12 maps (four for each) visualizing the problems and actors in each country's sector and the project's potential for systemic change. The Causal Loop diagram digitized using Stella Architect, a software that helps to visualize and communicate how complex systems work, and the value network maps were digitized in Miro, a digital collaboration platform designed to help teams create maps and diagrams remotely. Points for impact assessment along the project's timelines were discussed with stakeholders and implementing partners, taking into consideration the results framework of the project.

Section 4 provides the results of the workshops. It focuses on describing and explaining the final systems change maps for every country before presenting priorities and recommendations for impact assessment. We first present the results from the CLDs to explain the interconnectedness of the problems to be solved, followed by a visualization of the network of relationships among actors. Next, we present the socioeconomic potential of the project before pointing to key points for impact assessments in the short-term, mid-term and long term. Although it would be logical to follow the results framework of the project, this study only focuses on identifying all the potential impact points of the project without detailing activities that are in Norad-Fasa's monitoring, evaluation and learning plan (Cullhaj et al. 2022).

Photo credit: Agnes Chileya/WorldFish

A participant showing how the project will work with existing networks in Zambia's feed sector.

3. Norad-Fasa's systems theory of change

3.1. Zambia

Using the output of the workshop in Zambia, this section outlines the current problems and issues facing the Zambian feed sector and the existing network of actors that either address or influence the identified problems. Based on stakeholder systems mapping, the section shows how Norad-Fasa will tackle the problems by developing and scaling sustainable feeds based on new locally available fish feed ingredients.

3.1.1. Understanding challenges facing Zambia's aquatic food system

To understand the root causes and consequences of the main problems facing the Zambian aquatic food system, we synthesized the preliminary CLDs produced by the workshop. Although each group identified different ways of how these problems affect the country's aquatic food system, synthesizing and merging the three CLDs into one map provided a holistic understanding of the challenges facing the system, with a focus on fish feed.

Figure 2 shows the CLD developed during the workshop. The CLD depicts how different issues in Zambia's aquatic food system interact at multiple scales and across scales to negatively influence the system: inadequate funding in the fish feed industry, limited research activities on local fish feed ingredients, poor stakeholder links, limited opportunities for women and youths, a lack of technical knowledge on fish feeds, a lack of market knowledge, limited fish nutrition, low general knowledge on fish feeds from local ingredients, and limited knowledge on environmental management. Furthermore, the CLD illustrates how these immediate effects translate into limited access, availability and affordability of fish feeds as well as increased farm waste among small-scale aquaculture farmers in Zambia. In addition, the map shows how this, in turn, reduces household resilience to climate change, increases household food insecurity, poverty and rural unemployment. Drawing from the co-created CLDs and workshop discussions, we explain the complexity of the main problems and issues surrounding fish feeds in Zambia's aquatic food system.

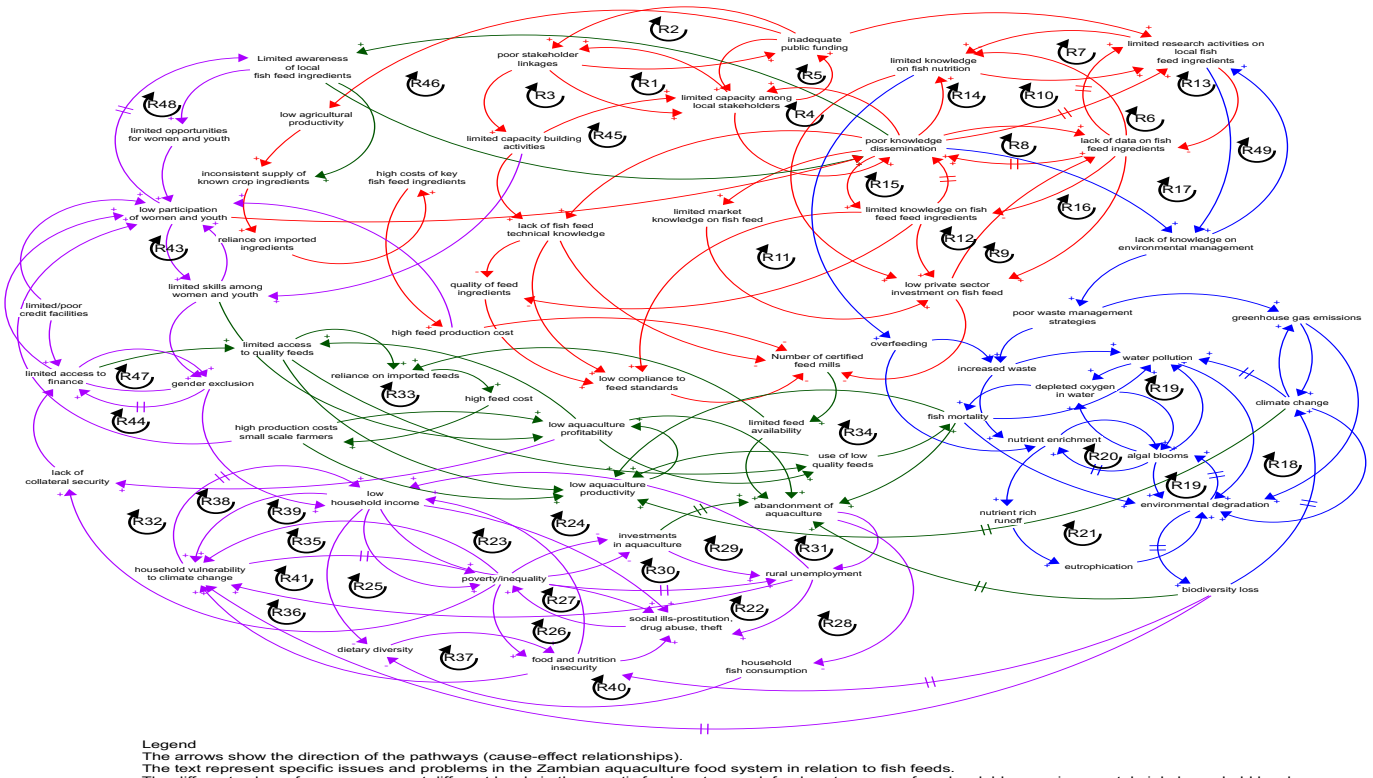


Figure 2. Problems and issues facing Zambia's feed sector.

First, inflation and a limited supply of local ingredients are the main reasons behind the high cost of feed production in the feed sector. Inflation increases the costs of raw materials, and the inconsistent supply of local ingredients leads to heavy dependence on expensive imported ingredients. This increases the cost of producing fish feed and, consequently, results in the current high prices of fish feed in the country's aquatic feed market. At the same time, high feed prices are a result of multiple issues at different levels of the value chain. For instance, the inadequate allocation of public resources lessens the capacity of stakeholders, weakens stakeholder links and reduces research activities on local feed ingredients.

With inadequate funding and poor stakeholder links, this results in limited opportunities for capacity development among local stakeholders, such as extension officers, feed technologists, feed millers and farmers, and also limits opportunities for collaboration with other stakeholders.

Similarly, limited collaboration and inadequate funding in the fish feed industry reduce capacity development opportunities such as training for researchers, technologists, extension officers and other relevant stakeholders. As a result, this hampers the ability to integrate and spread best practices and knowledge on fish feed (Figure 2, top of the CLD).

Limited capacity among local stakeholders explains why knowledge has been so poorly communicated. Sometimes research outputs or knowledge products are not packaged well for other stakeholders, such as feed millers and farmers, to use and understand easily. And at times, research outputs are too technical and not simplified for easy policy or extension use. The CLD shows that poor communication is a possible explanation for many of the problems in the aquatic feed sector: the lack of knowledge on fish nutrition among actors, the limited knowledge on fish feed ingredients, the lack of technical knowledge on how to make fish feeds, and the general lack of knowledge on fish feed. Similarly, the lack of research activities on local ingredients explains the absence of data on local fish feed ingredients. This lack of data increases the lack of knowledge on the nutritional requirements of fish and the lack of general knowledge of local fish feed ingredients (in terms of price, demand and supply) among farmers, feed millers and those in the private sector.

The result of all this is limited investment in Zambia's aquafeed industry, which, together with the challenges in complying with feed standards, reduces the number of feed millers in the country, constraining the supply of fish feed. This in turn affects the availability of quality fish feed, resulting in increased dependence on feed imports. This causes the cost of production to rise in the local feed industry, increasing the prices of fish feed. Similarly, the limited knowledge among feed millers and farmers on how to make fish feeds leads to poor-quality feeds in the country, resulting in low compliance levels among small-scale feed millers.

For women and youths in the sector, poor communication and poor stakeholder links limit opportunities for them (Figure 2, left side of the CLD), so they are often unable to participate as much they would like. High production costs and limited access to credit to purchase already expensive feeds further exacerbate the problem. Low participation of women and youths in aquaculture coupled with limited training opportunities reduce aquaculture skills among women and youths. This leads to both gender and social exclusion and other issues, such as limited access to finance and limited availability of quality feed in the Zambian market, that reduce access among small-scale aquaculture farmers to quality feeds.

Figure 2 also shows how the problems of high feed prices, poor access to quality feeds, lack of availability of feeds and gender exclusion explain the socioeconomic and ecological problems in Zambia's aquatic food system. The high cost of feed in the country increases aquaculture production costs. This in turn, together with limited access to quality feeds and limited fish farming skills, lowers the productivity of small-scale aquaculture, leading to reduced profits and thus income for farmers. The end result is that farmers often abandon aquaculture, which increases rural unemployment, lowers household fish consumption, shrinks the expansion of aquaculture activities and lowers household income. The effects of these socioeconomic issues in Zambia are high levels of poverty and

inequality, high household food insecurity and low household resilience against socioeconomic and ecological shocks.

Finally, poor communication of information and limited research on fish feed ingredients result in limited knowledge of environmental management in aquatic food systems (Figure 2, right side). This limits the available knowledge on the circular economy and environmental management, leading to poor waste management strategies among farmers and feed millers. Such strategies then increase environmental pollution, which raises greenhouse gas (GHG) emissions and water pollution. Emissions from the aquatic feed industry and aquaculture contribute to climate change, while high levels of water pollution reduce aquatic health, leading to higher rates of fish mortality and therefore low productivity and profitability of small-scale fish farmers. Overall, these problems have several negative feedback effects to the sustainable development of small-scale aquaculture systems in Zambia.

3.1.2. Understanding value networks in Zambia's aquatic food system

This section describes the existing network of actors and their relationships in Zambia's aquatic food system. Using the VNM tool, workshop participants identified key actors and their relationships by focusing on those who are either directly or indirectly experiencing these problems, those intentionally or unintentionally causing the problems and those preventing any possible resolutions to the problems, as well as those who have been neglected, overlooked or silenced.

By relating problems to the actor, it was possible to get a broader understanding of the country's aquatic food system to further understand the problems in the feed sector. Figure 3 provides a co-created VNM of Zambia's aquatic feed sector. It shows the network of actors and how they help address or influence the complex problems relating to fish feed. The VNM shows several groups of actors from

- the public sector, including the central government and its agencies, such as the Zambian Bureau of Standards (ZABS), Ministry of Fisheries and Livestock (MFL) and Ministry of Agriculture (MOA), as well as research institutes like universities, public research centers and public extension services;
- the private sector, including private extension companies, financial institutions, fish processors and agro-dealers, as well as feed millers, both small and large scale, such as Savanna Streams, Farm Feeds, Olympic Milling, Tiger Feeds, Novatek Animal Feeds, Skretting and Aller Aqua;
- grow-out farmers, hatchery farmers, crop farmers and livestock farmers;
- fish and crop farmers associations, as well as international and national NGOs;
- distributors, including transporters, supermarkets, retailers, fish aggregators, cold chains and wholesalers;
- household consumers.

The VNM reveals a sophisticated network of relationships among actors. The arrows show the direction of resource flow, and the letters along the arrows represent the type of shared resources. By focusing on the resources, we can see the type of relationship and how best to leverage the resources for the success of the Norad-Fasa project and beyond.

First, the VNM shows that fish farmers exchange resources with several actors in the system, namely feed millers, agro-dealers, extension officers, researchers, finance institutions, transporters and consumers. These fish farmers get their feed directly from commercial feed millers or indirectly from agro-dealers. However, these suppliers are often located far from rural areas, where most fish farmers operate.

Well-resourced farmers in Zambia produce their own fish feed, while others partner with feed millers to ensure a sustainable supply of feed. However, because of the growing number of small-scale aquaculture farmers, the supply of fish feed is not enough to meet the country's growing demand. Only a few large-scale millers export their feed to other countries, while most small-scale millers focus on the local market. Farmers get advice from public or private extension services regulated by the government and its agencies, such as the MFL. They also receive advice and funding from NGOs that try to support sustainable aquaculture development in the country.

