Czech University of Life Sciences Prague

Faculty of Economics and Management

Department of Information Technologies

Diploma Thesis

Smart devices in agriculture

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Faculty of Economics and Management

DIPLOMA THESIS ASSIGNMENT

Bc. Vipulkumar Baldevbhai Sharma

Informatics

Thesis title

Smart devices in agriculture

Objectives of thesis

The main objective of this theses is to analyze the usage of the smart devices for crops in challenging weather conditions.
Partial goal of the thesis are such as following:

- To make literature review of current usage of smart device in agriculture.

- To develop a case study of using smart devices for crops in challenging weather conditions.

- To evaluate the proposed solution and to make recommendations.

Methodology

The literature review will be based on the latest industry and scholar resources.

Practical part is made of the case study focused on the smart device implementation for crops in challenging weather conditions. Analytical, synthetical and deductive approaches will be used. Based on the results of the case study final recommendations will be formulated.

The proposed extent of the thesis

60 – 80 pages

Keywords

Smart device, crops, weather, agriculture, Internet of Things, precision agriculture.

Recommended information sources

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Declaration

I, declare that I have worked on my diploma thesis titled “Smart devices in agriculture" by myself and I have used only the sources mentioned at the end of the thesis. As the author of the diploma thesis, I declare that the thesis does not break copyrights of any their person.

In Prague on date of submission ______________________________

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Smart devices in agriculture

Abstract

In the most recent times, advance technology has changed agriculture industry. An effective usage of machinery and tools has added value in the agriculture industry and especially for traditional farming process. However, there are several factors causing challenges in farming sector. Climate change, water supply, sunlight, land fertility etc. Ae major challenges causing limited and depended productions in current agriculture industry.

The review of the topic is based on a significant review of secondary data and will be qualitative in nature. The same will be collected from articles, reports, case studies and publications. In addition, the information collected from the database of various case studies is used to supplement the current literature of enriching secondary published data to reach a conclusion. Thesis has focused the past and the current production mechanism of crops and animals.

The information is collected from case study of Thorilex Ltd. Located Prague, Czech Republic. The qualitative data to be used in the study comprises nutrition balance, sunlight effectiveness, PH stabilization process, aggregate water supply technique, project realization phases including investment plan etc. to analyses usage of smart devices to grow crops/animals in multiple weather conditions.

Keywords: Aquaponics, Agriculture, Water Supply, Nutrition, Crops, smart Device, Farming etc.

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1 Introduction

Agriculture is the main source for the food on the earth for the human being or for the live spices. If we think in terms of economic way in the world wide, it‘s play a big role in economic growth of the agriculture based country like, for rice India, China, for corn United States of America. Unfortunately some farmers from developed countries are still using the traditional method of farming [1]. Production of crop in the agriculture can be increased by understanding and forecasting crop performance in variety of environmental conditions.

Different type of farming technique used in different part of the world. This is because of weather condition of that region. This will affect the quality of same crops grown in different region. Due to this, it’s not possible to grow the same crops grown in warm weather to grow in cold region. For that we can take a help from technology. Data collected manually in the field based agriculture studies during different weather condition will help to improve the crop production and its quality. Unfortunately this data was collected manually in the different location with some challenging weather condition. Data collection for the crop studies in the remote and distributed location is very low, also these data collected manually, led to the invalid conclusion because of solar radiation readings in the afternoon after even a short rain or overcast in the morning are invalid, and should not be used in assessing crop performance.

Use of smart devices like weather sensors and climate controller connected with network help to improve the data quality as well gives the accurate data. These devices are used to improve and help against challenging climate. Different type of farming technique used in some part of the world. This is because of weather condition of the region. Using smart devices and using the data taken by the theses devices will improve the farming technique. Now a days it can be seen that, this is changed whole farming techniques, not just the change make more easily for farmer. Using a smart devices in the agriculture will change the whole farming style from cropping to send crop in the market. It’s also change the life style of the farmer.

Farming started as a full fill human‘s basic needs. As the time goes it’s become the part of economic growth. Farming become the part of industries now and in some part of the world or in some countries it is main source of the income.

2 Objectives and Methodology

2.1 Objectives

The main objective of this thesis is aimed towards making an effective analysis in the usage of the smart devices for crops in challenging weather conditions.

Partial goal of the thesis are such as following:

- To make literature review of current usage of smart device in agriculture.
- To develop a case study of using smart devices for crop production in challenging weather conditions
- To evaluate the proposed solution and to make recommendations.

2.2 Methodology

The review of the topic is based on a significant review of secondary data and will be qualitative in nature. The same will be collected from articles, reports, case studies and publications. In addition, the information collected from the database of various case studies is used to supplement the current literature of enriching secondary published data to reach a conclusion. Thesis has focused the past and the current production mechanism of crops and animals.

The data is collected from case study of Thorilex Ltd. (Prague, Czech Republic). The qualitative data to be used in the study comprises nutrition balance, sunlight effectiveness, PH stabilization process, aggregate water supply technique, project realization phases including investment plan etc. to analyses usage of smart devices to grow crops/animals in multiple weather conditions. Through which, the smart device's performance was analyzed and evaluated so that any conclusions can be reached with recommendations for better implementation, based on current trends. Any problem areas that need to focus on various evaluation measures and the farming sector have been researched so far.

3 Literature Review

Since, decades farming is the main source of the food for the live spices and time flies it is become the source of income as well.

We all know before farming, people lived by hunting animals and gathering plants. When they feel supplies ran out, these hunter-gatherers moved on to find another place. Farming help people get the food without travelling, also they start to leave same place and society. They start to grow crops or raised animals at nearby land.

This is how society start to build or we can say farming was the main thing to help create a society.

Aquaponics at the present stage is a relatively new agricultural area with

Fish and vegetables in a mutually interconnected environment, which during natural cycles [43], Nutrients for more sustainable agriculture, now known as permaculture. In addition to the ancient techniques used by different cultures for History, modern Aquaponics began in 1977 with the study of possibilities Nitrates from aquaculture waste that are recirculated. Attempts have been made to remove nitrates with plants as bio filters among the various options [44], which led to the birth of aquaponics. Other without relying on the substitution of vegetable ice, in particular bacterial, Aquaponics as an independent technique that was used in the Eighties with the parts of Mark A crushing system based solely on the interaction between fish, vegetables, and bacteria. They also adopted methods of flood-protection methods in a sandbox for this system, in which

The plants are grown in a porous, relaxed environment that is systematically flooded and dehydrated at the same time, researchers at the University of the Virgin Islands started on the commercial benefits of linked fish and plant systems [45]. In the mid-1990s, deep-sea access was adopted by them insist on floating rafts in plants whose roots are built into ventilated water Media.

