OUR TEAM

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1 - Solution Summary

Our team solves the wicked problem of water pollution with an innovative aquaponics System to grow fish (Tilapia), vegetables, and duckweed. In this system, high nutrient water is circulated from the fish to the crops. The crops then absorb the nutrients in the circulated water in order to grow without soil or excessive fertilizer application. The grown duckweed is in turn used to feed the fish, significantly reducing the use of external fish feed. The vegetables and fish, on the other hand, are for human consumption. Waste from fish and vegetables after human consumption is recirculated back into the aquaponics system as compost tea to supplement the crop's growth. With this, we remove inorganic fertilizer application in growing vegetables, reduce water usage by up to 90%, maximize crop yield, reduce land usage and rule out waste in our system as we ensure maximum usage of resources. Most importantly, we contribute to the circular economy by reducing the contribution of agricultural practices to water pollution as the sources of pollutants are either eliminated (chemical fertilizers) or kept in the loop (uneaten fish feed and their excreta) in our sustainable farming system.

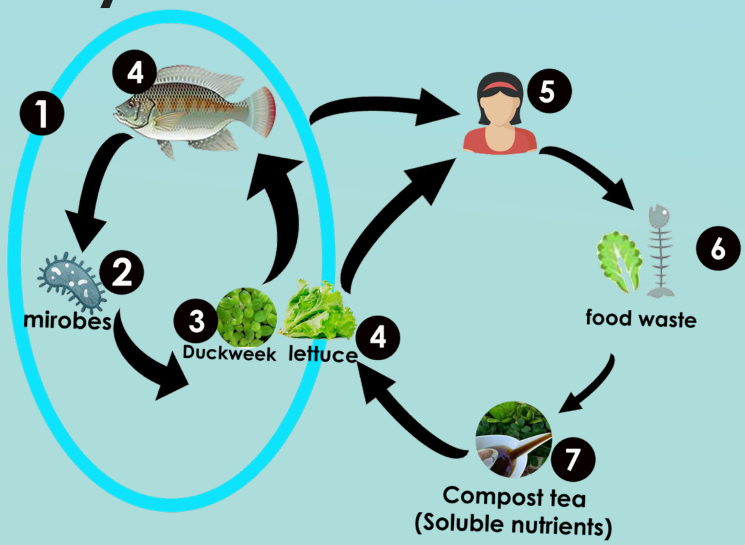


Figure 1. The circular flow chart

Why Tilapia and Lettuce?

Tilapia

- Resistant to diseases and parasites
- Excellent source of nutrients like vitamins B12,omega 3, fatty acids.
- Omnivorous with a wide range of diets
- Numerous recipes in Ghana Eg Banku and Tilapia,Tilapia Soup, Koobi for local delicacies, etc
- Strengthen bones and boost immunity.
- Breeds faster
- High patronage in Ghanaian communities.

Lettuce

- Grows faster
- Good source of nutrients (Vitamins A, K, C folate, iron, minerals, etc) that are lacking in most Ghanaian meals.
- Antioxidant

2 - CONTEXT

2.1.1 - Background

The world population grew from 1 billion people in 1800 to 7.9 billion in 2022. With this increase in the global population, the rate of pollution growth has consistently been on the rise. According to data from The Pacific Institute for Studies in Development, Environment, and Security, about 2 million tons of sewage, industrial, and agricultural waste is released into water all around the world every day.

2.1.2 - History of the Wicked Problem

Water pollution intensified with the advent of the Industrial Revolution, when factory operations began releasing pollutants directly into rivers and streams. But today, in many countries, the biggest source of water pollution is agriculture while worldwide, the most common chemical contaminant found in groundwater aquifers is nitrate from farming(FAO). Farms discharge large quantities of agrochemicals, organic matter, sediments and saline drainage into water bodies.

