Data-driven Aquaculture technical and financial training guide

Tanzania, 2022

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Introduction

Background

The aquaculture sector in Tanzania has great potential. This is due to the growing demand for locally produced fish, population growth and declining supply from wild catch. However, the aquaculture sector has not unlocked its full potential as it lacks proven examples, best practices, practical knowledge and skills, technology and quality inputs.

For the Tanzanian aquaculture industry to develop, it is crucial to improve farmers' technical and economic performance in both extensive pond and cage systems. Currently, many fish farmers make a loss due to inefficient decision-making and farming strategies. Gaining insights into farmers' training needs can help the sector to develop tailor-made training methods to increase farmers' production, business profitability and sustainability. Current training courses are based on outdated, inaccurate, or international literature and therefore not tailor-made to the situation in Tanzania. Each country has specific conditions in terms of its climate, market, costs, and educational levels and therefore requires training methods which cater to these specific conditions.

A data-driven training method tailored to the specific Tanzanian farming conditions allows for systemic sector development by contributing to different elements of the system. The training itself would allow trainers to help farmers improve their farming strategy by giving tailor-made training and advice. The training will help farmers collect and analyse their data and prepare their business case. By supplementing technical training with financial training, their business cases have better chances of surviving through successful application for loans and investments.

The training guide & training tool

Proper training can help farmers to professionalize their farms in a way that they could attract investments and become commercially viable. For the sector this would also have positive consequences as aquaculture institutes may receive contemporary and local data, which can be used to tailor the curricula to the Tanzanian context. By tailoring the training to the local context, the distance between education and employment can be reduced.

For the development of this **technical and financial training guide**, data has been collected at 5 farmers in Tanzania; 2 cage farmers and 3 pond farmers. The data has been recorded over a period from February to August 2022. The technical guide starts with an analysis of the recorded data. Based on these observations, a range of topics are introduced that will be addressed in the tailor-made training section. Following the same method, a range of financial topics is covered.

Accompanying this training guide, one can find a **training tool** in Excel. The training tool contains a technical dashboard and data registration form. Data recorded in the registration form is automatically visualised in the dashboard, in which the parameters for the different technical dimensions are incorporated.

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2. Technical Analysis

Data collection & measurements

During six months, data were collected from farmers. For each farmer, the feed conversion rate (FCR) and special growth rate (SGR) were calculated as farm productivity and efficiency indicators. Next, each technical parameter recorded during the data collection was analyzed and compared with the FCR and SGR. In this way, the influence of these parameters on the farm productivity and efficiency. Based on this analysis, training goals are established together with training material to fill these knowledge gaps.

	Ponds farmers		Cage farmers		
Parameters on average	Farm 1	Farm 2	Farm 3	Farm 4	Farm 5
FCR	**0.93**	**0.81**	**0.75**	**1.52**	**1.05**
SGR	**-**	**2.65**	**0.4**	**1.5**	**1.36**
Temperature morning	28.1	28.2	25.1 ºC	24.7	25.2
Temperature afternoon	35.2	32.2	26.9 ºC	25.7	26.7
Oxygen morning	2.5	3.8	4.9	6.2	5.11
Oxygen afternoon	10.1	8.2	6.6	7.3	6.0
PH morning	7.9	7.5	7.5	7.4	7.9
PH afternoon	7.9	7.5	7.5	7.5	8
Ammonia	<0.05	0.05	<0.05	<0.05	<0.05
Nitrite	<0.1	0.1	<0.01	<0.01	<0.01
Nitrate	<0.5	<0.5	0.5	<0.5	<0.5
Secchi depth	21	34	55	>150	123
Feeding strategy	Restricted feeding	Restricted feeding	Response feeding	Restricted feeding	Response feeding
Feeding times	21.2	2.7	2	3	2.6
Recorded mortality rate	>1%	>1%	>1%	>1%	11%
Actual mortality	53%	95%	-	-	-
Stocking density fish/me	7	-	30	49	16

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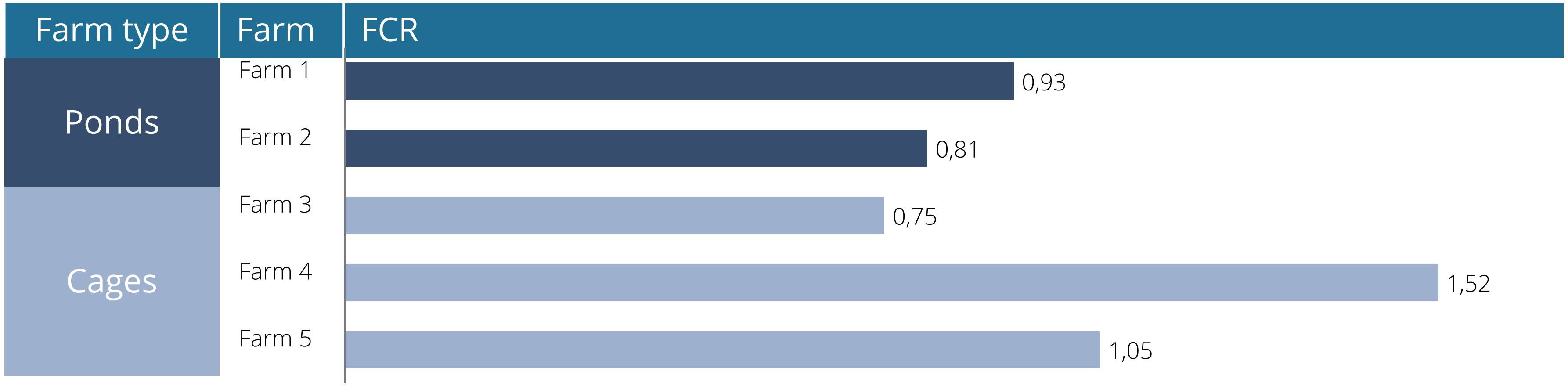
FCR – Feed Conversion Rates

On average, the FCR measured on the five farms was very low, too low to be considered reliable. Only one farm has an FCR that can be regarded as realistic. After speaking to farmers about their data collection, **three main problems** could have caused the differences.



1. In some cases scales were broken and actual amount of feed given was poorly recorded.

2. In some cases there was miscommunication between the farm management and employees. Procedures were not always clear and issues with registration were often found.

3. In some cases stocking, harvest and sampling information was poorly registered. It was therefore not always clear how many fish were actually stocked and harvested.

Based on the information above it is clear that there is a specific training gap in data collection on the farm. Collecting data and doing a proper analysis will allow farmers to take control of the farm. Before the data collection on a farm including the management of employees is arranged it will be hard and inefficient to make specific changes to address the FCR. Training in Tanzania should therefore include a part of data collection and employee management.

SGR – Special Growth Rate

Most SGRs are relatively low (the guideline is usually around 2%). This can also be seen in the small harvests among the participating farmers. A longer growth rate means more investments in costs such as labor but also a longer time before the cash flow starts for starting farms. A long growth rate can therefore cause significant problems for Tanzanian farmers. The low growth rate can be caused by various causes that will be analyzed in the rest of this tool.

Farm type	Farm	SGR
Ponds	Farm 1	
	Farm 2	2,65
Cages	Farm 3	0,40
	Farm 4	1,50
	Farm 5	1,36

* Due to a lock of harvesting data no SGR could be calculated for farm 1

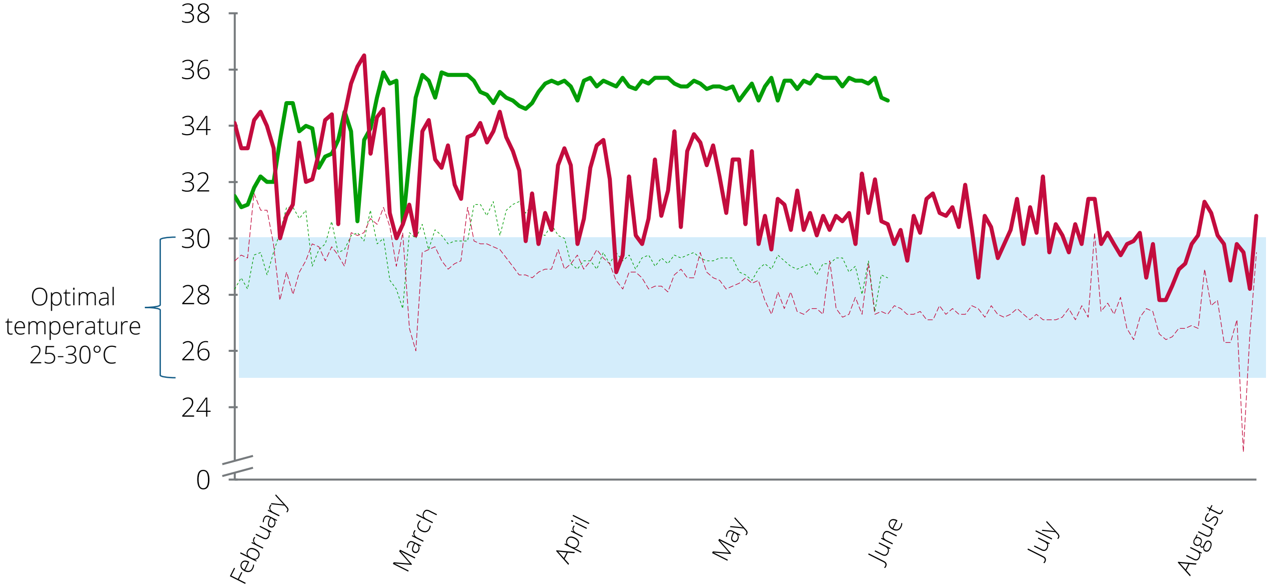
Water temperature

The farmers measured the temperature, and the results can be seen below. The cage farmer results sometimes seem on the low side, but nothing extreme or unexpected. The only training goal for cage farmers could be site selection to select parts of the lake with minimal temperature changes.