These are the two options and the last traces of channels imported from Hydrophone, There are many types of farming, we can have classified by type of crops and its growing system

3.1 Types of farming

There is different type of farming technique used by the farmer around the world based on their land, weather and water condition. Specially based on their needs. As we know leaving style, food style and basic need of life is different as per the region and climate of region. In cold region there is more consumption of meat but in warm is opposite at they do eat more vegetables.

3.1.1 Arable farming

Arable farming is influenced by human and physical factors compare to other types of farming. In this type of farming people stop moving from one place to another.
Grains like Oat, rice, wheat such type of crops known as Arable crops. This type of crops required good soil and warm and humid climate to grow successfully. It required flat land to grow and harvest successfully.
Such this type of farming is concentrated in the east and south of Asia and the UK where the, soil and relief of the land allow it to be profitable. Due flat land it's easy to be ploughing and less human power required. Due to open area farming more patsies required to take care of crops. [2]

3.1.2 Pastoral farming

Pastoral farming is a type of farming where producing livestock i.e. Dairy farming, beef cattle, and sheep for wool. It's also known as livestock farming Arable farming concentrates on crops, where pastoral farming concentrate on livestock. Finally, Mixed farming incorporates livestock and crops on a single farm.
Some farmer grows crops that is help only for livestock. Using this farming technique farmer will get animal product and crops. Animal product like sheep wool from the sheep, Milk from the cow and Nany goat with help to produce dairy product like, cheese, yogurt etc.
Biggest advantage of these farming is, it can be done in dry region where there is no possibility of growing crops. These animals can be used for ploughing the farm, transportation or for moving. It can be used for transportation also where it's not possible by vehicles. Pastoral farmers can grow food for their animals, but it is not

possible for farmers who leaves in dry region, so they need to buy food for their animal that will be very expensive for them and it will affect the price of animal product.

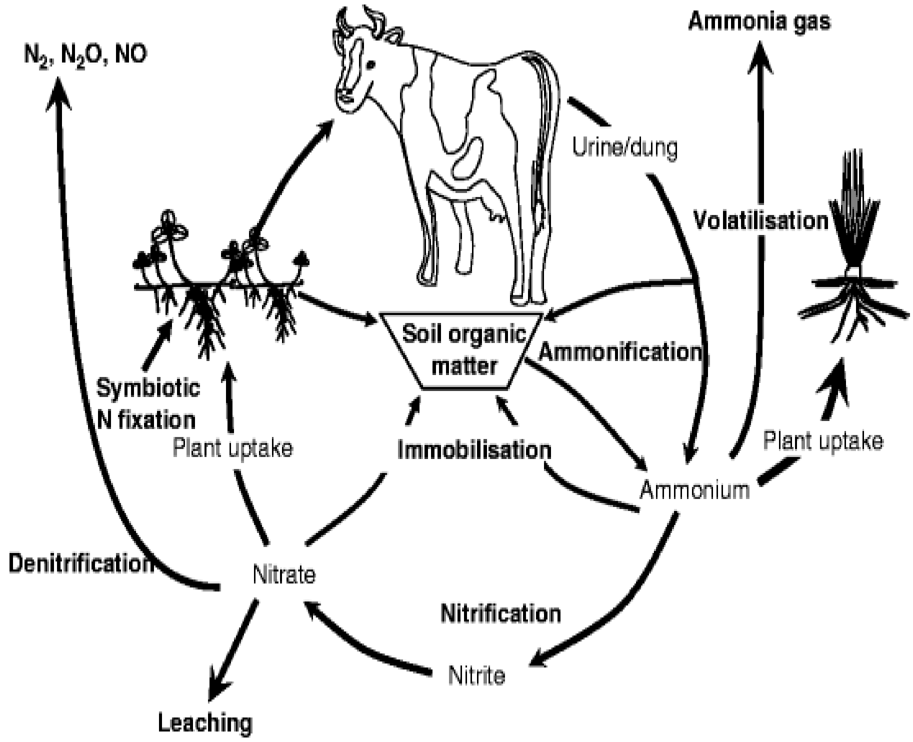


Figure 1 Pastoral farming, (S, 2011)

3.1.3 Mixed Crops and animals

Farmers from tropical and temperate country used to do mixed farming i.e. crops and animal. Best advantages of the mixed farming are, when crop used to feed animals and waste of that animals are used as fertilizer for the crops.

Verity of the mixed farming is widely used in worldwide. Mixed farming system gives advantage of recycled of fertilized soil. This system of farming secures the lifestyle of farmers in society and help to produce food and other commodities for markets. Many high specialized crops and livestock systems developed in developed country to get an advantage of mixed farming.

Mixed farming process less relay on the natural resources like fertilizer for crop or food for animal. Farmer can grow the grass for the animal like cow, ox, goat, sheep etc. Where waste of these animal can be used as fertilizer for the crops (grass) [2].

3.2 Aquaculture or hydroculture

In this modern era some of the farming technique are very famous in these days i.e. **Hydroponics, aquaponics, aeroponics** etc**.** These techniques were established in the beginning of 1900’s.

These techniques were not popular at that time due to lack of technology, as they were itself a challenge. In more detail like **hydroponics** is the soil less farming. **Aeroponics,** this process helps to grow plant by mist and reject to use of soil. Also, these processes have been done inside or indoor, less possibilities of pest and other weeds.

Aquaponics this process is very good example of mixed farming in this system not only the corps, but you can grow fish together. Also, to grow a crop there is no required of soil on it.

3.2.1 Hydroponics System

Hydroponics is the part of hydroculture or aquaculture, it is the process to grow plant in the water, i.e. soil less. Hydroponics is the process of farming where you do not required soil to farming or grow the plant.

In this technology you can grow vegetable, flowers. And some other crops. In this process the roots of the plant are grow in the water. This water contains some minerals and nutrition to help grow faster. This mineral can be the bio product like, fish waste or normal nutrition’s. These nutrition is directly dissolved

Figure 2 Hydroponics System (Mart, 1990)

3.2.2 **Deepwater Culture**

This one of the easiest method the in hydroponics to grow the plants. It is also known as the reservoir method. In deep water culture hydroponics system, the roots are stayed in the nutrition water and this water is circulated by the normal aquarium pump to give the oxygen to the roots.

The main benefit of the DWS (deep water culture) is there is no drip or spray water system used to create a clog, hence its very good to produce fine organic vegetables.

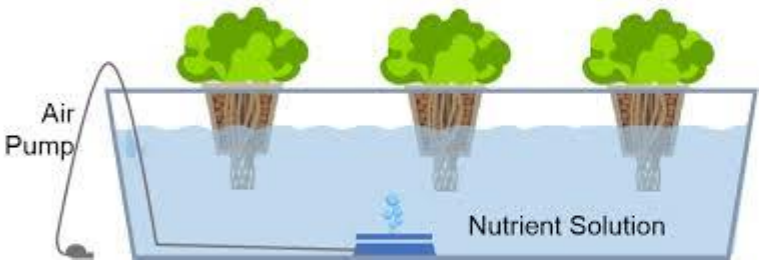


Figure 3 Deepwater Culture (Leaffin, 2019)

3.2.3 **Nutrient Film Technique**

In this type of system water is continuously circulated to provide nutrition to the roots. In this technique system is slightly tilted to give gravitational force to water to help make flow smooth as per shown below.