2.1.3 - The Global Picture

According to Eduardo Mansur, Director of FAO's Water and Land Division, in most high-income countries and many emerging economies, agricultural pollution has "overtaken contamination from settlements and industries as the main factor in the degradation of inland and coastal waters." The growing human population has accelerated the demand for crop production. This growth has been achieved mainly through the intensive use of inputs such as pesticides and chemical fertilizers whose excesses run off into water bodies. Land is another resource that agriculture has exploited and continues to exploit. According to FAO, agricultural land area is approximately five billion hectares, or 38 percent of the global land surface. Land clearing for agriculture frequently results in land degradation and increased erosion and sediment loads on waterways. Aquaculture also contributes to water pollution through organic pollution and eutrophication (a buildup of excess nutrients primarily organic nitrogen and phosphorus and wastes in an ecosystem) . Every year, unsafe water contributes to 1.2 million deaths in the world (Our World in Data).

2.1.4 - The Situation in Ghana

In Ghana, both crop farming and aquaculture pollution exist at different parts of the country. Most farms are strategically situated near water bodies to allow easy access to water for irrigation. While this serves to reduce cost of irrigation, these near water sources are easily polluted by the factors stated above. The immediate effects on these farmers themselves include skin irritations, headaches, general body weakness, difficulty in breathing and dizziness. Some women farmers had accumulated pesticide residues in breast milk above the 'tolerable daily intake' guidelines beyond which they have adverse health effects on their children.

2.2 - Scope

Water pollution is an issue of global concern as it is experienced in different parts of the world. Once water is contaminated, it is difficult and costly to remove pollutants. For countries like Ghana, there is the lack of resources and the money to remedy this problem once it has occurred, making it imperative that it is tackled at the root.

2.3 - Location

Our team is thinking global while acting local. As such, we are focusing on Ayeduase, a community in the Kumasi Metropolis in the Ashanti Region of Ghana, near the Kwame Nkrumah University of Science and Technology (KNUST). Inhabitants of this community are involved in diverse forms of occupation including farming. In most educational facilities such as KNUST, there is vast land that the community dwellers utilize to grow diverse crops. On the KNUST campus, for example, the farmers grow lettuce near streams and ponds to get easy access to water for irrigation, making it our ideal location for piloting the project. (MC8G+4QX, Kumasi).

Figure 2. A water source near a farm in Ayeduase

2.4 - Stakeholders/ Influencers

Farmers/ Employees | **Restaurants** | **University Agric Department** | **Environmental protection Agency** | **Local Ministry of fisheries and Aquaculture** | **Organic Food Markets**

3.1 - DETAILED SUMMARY

In Ayeduase, a community within the Kumasi Metropolis in the Ashanti Region, lettuce plantation is largely practiced near water bodies, making it our location for piloting. Our team solves the wicked problem with our innovative aquaponics system while embracing the circular economy. Aquaponics is a self-supporting food production system that combines recirculating aquaculture with plant culture in the absence of soil (hydroponics).
Our team focuses on growing fish, duckweed, and vegetables with a Nutrient Film Technique aquaponics system because it is more viable than the other forms for large-scale production. Our design would follow the order of fish culture tank, solids filtration, biological filtration, hydroponic component, and sump.

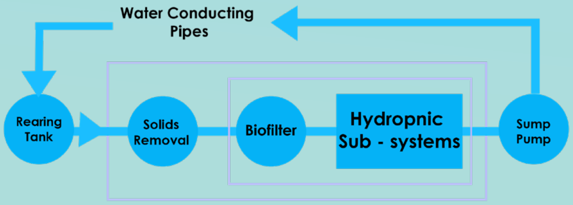


Figure 3. Order of System Design

Fish Culture Tank: Our pond would be made from High-Density Polyethylene (HDPE) plastic molded into conical forms. This is because HDPE is UV stable with a long lifespan of about 30 years. The conical shape will allow excessive solid waste to concentrate at the bottom and be easily flushed. The flushed solid waste will form part of the sludge that will be given to the compost and recycling companies.

3.2 - Creating Effective Flows

Note: Description here explains Figure 1, Circular flow Chart

1)Our team creates a loop to allow the flow of nutrients from fish to plants and humans. This is achieved by pumping nutrient-rich water from the fish tank throughout the system to grow vegetables and duckweed.
2)Useful microbes break down the nutrients in the water to forms that could be absorbed by the plants

3)The duckweed is used to supplement fish feed.