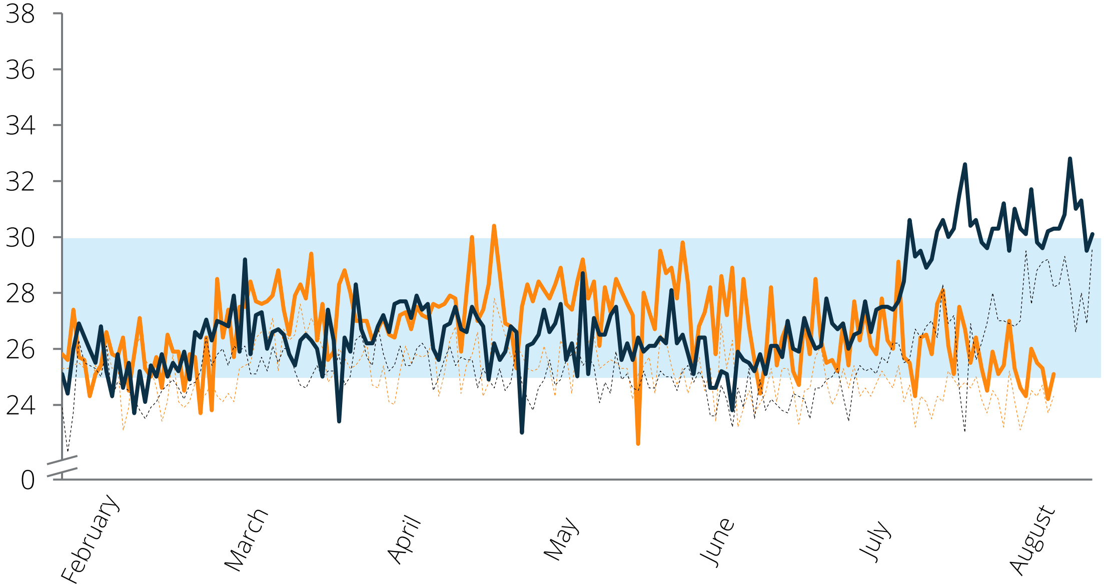
The situation for pond farmers is, however, more concerning. The issue found is two-folded. The first issue is the afternoon temperature that in both farms significantly exceeded the 30C. Nile tilapia is uncomfortable with this temperature. The other problem is the large fluctuations in water temperature between the morning and afternoon. An average difference of more than 7 degrees was recorded at one of the farms, while the other had an average difference of five. These problems likely were caused by the low water level of the ponds caused by the water shortage in Bagamoyo. As tilapia prefers a stable environment, these differences can be considered significant and severe obstacles to profitable and sustainable fish farming.

Consequences of the problems mentioned can be **slow growth** (reported by the majority of farmers), **high FCR**, and **weak immune systems** leading to more chances of diseases and health problems (one pond farm mentioned significant problems with parasites leading to increased mortality. Training goals should therefore be aimed at **site selection**, but especially for pond farmers at avoiding high-temperatures daily water temperature fluctuations.

Pond farm water temperature, in degrees Celsius °C
February – August 2022



Cage Farm water temperature*, in degrees Celsius °C
February – August 2022



Farm 1 Morning
Farm 1 Afternoon
Farm 2 Morning
Farm 2 afternoon
Farm 3 Morning
Farm 3 Afternoon
Farm 5 Morning
Farm 5 Afternoon

Notes: *To maintain legibility, only two of the three cage farms are presented in the graph.

Oxygen levels

Oxygen was measured both in the morning and afternoon. The results can be found below.

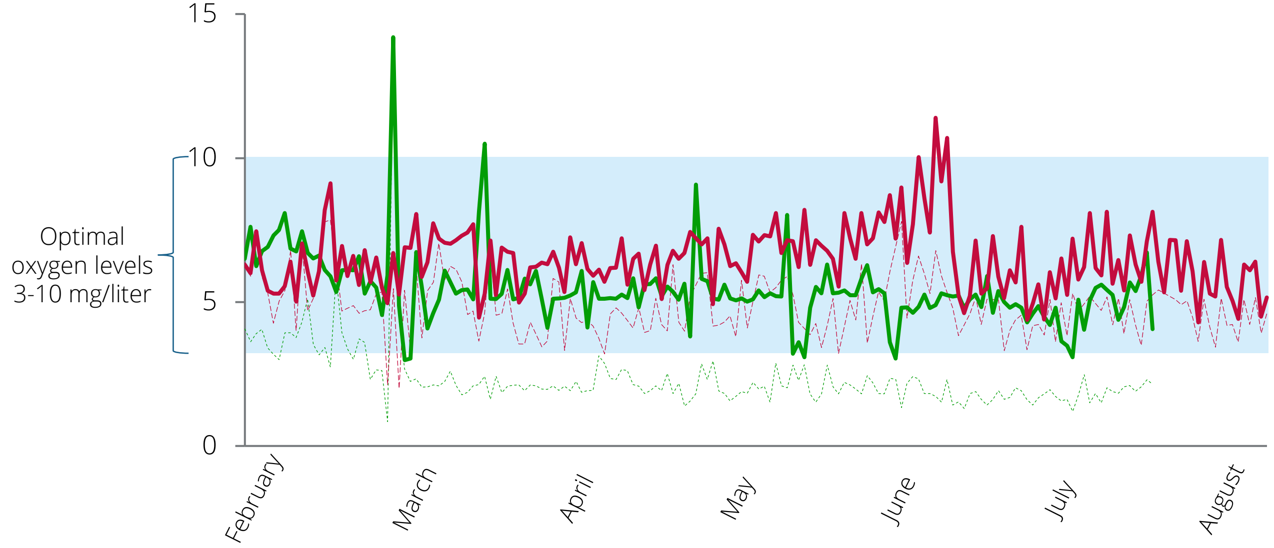
For cage farmers, no direct issues were found. The only surprising fact was that in all farms, the oxygen levels in the afternoon were higher than in the morning. This is the opposite of what one would suspect in cage culture. Typically, the enormous densities of fish consume oxygen throughout the day, and the oxygen levels recover at night. Due to the relatively low stocking densities, the cages are not used to their full potential. This might respond to Lake Victoria's high fish mortality caused by upwelling. In the entire lake, farmers lower their stocking density to reduce the risk in case of sudden oxygen shortages.

In the case of pond farmers, the oxygen shortage in the morning is significant. In ponds, oxygen levels are expected to be lower than in the afternoon. However, we do see for pond famer the oxygen level in such a low level that it can limit the growth rate and FCR. The first possible cause is the stocking density in some farms. This is too high. This can contribute to oxygen shortages and other water quality-related issues.

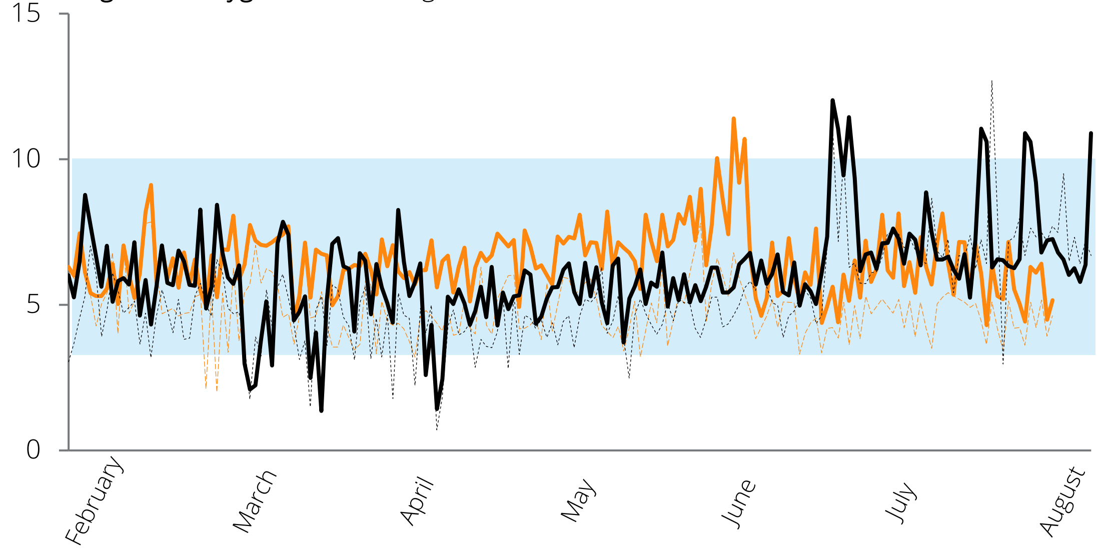
Another thing is the feeding rate. Overfeeding can lead to a variety of water quality-related issues. As in most cases, the feeding rates were not recorded to come to reliable conclusions, it I still a realistic scenario that the feeding rate was outside optimum.