The main thing to work system smooth is based on slope of channel and thickness of it. Improper slope or balance of the channel directed to the failure of the system. Proper flow of water gives the proper amount of water and the nutrition on it will make the system smother in operation and gives correct output.

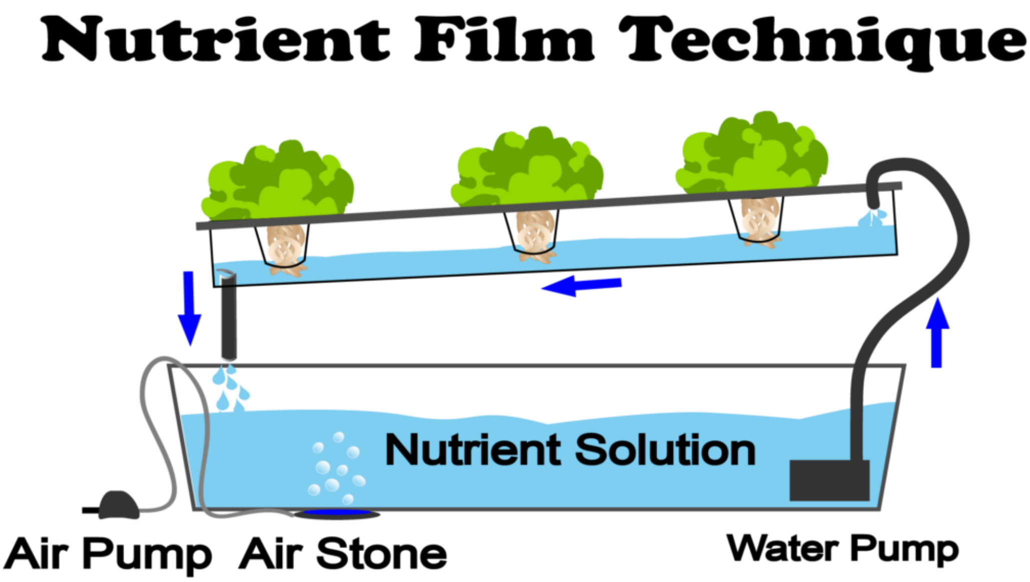


Figure 4 Nutrient Film Technique (Nosoilsolution, 2019)

3.2.4 Aquaponics System

Aquaponics is nothing but the combination of aquaculture and hydroponics. You can rise fish and grow vegetables (without soil) at the same time using one system. It is the good combination of nutrition for the plan made from the waste of fish and for fish good quality or filtered water came from the plant roots.

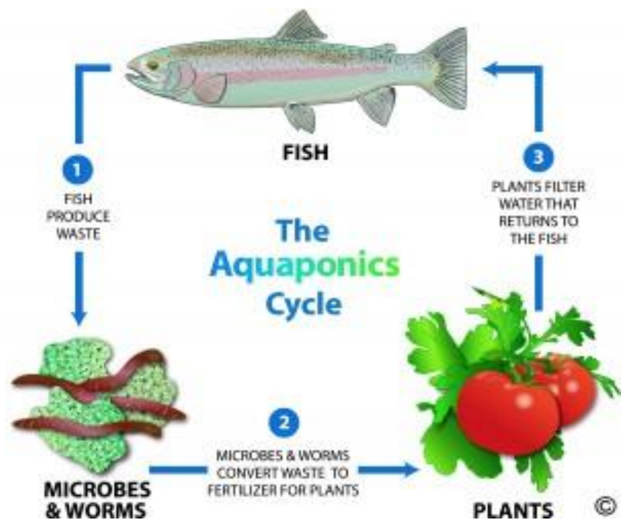


Figure 5Aquaponics System (Bernstein, 2011)

3.3 Aquaponics

Aquaculture has been carried out in different parts of the world in different age groups. First Was around 2000 BC in China. What about the farmer's food? Fish caught on ponds during the dry season rapidly evolved to a well-cold method Agriculture. Approx. 500 BC in A.D., Fan Lai wrote the book "A classic Fish culture" that is the first record of fish farming. During the Tchang dynasty (618-906 AD) it happened that the surname of the dynasty was Li, which was also a popular name the carp most often grown. The emperor forbids the cultivation of carp, Farmers had to look for new species of fish to grow. This led to an explosion Aquaculture, adding dozens of new species to the population and developing new methods such as a mixture of different species in the same pond, each occupying a niche and Total productivity says [45].

In Europe, in addition to the ancient Romans, aquaculture began in small ponds or lakes Monasteries that have grown their own fish. This technique has been used in areas without Lakes or seas because it provides fresh fish without relying on salting [46] with the advent of rail transport in the 19th century was abandoned in favor of traditional fishing. Late 19 and 20 centuries in the 19th century. Century, aquaculture was at the center of sea species domestication Controlled environment near water sources (rice 2010) Lead to the creation of aquaculture companies and to arrival in modern aquaculture How he understands today.

During all these periods, wastewater produced in aquaculture has just been released. Environment and for fresh water. Until the Seventies, when the first effort to create an aquaculture process capable of cleansing their own water and Reuse. Finally, this effort ended with the creation of SAR and At Aquaponics. For the remainder of this chapter, we will only talk about the remote access system 16th the whole time because the only aquaculture technique is to put things together With Aquaponics

3.3.1 **Aquaponics Principles**

Aquaponics combines hydroponic culture with the return of aquaculture elements. Conventional hydroponics requires mineral fertilizers to provide the necessary nutrients, but aquaponics uses available fish water, which is rich in fish waste, as a nutrient for plant growth. Another advantage of this combination is that excess nutrients need not be eliminated by regular freshwater exchange enriched with fresh water, as practiced in aquaculture systems. The system creates a symbiosis between fish, microorganisms and plants and promotes the sustainable use of water and nutrients, including their recycling (Figure 8). In this synergic interaction, the relevant ecological weaknesses of aquaculture and hydroponics are transformed into forces. This combination significantly minimizes the need for nutrient and waste input, as opposed to operating as separate systems.