4)The grown fish and vegetables are sold for (5)human consumption.
6)Waste from fish and vegetables after human consumption will be collected by compost and recycling companies and together with the harvested sludge that we will deliver to them, converted into compost through aerobic and anaerobic processes.
7)We will obtain compost from our partner company and convert it into compost tea which will serve as a soluble nutrient that will be added to the pipe channels to supplement the plant growth.

Biofiltration: Biological filtration refers to the breakdown of ammonia (NH3 and NH4+) into nitrite (NO2) and then further into nitrate (NO3) by naturally occurring, nitrifying bacteria. We will have a dedicated tank filled with granular media to provide the needed surface area for bacteria colonization.

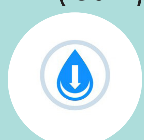
Hydroponic component: Our team will be using the Nutrient Film Technique for our hydroponic component. The plants will be inserted into the top of shallow horizontal channels. A small film of water will be pumped through the channel after the biofiltration, coming into contact with plant roots that utilize those nutrients for growth.

Sump: We have a sump to collect the water after it passes through the hydroponic system. This will allow us to run water sample quality test and make amendments or further water treatment without overwhelming the fish or the hydroponic component. The water is then redistributed and the cycle continues.

Pump: The redistribution of water throughout the system will be done with a solar-powered pump which will pump water from the sump to the desired heights. Learning from our prototype, we realize we would not need a complex solar installation to achieve this feat. The identified pump that would be purchased comes furnished with its solar panel, reducing the complexity of our operation.

3.3 - INCENTIVES

(Compared to Traditional farming)

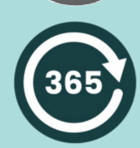


90% reduction in water usage
(water is recycled and reused)

85% reduction in land usage
(vertical farming is employed)

Accelerated crop Growth
(plants have constant access to organic nutrients)

Minimal Waste
(resources are circulated back into the system)



Year-round farming
(farming does not depend on weather conditions)

3.4 - ECONOMIC FEASIBILITY

Our solution would generate an adequate amount of cash flow and profits, withstand the risks it will encounter, remain viable in the long term and meet the set goals. In the first few years, we will be selling directly to bulk purchasers with storage capacity like restaurants, hotels, cold store operators, wholesale shops, etc to eliminate the cost of storage in our operation. Nutrient-laden biomass or water too would be harvested and traded with compost and recycling companies for compost tea to supplement plants' growth. In the long term, we will set up a restaurant to serve fish and lettuce meals to draw in extra revenue with value addition. However, being futuristic, the restaurant will as well operate on the principles of the circular economy. This will be done by helping customers plan and order only food they can consume. In the extreme cases of excess, we will give the option to customers to bag it home for their pets or otherwise give it to compost and recycling companies. Reusable napkins and glassware will be used. This cuts the cost of external fertilizer.

3.5 - INNOVATION

We will incorporate mechanical filtration in our system to further purify the water. This only becomes necessary in a very high nutrient build-up where absorption by plants and other filtration processes in the system is not able to cleanse the water enough for the fish. To cut down costs, this would be done only when necessary. As such, we have started talks with the Artificial Intelligence Unit under the Physics Department of Eduardo Mondlane University in Mozambique to inculcate automatic sensors in our system. When the water collects in the sump, the sensors will determine the turbidity, pH levels, ammonia, and nitrites. When these parameters are above the normal level, the water will be automatically redirected through a different channel for mechanical filtration using reverse osmosis desalination technology. Reverse osmosis plays an important role in reversing the concentrations within our systems without killing beneficial plant growth, and thermally promoting rhizobacteria. We propose reverse osmosis which, unlike common thermal desalinization solutions, preserves the integrity of the bacteria. Here, the inflow direction of the nutrient concentrator is reversed. Instead of increasing the concentration of each hydroponics sump, the revised design aims at extracting and concentrating nutrients from the aquaculture system and leading back demineralized water. This inverted process flow does not affect the system's mass balance. When the RO system is cleaned, the accumulated biomass from the filters will contribute to the nutrient-laden biomass that will be traded with composting and recycling companies.