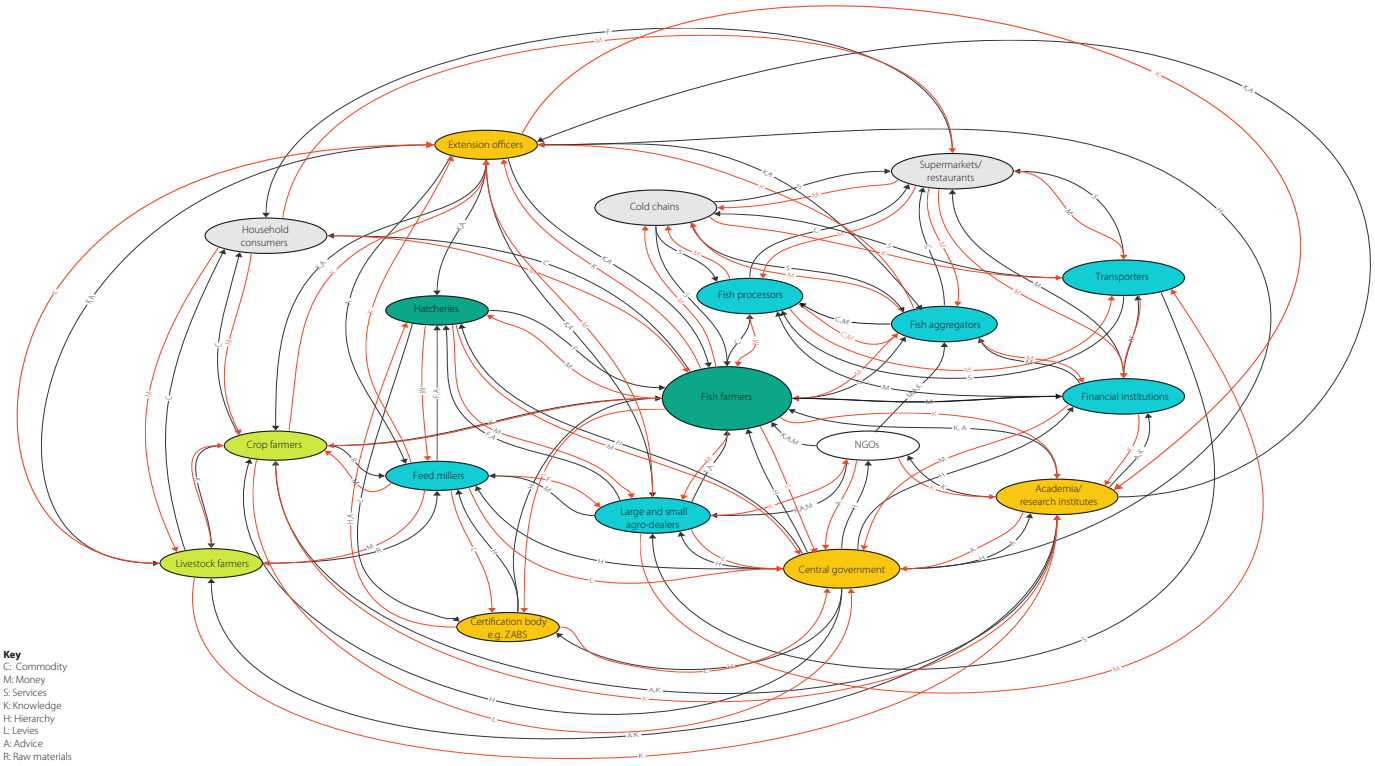


Figure 3. The VNM of Zambia's feed sector.

Fish farmers also receive advice on best feeding practices from feed millers. These farmers are also increasingly engaging with research institutes by participating in action research and experimenting and testing innovations on fish feed. During feedback sessions with researchers, fish farmers receive advice, accumulate new knowledge and gain new skills on fish feeding practices. They then supply their fish produce to fish aggregators, fish processors, wholesalers, cold chains or retailers, or sell directly to consumers. Local microfinance institutions (MFIs) finance the production, processing and marketing activities of fish farmers, with interest paid on loans. However, because of limited collateral, the majority of the farmers fail to access credit to expand their production.

There are several networks of feed millers with other actors in Zambia's aquatic food system. Feed millers buy raw materials for feed ingredients from livestock and crop farmers. They also import most of their key ingredients. Their feed products are certified by ZABS, a statutory body under the Ministry of Commerce, Trade, and Industry that is responsible for creating and maintaining, standards, quality control, quality assurance, quality inspection and certification. Feed millers exchange knowledge and advice with extension officers on the use and performance of the fish feed. Small-scale mills, in particular, are increasingly receiving support through NGOs, who in turn receive information from them that is important for their policy recommendations. Feed millers exchange information with and receive advice from research institutes as well, and local banks and MFIs finance their activities. To move their raw materials and distribute their feed products to the markets, feed millers work with local and regional transporters, who sell their services to most actors in the system. The activities of all actors are regulated by the central government.

3.1.3. Norad-Fasa and systemic change in Zambia's aquatic food system

The implementation of the Norad-Fasa project in Zambia has three key components that attempt to tackle the identified problems and issues in the country's aquatic feed sector. Through a participatory process involving collective envisioning and systems mapping, the workshop revealed several ways in which the project's activities will help transform or at least address the intertwined problems of availability, affordability and accessibility of quality fish feeds in the country, as shown in Figure 4.

Through the different activities linked to achieving these outcomes, the project will tackle multiple issues in the feed sector, which will have short-

term, mid-term and long-term consequences, both intended and unintended. First, through the various training opportunities throughout Norad-Fasa's life cycle, either directly from the project or indirectly through partner stakeholders, it will improve the capacity of fish farmers, feed millers and other stakeholders, such as extension officers. For example, training on new ingredients, sustainable feeds and feed formulation practices, as well as on the use of an open access database and printed manuals/booklets, will enhance the capacity of local stakeholders. The project will also tailor different types of training to the Zambian context, using YouTube channels and making digital announcements of workshops and their benefits via radio, WhatsApp and social media. In doing so, the project will help fish farmers, feed millers, extension agents and fish feed technologists become more knowledgeable about fish nutrition, local fish feed ingredients, marketing such ingredients and how fish feeds are made.

At the same time, in addition to spreading knowledge effectively, the various research activities will increase the availability and access to data on local fish feed ingredients. In the short to medium term, this will improve the quality of locally produced feed in Zambia. In the medium to long term, it will raise investments in the country's aquatic feed sector. This, in turn, will allow new players to enter the industry and so increase the number of feed millers. With more feed millers, and better feed, more quality fish feed made from local ingredients will become available.

As the demand for raw materials needed to make these feeds rises, suppliers will increase their production. More supply will then reduce the dependence on costly imported ingredients. Assuming controlled inflation, the use of local raw materials will lower feed manufacturing costs, which will remove barriers to entry and so attract more feed millers. This will ultimately reduce the feed prices seen in the country's feed industry.

For women and youths, communicating information about local ingredients, both digitally and through in-person training, will improve opportunities for them in the feed sector. In combination, better technical knowledge on local ingredients, greater public knowledge of fish nutrition, increased marketing information and reduced costs of feed production will all raise the participation of women and youths in the feed milling sector, meaning more small-scale feed millers. Women and youths will also have more opportunities to venture into small-scale aquaculture, reducing gender and social exclusion.

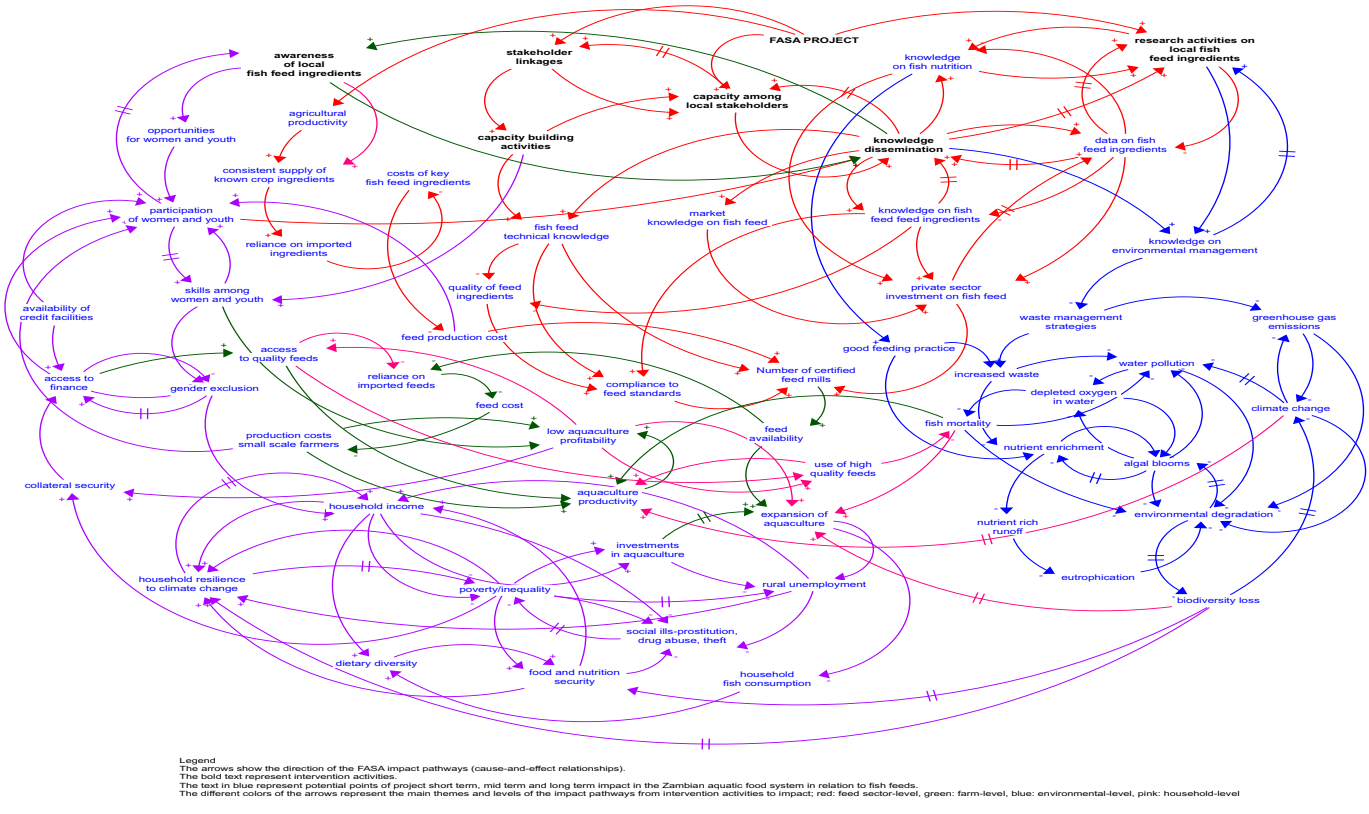


Figure 4. Norad-Fasa's systems TOC for Zambia's aquatic food system.

As quality feed becomes locally available and affordable, both women and youths will be able to access it. Norad-Fasa's use of gender and socially inclusive communications will ensure access to low-cost quality fish feeds developed by the project. This will have several positive effects, influenced by multiple interacting issues. Low feed prices will reduce the cost of fish production in the country's small-scale aquatic food system. This will in turn increase the productivity of small-scale aquaculture and thus farm profits.

For the environment, various research activities and greater public knowledge on environmental sustainability and climate change, with a focus on feeds derived from new local ingredients, will improve knowledge on waste management. Coupled with increased knowledge of the circular economy and waste management, farmers and feed milers will develop effective farm waste management strategies. The subsequent reduction in farm waste will decrease GHG emissions and water pollution and so improve survival rates among fish, which will increase the productivity and profitability of small-scale aquaculture.

This increased profitability in aquaculture will have several benefits for Zambia's aquatic food system. First, as aquaculture becomes more profitable, its contribution to household income also increases, leaving households with more money to buy food. This will lead to a decline in food and nutrition insecurity, poverty and income inequality among households.

Additionally, greater profits will allow farmers to invest more income into expanding their aquaculture activities. This will increase rural employment and household income, reducing social ills among youths such as drug abuse, theft, prostitution, etc. Furthermore, as small-scale aquaculture becomes more profitable and sustainable, fewer farmers will abandon their farms. This will not only reduce rural unemployment but ensure consistent fish consumption among rural households and reduce micronutrient deficiencies in rural parts of the country. Taken together, all of these factors will strengthen the capacity of households and communities to prepare, cope and adapt to socioecological and economic shocks. Similarly, increased income and rural employment has several feedback effects in the aquatic food system, such as better access to finance because of increased collateral security.

3.1.4. Norad-Fasa and value network change in the Zambian aquatic food system

The project's activities in Zambia are funded by Norad and implemented by WorldFish and its partners, WorldFish Zambia, the NRDC and Aller Aqua Zambia. Norad-Fasa has also partnered with NAGI Enterprise and Includovate to assess its impact on climate change and ensure that the project is socially and gender inclusive. The project will work directly work with

- the public sector, specifically the central government and its agencies, such as ZABS, the MFL and MOA, as well as research institutes like the NRDC and public extension services;
- the private sector, including private extension companies, agro-dealers and feed millers, both small and large scale, such as Butemwe Milling;
- farmers and their associations, including the Zambian National Farmers Union and the Aquaculture Development Association of Zambia, as well as crop and livestock ingredients farmers;
- local NGOs, such as Musika Initiative Zambia, a nonprofit company that focuses on deploying and scaling solutions to small- and medium-scale aquaculture;
- distributors, including feed ingredient transporters.