The recommended training goals coming from the oxygen levels are, therefore: 1) Site selection; 2) Stocking density; 3) Feeding ratios

Pond farm oxygen levels, in mg/liter



Cage farm oxygen levels, in mg/liter



Farm 1 Morning
Farm 1 Afternoon
Farm 2 Morning
Farm 2 afternoon
Farm 3 Morning
Farm 3 Afternoon
Farm 5 Morning
Farm 5 Afternoon

Notes: *To maintain legibility, only two of the three cage farms are presented in the graph.

pH and Ammonia, Nitrite and Nitrate

Average pH, Ammonia, Nitrite and Nitrate levels were low among all farmers and did not form a threat to production. Only one farmer at one point noticed a small nitrite peak, likely resulting from common oxygen values in the point due to unnoticed high mortality. There, therefore, do not seem to be particular training goals attached to the pH and total ammonia nitrogen. This might, however, change in the future if farmers start to produce more to their potential. More intensive production will lead to more difficult water quality management. These farmers will still need to intensify first. This should not be a priority at this stage. However, a simple tool that can show these parameters' benchmarks can help them prepare them once they have more intensified production.

During the entire data collection, no questions were asked regarding the measurements itself. The instructions at the first training were clear enough for farmers to do measurements independently. Interesting enough most training seems to focus on how to do measurements. The data however indicated that **data-registration** and **data analysis** deserve more priority than actual training on the measurements themselves.

Farm type	Farm	pH morning	pH afternoon	Ammonia	Nitrite	Nitrate
Ponds	Farm 1	7.9	7.9	<0.05	<0.1	<0.5
	Farm 2	7.5	7.5	0.05	0.1	<0.5
Cages	Farm 3	7.5	7.5	<0.05	<0.01	0.5
	Farm 4	7.4	7.5	<0.05	<0.01	<0.5
	Farm 5	<0.5	<0.5	0.5	<0.5	<0.5

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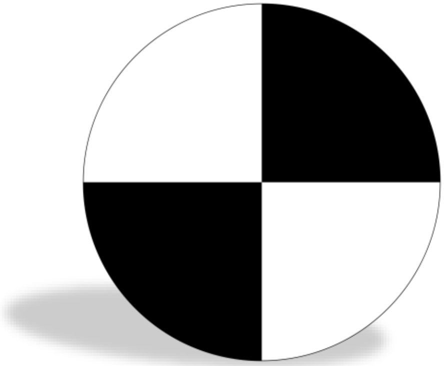
Secchi depth

None of the cage farmers reported any issues regarding the Secchi depth at their farms.

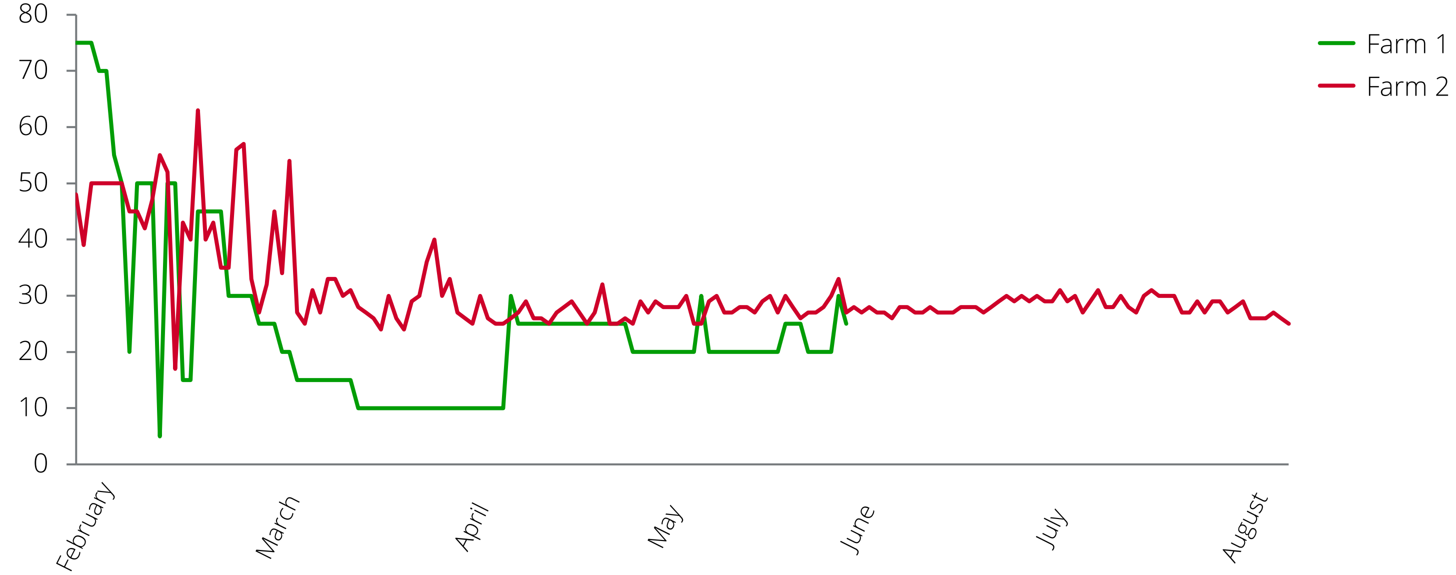
The pond farmers reported average Secchi depths that are below optimum. Further, some of the pond farmers said sudden rapid fluctuations, as seen on the right graph.

The low average Secchi depth likely comes from high algae growth due to direct sunlight, overfeeding and high stocking densities. This high algae growth results in poor water quality, such as low oxygen values causing water quality fluctuations and leading to rapid algae growth or mortality. These fluctuations cause stress among the fish, leading to poor production results such as high FCR, low SGR and high mortality.

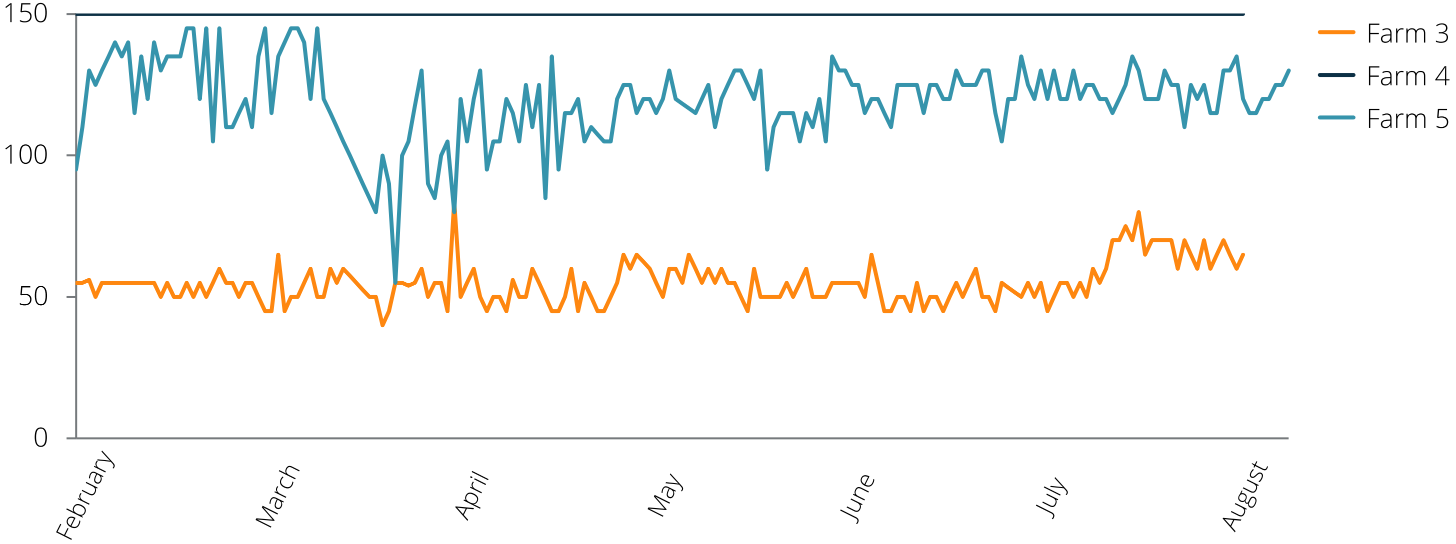
Training topics resulting from Secchi depth are therefore stocking densities and feeding strategies that can be used to control the algae growth.



Pond Farm Secchi Depth, in cm*



Cage Farm Secchi Depth, in cm*



Notes: * Please note, the displayed range of the Y-axis (depth in cm) differs for pond and cage farmers.