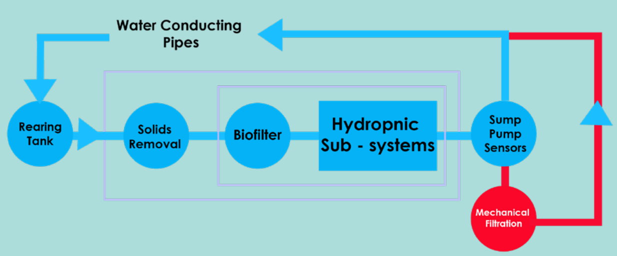


Figure 4. Order of System Design with Mechanical Filtration

3.6 - Customer /User Validation

Needs
•Clean water/water preservation
•Accelerated food production

Benefits
•Water pollution reduced
•Food security promoted and nutrition improved

To Whom
•Aquatic and terrestrial life
•Growing Population

Global impact
•Zero Hunger (SDG 2)
•Clean water and sanitation (SDG 6)

4 - IMPACT ASSESSMENT

4.1 - OUTCOMES

Socio-Economic Impact

- We create a value chain to offer employment for people.
- Promote health and reduce malnutrition.
- Ensuring food security for a growing populace.
- Educational tool for knowledge transfer in Agricultural Sciences.

Environmental Impact

- Reduced chemical usage.
- Reduced water pollution.
- Preservation of aquatic life.
- Building of sustainable cities.

4.2 - UNIQUE VALUE

Unlike most aquaponics designs, our model will minimize the usage of external fish feed, as the duck weed grown within our system will be used to feed the Tilapia. Also, our pumps will be powered by solar energy which makes it possible to build in even the remotest of places where conventional electricity is not available.
This is possible because we are piloting in a temperate zone where solar energy is abundant, having about 10 hours of direct sunlight in a day. During rainy seasons, the duration of direct sunlight is reduced averagely to about 6 hours. Using a 60-cell solar panel with dimensions 5.4ft by 3.4ft, it will have an output of 270 - 300 watts. Multiplying with the hours of direct sunlight received (290*10 = 2900), our panels will give a daily power output of 2.9kw. In the worst case scenario (6 hours of sunlight), our panel will produce (290*6 = 1.74kw) 1.7Kw power output, which is still enough for the pumps we will be using.

5 - PROTOTYPING

5.1 - Progress

Our team has managed to test the idea by building a media-based aquaponics system. This is being used to rear 50 fish and grow 50 lettuce heads with duckweed spread on the pond surface. We used media-based (flood and drain method) because it is convenient for a small-scale test such as the prototype we built. On a large scale, Nutrient Film Technique would be used as it is convenient and profitable and uses the same principles of nutrients flow like the media base we tested. A High Density Polyethylene (HDPE) Intermediate Bulk Container (IBC) was cut into two and used as the fish tank and grow bed. We made sure the container was food grade to prevent contamination. We built a swirl separator for the solid filtration. We were able to test the solar economics by using a solar powered pump. We are yet to test the artificial intelligence incorporation into our system.

Team member at lettuce farm to interact with farmers

Team member at the local ministry of fisheries and aquaculture

Mini water pump with solar panel

Aerial view of Prototype

Team member tending our Prototype System

Solid filtration by sedimentation component

Team member interacting with fisherman

Dedicated workspace to our team through our partnership with the AI department

5.2 - Perspective

Working with our mentor on our prototype, we had the opportunity to learn from an expert's point of view. It was brought to our attention the need to have a replacement for all water lost through evaporation, transpiration into plants, cleaning, and harvesting. For the start, we will be using normal tap water for this purpose. In the long term, our team will be researching into ways to conveniently harvest rain water, another under-utilized water source, for this purpose to further boost the circular economy.