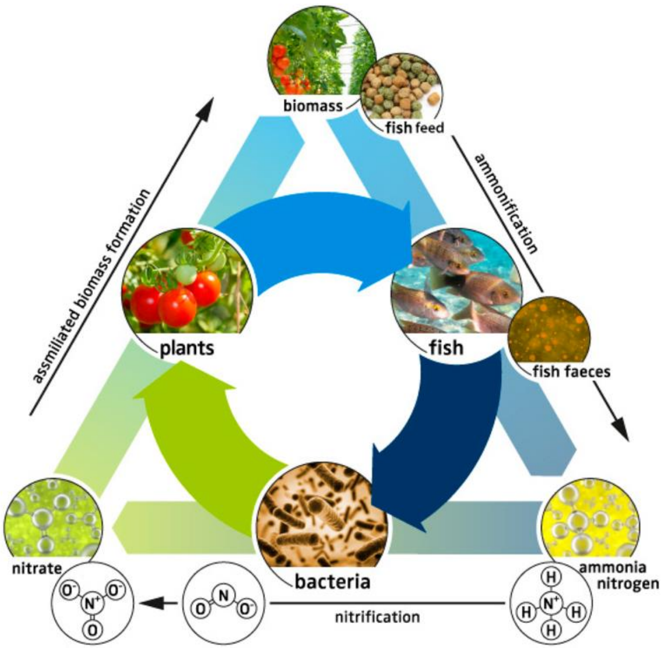


Figure 6 Aquaponics Principle (Goddek, et al., 2015)

Plants require macronutrients (e.g. C, H, O, N, P, K, CA, S, and Mg) and micronuclei (e.g. FE, CL, MN, B, Zn, Cu and MO) that are necessary for their growth. Hydroponic solutions contain clearly defined proportions of these elements [33] and are added to the Hydroponic solution in ionic form, with the exception of C, H and O, which are available from air and water. In the aquaponics systems of nutrient absorption of plants from fish tanks, fish wastes are rich in dissolved nutrients (excrement, urine and excretory), including soluble and solid organic compounds. Soluble in water for ionic form and assimilated to plants. In order to maintain adequate plant growth, micro and macronutrient concentrations must be monitored. Some nutrients should be replenished at regular intervals to accommodate their concentrations, for example, iron is often insufficient for fish waste [34, 35]

Aquaponics systems must be able to adapt to the various communities of microorganisms involved in the treatment and solubility of fish waste. Ammonia (NH4MD) from fish urine and excretion of gills can accumulate in toxic amounts, unless it is removed from the system. This can be done by a gradual microbial transfer to nitrate. One of the most important microbial components is a consortium of autotrophic bacteria that is established as a biofilm on solid surfaces in the system and consists mainly of Nitrosomonas (e.g., nitro). Nitrobacteria (e.g. Interspinous SP., Nitrobacter SP.). The ammonia in the system is transformed into nitrite (NO2MD) Nitroselacteria prior to conversion into nitrate (NO3) Nitrobacteria [36]. The final product of this bacterial conversion, nitrate, is much less toxic to fish and because of its bioconversion, the main source of nitrogen for plant growth in aquaponics systems [37, 38, 39]. Most systems require a special bio filtration unit in which intensive nitrification takes place.

The optimal relationship between fish and plants must be established in order to find the right balance between the production of fish nutrients and the plant intake in each system. Rakocy [40] reports that this could be based on the feed rate, i.e. on this basis, a value between 60 and 100 grams per day is recommended for 1 M-2 for green leaves that grow on hydroponic rafting systems [41]. In et al. [42] An optimal ratio of 15 to 42 grams of fish was found, which is fed to 1 m2 of plants, which grow with African sums (Clarias Gariepinus) for eight water spinach plants (Ipomoea aquatic). Finding the right balance therefore requires basic knowledge and experience with the following criteria: (1) fish species and food use rates; 2. the composition of the fish feed, for example, the quantity of pure protein converted into total ammonia (TAN); 3. The frequency of feeding; 4. The nature and construction of the hydroponic system; 5. Species and physiological stages of crops (green vegetable and fruit vegetable); (6) the density of plant seed and (7) aquatic chemical composition affected by the rate of mineralization of fish waste. Since fish, microorganisms and plants are in the same water loop, environmental parameters such as temperature, pH and concentration of minerals must be as close to optimal growth conditions as possible.

Aquaponics is the integration of hydroponics with aquaculture is increased bio-integration food production system.

Steven Diver a NCAT agriculture specialist says, in aquaponics nutrition in rich water from the fish tank is good enough to fertilize the hydroponics production or hydrophones base farm. And the water circulated from the hydroponics beds or farm is good for the fish as well.

The toxic water generated from the fish which contains ammonia , nitrates and phosphorus which is bio or fertilizer for the vegetables, flowers and some herbs which are the maim product that can grow in hydroponics.

The process of circulating water in the aquaponics make hydroponics system is a bio filter and stripping off all the toxic acid from the water and provide fresh water to the fish. The nitrifying bacteria leaves in the gavels and the roots of the plant playing big role, without them the process of microorganism the whole process stop functioning.

The food production by the aquaponics model or system work on certain principle

- The waste product of one system is the fertilizer or nutrition of another system.
- Combination of plant and fish result in a polyculture that increase variance and crop.
- Same water is used for both system with filter by each system itself.
- As water is re-used in both system production of vegetable and fish is gained in the desert of law water region.

3.3.2 Plants that can be grown in Aquaponics

- In the aquaponics the plants can be grown form the leaves family like coriander, mint latus etc.

- Vegetables like tomatoes, peppers, cucumbers, pea's broccoli, etc. Fruits like bananas, beets, radishes.

3.3.3 Fish can be grown in Aquaponics

- In the aquaponics you can grow fish Nile Tilapia, Red Tilapia, Sunfish, Koi, fancy goldfish, pacu etc.
- Some ornamental fish such as angelfish, tetras, molies, etc.

3.3.4 Technical Challenges

Aquaponics system design and application can be considered a highly multidisciplinary approach likeness from environmental, mechanical and civil engineering design concepts as well as aquatic and plant related biology, biochemistry, and biotechnology.

System specific measurements and control technologies also require knowledge of subjects related to the field of computer science for automatic control systems. This high level of complexity necessarily demands in-depth knowledge and expertise of all involved fields. The biggest challenge in commercial aquaponics is its multi-disciplinarily, needing further expertise in economics, finance and marketing. Thus, a high degree of field-specific insight in terms of both practical and in-depth theoretical knowledge is required.

This leads to an increasing level of complexity, which directly affects the efficiency factors of the running system. In the interest of highest efficiency and productivity, some numerical trade-offs are recommended and are outlined below. They include pH stabilization, nutrient balance, phosphorus, and pest management.[9]

System design with lack of knowledge or infused by the people with less knowledge led to the system failure.

3.3.5 **Why Aquaponics**

We might have the question why only the aquaponics, we have discussed about the aquaponics its structure and process, how it works, and hardware used. Here we can see why it is better than the other farming.