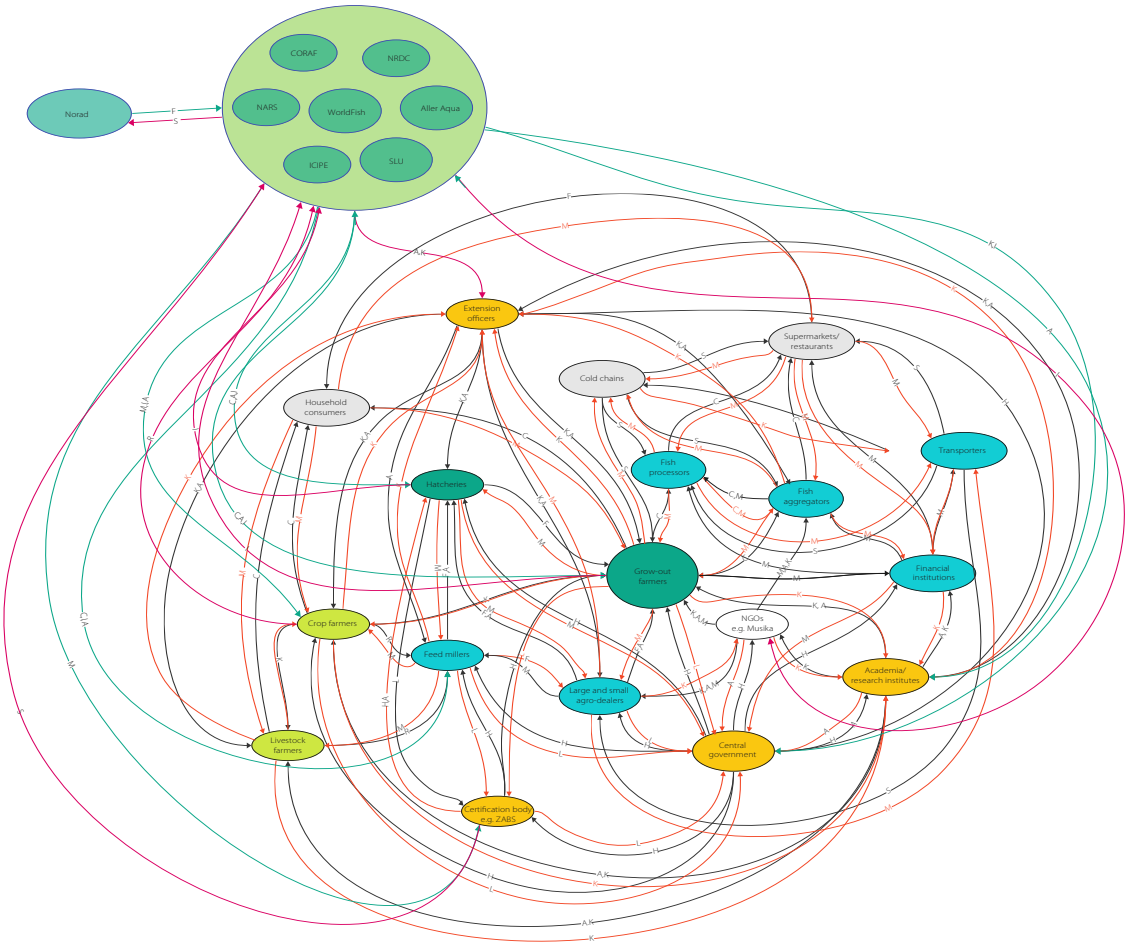
The project leaders from WorldFish Zambia gave a detailed presentation of how Norad-Fasa will work with various stakeholders in the country's aquatic food systems to achieve the desired outcome. After the presentation, the participants collectively mapped how the project will complement the existing systems networks, or at least reorganize them. Figure 5 shows the new networks of relationships in the process of contributing to systemic change.

First, the project will conduct experiments with the National Aquaculture Research and Development Centre on the nutrient requirements of new strains of tilapia, and Minsanfu on the requirements of local strains of tilapia and catfish. This process will strengthen the capacity of local research institutes and exchange knowledge and experience

between project researchers and local researchers. The project will also exchange information with crop ingredient farmers throughout Zambia, using various research activities to scope and identify all locally available ingredients in the country. The researchers will receive important information on the seasonal availability and quantity of the ingredients, and through feedback sessions farmers will receive information on the most profitable ingredients, as well as advice on how to manage farm waste. These farmers will also get new links to sell raw materials for crops to feed millers. The process will also engage transporters of feed and raw materials for their services.

The project will work directly with small-scale feed millers such as Butemwe Milling to build their capacity on how to make feeds and process raw materials and to increase their knowledge of the nutritional requirements of tilapia and catfish. At the same time, the project will work with large-scale commercial feed millers such as Aller Aqua Zambia and Novateck to develop fish feeds using local ingredients. Feed millers will receive up-to-date knowledge and data on fish nutrition, markets for local ingredients and validated feed formulas. In turn, the project will receive information and data from the feed millers and use it to improve experiments and increase the knowledge on fish feeds from local ingredents.

The project will also work with small- and medium-scale aquaculture farmers, both hatcheries and grow-out farmers. Since farmers are the end users of the developed fish feeds, the various research teams under the project will work with with farmers to access, test and use the feeds and evaluate their socioeconomic impact. The project has partnered Kemo Fish Farming Cooperative to do on-farm trials on the feeds that the project develops. As the project is implemented, reseachers will exchange knowledge and information with farmers and their associations, and vice versa. Farmers and their associations will receive advice and training on how to make and use feeds using local ingridients, while the project will share data and knowledge with farmers using the latest available digital tools.



Key
C: Commodity
M: Money
S: Services
K: Knowledge
H: Hierarchy
L: Levies
A: Advice
R: Raw materials
F: Funding
I: Information

Legend
The bubbles represent the main actors in the Zambian fish feed sector. The arrows show the network of relationships in terms of the exchange of resources.
The red and green arrows show the new relationships due to the Norad-Fasa project.
National Agriculture Research Systems (NARS), Swedish University of Agricultural Sciences (SLU)

Figure 5. Norad-Fasa in Zambia's value network.

The project will also work with with various government agencies to develop and scale fish feeds using new local ingredients. Implementing partners will work with the MFL and MOA to make recommendations that will inform policymaking on the development of fish feed using local ingredients. The project's activities will operate under the regulations of the central government, which will inspect how the feeds are developed and scaled using local ingredients to ensure they comply with standards set by ZABS. Scaling the intervention will involve sharing and exchanging both financial and nonfinancial resources between local NGOs, the MFL and other local authorities. Local NGOs such as Musika will be involved in scaling the products to attract more investment and reach wider groups. The project, farmers and partners will also exchange knowledge and information related to scaling.

3.2. Kenya

3.2.1. Understanding the challenges facing Kenya's aquatic food system

To understand the root causes and consequences of the main problems facing the Kenyan aquatic food system, we studied three preliminary CLDs that the workshop produced. Although the groups identified several issues that affect the Kenyan aquatic food system, synthesizing and merging the CLDs provides a holistic overview of the challenges facing the country's feed sector and aquatic food system. Figure 6 shows the co-created CLD visualizing the drivers and consequences of problems in the system. It illuminates how different issues in the system interact at and across multiple scales to influence the aquatic feed sector. The mapping process identified the high cost of feed, the limited availability of quality feeds and limited access to quality feeds as the main problems affecting the sustainability of aquaculture in country. These problems are a result of the limited capacity of local stakeholders and the paucity of research on local ingredients. At the same time, these problems have several interconnected consequences among value chains, farming systems and households.

With few development opportunities, the limited capacity of local stakeholders to integrate best practices into the fish feed sector reduces the spread of knowledge. For instance, research outputs on fish feeds are not communicated to those who need the information most, such as farmers, feed millers, policymakers and practitioners. This lack of knowledge on products will result in limited market knowledge on ingredients, in terms of type, seasonality, quantity, prices and demand. Similarly, this explains the limited knowledge on fish nutrition among feed millers, farmers and practitioners, resulting in a general lack of knowledge on local ingredients.

With the limited knowledge and market information on local ingredients and the limited knowledge on fish nutrition, investments in Kenya's fish feed industry have decreased and with it the number of local feed millers in the country. This, combined with limited knowledge on local ingredients and feed formulations among farmers and feed millers, reduces the availability of quality fish feeds in the feed market. Similarly, limited knowledge on feed formulations among millers reduces the supply of high-quality feed, leading to overreliance on imported ingredients. This, along with the limited availability of quality feeds in local markets, explains the high feed prices seen in Kenya's fish feed market.

In the Kenya's aquatic food system, there are not many fish feeds available (Figure 6). The CLD shows that poor public funding has limited research activities, leading to a lack of comprehensive and appropriate data on fish feed ingredients and the nutritional requirements of fish. Without comprehensive digital databases on these ingredients, feeds are inevitably of low quality. This is exacerbated by the limited technical knowhow on feed formulations among key stakeholders, such as extension officers and technologists.

At the same time, the fish feed industry faces problems associated with poor transportation, handling and storage of feed ingredients. Combined with low-quality feeds, the result is that few quality feeds are available in the country's aquatic food system.

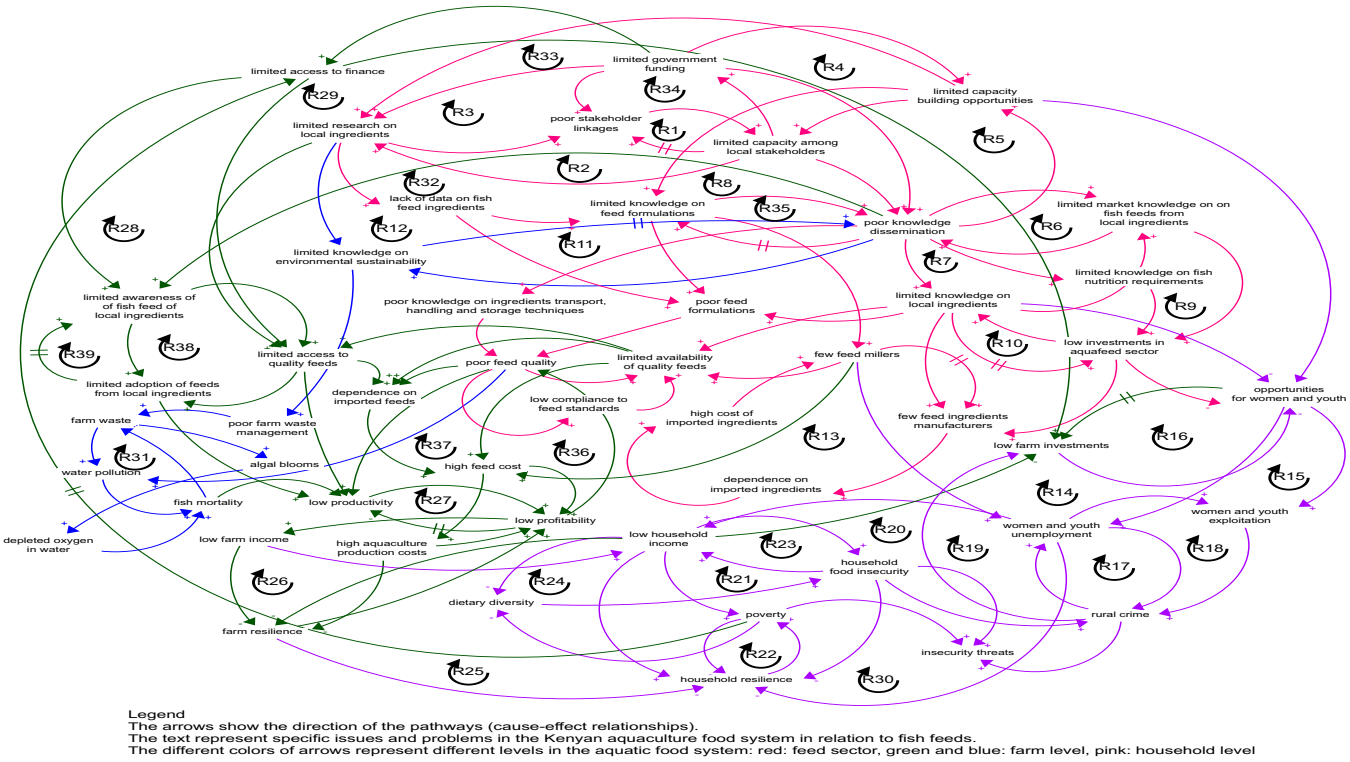


Figure 6. The problems and issues facing Kenya's feed sector.

To make matters even worse, farmers have limited access to the few quality feeds available because they lack the collateral security needed to apply for loans. On top of this, there are few credit facilities, and those that are available are not tailored to the needs and dynamics of small-scale aquaculture. Most small aquaculture farmers are poor and do not know how to maintain proper records to support their credit applications. Compounding these problems is the inability of stakeholders to raise awareness on how to make fish feeds using local ingredients. The overall result of all these factors is limited access to low-cost quality fish feeds.

The map in Figure 6 also shows how the limited capacity and lack of knowledge on environmental management strategies in relation to feeds affect Kenya's aquatic food system. The CLD shows that this overall lack of knowledge inhibits environmental sustainability among farmers and other stakeholders. This results in poor waste management, such as the rampant depositing of agricultural waste into rivers seen in Kenya. Poor waste management leads to water pollution, which, together with poor quality feed, poor feeding practices and limited skills, explains the high mortality rates of fish reported among many farmers.

The Specify shows how the different pathways converge at low farm productivity. That is, the limited access to high quality feeds, the limited availability of quality feeds, the high cost of feed and high rates of fish mortality together explain the low production levels among small-scale aquaculture farmers in Kenya. Low productivity results in low profits, which leads to higher production costs and feed costs.