Also, we have been able to secure a partnership with the Artificial Intelligence Unit under the Physics Department of Eduardo Mondlane University in Mozambique following the announcement by the Wege Prize to the university. Our discussions with them brought new thoughts in our prototype stage to include automatic sensors in the future to check water quality and monitor and track diseases among the fish.

5.3 - Learning

We have learned from research that tilapia would be the ideal type of fish for our project. One reason being that it is omnivorous and able to survive on a wide range of diets. This allows duckweed grown in our system to be used as supplement feed to significantly reduce the cost of fish feed. We have also found the probability of bacterial infections in our system. This is mainly introduced by outside factors when sanitation methods are not utmost, as such helping us inculcate strict sanitation measures going forward. Most importantly, we have found that our model is feasible with a great potential of solving the wicked problem and having ripple effects on other sectors.

6 - Barrier Acknowledgements

In the case of bacterial infections like Aeromonas, Columnaris, etc in fish, chemical treatments are the ideal solution as it stands now, hence undermining our model to be a zero chemicals system. However, treatment would be done by isolating infected school of fish and treating them in separate containers to reduce the effect in our system. Infected fish could be identified by physical characteristics like tattered fins, bumpy growth on skin, increased gill movements etc. However, this would not be an effective mode of identification as we expand, as such, we will be working with our partners to use sensors and AI to monitor fish movements and identify bacterial infections in our system. We will also have a research and development team to research into novel organic means of bacteria and parasite treatment in other to achieve a zero chemical system.

BUSINESS MODEL CANVAS

Key Partners

Local Farmers

Organic food Markets

Restaurants

Materials Suppliers

Ministry of Fisheries and Aquaculture

Ministry of Agriculture

Compost and Recycling Companies

AI Department

Key Activities

System design

Market search

Farming operations

Developing customer relationships

Sales of Produce

Maintaining and testing nutrient and waste balance

Key Resources

Technical knowledge

Land

AI Software

Materials (Biofilter, tanks, pumps etc)

Value Proposition

Urban Farming

Relative moderate prices

Reduced Water pollution

Organic and Healthy Produce

Reliable supply of produce

Customer Relationship

Prompt Customer Response

Receive and work on Customer Feedbacks

Intermittent promotions

Customer Segment

Restaurants

Hotels

Schools

Wholesalers

Channels

Direct sales:

No intermediaries hence higher profit margins

Partner channels

Cost Structure

Startup Cost:

Sourcing materials and system parts

Land acquisition

Registration and Licensing

Promotional cost

Operating costs:

Fish feed and nursery

Seedlings

Packaging

Marketing and Branding

Research and Development

Maintenance

Revenue Stream

Sales of vegetables

Sales of fish

Planning, designing, and supervising the construction of aquaponic systems for 3rd parties

Operate Organic Restaurant in the long term

DETAILED MATERIAL ANALYSIS

High-Density Polyethylene tank

Compared to other materials, polyethylene is very affordable and widely available; food-safe; light-weight; highly malleable; non-corrosive; UV resistant, and cleanable. It is easy to install, relatively inexpensive, and durable, with an expected life of 20 to 30 years. As a polymer, polyethylene does not generate hazardous substances during its decomposition and can be upcycled.

Reverse Osmosis filter

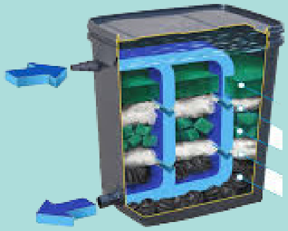
The mechanical filtration component would use the reverse osmosis principle. Unlike the common thermal desalinization solutions, reverse osmosis technology retains the integrity of the bacteria which is needed in our system.

Solar Powered In-line impeller pump.

Solar energy is a clean source of energy and is abundant in our pilot location, Ghana. It is an under-utilized resource, making it necessary that we tap into it to power our pumps. Correct pump power ratings will be used to avoid wastage of energy.
These pumps have durable parts and common recycling companies can handle the disposal at end-of-life. The pump and motor can be returned to the producer at the end of life for safe recycling.