- Six time more crops than the traditional farming.
- Water usage is 90% less than the traditional farming.
- As this is indoor growing system there is no season restriction to grow plant. For example, the crops than can be grown only in winter, it can be grown in summer.
- In this system, water will be recycled, same water will be used multiple time as shown in the fig. 7. This system is suitable for any kind of climate, it can be dry land or law water area.
- Less pests to deal with since we are growing indoors.
- There's no weeding!
- Plants Grows Twice as Fast! Due to the naturally fertilized water from the fish.
- For the commercial farmer, aquaponics produces two streams of income, fish and veggies, rather than just one.
- Our aquaponics farm does NOT require farmland with fertile soil, or even land with soil; aquaponics can be done just as successfully on sand, gravel, or rocky surfaces, which could never be used as conventional farmland.
- Because we hang our grow lights vertically and use both sides of the light (no reflector), our lights are twice as efficient, as they are growing two areas of plants versus the standard one area. [23]

This is not only limited indoor hygiene system, but if, it will be established as a large-scale farming industry too, it will environment friendly too.

- The system uses less than 90% water than the regular or traditional farming. In this way reduced of water usage.
- In traditional farming more, water and fertilizer used, and that excessive fertilizer make it to the river. Which resulting the harmful side effects.

- As this is indoor farming less energy user even usage of grow light. Also, there is alternative to use recycle energy like solar, wind turbine, hydroelectric can be used.
- Usage of land can be reduced, as it will use to 6 times less land than the traditional farming.

  Here are some number based on research done by one company in Oklahoma. In 1sq foot, yield **14 pounds** of tomatoes in aquaponics where in normal ½ **pounds**. Same size of are consumes **13 gallons** of water in regular farming where aquaponics consumes only **5%** of that water. If the system placed in 1000ft2 it will provide food for 24 adults, for whole year for 3 times a day. [24]

3.4 Smart Aquaponics

The optimal, sustainable and cost-effective use of our land and water resources is crucial. This concern has increased risks for new innovative technologies that can meet these requirements appropriately. Technology is growing and today's technology is able to automate the entire agricultural system. To understand this new paradigm, look at various automated aquaponics systems. Smart and cost-effective digital wireless technology is an automated system that allows us to stay connected to water quality parameters to maintain operation. From a technological point of view, WSN integration must be used to monitor soil moisture, temperature, light, pH and water level from any remote location via a web interface. The large underwater mobile network (UWSN) is a unique network prototype used for exploration of the aquatic environment [6].

Using WSN, it proposes a cost-effective and reliable microsensor that can be recycled on a large scale to monitor and control parameters that control the return on assets. The system includes two types of sensors (IRIS and TelosB), special soil moisture sensors, relay-fed electrical valves and Java applications used for data aggregation [7]. The development of scalable mobile UWSN is therefore a challenge to withstand interdisciplinary efforts in acoustic communication, signal processing and mobile Acoustic network protocol. The network of water sensors is called the field for sensor nodes, which can be freely distributed in water environments. This work is called a network of water sensors with a pH-measurement application with magneto elastic sensors. This system is self-contained, communication is multi cable, and nodes can be used to control switches that can be used for pre-defined monitoring and control tools. Because the system is aligned with the RSW, this can lead to significant changes in the agricultural system.

WSN is a collection of small, low-cost nodes that work together to detect and handle different physical approvals and to efficiently allocate data over the network. In [8] he designed Prasanna et al control system integrated with aquaponics according to STR, which watched the distribution of ecosystem temperature, soil moisture, soil pH, water level and light intensity over a period. For the implementation of wireless sensor platform uses Micas'. The Data is collected via the board MDA100CB, which has a thermistor, light sensor and a general area of prototyping. The data gathered has evolved into revenue factors that could help to make efficient use of resources to increase productivity.

Wang et al. [9] designed a smart monitoring and control system based on OpenWrt, which is used for flow meters, pH, ultrasonic control sensors and digital temperature sensors as well as for conditioning. Signal control and control of closed loops. It is an intelligent interactive application that explorations and processes data captured by a webcam and some intelligent sensors for the interface of a human computer. Meanwhile, users can also use mobile devices to remotely monitor and control intelligent aquaponics. The hardware system consists of Arduino and WRTnod, where WRTnode is an open source development consulting tool based on Wi-Fi AP-SOC.

Guerrero et al. [10] designed a system that used the controls of a wireless sensor network to monitor the internal aquaponics system. This research report focused on the use of Wireless sensor network (WSN) for remote monitoring and control of various water voltages in the aquaponics systems, which served as a model for water BIOM present in nature. The aquaponics system is not necessarily a tight system, because fish had to be fed almost daily, so a vending machine was created for food.

This system used Arduino as a microcontroller and each command was tested in a simulated array environment and each executed as expected. This article describes a control system that is more accessible for troubleshooting the aquaponics system.

Espinosa-Faller et al. [11] established the applicability of the wireless sensor network technology for "Zig Bee" to the return of aquaculture systems. As part of this work, they develop cost-effective modules and a network of ZigBee-based wireless sensors to monitor the circulating aquaculture system. Temperature, dissolved oxygen, water pressure and electric current sensors were included in the configuration. Sensor readings and broadcast modules over a dozen wireless networks that have been tuned and verified. The modules were installed in the aquaculture system for recirculation to transmit the values of the sensors to the network coordinator. A tracking program has been created that displays and stores sensor values and compares them to reference limits. If reference limits have been reached, a warning is issued. E-mail and SMS notifications can also be sent to your mobile phone by your system administrator to receive immediate action. The Web interface allows you to access sensor values on the Internet. The system monitors some of the associated variables in real-time recirculation of aquaculture and sends alerts when the reference limit has been reached.

In an easy-to-use, Arduino-controlled system, the Arduino microcontroller is designed to regulate the frequency of the system cycle, allowing the user to enter the Aquaponics' cycles and insert into a flexible, electronically accurate dynamic system that can be Regulated and adapted for the specific application of aquaponics. Aquaponics automation projects with Arduino (ADACS), which use the postal API to warn owners of failed/overloaded pumps in case the environmental circumstances move outside different ranges of users and when the light development is turned off or not turn on. The DAQ environment is an open source Arduino shield, which is used here to monitor air temperature, comparative humidity and light in water beds.

Therefore, the Smart Aquaponics system ensures constant monitoring of the system status and tolerates the user to detect potential problems such as the pH values of the aquarium from the outset and to take action. Mandatory. In addition, in the above systems, the system of aquaponics may not be monitored constantly. The user can regulate the timing of aquaponics cycles for optimum efficiency and balanced energy consumption. In addition, the system can be remotely controlled and monitored, if necessary, over the Internet.

Basic structure in Aquaponics using smart device and its development,

As per the fig.4 shows the basic structure of smart aquaponics. As we have discussed earlier, the typical hydroponics still relay on the natural environment hence must face the natural challenges. Using the smart devices, we cannot ignore the climate challenge, but we can minimize the distraction from it.