Feeding strategy

The observed farmers used various feeding techniques. Each of these feeding techniques can be successful if executed properly. As can be seen in the calculated FCRs, **the data was not reliable enough to make hard conclusions** on the feeding rates used. Instead, farmers were asked to show calculations (if any) on the daily feeding amount. Most of these farmers could not precisely determine how they calculated the feeding amount or made errors in their calculations.

Another indication that feeding is not happening as in best practice is the fluctuating oxygen levels that especially pond farmer's experience.

On feed quality, most farmers seemed to be better aware of how to assess feed quality. Also, the benefits of buying commercial, extruded feeds were well known.

It can therefore be concluded that feeding & feeding strategies should be a priority among training topics.

Mortality

Recorded mortality on all farms was within accepted ranges (<10%). Only one farm went slightly above it, but this forms no reason for concern. Due to the low SGR resulting in a long growth time, the actual mortality could only be calculated in a few cases. This mortality was structurally higher than the counted mortality. This can have two reasons: the number of fish stocked was much lower due to poor data registration (see next page for full explanation)

The other reason, confirmed by one farmer, is that mortality was not correctly recorded. After harvest, many fish were found at the bottom of the pond in various stages of decomposition.

In both options, farmers were unaware of how many fish were in their production unit during the production cycle. As visible confirmation in most cases is impossible. The primary sign that the stocking density differs from the records, is the feed intake. When the feed intake for a longer time seems disproportionate compared to the registered fee consumption, steps need to be taken to find out what happened. The training goal resulting from the mortality observations is therefore feeding & feed intake.

Data collection

As earlier described, FCR and mortality data show that data collection on farms did not always bring accurate results. The issue was two-folded.

During the project, we noticed that data collection and structured data registration was a challenge not many farmers faced before.

Another issue was the management of employees or staff. During the project, we mainly dealt with farm owners or farm managers directly, while data collection was mostly performed by farm workers. A common issue was that communication among farm owner, farm managers, and employees were not always ideal. Data could not be found because different parties obtained it and could/would not share it. Or instructions were lost in translation, and wrong procedures were followed. This is partly because farmers get a lot of advice from third parties (e.g. consultants, fisheries offers), and some farmers find it hard to select the "right" advice and follow one set of instructions. This sometimes leads to a scattered and inefficient result.

A training topic should therefore be **data-collection**, including farm instructions. This step is crucial before and after other improvements or intensification on farms.

Overall conclusions

After several training topics have been identified in the analysis of collected data. Besides the analysis, we also noticed that none of the visited farms took biosecurity measures. This, therefore, has been added to make a list complete

- Feeding techniques
- Data registration and management
- Dealing with warm temperatures
- Stocking density
- Biosecurity

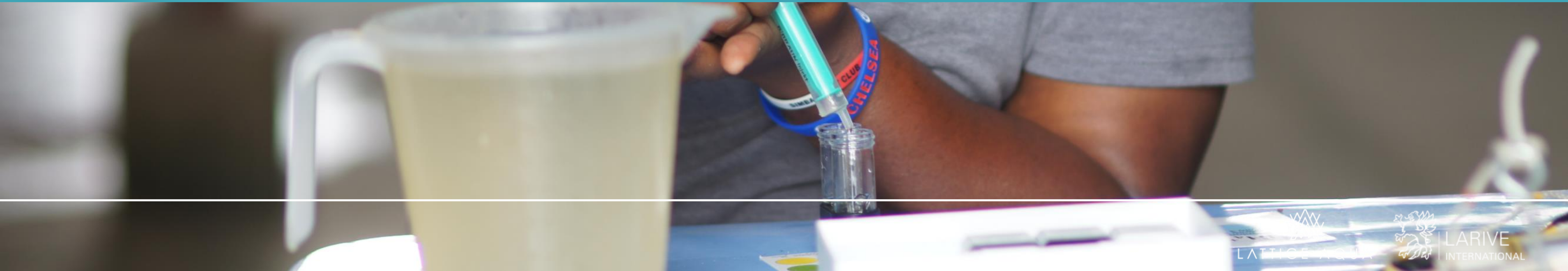
Interesting to see are the differences with previous training material. Usually, water quality was given, focusing on nitrification and the total ammonia nitrogen components. Further information was often general in specific approaches difficult for farmers to follow as they had to process a lot of information at once. Our analysis shows that water quality-related problems are mostly limited when the stocking densities are under control. Further, targeting high temperatures, temperature fluctuations, and stocking densities can prevent most water quality-related issues. This allows specific straining material (developed in the next section) to benefit farmers better.

Further, a clear conclusion is that farmers struggle with feeding ratios, especially the calculations. Farmers are roughly aware of the benefits of quality feeds and why it is important to use the right feeding amounts. In the actual analysis, things, however, seem to go wrong. This is in line with feedback received from previous trainings established. Here especially, topics requiring measures were found difficult. Therefore, we focus extra on relevant calculations in the training content.

Data collection can also be done more in-depth as previous trainings focused on learning how to make measurements. Data collection showed that farmers quickly pick up how to measure water quality, but structured registration seems to be a more significant challenge. That is why we will develop a separate data tool to assist with registration.

Overall, the abovementioned topics show farmers can benefit from tailor-made training and reduce the necessary information flow to reach a maximum effect.

3. Technical training



Feeding techniques

- The objective of feeding fish is to provide the nutritional requirements for good health, optimum growth, optimum yield and minimum waste within reasonable cost in order to optimize profits.
- Feeding floating feeds leads to better feed uptake and allows the farmer to see the fish's appetite.
- Timing differs per location and mostly depends on sunlight and temperature. Tilapia does not eat at night and will only get active if the water temperature within the optimum range.
- It is important to realize is that the actual feed requirement of the fish can differ day to day as it is influenced by numerous factors. Observation of the fish combined with experience in the same location is therefore crucial.

Steps to feeding fish correctly

1) Calculate required feed for entire production cycle.

2) Store feed properly

3) Calculate and feed the correct feed amount to feed in a day.

4) Assess fish appetite and adjust feed amount accordingly.

5) Always feed at a set time each day.

6) Always weigh and record the total fed amounts and feeding times.

Feed Storage

Your storage building should be:

1) Dark and cool

2) Big enough to store at least amount of feed required for 3 months

3) Rodent-proof

4) Have a gap between wall and stack of feed to prevent spoilage

5) Sorted by the first in, first out principle

Feed requirement

➢ Feed is the largest expense in pond farming. It is important that you calculate the required feed amount and the total required money before starting a production cycle. Calculating the total amount of feed shows you whether the planned production costs actually fit your available budget. If not, you should produce in fewer units or not start fish farming.

➢ In the first years, you can use estimations based on body weight. The experience of previous years can help to determine the realistic feed requirement on a specific farm in a location.

Feed requirement

- Calculating the feed requirements

Feed requirement= $Life\ start\ feed\ amount\ (kg)\ *\ price\ (kg) + Grow - out\ feed\ amount\ (kg) * price\ (kg)$

Example of feed requirement calculation

- An example of the 300 Kg feed used 50 the Kg is starters feed and 250Kg is grow out feed. Starters feed costs 10,000TZs/Kg and grow-out feed costs 8000TZs/Kg The feed requirement is therefore

Life start feed amount= 50Kg

Price starters feed = 10,000 Tzs

Grow out feed= 250Kg

Price grow out feed=8000TZS

Life start feed amount * price = (50*10,000=500,000)

Grow out feed * price = (250*8,000=2,000,000)

Total = 500,000+2,000,000 = 2,500,000 TZS

FCR

- Calculating the Feed Conversion Rates

$$FCR = \frac{Total\ feed\ given\ (kg)}{Final\ fish\ biomass\ (kg) - initial\ fish\ biomass\ (kg)}$$

- Biomass
  - The biomass can be calculated by multiplying the number of fish, by the weight of the fish. The initial biomass is calculated when stocking fingerlings, and the final biomass is calculated at the harvest.

- Example of FCR calculation:
  - In a complete growth cycle 300kg of feed was used. The **biomass** of the fingerlings at the start was 50kg **(initial biomass)**. The number of fish harvested was 250kg (**final biomass**)

The FCR is therefore: 300/(250-50)= **1.5**

Calculate daily feeding amount

- The objective of feeding fish is to provide the nutritional requirements for **good health**, **optimum growth, optimum yield** and **minimum waste** within reasonable cost so as to optimize profits.

- When fish are fed correctly, growth rates are good and uniform across the population, feed conversion ratios (FCRs) are low and water quality is easier to manage. The table to the right, courtesy of Skretting, shows the different feed sizes for different fish weights and the correct feeding recommendations in % body weight of fish.