The CLD also shows how the low profitability of aquaculture affects various livelihood outcomes in Kenya's aquatic food system, such as poverty, household resilience and food insecurity. Low profits mean fish farms contribute less to household income. As a result, households often sink into poverty and are unable to buy more foods to diversify their diets. Poor households in Kenya often do not have enough to eat and find it difficult to cope and adapt to the shocks brought about by climate change. Similarly, low farm income and limited farming skills in small-scale aquaculture explain why farm resilience in the sector is low. Because of this, farmers often abandon aquaculture in times of shocks, such as rising prices, the COVID-19 pandemic and the effects of climate change. The result is lower household incomes and higher rural unemployment.

The CLD also shows that low-income households find it difficult to invest in fish farming. Without such investment, there are fewer opportunities available for women and youths, leading to higher rates of rural unemployment. Because women and youths are unable to contribute as much to household income, poverty, food insecurity and low household resilience ensue, exposing them to exploitation, such as *jaboya* (sex for fish). This increases crime in fish farming communities, which, coupled with high food insecurity and poverty, poses threats to rural areas and Kenya at large.

Overall, the co-created CLD shows just how complex the problems surrounding fish feeds are. Kenya faces a shortage of quality fish feeds. The feed is also expensive, making it difficult for many farmers to remain in business. Similarly, participants identified issues surrounding access to fish feed. By collectively identifying the causes and consequences of the problems, it is possible to collectively envision how Norad-Fasa will tackle or at least help address these problems.

3.2.2. Understanding the value networks in Kenya's aquatic food system

This section describes the actors in Kenya's aquatic food system and their relationships. The workshop participants collectively identified the key actors who are either directly or indirectly experiencing the problems, intentionally or unintentionally causing the problems, preventing any possible resolution to the problems, as well as those who are neglected, overlooked or silenced. By attributing the problems to the actors, it was possible to get an in-depth understanding of the difficulties facing the fish feed sector. Figure 7 shows a simplified VNM that highlights the main actors and how they either address or influence the problems in the feed sector. The VNM identifies the following groups of actors:

- grow-out farmers and hatcheries
- private sector actors, such as fish aggregators, fish processors, input aggregators, local ingredient producers, feed millers, financial institutions, transporters and agro-dealers
- civil society organizations, including local NGOs, fish farmer cooperatives and lobby groups, like the Kenya Association of Manufacturers and the Association of Kenya Animal Feed Manufacturers
- public sector actors, including the central government, Ministry of Agriculture, Livestock and Fisheries, and certification bureaus, such as the National Environment Management Authority and KEBS
- research institutes, including the KMFRI, Jomo Kenyatta University of Agriculture and Technology (JKUAT) and the University of Eldoret (UE)
- household consumers.

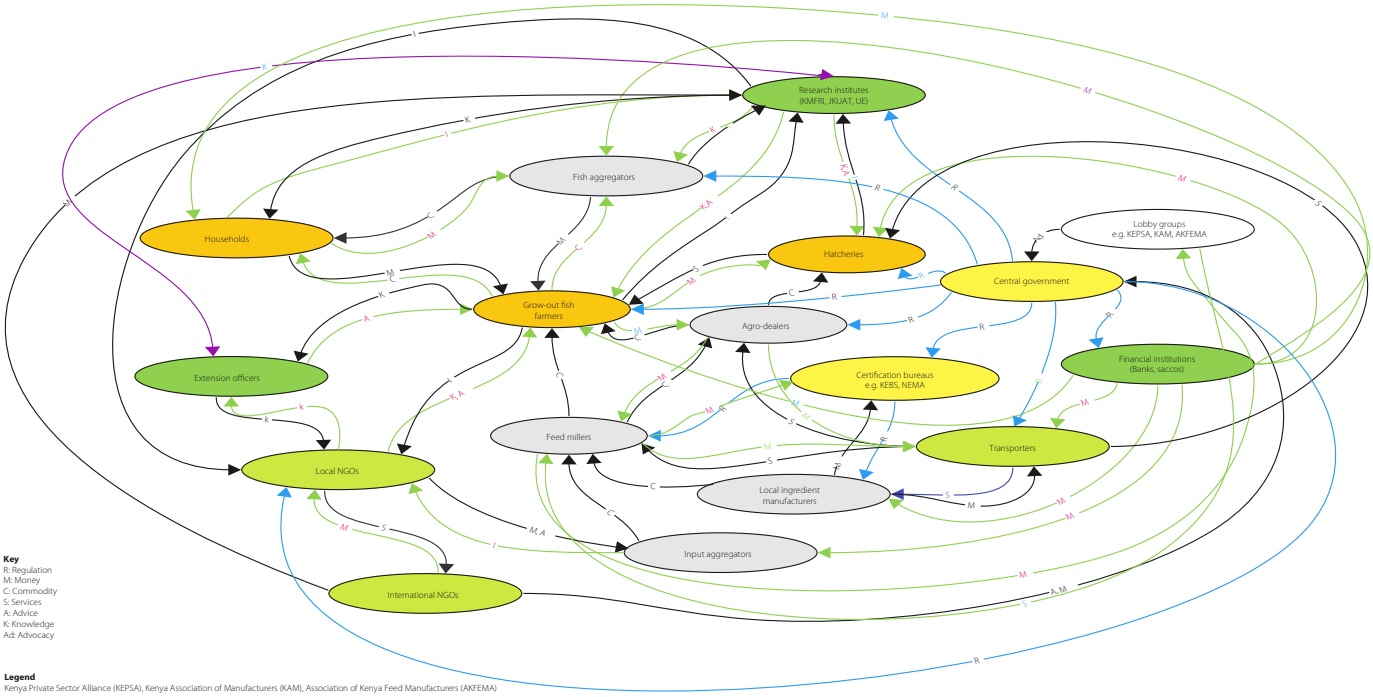


Figure 7. The VNM of Kenya's feed sector.

The workshop revealed a sophisticated exchange of resources in Kenya's aquatic food system. By focusing on this, we can see the type of relationships in the network and how best to leverage the resources so that the project is successful. First, the VNM shows that grow-out farmers and hatcheries are at the center of the problems. Grow-out farmers buy fish feed directly from feed millers or indirectly through agro-dealers. During transactions, farmers and feed millers do not share advice or knowledge on how to use or make fish feeds. As a result, this makes poor feeding practices and feed formulations even worse. Although local banks and savings and credit co-operative societies (***saccos***) offer credit to both grow-out farmers and hatcheries, banks often set collateral requirements that are beyond the reach of many farmers, making it difficult for them to access quality feeds.

Grow-out farmers and hatcheries are linked to both private and public extension officers as well as local NGOs that support the growth of the aquatic food system in Kenya. Farmers receive advice on best management practices, such as how to make and use feed. In exchange, farmers provide them with information that makes for important feedback for policymakers.

Several research institutes also work with farmers. In their activities, these institutes work with farmers to accumulate data. In return, farmers learn about the various functions of their fish farming businesses. Given the limited research activities on fish farming in Kenya, this relationship is still weak.

In addition, farmers sell fish to households, helping them meet their nutritional needs. They also sell their fish to aggregators, who in turn sell them to fish processors, supermarkets, wholesalers or restaurants. Currently, demand for fish in Kenya is growing, but supply is still limited.

The VNM also reveals how financial institutions interact with various actors surrounding fish feed. The map shows a bi-directional relationship between financial institutions and other actors, such as agro-dealers, producers of local ingredients, input aggregators, and grow-out farmers and hatcheries. As they try to start a business, expand business or provide a service, these actors receive loans from financial institutions and pay interest on it.

The central government plays a key role in regulating all activities in the sector. It provides guidelines and operating rules to its agencies, such as fisheries departments, research institutes and certification bureaus. This creates a viable operating environment for feed millers, farmers and others. However, given the inconsistency of policy and limited government resources, enforcement is often weak. This results in low compliance of feed standards and thus poor quality feeds on the market.

Transporters are also important in Kenya's aquatic feed sector. They provide services to feed millers, farmers, aggregators, fish processors, fish traders and local feed manufacturers. Although the importance of their services seems obvious, there is limited knowledge in Kenya on how to transport, handle and store ingredients. Without proper knowledge, the quality of ingredients cannot be guaranteed.

3.2.3. Norad-Fasa and systemic change in Kenya's aquatic food system

The implementing partner of Norad-Fasa gave a detailed presentation of the main components of the project, and how it will implement the related activities in Kenya. The project has three overarching components. First, it will enhance the capacity of at least two stakeholder groups to integrate best practices for a more sustainable feed sector and to adopt new knowledge on the nutrient requirements of multiple improved strains of tilapia and African catfish. To achieve this objective, the project will provide capacity development to local research institutes, feed millers, farmers and other stakeholders on how to process, store and make local fish feed ingredients.

Second, the project will identify and improve at least 15 local ingredients through various processing techniques and make sure that stakeholders in Kenya, including local millers and farmers, are able to use them. The project will provide farmers with new knowledge and data on the nutrient requirements of improved strains of tilapia and African catfish to make and adapt new local feeds. It will also hold training workshops and field demonstrations to improve the knowledge and capacity of millers, farmers and other stakeholders on how to use new ingredients.

Third, the project will help at least 3000 farmers access, test and use new feeds and feed solutions using the knowledge and innovations it develops. To achieve this, the project will

- co-develop integrated knowledge for enabling the scaling environment and strategies for scaling up the use of new feeds and feed management approaches in Kenya with stakeholders;
- build and operationalize strategic partnerships to scale the use of the project's innovations and knowledge;
- deliver strategic capacity development and public awareness campaigns in order to spread information about the knowledge, innovations and tools that the project develops.

Participants identified several pathways on how Norad-Fasa will address the problems of access, availability and affordability of fish feed in Kenya's aquatic food system. Figure 8 shows the different pathways emerging from the mapping of systemic change session. The CLD shows how developing the capacity of local stakeholders will ultimately increase the availability of quality feeds. The various research communications, workshops, training and information sessions will enhance the capacity of local stakeholders to efficiently integrate and make available the knowledge on the nutritional requirements of tilapia and catfish.

Communicating knowledge efficiently and effectively will have several benefits. It will improve market information on local fish feed ingredients, increase the availability of knowledge on local ingredients in terms of quantity, seasonal availability, prices and demand, and help farmers and feed millers learn how feed is made. All of this will raise investments and participation in the fish feed sector. This will increase the number of feed millers, who will increase the availability of high-quality fish feed in the market because they know more about local ingredients and how to make better fish feed.

Similarly, this will reduce the dependence on costly imported ingredients, making it easier to manufacture fish feed more efficiently in Kenya. This will, ultimately, result in lower prices of feed for farmers, which will reduce the cost of feed in aquaculture.

The several collaborative research activities to identify local ingredients and improve their quality will also help increase data on these ingredients. These activities will strengthen stakeholder links in the system, making it more effective and efficient to share knowledge among stakeholders, such as local research institutes, feed millers, farmers and NGOs. Access to knowledge will enhance the technical abilities of stakeholders to integrate best practices and teach them to relevant users, which will improve knowledge on feed types. In combination, these factors will increase the use of science-backed fish feed formulations.

At the same time, using local television broadcasting services, workshops, seminars and conferences to spread knowledge will improve how feed ingredients are transported, handled and stored, leading to better availability of high quality feed in the country's fish feed market. This will raise public awareness on the benefits of using local fish feed ingredients, making it easier to access and use local ingredients to make feeds. Meanwhile, these activities will increase knowledge on environmental management strategies in Kenya's aquatic food system, which in turn will improve waste management, leading to lower water pollution and fish mortalities. Taken together, all of these improvements will increase aquaculture productivity.

Another benefit of developing and scaling fish feeds using local ingredients is that it will help address the socioecological problems of poverty, household vulnerability to climate shocks and rural unemployment. Improved farm productivity increases farm profits and therefore household income. With higher income, families can spend more on different kinds of foods, which lowers food and nutrition security among aquaculture households. Also, households with more income are likely to invest a portion of it into expanding aquaculture. When they do, this creates income generating opportunities for women and youths. This is further supported by an increase in knowledge and skills needed for aquaculture. More opportunities for women and youths will reduce rural unemployment, leading to higher household income and thus lower crime. Having more opportunities will also reduce the exploitation of women and youths in the fishery sector.

On top of all this, making farms more profitable and reducing production costs will sustain aquaculture activities even in times of shocks. High farm resilience, low poverty and stronger household food security increase the ability of households and rural communities to cope with socioecological and economic shocks. When households have enough food and more income from fish farming, there is less idleness in rural communities, resulting in a greater sense of peace and reduced social security threats.