Figure 7 Smart Aquaponics

Above figure gives the basic idea of usage of smart devices.

We all know there are three main things required to for farming or in agriculture.

1. Sunlight (Climate)
2. Water
3. Fertilized or composes soil. (land)

Using hydroponics system, we can substitute soil with the gravels, sand or some artificial sponge.

3.4.1 Sunlight

Plant needed light to grow and the Sun is the main source for the light. The plant generates their own food with the process of photosynthesis. This process contains light, water, Oxygen and carbon dioxide. It is not possible for all the region to have enough light to grow the plant. Every plant or tress has different requirement for the light. Artificial light can be taking place of sunlight for indoor farming and it will easily to be controlled by the help of smart devices like light sensors connected with controllers. There is also heat included in the sunlight which can be replaced by the heater with the help of temperature controller. Using a normal artificial light will harm the plant so in place of using normal light need to use UV protected light or garden light.

3.4.2 PH stabilization

As we all know the main source of natural resources is the water for aquaponics system. Natural water contains so many things like minerals, and some acids. That will be check by the pH level. As it is critical to all living organisms within a cycling system that includes fish, plants and bacteria. The optimal pH for each living component is different. Most plants need a pH value between 6 and 6.5 in order to enhance the uptake of nutrients. The fish species Tilapia (Oreochromis) is known to be disease-resistant and tolerant to large fluctuations in pH value with a tolerance between pH 3.7 and 11 but achieves best growth performance between pH 7.0 and 9.0. The nitrifying bacteria have a higher optimum pH, which is above 7. Villa Verde [11] observed that nitrification efficiency increased linearly by 13% per pH unit within a pH range between 5.0 and 9.0 with the highest activity of ammonium oxidizers at 8.2. Similar observations were made by Antoniou et al. [12], who report the overall nitrification pH of approximately 7.8. Based on these data, the highest possible pH value should be consistent with the prevention of ammonia accumulation in the system. Then, the ideal pH value for the system is between 6.8 and 7.0. Although root uptake of nitrate raises pH as bicarbonate ions are released in exchange, the acidity producing nitrification process has a higher impact on the overall system pH, leading to a constant and slight decrease in the pH-value.

There are two main things help to follow this process:

(1) The dietary supplements are the most relevant method in use. By adding carbonate, bidirectional system or hydroxide, the PH value can be adjusted temporarily depending on the requirement. In addition, they have increased alkaline parameters that inhibit large PH fluctuations and thus maintain the stable system. Buffers should preferably be based on calcium, potassium and magnesium compounds because they compensate for the possible nutrient deficiency of these essential nutrients for plants. In terms of the structure of supplementation, it is important to look for a balance between these three elements.

(2) A suggested alternative approach is the implementation of the Liquefied lime-bed reactor concept [13] into the field of aquaponics. This water neutralization concept consists of the controlled addition of dissolved limestone ($CaCO_3$) to the acid water that leads to a continuous pH-elevating effect due to carbonate solubilisation that releases hydroxide anions (OH^-).

$$CaCO_3(s) \rightleftharpoons Ca^{2+} + CO_3^{2-}$$

Depending on pH, when $CaCO_3$ dissolves, some carbonate hydrolyses produce HCO_3^-

$$CO_3^{2-} + H_2O \rightleftharpoons HCO_3^- + OH^-$$

The degree to which the pH is raised is dependent on the adjustable flow rate. However, this concept requires preliminary empirical measurements with respect to the system's steady pH-drop in order to determine the size of the lime-bed reactor taking the specific flowrate into consideration.

3.4.3 Nutrient balance

Aquaponics' challenge is to use nutrient intake effectively, reduce your rejection and tend to a Zero discharge system [14, 15]. Fish food, the main nutrient source, can be divided into assimilated food stuffs, uneaten foods and soluble and solid fish stools. The soluble excreta's is mainly ammonia and is the most available mineral until it is successively converted by nitrifying bacteria into nitrite and nitrate. Uneaten Foods and solid feces from organic substances should be dissolved by ionic mineral forms that are easily assimilated by plants. Minerals have different solubility levels and do not accumulate uniformly [16, 17], which affects their concentrations in the water.

The chemical and physical mechanisms of all microscopic organisms linked, and solubility are not well understood [18, 19]. According to current SAR practices, solid waste has only been partially dissolved, because it is filtered mechanically per day. These filtered wastes can be completely mineralized on the outside

Given the objective of achieving a low ecological footprint, a concept for a Shuya relief system should be maintained, says Neori *et al*. But more research on fish waste is needed to put all the nutrients in plant biomass Convert.

Mineralization has two methods for the organic matter that can be applied

(1) Digestion of Anorexia, the mineralization or disposal units that use the capabilities of hetero trophic bacteria (e.g. Lactobacillus plantar) [20].

(2) Use Kechue species such as Lumbricals rebellious to enable organic waste to enrich compounds in wet manure or to develop litters. Vermiculture worm casts can have a high degree of mineralization as microscopic and organic compounds. In addition to external sources (e.g. food waste), the aquaponics system was also provided with additional organic feed fertilizer for insects [21].

3.4.4 Phosphorous

All the minerals required attention, but the phosphorus required special attention as it is a microelement, which is comprehend by the plant in its ionic orthophosphate form. It is imperative for growth of flower and vegetables and other spices or herbs. In recirculated aquaculture system 30%-65% of the phosphorus added via fish feeder, which is lost via fish solid excretion that is filtered out by the filter. In addition, organic P, which is soluble as orthophosphate, may fail with calcium, so these elements are less available in the solution. Therefore, in the experiments of aquaponics, the range of 1 – 17 mg L-1 is reported, but the recommended concentrations in the standard hydroponic culture tended to be between 40 and 60 mg L-1 this difference suggests that phosphate should be absorbed into the aquaponics systems, for fruit vegetables that do not yet have satisfactory yields in aquaponics layers [27]. Phosphorus is a limited and precious source of mining and, consequently, a costly component of hydroponic solutions. Enough phosphorus production will undoubtedly be of great interest in the near future. It is therefore necessary to find a solution for re-use of wastewater rich in P.