The importance of feed

Feed type determines

1. Fish growth rate
2. Nutrient loading (and ultimately carrying capacity in the production unit), hence water quality within the culture system
3. Economic viability of the enterprise; 50-70% of variable production costs in a normal production cycle are due to feed
4. Health status of the fish

Feeding fish correctly means:

1. Giving feed of the correct nutritional quality for the specified age of fish
2. Feeding the right feed size for easy consumption
3. Feeding the correct amounts, following feed advice, feed list
4. Feeding at the right time(s) each day

	start weight g	end weight g	Feeding recommendation at 24-30C (% of bodyweight)
Nutra Tilapia 0	0	0.35	42-21% Week 1 21-10% Week 2 10-9% Week 3
Nutra Tilapia 80	0.35	2.5	9-8%
Nutra Tilapia 120	2.5	10	8-7%
Nutra Tilapia 160	10	25	7-6%
Tilapia 2 mm	25	60	5.5 -> 5.0 %
Tilapia 3 mm	60	200	5.0 -> 3.7 %
Tilapia 4.5 mm	200	750	3.7 -> 1.6%

Examples realistic feeding calculations

Ponds

- There is a fixed stocking rate for ponds, based on the level of intensity of the culture system. If no extra aeration is added 3fish/m2 is ideal.
    - For example, a 300m2 pond will hold (300m2 * 3) = 900 fish. It is also important to put in an extra 10% to cater for mortalities. Therefore, the pond will hold (900fish + 10% of 900) = 990 fish.
- This number of fish will then determine how much feed can be given. Just like stocking rates depend on type of culture system, feeding rate depend on fish size.
    - For example, feeding at 3% of body weight of fish that are 50g would mean that daily feed into the pond is (3% of 50 * 990 fish)/1000 =1.5kg.
- This calculation gives an indicative figure, and it is always important for the farmer to observe the response of the fish to the feed.

Cages

- For cages, due to the constant replenishment of the water by waves, one uses significantly higher stocking densities than in ponds. Stocking densities as high as 60-90 fish/m3 is common, especially when the cage is properly position in healthy water body. Professional well functioning farms can sometimes go to 120 fish /m3

- With the high stocking density, one therefore feeds many kgs of feed in a day.
    - For example, a 6m*6m*6m cage has a volume of 216m3. with a stocking density of say 80fish/m3, one stocks 17,280fish. if the fish have average weight of 50g and the farmer feeds them at a feeding rate of 3% of body weight, then he feeds (3% of 50* 17280fish)/1000 = 25.9kg.

Change in biomass

Once the fish have been fed, they will grow in weight. In order to know how much they have grown the following formula can be used:
New biomass old biomass + (feed given/FCR)

An example the total biomass in a pond is 100Kg the fish are fed 3Kg and have an FCR of 1.5, the new biomass in the pond is, therefore, 100+(3/1.5)=102Kg

Note for trainers: From previous experience it is known that calculations are often perceived as difficult for trainees. It would be good to give this a special focus.

Data collection

- Tilapia farmers should **keep good records** of their farm activities. By keeping records, a farmer can better **plan production**, indicate **areas for improvement**, efficiently buy fingerlings, feed and other inputs, define good farming practices and **avoid repeating mistakes**. Records are essential for traceability, when seeking certification and when applying for loans.
- It is advised to monitor farm data in **datasheets**. Each production unit should have a good overview of the performance of the unit.
- It is advised to distinguish between one-time, daily and weekly parameters to monitor. Measurements should always be taken at a set time during the day. On observation forms , pond number date and time should be clearly marked. It is recommended to add all recorded data and analyse the data regularly.
- Important is **involve employees actively in data collection**. Data that is not properly recorded right away is likely to contain mistakes once it is recorded in datasheets. It is therefore important all employees are involved in data recording, treat this as a priority, and let the manager regularly check for accuracy.

How often do you record the data?

Daily

Feeding & mortalities
- ✓ Given feed (brand and type)
- ✓ Amount of feed given
- ✓ Feeding time(s)
- ✓ Number of dead fish
- ✓ Expected cause of mortality
- ✓ Medication used
- ✓ Remark(s)

Water quality
- ✓ Water temperature
- ✓ Oxygen levels
- ✓ Remark(s)

Twice weekly

Water quality
- ✓ pH

Weekly

Water quality
- ✓ Ammonia
- ✓ Nitrite
- ✓ Nitrate

One time in a production cycle

Stocking & harvesting data
- ✓ Stocking date
- ✓ Number of fish stocked
- ✓ Fingerling price
- ✓ Stocking biomass (kg)
- ✓ Harvested biomass (kg)
- ✓ Number of fish harvested

For input on data registration please look at the attached data tool

Temperature & stress

- In the table on the next page the effects of temperature on fish growth can be seen. From the collected data we know that farmers in Tanzania struggle more with warm temperatures and temperature fluctuations. Both issues can cause stress for the fish, negatively impacting their growth.

Dealing with temperature

- For **cages**, dealing with high temperatures or fluctuations mainly depends on **site selection**. Prior to the construction of a farm, the temperature should be measured for an extended period to ensure the temperature range is within the optimal range.

- **Site selection** is also crucial for **pond** farmers. However, they have slightly more options to control temperature and reduce fluctuations.

    - Provide **some cover against direct sunlight**.
    - **Increasing or reducing water exchange** could help, depending on the temperature of the source water.
    - The last significant step is to **improve the overall water level** in the ponds.

Larger water bodies take longer to warm up and cool down. Therefore, filling the ponds to maximum water level will reduce temperature fluctuations. Recent restrictions Recent restrictions to limit the water used for fish farming, especially in the Bagamoyo region, specify the options to do this and general agriculture in the area. Therefore, the **local political climate** must be considered well before investing in a particular location.

The effect of stress

Stress has a negative impact on the fish and ultimately on the production. It is the fish farmers responsibility to ensure that the conditions are favorable to the fish, and as such keeping stress levels as low as possible. Therefore, it is good practice in aquaculture to record water quality, to have the correct stocking densities and to have the correct flows in the tanks. Fish can, however, tolerate small stresses.

Once a vibration has been detected, there is a response to the stressor. The following picture shows the types of responses to the different stressors.

Upon detection of a stressor the primary response of the fish is to elevate hormone levels. The level of the stress hormone, cortisol, rises in the blood and if not brought back to normal, the fish will show secondary and tertiary responses, such as changes in behaviour and often disease.

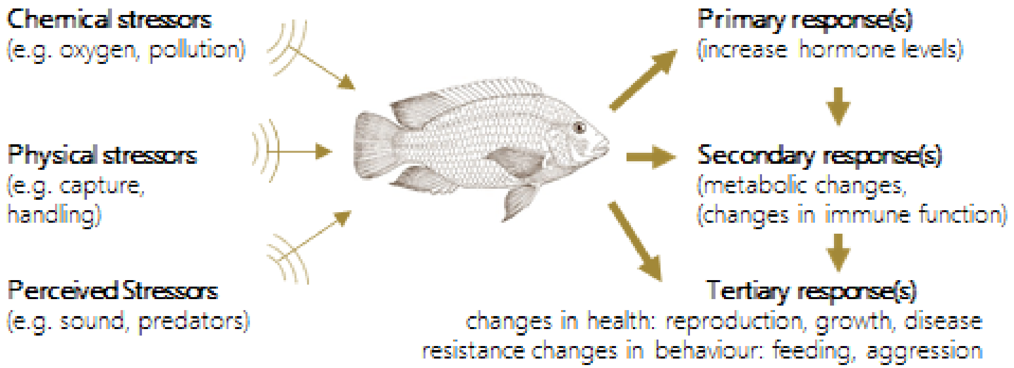
Recognizing stress

- **Gasping at the surface**: Fish gasping at the water surface is a sign of stress brought by poor water conditions, usually a lack of oxygen or high ammonia.

- **Appetite**: The appetite decreases or ceases to exist.

- **Strange swimming**: Jumping, grouping, hiding. When overfed, fish jump easier when slightly disturbed by shadow or vibration.

- **Swimming frantically** without going anywhere, **rubbing** against solid structure(flashing) or locking his fins at his side are not just signs of stress. These are already signs of disease agents.