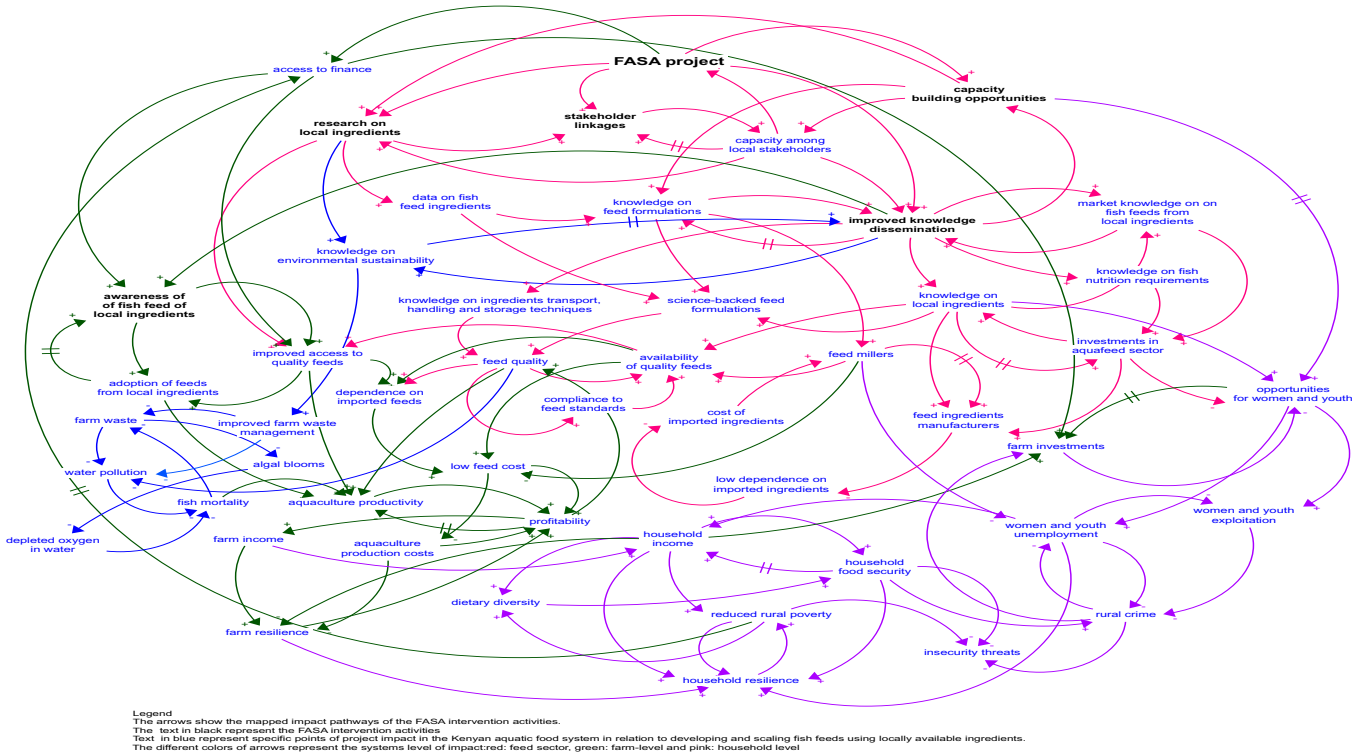


Figure 8. Systemic change in Kenya.

3.2.4. Norad-Fasa and value network change in Kenya's aquatic food system

The ICIPE will lead the implementation of the project in Kenya. The project has partnered with NAGI Enterprises, Includovate, the KMFRI, Kamuthanga Fish Farm, Machakos, Victory Farms Ltd, national universities such as the UE, the Jabali Fish Farm, BMUs, county governments and KEBS.

The lead implementing partner in Kenya gave a detailed presentation of how the project will work with various stakeholders in the country's aquatic food systems to achieve the desired outcomes. After the presentation, the participants mapped how Norad-Fasa will complement the existing systems network structure, or at least reorganize the networks during the course of the project. Figure 9 shows the new relationships brought by the project as it tries to transform systems. As it attempts to develop and scale fish feeds using local ingredients, the project's partners will exchange resources with various actors in Kenya's aquatic food system. First, the ICIPE will work with the KMFRI and the UE to identify and improve locally available ingredients. In doing so, the project will learn and exchange lessons from the experiences of these local research institutes in relation to fish feed sector.

The project will also receive the support of 10 local master's students while funding their studies at local universities and doing experiments at the ICIPE. The project's partners will also work with local feed millers to build their capacity and to exchange information and knowledge on local ingredients. In particular, feed millers will learn from the experiences and expertise on how to use BSF larvae as a protein-rich ingredient, along with other available ingredients, and how to process it. In turn, the partners will receive information to improve data and knowledge on insect-based fish feed ingredients.

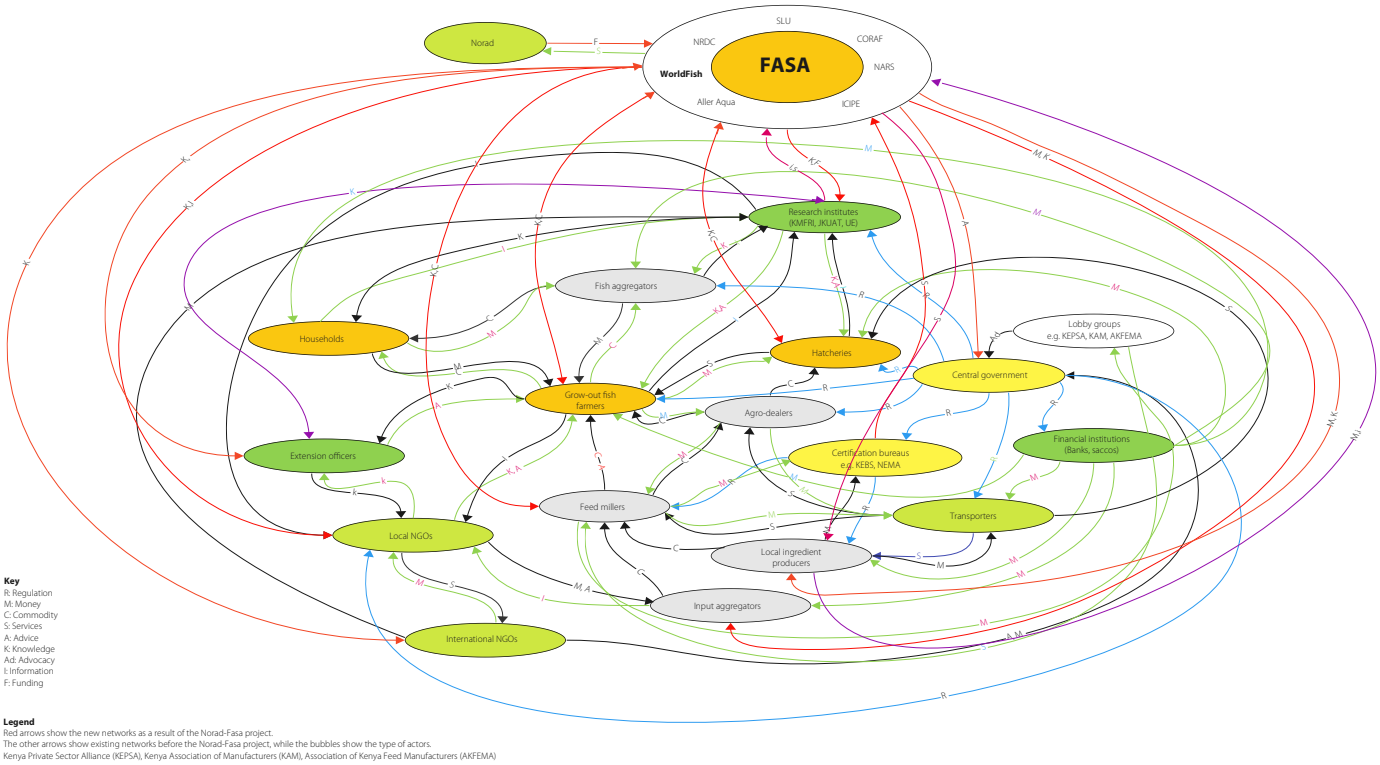


Figure 9. Norad-Fasa and value networks in Kenya's aquatic feed sector.

The project will also work with producers of local feed ingredients, especially those producing insects such as the BSF larvae and other ingredients. These producers will receive advice and knowledge on the best ways to grow, handle and store local ingredients. In exchange for producing these ingredients, they will also receive financial support.

The project will also work with several groups of large farmers, both grow-out and hatcheries, to test the developed feed ingredients on their farms. Through field demonstrations, these farmers will learn how to use local ingredients to make their own feeds and learn more about fish nutrition. In turn, the project will learn how to make better feeds so that it can scale them more widely to small-scale farmers in the country.

The project will also work with small-scale farmers during the scaling stage to improve access, testing and use of feeds made from local ingredients. Farmers will learn how to make fish feeds and to access information on the nutritional requirements of fish through digital platforms, television programs, demonstration farms and field days. In doing so, the project will also work with the Ministry of Agriculture, Lands and Fisheries to exchange information and advice on using local ingredients. Extension officers and other local NGOs working with fish farmers will receive training and knowledge on the use and benefits of local ingredients in fish feeds.

In addition, the project will work with KEBS to make sure that the developed feeds meet Kenya's standards. The project will work with county governments to ensure it complies with local bylaws and respects community standards. These governments will give Norad-Fasa access to information and in turn receive advice from the project. Similarly, the project will work with BMUs to ensure that it creates ways to communicate and scale strategies with the participation of communities.

3.3. Nigeria

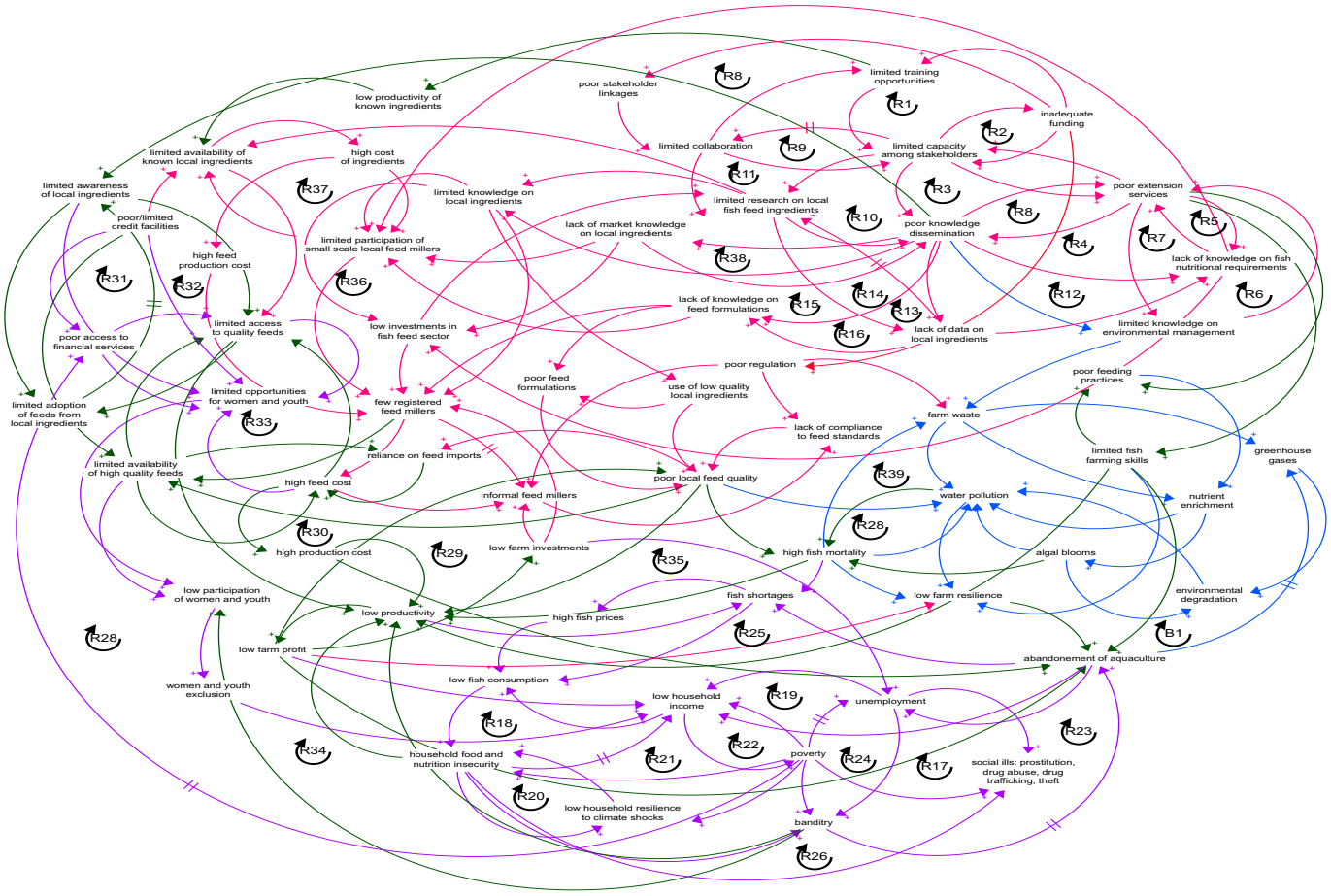
3.3.1. Understanding the challenges facing Nigeria's aquatic food system

The workshop revealed several issues and problems in the Nigerian aquatic food system in relation to fish feeds. Using CLDs, participants mapped the drivers and consequences of problems in the country's aquatic feed sector, as shown in Figure 10. There are multiple issues: limited availability of local ingredients, low market knowledge of these ingredients, limited knowledge of fish nutrition, limited knowledge on feed formulations and lack

of knowledge on environmental management. In general, the map shows different pathways through which these issues lead to low-quality feed, high feed costs, limited access to quality feeds and high food waste in Nigeria's aquatic food system. In addition, the CLD shows how these problems result in low productivity, water pollution, abandonment of aquaculture and limited opportunities for women and youths in the aquatic food system. It also shows how these intertwined issues ultimately explain high food and nutrition insecurity, low household resilience, poverty, gender exclusion and social security threats experienced among rural communities in Nigeria.

First, the co-created CLD shows how limited capacity among stakeholders, mainly because of limited training opportunities on fish feeds, limited collaboration and inadequate government funding on fish feeds, lead to poor extension services, poor knowledge dissemination and limited research activities on local fish feed ingredients. Poor communication on technical knowledge of fish feeds will result in limited knowledge reaching extension officers and therefore limited knowledge on fish nutrition reaching feed millers and farmers. Simultaneously, the limited research activities on fish feeds lead to lack of data on local ingredients. Taken together, all of these factors result in poorly made feed.