Up to 65% P can be wasted in the form of sewage sludge from aquaculture, it is necessary to develop recovery solutions to achieve zero systems. For example, a rich leachate could be obtained by digestion of sludge with some microorganisms that dissolve after P [20] and then reintroduce into the hydroponic part of the system. The goal is to develop a system of return to zero discharge with maximum nutrient recycling, which is transformed into plant biomass and improves yield. [9]

3.4.5 Pests and diseases

Another aspect that needs further improvement for pest and disease management. Aquaponics systems are characterized by a broader range of microflora than conventional hydroponic systems, especially since fish breeding and bio filtration occur in the same water loop. Conventional pesticides used in hydroponics must not be used in aquaponics because there is a risk of toxicity to fish and the required biofilms (e.g. autotrophic nitrification of biofilm) [27]. The need to maintain nitrification of microorganisms and other nutritional solutions also prevents the use of antibiotics and fungicides to control and destroy fish pathogens in the aquatic environment. In addition, antibiotics are not approved for use in plants, therefore, their use should be avoided against fish pathogens in aquaponics systems. These restrictions require innovative solutions to manage pests and diseases in fish and plants that mitigate the impact on the fish and micro-organisms required. Pests and pathogens of plants and fish can be divided into four different categories based on specific solutions for substitution treatment. They are (1) plant pests – especially insects that deplete leaves and roots (e.g. aphids, spiders); (2) Plant diseases – micro-organisms (e.g. bacteria, fungi) and viruses that attack plants; 3. Fish pests (e.g. path); (4) Fish diseases caused by viruses and micro-organisms.

It is possible to use ground and cultural practices that reduce the incidence of diseases such as preventive hygiene measures, low fish and/or plant density and/or environmental conditions that reduce relative humidity around plants. In addition to these practices, there are already some innovative methods of biological control for plants grown in the field or in greenhouses. These methods are based on the use of micro-organisms with biocontrol activities [9] or extracts of such microorganisms or plant extracts (including essential oils) which have a high antimicrobial yield and time. Short stay [9]. It will be difficult to choose these methods and adapt them to the aquaponics systems because they are compatible with other living organisms in the system. In addition, microbial diversity can be beneficial for plants. The presence of some reciprocal microorganisms in the biosphere of the plant can delay the development of pathogens [9] and at the same time promote growth (e.g. Rhizobacie, which promote plant growth and fungi. As the presence of the broad microflora is one of the aquaponics, it is also necessary to establish the incidence of pathogens and risks to human health in order to assess the safety of aquaponics and to carry out control. Reasonable quality. These challenges can lead to the production of quality products that are free from certified pesticides (e.g. organic), thereby achieving higher market prices and leading to a healthier population [28].

3.4.6 Other Challenges

Another challenge is the regulation of nitrate levels in aquaponics. Leaf vegetables require 100 – 200 mg L − 1 concentration of NO3-N, fruit vegetables level under specific growth phases [29]. Intermittent high nitrate intervals may be harmful to fish and nitrate concentrations must remain below a certain threshold in order to avoid negative physical effects for susceptible species (e.g. 100, 140, 250 mg L − 1 NO3-N for Oncorhynchus mykiss, Explains Clarias Gariepinus, Oreochromis niloticus, respectively).

It is therefore particularly important to determine the best practical method (BPM): The ratio of the plant before the assembly and/or the execution of the controlled flow in the system to the required nitrate values. Some denitrification tanks are already used in RAS [30], but the technology is not yet fully developed.

This approach consists of creating anoxic conditions in a pillar that use mud as an organic carbon source for heterotrophic denitrifying microorganisms and circulates water rich in nitrate. If anoxic conditions are used in the mud, heterotrophic microorganisms can use nitrate instead of oxygen as an electron damper and gradually reduce it to gaseous nitrogen (N2) [31]. An essential step is to provide further bio filtration before restoring the treated water in the system to reduce the risk of toxic ions of NO2 from the denitrification process.

In environmental conditions, population density is the most important parameter for the welfare of fish. For outdoor aquaponics plants such as UVI, the normal density of tilapia fish is approximately 30 – 40 kg − 3 without the use of pure oxygen. In greenhouses it is possible to achieve higher densities up to 60 kg − 3 [9]; This can be since under longer conditions of daylight, higher content of algae and cyanide and greater oxygen, increased photosynthesis is produced. However, these properties must not be generalized. In fact, different types of fish require different optimal water quality; For example, hot water types of tilapia require dissolved oxygen content of 4 – 6 mg l − 1, while trout species in cold water require at least 6 – 8 mg l − 1 to [32]. It's not just dissolved oxygen, which is stable. Large fluctuations in temperature and pH deterioration may affect fish, plants and nitrifying by microorganisms [9]. However, temperatures of hot water types, such as tilapia and nitrifying bacteria, can be 25 ° to 30 ° C, while most plants prefer cooler water temperatures (about 20 ° C – 25 ° C).

Until now, Aquaponics has been built on trade between fish and plant needs. To achieve optimal conditions for fish and plants, it is now necessary to develop: (1) Focus on the interdependent parameters of the two components of the system (for example, a combination of fish and species), which would preferably be similar to ambient conditions at the same temperature and PH range that Ensure the nitrification of bacteria; or (2) physical separation in two circulation loops, i.e. Aquaculture Hydroponic Loop, described as systems in which the optimal state of each system is used with regular exchange of water between them. These are different approaches that can contribute to the breakthrough of commercial aquaponics.

3.5 System architecture of smart aquaponics

The smart Aquaponics system has been developed by seven modules: Integrated data Acquisition Unit, alarm system, systems Improvement unit, CPU, Web application, mobile application and cloud server, as shown in Figure 9. The system can be divided in 3 unit i.e. Data acquisition unit, System rectification unit, Central processing unit.

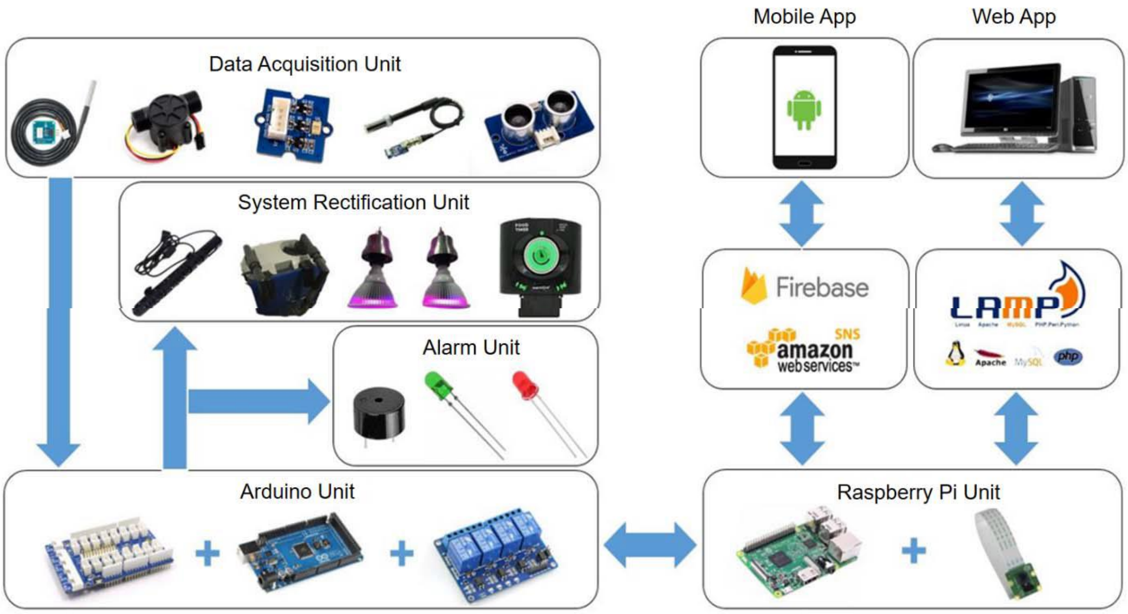


Figure 8 System architecture

3.5.1 Data acquisition unit

In this unit we are using various type of sensors i.e., water temperature, Water flow, Light sensor for the environment, pH level. These all censors have different characteristic and have different role to collect the data. This data store in data storage device that is linked with cloud server. This data will be process and will be very help full to create better system.