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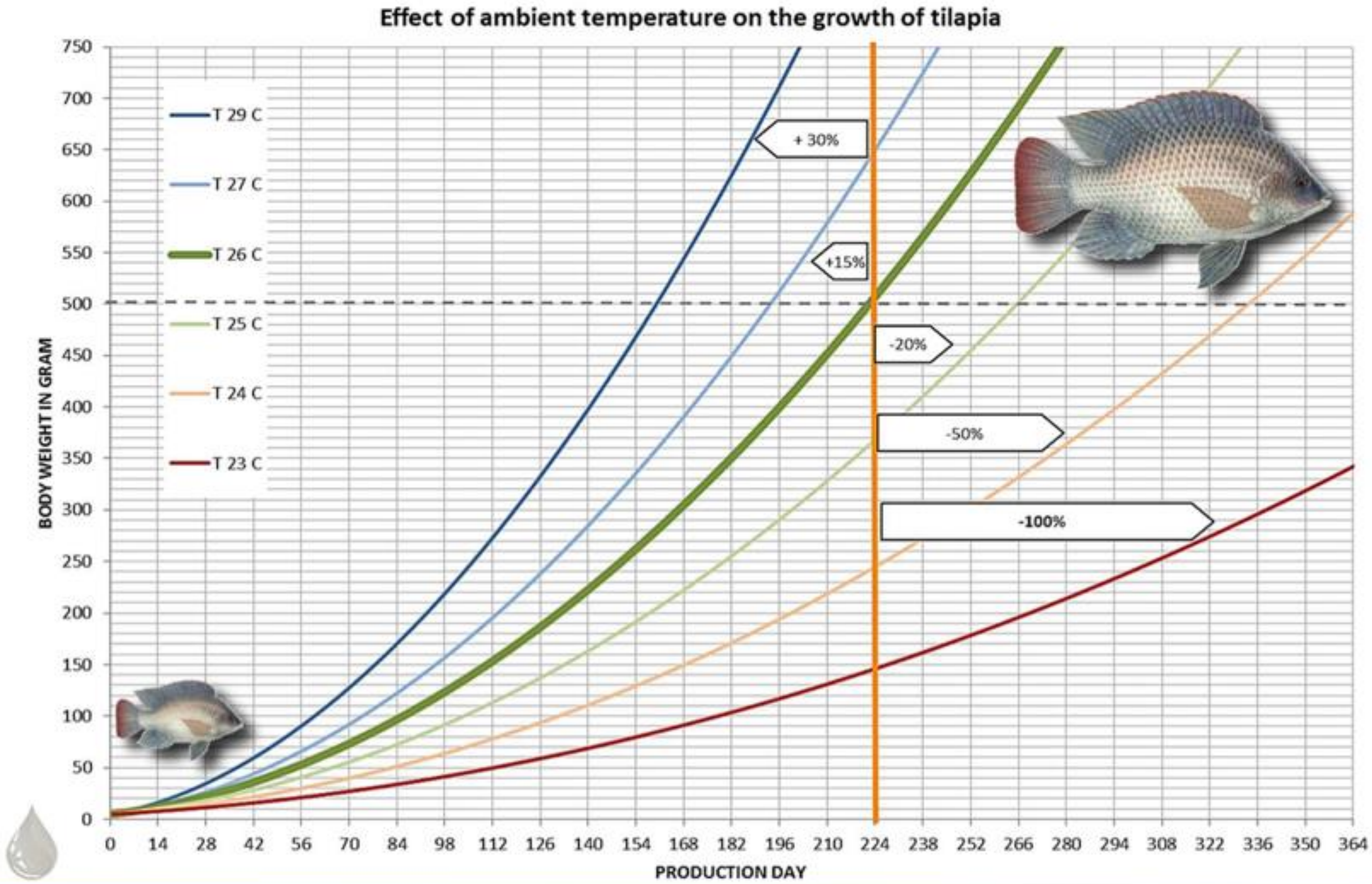
12.1 Factors affecting growth of fish



Stocking density

- Usually, the stocking density is determined by **oxygen level**, but also other factors such as **water quality** parameters can be limiting. In all cases, the maximum stocking density becomes visible when the fish are at their largest, near harvest weight. For an overview of the maximum allowable water quality parameters please see the next page.

- However, your stocking density should always be based on **previous production results** at your own farm. A farmer should **test the performance** of the fish with higher and lower densities to find the optimal stocking density. The performance of your fish can be measured using the key data indicators. A farmer should consider that high stocking densities are more difficult to manage.

Farming intensity	Guidelines for stocking densities
Extensive, no or little water exchange	1-3 fish/m²
Semi-intensive, night-time aeration in summer	3-4 fish/m²
Cage	80-120*/m3 Caution is needed because of upwelling in lake Victoria

Fish farming protocols – water quality

Parameter	Why	When to measure	Optimal range	Possible reason	Possible solution
Temperature	Temperature outside the optimal range is bad for the growth rate and wellbeing of the fish.	- Daily - In the mornin and afteroon	25-30 °c	1. Influenced by weather 2. Water exchange not optimal 3. Low water level which is sensitive for temperature fluctuations	1. Harvest prior to extremely warm or cold periods. Avoid stocking prior to extremely warm or cold periods. 2. Adjust water flow* 3. Adjust water level* 4. Build greenhouse*
pH	Tilapia kept in water with a suboptimal PH are constantly stressed and will not grow well. It also has a strong influence on the toxicity of ammonia.	- 2x per week. - Always measured at the end of the day.	7-9 pH	1. Too much water exchange 2. Too high algae growth 3. Low alkalinity buffer	1. Adapt water exchange 2. Use fertilization to steady the growth of algae 3. Feed high quality feeds with a high digestibility to minimize waste production. 4. Lime low alkalinity ponds 5. Apply a soluble calcium source such as gypsum (calcium sulfate) to ponds with moderate to high alkalinity but low calcium concentration.
O_2 Oxygen	Fish consume oxygen when feeding. When oxygen is decreasing the efficiency of digesting decreases as well. This leads to a high FCR.	- Twice daily - in the morning and the afternoon	3-10 mg/l,	1. Maximum feeding capacity 2. Feeding not properly spread over the day 3. High growth of algae 4. Stocking density too high	1. Grading or harvesting 2. Adjust feeding lines
NH_3 Ammonia	Ammonia is a waste product excreted by fish. At a low pH it is much less toxic compare to a high pH. Ammonia can be consumed by bacteria in the nitrification process. Also algea absorb ammonia.	- Weekly - Extra when fish show signs of discomfort	<0.2 mg/l at a pH of 8.5 or higher <1mg/l at a pH of 7.3 or lower	1. Nitrification suboptimal (not enough oxygen or pH too low) 2. Start-up phase after disinfection 3. Maximum feeding capacity exceeded 4. Overstocked	1. Control aeration 2. Adjust water exchange 3. Feed with care and use quality feeds 4. Reduce stocking density 5. Supplementation with organic carbon (sugar or molasses) 6. Check if there are clear signs of dead algae in combination with water quality parameters
NO_2^- Nitrite	Nitrite is a toxic intermediate product in the nitrification process	- Weekly - Extra when fish show signs of discomfort	<2mg/l	1. Reduced nitrification due to low oxygen or pH level	1. Increase water exchange 2. Increase aeration 3. Increase pH 4. Add salt as this outcompetes the uptake of nitrite by fish
NO_3^- Nitrate	Nitrate is the final product of the nitrification process and only toxic in high concentrations	- Weekly - when fish show signs of discomfort	<250mg/l for fingerlings < 600mg/l for grow out	1. Nitrification process is running efficiently	1. Increase water exchange

* Temperature in ponds is something that usually cannot be altered significantly.

Biosecurity measures

- Biosecurity is a collective term for measures intended to prevent the introduction and spread of infection. Biosecurity is essential in fish farming to maintain healthy, living fish and a viable economy. The following steps should be taken at every facility handling live fish.

1. New arrivals
Newly arrived fish should always be placed in a separate quarantine area away from the farm. Fish should be observed for overall health and any signs of disease before placing them in the regular production units.

2. Farm setup
A farm should be constructed such that different parts of production are separated. Young fish are more vulnerable to diseases than older fish. Therefore, it is recommended to separate a hatchery, nursery, and grow-out unit so the infection cannot spread among these parts.

3. Barriers
Barriers are needed to prevent pathogens from entering the farm and spreading among production units. Footbaths with disinfectants should be installed at the farm entrance and the various farm departments. In this way, visitors and employees can disinfect their shoes and prevent the spread of pathogens. Furthermore, they should wash their hands with soap and disinfect them in the same position. As a general principle, visitors SHOULD NOT touch the water and fish in the production unit.

4. Visitor registration
Visitors should only be allowed on the farm after permission from the farm management. All visitors should be registered, including their contact details. While on the farm, visitors should never be left on their own.

5. Removal of dead fish
Any dead fish or eggs must be removed from the water as soon as possible and discarded properly to prevent the growth of pathogens on dead tissue.

6. Disinfect equipment
Any equipment such as nets and buckets should be used for specific production units only. After use, the material should be disinfected.

7. Pest control
The occurrence of pests at the farm should be minimized. Measurements against rats, birds, and other problems should be taken. Typical examples are proper feed storage and bird nets.

Cleaning and disinfection

Why is disinfection important?

- During production, a lot of bacteria develop in the tank. Surfaces will have a microfilm layer that can harbour bacteria and parasites that will continue to grow. The bacteria in the tank can bring about the disease to the new stock if not removed, especially as the new stock will be juvenile stock.

<u>A clean production unit will be more efficient and productive</u>

How to disinfect tanks and ponds?

- There are two types of disinfectant that can be used, Calcium Carbonate ($CaCO_3$) and hydrogen peroxide (H_2O_2). Especially after the use of H_2O_2 a system has to be thoroughly cleaned.