In addition to their effect on the availability of data on local ingredients, limited research activities on these ingredients leads to a general lack of knowledge of them among farmers and feed millers. This reduces investments in Nigeria's feed industry. Limited knowledge on feed formulations, lack of fish nutrition, general lack of knowledge on fish feed ingredients and the high cost of imported ingredients all add to the low levels of participation among small-scale feed millers in the country's feed sector. This reduces the number of feed millers in the Nigerian aquatic food system, which in turn reduces the availability of quality feeds for fish farmers. This forces farmers to rely on expensive feed imports and creates opportunities for collusion among the remaining millers, leading to inflated prices.



Legend
The arrows show the direction of the pathways (cause-and-effect relationships).
The text in black represent specific issues and problems in the Nigerian aquatic food system in relation to fish feeds.
The different colors of the arrows represent the main themes of the pathways from cause to effect; red: feed sector-level; green: farm-level; blue: environmental-level; pink: household-level

Figure 10. Drivers and consequences of problems in Nigeria's aquatic feed sector.

In addition, poor enforcement of standards by the government certification bodies, and the desperate search for alternative low-cost feeds, creates a thriving environment for informal, unregistered feed millers, who also often produce feeds of inconsistent quality that does not meet set standards. The result is a lack of quality feed available for aquaculture farmers.

The consequences of this are significant for Nigeria's aquatic food system, especially because limited viable credit opportunities for aquaculture farmers reduces their access to low-cost quality feeds, which are already limited. The high cost of feed and the increased use of poor-quality feeds lead to low productivity. This decreases the profitability of small-scale aquaculture. With less income coming from aquaculture, households have less money to spend. The result is higher levels of poverty and food insecurity among rural Nigerian households.

Low profits also hamper further investments in aquaculture, so many farmers abandon aquaculture altogether. With fewer opportunities for employment, women and youths contribute less to household income. At the same time, the decreased productivity and increased rates of abandonment result in a lower supply of fish in rural communities. The resulting fish shortages reduce household consumption, inhibiting dietary diversity. The effects of this are a high prevalence of micronutrient deficiencies among rural communities.

Another cause of gender and social exclusion is limited access to quality feeds and the high cost of feed in Nigeria, which leaves women and youths with fewer opportunities to participate in small-scale aquaculture. When they are excluded from aquaculture, they contribute less to household income, which can lead to poverty, food and nutrition insecurity, and even criminal activities such as theft, prostitution and banditry.

The CLD shows that a lack of knowledge among farmers and feed millers on environmental management strategies increases farm waste, which also increases water pollution. Polluted water increases the rates of fish mortality, reducing the productivity and profitability of aquaculture. Similarly, high rates of fish mortality, limited skills and low profitability all hinder the resilience of aquaculture farms, so many farmers abandon aquaculture in times of sudden shocks.

3.3.2. Understanding the value networks in the Nigerian aquatic food system

This section describes the current network of actors and their relationships in Nigeria's aquatic food system. Participants worked in three groups to identify the key actors who are directly or indirectly experiencing the problems, intentionally or unintentionally causing the problems, preventing any possible resolutions, as well as those who are neglected, overlooked or silenced actors. By relating problems to the actors, it was possible to get a broader understanding the aquatic food system and the complex problems in Nigeria's feed sector. Figure 19 provides a simplified VNM highlighting the main actors and how they help address or influence the problems in Nigeria's aquatic feed system.

The VNM identifies the following groups of actors:

- grow-out farmers and hatcheries who are either in the Catfish Farmer Association of Nigeria (CAFAN) or the Tilapia Aquaculture Development Association of Nigeria (TADAN), as well as crop ingredient farmers who are affiliated with the All Farmers Association of Nigeria and/or the Seed Entrepreneurs Association of Nigeria
- private sector feed millers, such as Olam, Skretting, Top Feed and Aller Aqua, as well as fabricators, importers of fish feed ingredients and fish processors
- distributors, such as agro-dealers, fish traders/mongers, crop ingredient aggregators and transporters
- household consumers, fish retailers and fish wholesalers
- enablers and regulators, including NGOs, financial institutions, universities and public research institutes, the central government, the Federal Department of Fisheries and Agriculture, as well as government agencies such as the Agriculture Research Council of Nigeria (ARCN), National Agency for Food and Drug Administration and Control (NAFDAC) and the Standards Organization of Nigeria (SON).

From the map, grow-out farmers and hatcheries relate to several actors in the system. Farmers buy their fish feed directly from feed millers. Because only a few large-scale feed millers like Olam, Skretting, Top Feed and Aller Aqua dominate the formal feed sector in Nigeria, the supply of fish seed is often outstripped by demand, pushing prices up. Farmers also receive feed indirectly through agro-dealers, who supply them with other aquaculture inputs as well. Although agro-dealers are important players in the sector, they do not provide advice to farmers in terms of how to use the supplied feeds. Farmers receive advice from extension officers, NGOs and other research institutes about aquaculture, the nutritional requirements of fish and correct feeding practices. However, without better technical skills and more widely spread knowledge, advice often fails to reach farmers. In addition, farmers pay transporters to ship their feed, other inputs and their produce to the market.

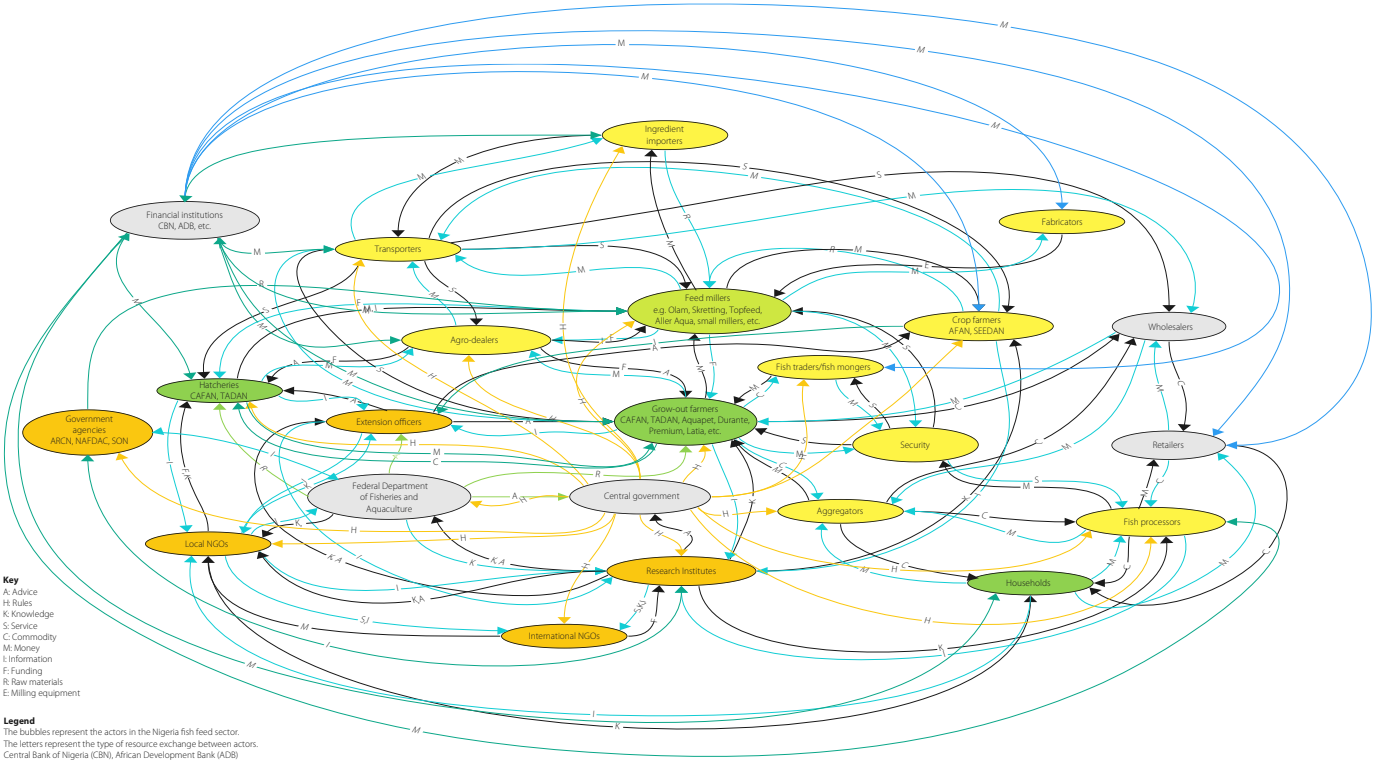


Figure 11. The VNM of Nigeria's feed sector.

Several types of financial institutions influence fish farmers: (i) banks, such as the Central Bank of Nigeria and the African Development Bank, (ii) MFIs, such as the Agricultural Cooperative and Rural Development Bank and the National Poverty Alleviation Programme and (iii) microfinance banks and NGO MFIs. Most of the financial institutions are located too far from fish farmers, and sometimes require collateral requirements that are beyond their resource base. Farmers are also linked to fish aggregators, fish processors, wholesalers, retailers and households as buyers and consumers of their produce.

The map also shows the complex relationships between feed millers and other actors in the system. Feed millers are linked to producers of crop ingredients, mainly maize, cassava, ground nut, soybean, yam, plantain, banana, cowpeas, millet, sorghum, rice and wheat. However, the nutritional composition and knowledge of feed ingredients is limited, such that Nigeria still depends on importers, who usually charge high prices to import ingredients because of inflation. Millers also link to transporters, whom they pay to distribute their feed to clients. In addition, these feed millers are financed by local banks and MFIs.

The VNM also shows the role of regulatory bodies in the feed sector. Government is the sole actor as the aquaculture legislative instrument in Nigeria. The central government mandates the NAFDAC, SON and ARCN to monitor, inspect and check for compliance in the feed industry. The government sets the policies and rules of the industry, policing how financial institutions, NGOs and other

research institutions operate in the sector. The Federal Department of Fisheries and Aquaculture (FDFA) and the Federal Ministry of Agriculture and Rural Development (FMARD) provide technologies and innovations like fish handling equipment as well as techniques of feeding and smoking fish, while research institutes and international NGOs provide policy advice to the government.

3.3.3. Norad-Fasa and systemic change in the Nigerian aquatic food system

There are several ways in which the activities of the Norad-Fasa project will tackle the problems of high feed costs, poor feed quality, limited availability and accessibility as well as excess farm waste and gender and social exclusion. Figure 12 shows the ways through which the different activities of the project will transform the country's aquatic food system while addressing the problems surrounding the cost, availability and access of fish feeds. The different pathways and interactions of different processes, activities, outcomes and impact represent the systems-based TOC that informs impact assessments.

First, the project aims to train and increase the collaboration of feed millers, farmers and other stakeholders, such as extension officers, on local ingredients. Enhanced capacity of at least two stakeholders in the feed sector will ensure the knowledge is communicated more effectively and increase research activities in the sector. Using workshops, television programs, conferences and written materials to spread awareness of fish nutrition will improve the public's knowledge of the nutritional requirements of tilapia and catfish. Spreading the knowledge of feed formulations more widely will help feed millers, farmers and other stakeholders learn more about them.

In addition, communicating knowledge of research on local ingredients effectively will increase the knowledge of these ingredients as well as market information in terms of price, seasonal availability and demand. This in turn will lead to more investment in the feed sector and greater numbers and participation of formal small-scale feed millers in the sector. This will boost the availability of quality feeds, reduce reliance on feed imports and lower the price of feeds and drive out informal feed millers, increasing compliance.

At the same time, an increase in research activities on local ingredients and in knowledge of them in terms of processing techniques and nutritional composition will increase their quality. Coupled with greater knowledge of local ingredients, how to make feeds and better access to data, this will improve feed formulations among farmers and feed millers, reducing the number of informal feed millers and thus leading to higher quality fish feed in local markets.