Resin pipes

Resin is common in recirculating aquaculture systems because it is light-weight, relatively inexpensive, easy to work with, widely available and most importantly, non-toxic. It does not generate hazardous substances during decomposition and it can be recycled or upcycled.



Biofilter

The biofilter will provide a large surface area for colonization by nitrifying bacteria. This is needed to convert ammonia into nitrate for plant absorption.

Sourcing Materials
Some of the materials used in our system such as the conical fish tank will be custom-made by our suppliers. Part like the solar-powered pump will be sourced from suppliers in China.

Incorporating Materials for Reuse and Upcycling
Materials like pipes and tanks used in our system are localized on the farm and can easily be retrieved for upcycling when they come to the end of their utility. Complex ones like the solar pump could be disassembled by technicians and have important components reused. Waste from our products (Fish and Vegetables) will also be recovered through our collaboration with waste composting and recycling companies to be processed into compost and compost tea.

Maximizing Materials Utility
We will practice a high maintenance culture to expand the materials' lifespan. We will also source high-standard, durable materials.

Considering Social Equity
We have chosen the safest materials to work with so that health hazards on the side of our manufacturers would be minimal. We will also be training local farmers in this relatively new technology in farming to boost their human capital and not that they would be entirely be displaced by this form of farming. While working with us, we would ensure fair wages for these farmers and reduce their exposure to chemical usage.

DETAILED ECONOMIC ANALYSIS

STRENGTHS

S

Clean food: produce is grown organically

A year-round supply of produce

Low operational costs

Passion driven and innovative team

WEAKNESS

W

The system can support limited crop types

High startup cost

Low technical skills within our pilot location

THREATS

T

Lower profits margin in the short term

Limited human resources for large scale operation as it is relatively new

Natural threats: Bacterial infections, diseases etc

OPPORTUNITIES

O

High demand for organic produce and fish by consumers

Ability to incorporate into urban buildings to build sustainable cities

Rising concern for the environment will affect patronage of produce.

Environmental Analysis

Internally as a team, we are driven by the need to maintain our system's integrity, that is zero waste, minimal chemicals usage, the maximum utility of resources and materials, etc. As such, decision-making will be based on which option pulls us closer to these goals. Consumers are driven by healthy and organic produce, which we would capitalize on. Most Ghanaians also prefer tilapia diets to other fish due to the taste, nutritional benefit, and wide range of recipes. Lettuce will also provide important nutrients which are missing in most Ghanaian diets. There are also governmental policies like "Planting and Rearing for Food and Jobs", grants, and training from the National Entrepreneurship and Innovation Program which is aligned with our business that we will benefit from.

Competitive Analysis

Traditional vegetable farmers, fishermen and those who practice aquaculture are our competitors. These groups bring similar products to the markets in isolation. We have the advantage of producing fresher and healthier foods that capitalize on consumers' health and nutritional drive. As much as 71% of the consumers are willing to pay over 50% price premiums for organic vegetables and over 82% are willing to pay 1%–50% price premiums for organic produce (Anifori, M. (2010) "Measuring Market Potential for Fresh Organic Fruit and Vegetable in Ghana' Kwame Nkrumah University of Science and Technology). Without charging premiums (Due to the effective system in our operation to reduce cost) we have an even higher advantage to win consumers with the organic value proposition.

Again, we have access to a year-round production to meet consumers' demands to build brand credibility and trust. In a long time, setting up our restaurants will ensure value addition to produce to increase sales.

Positioning

Our customers are driven by health consciousness, taste, and availability to decide what to eat. This we will capitalize on by communicating clearly how our produce is healthy while still working within cost. We will create effective channels for distribution to make food available as and when demanded.

RISK ANALYSIS

The risk inherent to our model is market acceptability, high cost of facilities and operations, diseases and pests, as well as environmental controls.

Strategies of Mitigating Risks.

Temperature control facilities
Strict adherence to hygiene protocols
Disease control
Testing and Training
Incentivizing and educating skeptical customers.