Disinfectant	Effect	Result
Calcium carbonate (lime)	Raise pH>10	Kills all bacteria and parasites
H_2O_2	Oxidizing agent	Kills nitrifying bacteria in water and micro-organisms

Caution! Wear protective clothing, gloves, eye and face protection

Calcium carbonate ($CaCO_3$)

How to use calcium carbonate

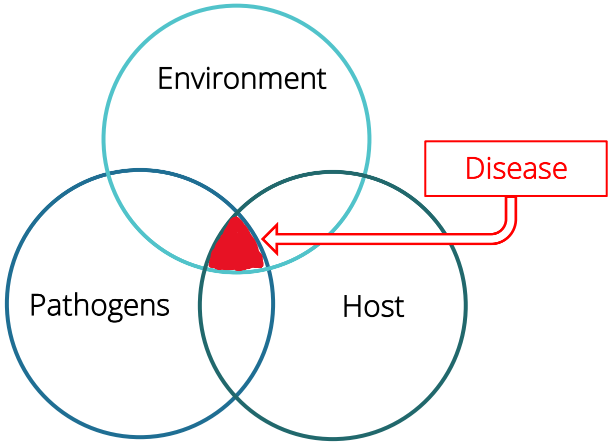
1. Clean production tank/ponds;
2. Fill production units with water, mixed with 1.2g/l $CaCO_3$;
3. Check pH is over 10, add more lime if necessary;
4. Turn on the tank;
5. Allow lime to move through tank/pond for 24/48 hours;
6. Drain water and rinse lime residue;
7. Top up with fresh water;
8. Check pH 6.5 -7.5 & stock

Hydrogen peroxide (H_2O_2)

How to use hydrogen peroxide

1. Refill tank/pond unit with fresh water
2. Add H_2O_2 1-2mg/l
3. Run system for 24 hours
4. H_2O_2 breaks down in water to H_2 and O_2

Disease triangle



Disease triangle

The disease triangle is a model that shows the interaction between the factors of pathogens, environment, and host. The risk for diseases is low when these three factors are in balance.

Pathogens

Pathogens are present in all systems. Pathogens are small organisms that can cause disease and health issues among fish. Pathogens can be **bacteria**, **parasites**, and **fungi**.

There are two different types of pathogens: **Opportunistic pathogens** are always present and are harmless under normal circumstances under a controlled environment within the desired parameters, and the fish are kept in good conditions.

Specialized pathogens are species-dependent and can harm the host even in small numbers. For these pathogens, a farmer must take measures to prevent introduction on the farm.

Environment

The **environment** is everything that surrounds the fish: the water, the air above the water, and the surrounding area of the production unit.

Disturbances such as loud noise from, for example, suboptimal water quality and predatory animals can cause stress. Stress may limit growth or even lead to mortality as a high level of stress makes fish more susceptible to diseases.

In **suboptimal water quality**, opportunistic pathogens get more chances to grow. When their numbers are high, they get more opportunities to infect the fish. It is therefore crucial that disturbances are minimized, and water quality parameters remain in their optimal range.

Host

Healthy hosts are less susceptible to diseases. If fish are not in optimal health conditions, they are more likely to get sick.

Key factors that can make the fish more susceptible to diseases include **stress** and a **suboptimal diet**.

A healthy host is less likely to get infected by a pathogen and can cope with periods of sub-optimal environment without getting sick.

4. Financial analysis

Financial Analysis

	Ponds farmers		Cage farmers		
	Farm 1	Farm 2	Farm 3	Farm 4	Farm 5
	Absolute value	Absolute value	Absolute value	Absolute value	Absolute value
Recorded expenditure items					
Fish feed	21,089,000	1,708,000	19,367,500	8,940,000	7,723,500
Fingerlings	N/A	8,820,000	N/A	N/A	2,000,000
Salary	11,600,500	4,610,000	2,408,000	33,775,000	4,050,000
Hormones	284,700	N/A	N/A	N/A	N/A
Transport	302,500	492,800	101,000	N/A	465,000
Fuel / diesel / petrol / oil / ethanol	3,551,150	N/A	788,904	7,249,555	N/A
Electricity	525,000	N/A	220,000	850,000	N/A
Aquaculture related equipment & services	2,873,000	2,014,000	618,000	120,000	725,000
Farm cleanliness	300,000	126,000	N/A	N/A	N/A
Other	1,517,200	3,205,000	248,000	10,000,000	450,000
Total costs	**42,047,750**	**20,975,800**	**23,571,404**	**60,934,555**	**15,413,500**
Recorded income items					
Sales of fish	45,837,000	N/A	45,041,000	173,376,920	11,350,000
Sales of fingerlings	N/A	N/A	4,250,000	63,000,000	N/A
Sales of fish feed	N/A	N/A	9,009,500	N/A	N/A
Sales of fish cages	N/A	N/A	N/A	68,000,000	N/A
Others	N/A	N/A	244,000	N/A	N/A
Total revenues	**45,837,000**	**N/A**	**58,544,500**	**304,376,920**	**11,350,000**

Financial Analysis

Displayed on the previous page, is the overview of expenses and revenues over the data collection period from February to August 2022. The data collection period did not cover a full production cycle, so the data may display different values than would be the case for a longer measurement period. As a result, farmer 2 has not been able to harvest and sell any fish during the data collection period.

Also, many of the sold and harvested fish were already being produced prior to the start of the data collection, of which the input costs are not included. These factors make it difficult to make sound evaluations of the financial health of the farms. In order to make cost/price analyses, more consistent and precise data collection is required.

What can be observed is that there is a high degree of variation between the cost distributions of the different farmers. Partly, these differences can be attributed to inconsistencies in data recording. For example, when looking at farm 4 (cages), salaries accounted for more than 50% of the total costs, while at farm 3 (cages) this is only 10%. For farmer 2 (ponds), the costs of feed only amounted to 8% of the total farm costs, while for farmer 1 (ponds) feed contributed to more than 50% of the total costs.

Under the “Other” category, many costs have been accounted for that are not always directly attributable to the day-to-day farm operations. These costs are to be considered, but are not as important and the main cost dimensions.

More of these inconsistencies are observed, and should be interpreted with caution. To make good evaluations regarding the financial health of the farms in the sample, it is necessary to improve the basic level of financial literacy and data recording skills.

The financial training guide, therefore, focuses especially on the labeling of costs and revenues, as well as basic but effective savings and inventory management strategies.

Financial Analysis

This tailor made training emphasises the financial aspects that farmers face while running their businesses. The purpose is to form a basic understanding of financials which in the future can help farmers answer questions such as: is my farm profitable or am I making losses? Would I benefit from building another cage or pond, and how long will it take before this earns me money? Should I hire another farm assistant, or consider scaling down?

However, in order to evaluate the financial health of farms and appraise potential investments, it is necessary to have a basic understanding of a range of financial topics. As for the technical topics, the most important thing is to collect and record the (financial) data to interpret it correctly.

During the data collection phase of this study, it was observed that the consistent recording of data was the biggest challenge. The collection of data is essential for the creation of business cases that are necessary to gain capital through loans or investments.

In this financial guide, the crucial aspects of running a small business are addressed, to improve the general financial literacy of farmers. Improvements need to be made on a basic level, before diving deeper into the financial specifics.

- Costs & revenues
- Fixed costs & variable costs
- Investments & returns
- Savings & unexpected costs
- Inventory management (FIFO)
- Making a budget

5. Financial training

Costs & revenues

Before going into depth on the different financial topics, first, some basic definitions are addressed. For many farmers, aquaculture is only one of many sources of income. It may be difficult to determine exactly if and how profitable the farming activities are. Being able to distinguish between revenues and costs for each income stream is essential to make the evaluation whether it is actually worth continuing your activities.

Doing so requires insights into your income and spending patterns. The best way of becoming more aware of how your cash flows, is by recording each and every movement of money. By categorizing each of the costs, in alongside each income stream, profits and losses can be calculated. When costs are applicable to multiple income streams, make sure that in the calculations these costs are fairly accounted for by dividing the costs by the number of applicable revenue streams.

Revenues

Definition: Revenues are any money that a business makes from selling its goods and services.

Example: if you sell 10 kg of fish in 1 production cycle, for 1,000 Tsh per kg. Your revenues per production cycle are: 100 x 1,000 = 100,000 Tsh

Examples of revenues:
- Sales of fish
- Sales of fingerlings
- Sales of services (e.g. Transporting goods for another farm, or assisting with building a pond)

Costs

Definition: costs are anything a business must pay for. Total costs can be broken down into fixed and variable costs (next slide).

Example: To produce 100kg of fish 1 production cycle, the total costs are 900 Tsh per kg. Your cost per production cycle are: 100 x 900 = 90,000 Tsh

Examples of costs:
- Feed
- Electricity
- Land lease
- Wages

Profits and losses

Definition: Profit is any revenue left after all the business costs have been paid.

Profit is calculated by subtracting the total costs from the total revenues.

When profit is a negative amount, we speak about **losses**, meaning that doing business costs you more money than it earns.

Example of profit: using the previous examples, a production of 100kg fish in 1 production cycle results in a profit: 100,000 – 90,000 = 10,000 Tsh

Fixed costs & variable costs

Running a farm costs money, and many of the costs can be directly attributed to the production; buying equipment, feed, fingerlings, hiring of staff. Other costs are less straightforward, especially if fish farming is not the only activity on the farm. Elements such as electricity, land lease, and transportation costs need to be accounted for, even if it is not solely used for fish farming. It is important to keep track of how much costs you make and to know how the costs can be explained in order to evaluate the financial health of your business.

Costs made at the farm level can be broken down into fixed and variable costs.