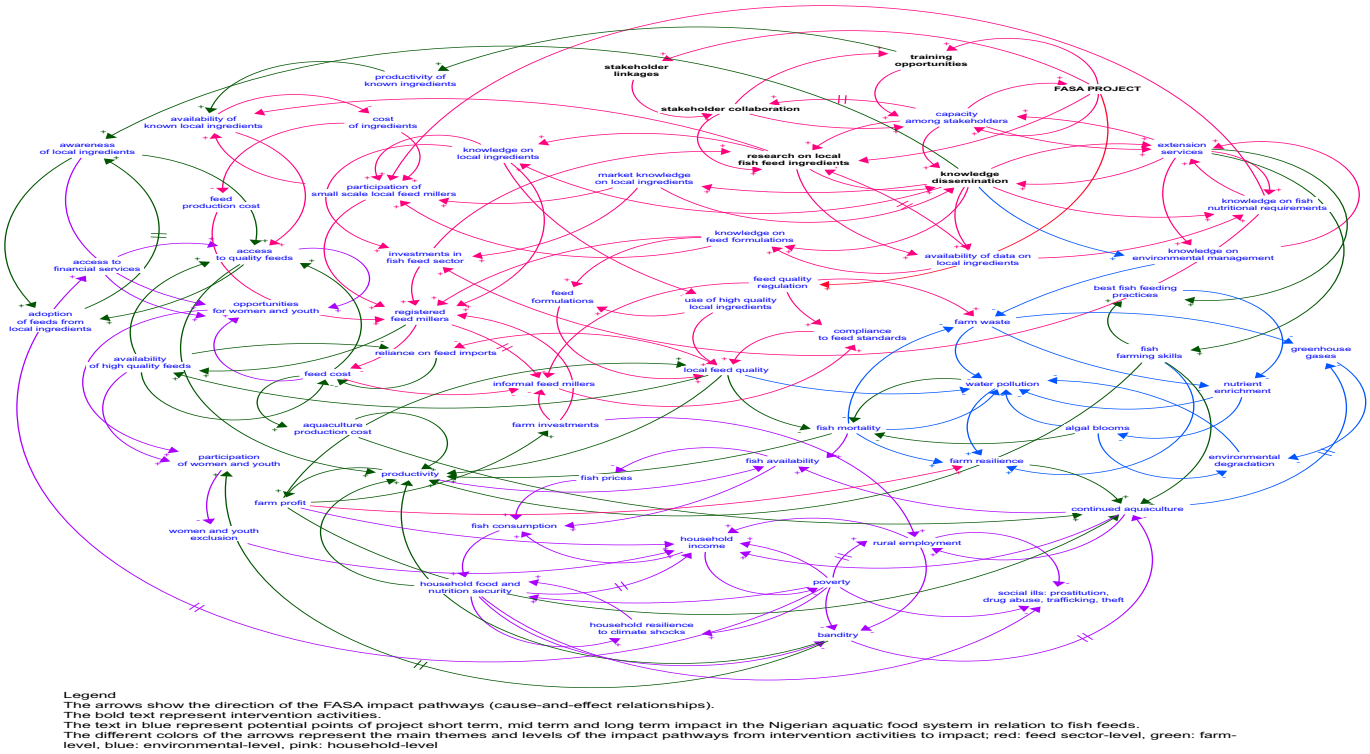


Figure 12. Norad-Fasa and systemic change in Nigeria's aquatic food system.

The public awareness activities of the project will increase access and use of fish feed from local ingredients. Similarly, increased availability of quality feeds in the market at low prices will improve access to feed for different groups of farmers. Meanwhile, wider knowledge of environmental management strategies will decrease waste among farmers and feed millers and in turn water and environmental pollution.

The CLD also shows what the effects of improved availability, improved access to quality feeds, lower feed prices and better waste management will have on Nigeria's aquatic food system. First, lower feed prices will decrease the cost of aquaculture production. Combined with increased availability and use of quality feeds and lower rates of fish mortality, this will improve productivity and therefore profitability. More profit improves the aquatic food system for farms, households and communities in multiple ways. It increases the contribution of aquaculture to household income, leading to lower rates of poverty and household food insecurity. It also increases investments in aquaculture, creating jobs for rural women and youths and reducing rural unemployment. In addition, higher productivity will increase the supply of fish in local markets and make more fish available for household consumption, which increases dietary diversity and household food security.

The CLD also shows how improved access to quality, affordable fish feeds will improve opportunities for women and youths. More women and youths will participate in aquaculture, contributing more to household income and strengthening their resilience to shocks. This will lead to lower rates of poverty and other social ills such as prostitution, theft, robbery, drug abuse and trafficking, and to a more peaceful society overall.

3.3.4. Norad-Fasa and value network change in Nigeria's aquatic food system

CORAF is implementing Norad-Fasa's activities in Nigeria. The project will work with grow-out farmers and hatcheries, small-scale and large-scale feed millers, crop farmers, local institutes, civil society organizations, and the government and its agencies, including the Federal Department of Agriculture and Fisheries, the SON, NAFDAC and ARCN. Figure 13 shows the new relationships between actors as a result of the project as it tries to address the pressing challenges in Nigeria's feed sector.

During the course of the project, different actors will work with each other, exchanging resources, both financial and nonfinancial, to achieve the desired outcome. First, the project's partners will work with local research institutes, both universities and public research centers.

The project will work with the Nigerian Institute for Oceanography and Marine Research, CORAF as well as both local and international universities. Together, they will identify potential local ingredients and conduct experiments, exchange information and knowledge on fish nutrition, increase market information for local ingredients, teach farmers and feed millers about the nutritional composition of local ingredients, and tackle other research-related issues that influence the activities and envisioned impact of the project. While doing so, the project will help develop the capacity of research institutes and increase their engagement with communities. This exchange of knowledge is also important for WorldFish and its partners as they try to advance knowledge on developing and scaling local fish feeds using local ingredients in SSA and beyond.

Second, the project will work with local feed millers, both small and large scale. The purpose of engaging large-scale feed millers like Skretting, Aller Aqua, Top feeds and Olam is to make it easier for actors to learn about local ingredients in Nigeria. Through demonstrations and workshops, the project will build the capacity of local feed millers and share the latest available information on how to process ingredients and make feeds. While working with feed millers, the project will encourage ingredient crop farmers to share resources. Different groups of crop farmers will have new or more links with feed millers. As new information on local ingredients becomes available, more feed millers will demand local ingredients from crop farmers. In turn, the crop farmers will also share knowledge and information with local research institutes, other farmers, feed millers and the project's partners. As they share information, these farmers will receive advice and market information on the most profitable crop ingredients. Third, the project will work with small-scale and large-scale tilapia and catfish farms, and

form long-term relationships between farmers, feed millers and research institutes. Some of the farms include but are not limited to Premium Aquaculture, Myira Farms, Latia, Great Aquaculture, Graceful AFFI, Aquapet and Durapet. During the course of the project, different groups of farmers from TADAN and CAFAN will share resources with small-scale feed millers and researchers from partner organizations. Farmers will have the opportunity to test and use the developed fish feeds using new ingredients. Through field days, workshops and demonstrations, farmers will learn more about fish nutrition. During this process, they will share information and receive advice from researchers on fish nutrition and feed formulations.

Norad-Fasa will also work with government agencies as it tries to develop and scale fish feeds using local ingredients. The central government will regulate all the project's activities in Nigeria. The project will work with the Federal Department of Agriculture and Fisheries to exchange information on local ingredients in the country and create and share new knowledge with other stakeholders. The SON, NAFDAC and ARCN will inspect, monitor and check that the ingredients and feed formulations developed as part of the project comply with government standards. In turn, the project will advise the government on policies. It will also train local extension officers and other stakeholders in the fish feed value chain on how to use local ingredients in feeds.

In summary, the workshop revealed clear ways for the Norad-Fasa project to increase the skills and resources of stakeholders involved in Nigeria's aquatic system, and how these new networks can support systemic change.

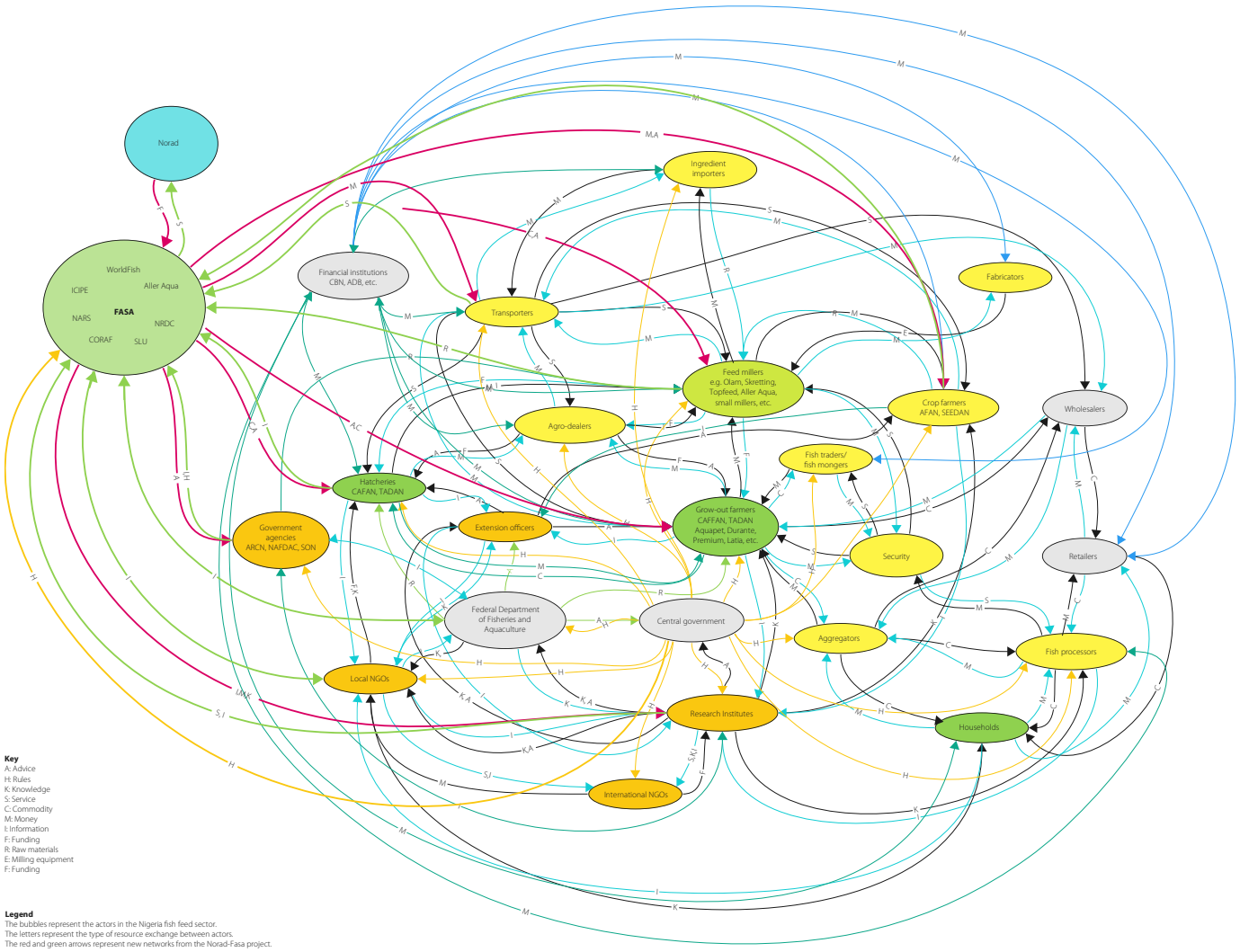


Figure 13. Norad-Fasa and value networks in Nigeria's aquatic feed sector.

4. Priorities for impact assessment and evaluation

Based on a synthesis of the co-created CLDs, this section presents the priorities for impact assessment of the Norad-Fasa project. Figure 14 shows the project's co-created systems TOC and the proposed impact assessments to capture the systemic wide effects of its activities in Zambia, Kenya and Nigeria. Drawing from the systems change map, it is important to differentiate between short-term, mid-term and long-term impacts of the project.

4.1. Short-term impact assessment

Assessing the short-term impact of the project will focus on evaluating research and capacity building activities among feed millers, farmers and other stakeholders. Based on the timeline of the project's activities, this assessment will be done in 2024–2025. By focusing on farmers and millers who attended capacity development activities, such as training sessions, visited demonstrations farms or attended field days, the assessment will focus on the following:

- changes or improvement in knowledge among farmers on how feeds are made
- knowledge of fish nutrition
- market information of local fish feed ingredients
- knowledge of how to process these ingredients
- transporting, handling and storing ingredients
- knowledge of opportunities in small-scale aquaculture
- knowledge of environmental sustainability
- availability and access to data on local ingredients (Figure 14, yellow bubbles).

By understanding these factors, it is possible to understand how in the short-term the project is addressing problems in the aquatic food systems of the three countries. This assessment will involve interviews and focus group discussions with farmers, local feed millers, staff from local research institutes, extension officers and other stakeholders involved in the capacity building activities.

4.2. Mid-term impact assessment

The mid-term assessment will come in 2026. It will attempt to assess the effect of changes in knowledge on feed formulations, fish nutrition, markets, opportunities in small-scale aquaculture and environmental sustainability gained through the project. Variables of focus will be (i) improved feed formulations and feed quality, (ii) new feed services and feed businesses established by farmers, youth cooperatives and other stakeholders, (iii) millers that change or improve their products based on knowledge and innovations developed by the project and (iv) NGOs, private sector partners or extension service providers that incorporate the project's knowledge and innovations into their offerings or services to farmers. This study will focus on the project's impact on the availability, access and use of quality low-cost fish feeds (Figure 14, blue bubbles). The assessment will combine qualitative and quantitative methods in the form of interviews, a survey and focus group discussion among feed millers and farmers.

4.3. Long-term impact assessment

The long-term impact assessment will try to understand the impact of the project on accessing and using feeds and ingredients that it develops. While assessing the accumulated knowledge and changes in behavior, the assessment will prioritize the impact of access and use of the feeds on the productivity and profitability among farmers who test new fish feeds as well as cooperatives promoting, testing and using these feeds. The assessment will also focus on changes in the income, fish consumption and resilience of households and in the participation of women and youths (Figure 12, dark and light green bubbles). It will make use of household questionnaires, focus group discussions and interviews to obtain a better understanding of the systemic socioeconomic impacts of the project.