Fixed costs

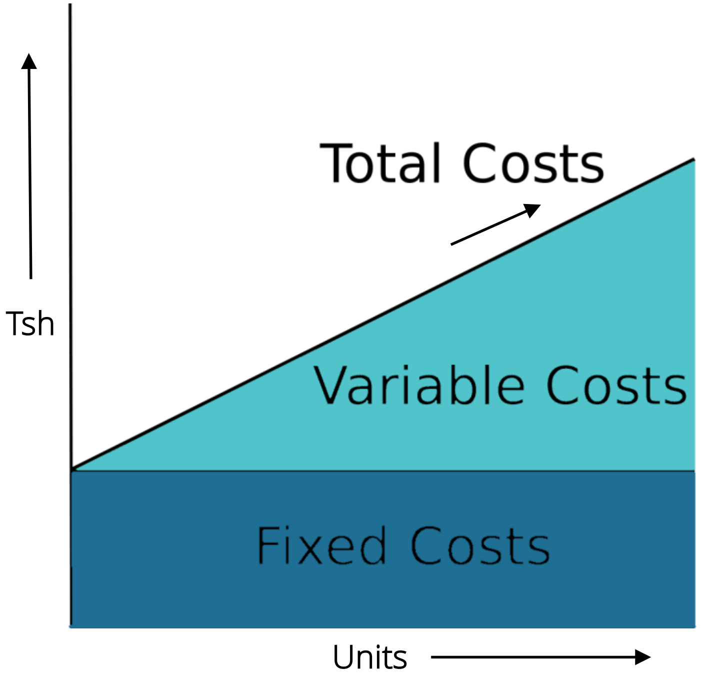
Definition: Fixed costs are those costs that need to be paid, independent of the production volume. These costs are fixed, meaning that they do not increase or decrease based on levels of output.

Example: if you have a land lease contract that is paid on a yearly basis. This same lease will need to be paid whether you produce 1kg or 10.000kg.

Examples of fixed costs:

- Insurance
- Land lease
- Rent
- Loan repayment
- Fixed-term employment
- Subscriptions

Please note, As you must pay fixed costs regardless of outputs, you should be careful about adding fixed costs if you have a (small) business.



Variable Costs

Definition: Variable costs are those costs that are linked to your production output. As you produce more, these costs increase as well.

Example: Variable costs scale up with production. For example, the feed costs for 10.000 kg of fish, will be much greater than the feed costs to produce 1 kg.

Examples of variable costs:

- Fingerlings
- Feed
- Electricity
- Packaging
- Water
- Billable wages
- Fuel
- Transportation

Total variable costs can be calculated by multiplying the costs per unit times the units produced.

Savings & unexpected costs

There are many things one can spend his or her hard-earned money on. Many expenses are necessary, and if there is money left, one can treat himself or others to something nice. However, when earning more than you spend (higher total revenues than total costs), one can think of saving up some money for expenses that may occur unexpectedly.

For example, the fence around the farm may be destroyed by a storm, cages could be stolen or the motorcycle may break down. Each of these examples has an impact on the capacity of the farm to function properly. Immediate restoration or replacement may be necessary to reduce the risks and losses for the farmer.

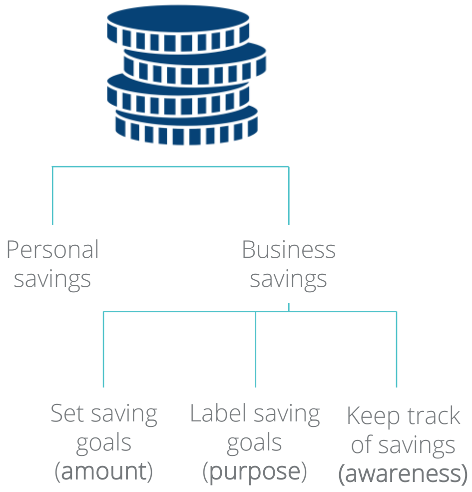
By saving some of the revenues made by fish farming or other activities, one will be better able to deal with these unexpected occurrences. Making use of savings rather than loans, reduces costs for farmers as they are less dependent on banks and money lenders. Short-term loans in Tanzania are often met with high-interest rates.

Saving money can be challenging, but there are some proven strategies that may make it easier. These principles can be applied both in business and in your personal life.

Label the savings

How?: When saving up money, make a (mental) label of your saving goal and for which you intend to use the money, and stick to it. When clearly reminding yourself of the purpose of the savings, it becomes less attractive to use the savings for another purpose.

Why?: if you saved up some money labeled for the birthday of your young cousin, you may feel less inclined to take this money when you go shopping. The same goes for farm-related savings. When you (mentally) assign money to the replacement of equipment, this money will not feel as available for other topics, as it would feel if you did not label any of your savings.



Record deposits and withdrawals

How?: Whether saving in a lock box, or at a bank or via mobile money, keep track of how much money is saved and spent. When making deposits or withdrawals, write down in a notebook or on your phone the purpose of the saving or expenses.

Why?: At a later stage, you can see how much is being saved without having to open the savings. Through the overview of expenses and deposits, you can gain insights into your saving behaviour and patterns and hold yourself accountable when not following your intentions.

Inventory management

It is of course essential that at all times, there is enough feed on the farm to feed the fish. This requires a certain degree of planning and on-farm communication amongst the team, as you will always need to purchase feed before running out of stock. At the same time, you do not want to stock up on too much feed as it may expire if you do not get to use it all in time. Consciously applying a certain strategy to this part of inventory management.

In order to make this feed inventory management as (cost) effective as possible, it is necessary to keep track of feed purchases and uses. By making calculations of the amount of feed that is to be used in a certain period, you can stock up on the right amounts and the time and costs of frequently peddling back and forth to the feed supplier.

After buying feed and storing it on the farm, it is important to easily distinguish between the new and old feed. The old feed is likely to go bad sooner than the new feed and should be used first. This inventory management method is called: First In, First Out (FIFO), and is often used for goods that are at risk of expiry.

First In First Out

Definition: The goods that are first purchased, are first used to reduce expiration and losses in quality. This is in order to maintain the effectiveness of feed and reduce costs for farmers.

Example: John purchased 60 bags of feed on 01/01/2022, the feed expires after six months. On 01/05/2022 20 bags are still in storage on John's farm, but he decides to buy another 40 bags of feed. John places the bags of feed in his storage and uses the new, fresh bags first. After a few months, he continues using the old bags of feed and notices that the feed has expired and has gone bad. The fish grow slower than they did when the feed was fresh; increasing the feed conversion rates and the relative costs per fish as more feed is required.

Takeaway: If john took a First In, First Out approach, he would first use feed from the batch that expires first, and not face the loss in quality later.

Making a budget

A **budget** is an estimation of the costs and incomes over a given period. It is important to make this forecast, to know where you can and need to spend your money.

As an exercise, you can make a similar overview of your own source of income and expenses as displayed below. The income sources and expenses are not limited to the examples shown below. A budget should reflect the income and costs that are occurring on your farm.

When making a budget, there will be some expenses and incomes that are known and others that need to be estimated. However, it is important to include all relevant items in the budget. The more realistic the estimation is made, the better the budget can be used for the financial planning of the farm.

Why make a budget?

1. It allows you to **assign your income** to different types of expenses;
2. It helps you **make decisions** about spending, saving and investing;
3. It encourages **disciplined spending**;
4. It gives **insight and control** over your finances;
5. It helps you **organize and manage** your money more effectively;
6. It helps you **plan for your future** and meet your financial goals.

Example: John's farm budget for a month, in Tsh

Income:		Expenses	
Fish sales	7,500,000	Feed	500,000
Cage sales	2,000,000	Frys	4,900,000
		Transport	200,000
		Salaries	1,000,000
		Equipment	400,000
		Maintenance	100,000
		Cleaning	35,000
		Security	200,000
		Savings	1,165,000
Total:	**9,500,000**	**Total:**	**9,500,000**

Investments and returns

An **investment** is an action undertaken now, in order to make more progress in the future. You can invest the time of your day into learning a craft. However, you can also invest money into assets, with the purpose of earning more money in the future. Whether it is by using this asset for increasing production (an additional pond or cage, livestock) or assuming the resale value of the asset (land, real estate) will increase in the future.

Investments can be risky: The money you spend today has the potential to earn you money in the future. However, if the investment does not work out, you spend money today that does not earn you money in the future. To reduce this risk, it is necessary to carefully evaluate investment opportunities; this requires some knowledge and experience.

Example – in Tsh

John has a farm with 1 pond. Per production cycle, this pond earns John 50,000 profit. If john digs another pond, he expects to earn a total of 100,000 per production cycle. Digging another pond costs 300,000.

Per production cycle for 1 pond:
- Total Costs: 450,000
- Total Revenues: 500,000
- Profit: 50,000
- Digging of the new pond: 300,000

If john decides to use his savings and dig the second pond today, after how many production cycles does the newly dug pond become profitable?

The **break-even** point, where there the total costs are equal to the total revenues, is in year 6. From year 7 onward the investment in the new pond will earn John a profit beyond the invested amount.

Evaluate each investment

1. **Why do you want to invest?**
- Evaluating an investment opportunity starts with the goal in mind.
- Do you want to invest in your current business?
- Or do you want to invest in something new and diversify?

2. **What do you expect from the investment?**
- What are the costs and how much do you expect to earn?
- How much time will it take to earn the invested amount back?
- Are your expectations realistic?

3. **Can you afford to invest?**
- How much money is necessary to make the investment
- Do you have enough savings, income, or access to other finance?
- What are the risks of this investment?
- If the investment is not a success, can you afford to lose this money?
- Are you able to sell the investment to someone else?

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