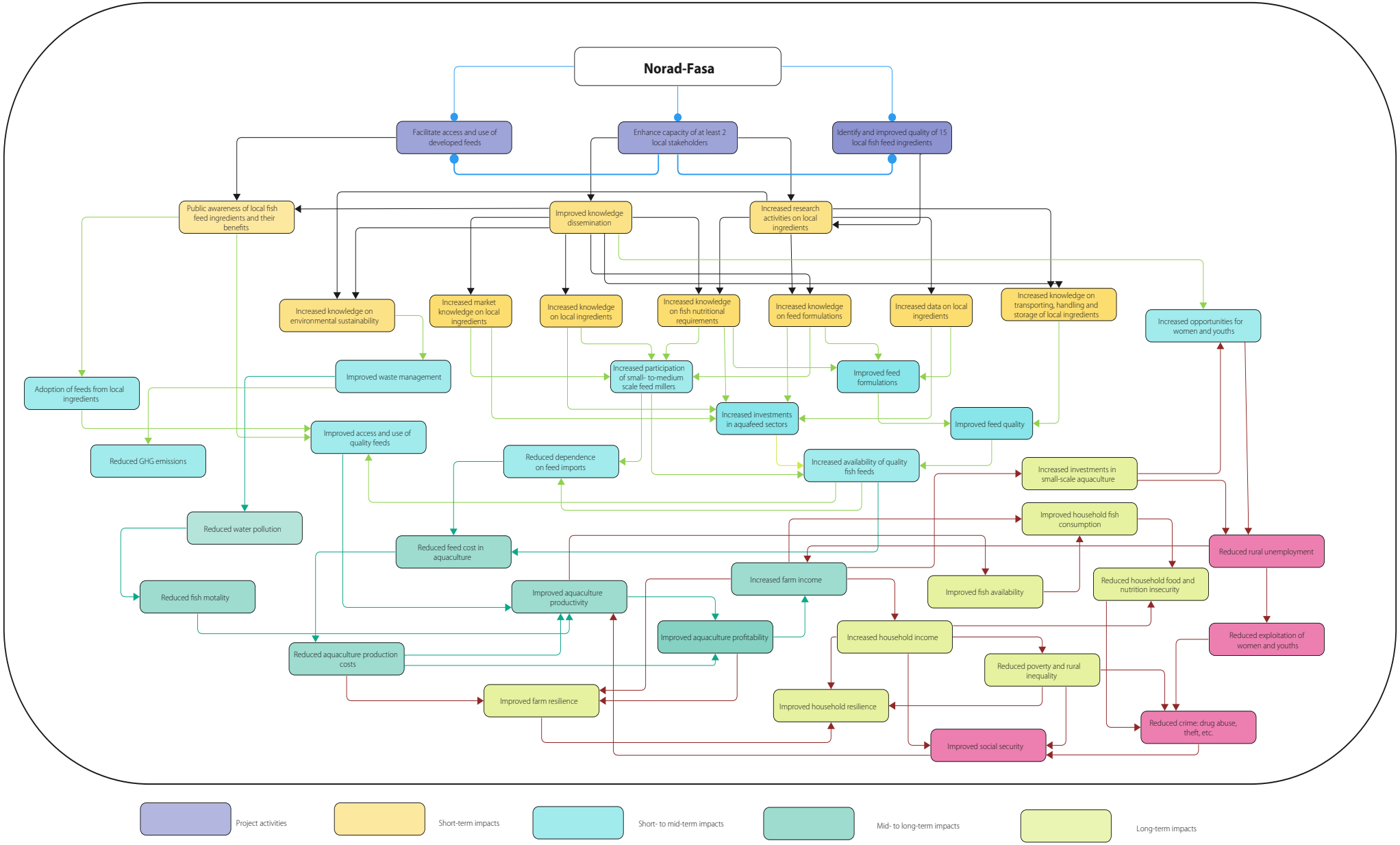


Figure 14. Norad-Fasa's systems TOC and impact assessment points.

Recommendations

It is important for the impact assessment to focus on both the intended and unintended consequences of the intervention since the project has potential to influence different parts of the aquatic food systems in question. Based on the systems maps in this report, it is necessary to profile and identify who the project's activities will likely impact, either directly or indirectly.

It is important to differentiate the short-term, mid-term and long-term impacts of the intervention. Accordingly, the project leaders must make sure that different activities such as training sessions, workshops, information sessions, demonstrations by different partners and farm trials are synchronized to ensure effective follow-up evaluations.

Implement, where appropriate, practical measures for consistently informing all project stakeholders and for equal participation by those who could be affected at suitable stages of impact assessment, including feed millers, demonstration farms, local research institutes, National Agriculture Research Services and local partners.

Improve local stakeholder collaboration to leverage existing networks and resources to achieve the project's objectives in a timely manner.

References

Brummett RE, Lazard J and Moehl J. 2008. African aquaculture: Realizing the potential. *Food Policy* 33(5):371–85. doi: 10.1016/j.foodpol.2008.01.005

Chia SY, Macharia J, Diiro GM, Kassie M, Ekesi S, van Loon JJA, Dicke M, Tanga CM and Gao Z. 2020. Smallholder farmers' knowledge and willingness to pay for insect-based feeds in Kenya. *PLoS One* 15(3):1–25. https://doi.org/10.1371/journal. pone.0230552

Cullhaj M, Ceccarelli V, Burcham L, Ali S, Ghazali S, Manyise T, Yossa R and Dam Lam R. 2022. Monitoring, evaluation and learning (MEL) plan: Development and Scaling of Sustainable Feeds for Resilient Aquatic Food Systems in Africa (FASA) project 2022–2027. Penang, Malaysia: WorldFish.

Dentoni D, Cucchi C, Roglic M, Lubberink R, Bender-Salazar R and Manyise T. 2023. Systems thinking, mapping and change in food and agriculture. *Bio-Based and Applied Economics* 11(4):277–301. doi: 10.36253/bae-13930

[DOF] Department of Fisheries. 2017. Department of Fisheries 2016 Annual Report. Chilanga, Zambia: Government of Zambia, Department of Fisheries.

European Commission. 2018. Value chain analysis: Aquaculture value chain analysis in Zambia, 2. Brussels European Commission.

Fagbenro O and Adebayo O. 2005. A review of the animal and aquafeed industries in Nigeria: A synthesis of the formulated animal and industry in sub-Saharan Africa. Rome: FAO.

Falch O. 2014. Strong growth predicted for aquaculture: Shrimp and tilapia expected to more than double by 2030. Oslo, Norway: Inocap. https://admin.mekke.no/data/downloads/284/Fish2030- prospectsforaquaculture.pdf

Genschick S, Kaminski AM, Kefi AS and Cole SM. 2017. Aquaculture in Zambia: An overview and evaluation of the sector's responsiveness to the needs of the poor. Lusaka Zambia: WorldFish and the Department of Fisheries.

Hecht T. 2007. Review of feeds and fertilizers for sustainable aquaculture development in sub-Saharan Africa. FAO Fisheries Technical Paper. Rome: FAO.

Kaminski A, Gellner M, Giese D, Jabborov S, Lootz M, Lundeba M, Nyika B, Patt N, Sadeghi A and Siachinga M. 2019. Opportunities and challenges for small-scale aquaculture in Zambia.

Kaminski AM, Genschick S, Kefi AS and Kruijssen F. 2018. Commercialization and upgrading in the aquaculture value chain in Zambia. *Aquaculture* 493(1):355–64. doi: 10.1016/j.aquaculture.2017.12.01

[KMFRI] Kenya Marine and Fisheries Research Institute. 2017. Kenya's aquaculture brief. Mombasa, Kenya: KMFRI.

[KNBS] Kenya National Bureau of Statistics. 2020. Economic survey Nairobi. Niarobi, Kenya: Kenya National Bureau of Statistics.

Leeuwis C, Boogaard BK and Atta-Krah K. 2021. How food systems change (or not): Governance implications for system transformation processes. *Food Security* 13(4). doi: 10.1007/s12571-021-01178-4

Meadows DH. 2008. *Thinking in Systems: A Primer*. Hartford, US: Chelsea Green Publishing.

[MOA and MFL] Ministry of Agriculture; Ministry of Fisheries and Livestock. 2016. Second National Agricultural Policy 2016. Lusaka, Zambia: Government of Zambia Ministry of Agriculture and Ministry of Fisheries and Livestock.

Munguti J, Odame H, Kirimi J, Obiero K, Ogello E and Liti D. 2021b. Fish feeds and feed management practices in the Kenyan aquaculture sector: Challenges and opportunities. *Aquatic Ecosystem Health and Management* 24(1). doi: 10.14321/aehm.024.01.12

Munguti J. Obiero K, Orina P, Mirera D, Kyule D, Mwaluma J, Opiyo M, Musa S, Ochiewo J, Njiru J and Ogello, E. 2021a. State of aquaculture report in Kenya 2021: Toward nutrition sensitive fish food production systems. Nairobi, Kenya: Techplus Media House.

Nyandat B and Owiti GO. 2013. Aquaculture needs assessment mission report. Report: SFFAO/2013/24. FAO SmartFish Programme of the Indian Ocean Commission. Ebene, Mauritius: FAO.

Nyonje BM, Charo-Karisa H, Macharia SK and Mbugua M. 2011. Aquaculture development in Kenya. Towards food security, poverty alleviation and wealth creation aquaculture development in Kenya: Status, potential and challenges. Nairobi, Kenya: Samaki News.

Opiyo MA, Marijani E, Muendo P, Odede R, Leschen W and CharoKarisa H. 2018. A review of aquaculture production and health management practices of farmed fish in Kenya. *International Journal of Veterinary Science and Medicine* 6:2:141–48. doi: 10.1016/j.ijvsm.2018.07.001

Sterman JD. 2000. *Business Dynamics: Systems Thinking and Modelling for a Complex World*. New York: McGraw.

Sterman JD. 2018. Fine-tuning your causal loop diagrams. Accessed on March 4, 2022. https://thesystemsthinker.com/fine-tuning-your-causal-loop-diagrams-part-i

Stroh P. 2015. *Systems Thinking for Social Change*. Chelsea Green Publishing. White River Junction, Vermont: Chelsea Green Publishing. https://www.chelseagreen.com/product/systems-thinking-forsocial-change

Theriault V and Smale M. 2021. The unintended consequences of the fertilizer subsidy program on crop species diversity in Mali. *Food Policy* 102. doi: 10.1016/j.foodpol.2021.102121

Udo I and Umanah S. 2017. Current status of the Nigerian aquafeed industry: A review. *International Journal of Innovative Studies in Aquatic Biology and Fisheries* 3(1):14–22.

Vega H. 2015. Review of systems thinking for social change: A practical guide to solving complex problems, avoiding unintended consequences, and achieving lasting results. *Foundation Review* 7(3). doi: 10.9707/1944-5660.1258

Wilkinson H, Hills D, Penn A and Barbrook-Johnson P. 2021. Building a system-based theory of change using participatory systems mapping. *Evaluation* 27(1):80–101.

Williams A, Kennedy S, Philipp F and Whiteman G. 2017. Systems thinking: A review of sustainability management research. *Journal of Cleaner Production* 148:866–81. doi: 10.1016/j.jclepro.2017.02.002

Appendix. Workshop program

Development and Scaling of Sustainable Feeds for Resilient Aquatic Food Systems in Sub-Saharan Africa (FASA)

Norad-Fasa Systems-Based Theory of Change Workshop: Zambia, Kenya, Nigeria

Date:
Location:

Understanding complex problems and existing networks in the aquatic feed sectors	
08:00–08:30	Welcome and tea
08:30–09:00	Welcome remarks
SESSION 1: MAPPING PROBLEMS IN SMALL-SCALE AQUACULTURE SYSTEMS	
09:00–09:30	Guidelines for mapping issues and challenges in aquaculture (aquatic feed sector)
09:30–12:00	Group activities: Mapping issues and challenges in aquaculture (participants break into two groups)
12:00–12:30	Group presentations of CLDs and reflections
12:30–13:30	Lunch
SESSION 2: MAPPING VALUE NETWORKS IN THE AQUATIC FEED SECTORS	
13:30–14:00	Guidelines for mapping networks in the aquatic feed sectors
14:00–16:00	Group activities: Mapping value networks in aquaculture (participants break into their groups)
16:00–16:30	Tea break
16:30–17:00	Group presentations of VNMs and reflection by participants
17:00–17:30	Presentation of the Norad-Fasa project (objectives, activities, partners)

Mapping systemic change from the Norad-Fasa project	
SESSION 3: MAPPING SYSTEMIC CHANGE USING CLDs	
08:00–08:30	Welcome and tea
08:30–09:00	Guidelines on mapping systemic change for the Norad-Fasa project
09:00–09:15	Presentation of the three main objectives of the Norad-Fasa project in laymen's terms
09:15–12:00	Group activity: Mapping the potential impact of the Norad-Fasa project (participants break into their groups)
12:00–12:30	Group presentation of systemic change maps and reflection by all participants
12:30–13:30	Lunch
SESSION 4: MAPPING NETWORK CHANGE IN THE AQUAFEED SECTOR	
13:30–14:00	Guidelines for mapping network change because of the Norad-Fasa project
14:00–15:30	Group activity: Mapping network change (participants break into their groups)
15:30–16:00	Tea break
16:00–17:00	Group presentation of network change maps and reflections by all participants
17:00–17:30	Closing remarks

Workshop participants in Zambia.

Workshop participants in Kenya.

Workshop participants in Nigeria.

About WorldFish

WorldFish is a leading international research organization working to transform aquatic food systems to reduce hunger, malnutrition, and poverty. It collaborates with international, regional, and national partners to co-develop and deliver scientific innovations, evidence for policy, and knowledge to enable equitable and inclusive impact for millions who depend on fish for their livelihoods. As a member of CGIAR, WorldFish contributes to building a food- and nutrition-secure future and restoring natural resources. Headquartered in Penang, Malaysia, with country offices across Africa, Asia, and the Pacific, WorldFish strives to create resilient and inclusive food systems for shared prosperity.

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