Temperature controller sensors contains two different type of temperature controller that is room temperature controller and water temperature controller.

Temperature controller sensors: It is used to maintain temperature around the plant bed according to the requirement of the plant. It will also help to collect the data and store for next season or next round of planting for same time of crops.

Water temperature sensors: It is used to maintain water temperature in the fish tank and water flowing through the waterbed. It's also gathered data for the future reference. These sensors act as per the weather changes and maintain the temperature accordingly specially in the cold region. As in this type of region ratio of fluctuation of temperature is very high.

Water Level controller: It is used to maintain the water level in the fish tank and in the growing bed. According to this sensor water pump will work and get on and off as per the requirement. It will send signal to the alarm unit when system get failed or not working properly. It is also keep storing data about the level of water in timely manner for example how long it will take to decrease the level of the water in the storage tank, fish tank or plant growing bed.

Light sensors: It is keep measuring the light density required for the plant as well for the fish tank. It will provide light to the plant accordingly weather condition. Any changes happening in the light inside the close area where the system installed. Its given signal to the alarm unit and the unit will be activated. It is also keep sending data to the data storing device for the future reference.

PH level sensors: It keep checking the pH level of the fish tank water which is floating from tank to the plant bed. PH level is the most important factor for the aquaponics as its affect both fish and the plant. Its keep getting the data and sent to the rectification unit and react accordingly. If the PH level of the water increased or decreased alarm unit get activated and start flashing the light and turn on the buzzer.

Alarm unit: In this unit required of a **green LED light**, a **red LED light**, and a **buzzer**. The green light will on when the system is healthy, but red light with buzzing sound to alert the user when the system is unhealthy or gives alert with some fault or not working properly. It can be any the malfunction of sensors or working device like water level controller or the motor used to flow a water.

3.5.2 System rectification Unit

This Unit consist of 4 devices, Heater, Primary water pump, Secondary water pump and fish fidder.

Heater will turn OFF and ON as per the weather condition or as per the climate change and the data provided by the temperature sensor or from data aquasition unit.

It helps to create the atmosphere required to grow plant as well maintain the water temperature as per the fish required.

Primary and **secondary** water pump used to water flow from the fish tank to the plant bed. If the primary motor malfunctioned the secondary motor will be activated. In-directly secondary motor work as back up and work make process running in case of primary water failure.

Fish feeder is work on timely manner or work as per the setup of timer. It will provide the food to the fish tank on certain time regularly [14].

3.5.3 Central processing Unit.

This unit work in two different section. The first section is used to communicate with sensor and actuators from the data acquisition unit, where second unit work as control unit for the whole system.

Section1: Contains relay board Arduino mega with 54 in/op pins and a grove mega shield. The groove mega shield mount on the Arduino to control the actuators from switching on and off the electric circuit.

Section2: It consists of Raspberry Pi3 model b and a camera module. Raspberry Pi was configured as a CCU (central control unit) for the entire system because it has inbuilt Bluetooth and Wi-Fi module. Also, it has high definition multimedia interface port that will help to connect visual display.

Web and Mobile application

The web application is hosted on Raspberry Pi to provide GUI to the interface for the system. It is also comparing the live and previous recorded data. It is also allowing to monitor and remotely control the actuator connected to the system. Where the mobile application is developed on Android platform. It is display live sensors data and help user to control remotely by service available to cloud server.

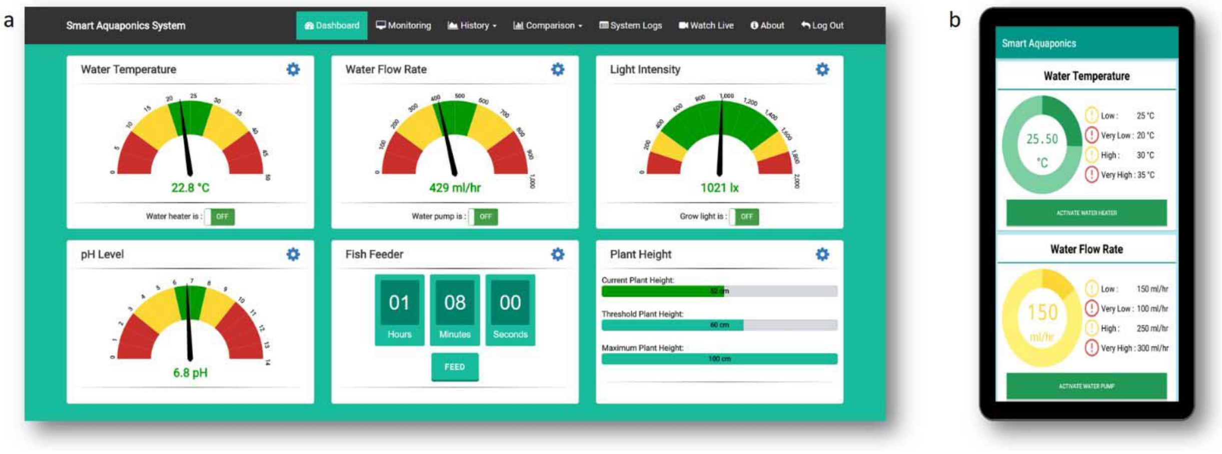


Figure 9 Web and Mobile application

Cloud server

The main aim of cloud server is to establish bridge to central processing unit and mobile application, also it will store data from the data acquisition unit and redirect back to the system central processing unit to activate heater water pump etc as per the requirement. [23]

3.5.4 System Implementation

As per the research done at the university of Glasgow Singapore. All the component was gathered as per the fig.9. All the component was carefully integrated after testing individually. After implementing all component, system was tested with different scenario. For example, if the temperature in the room is changed or increased and decreased from the desired temperature. Then alarm system triggered and send message to the user the check it and central processing unit start to control the heating device like as it needed it will increase or decrease the temperature.

The system will send out the message via SMS or email as per setting saved on the web-interface.

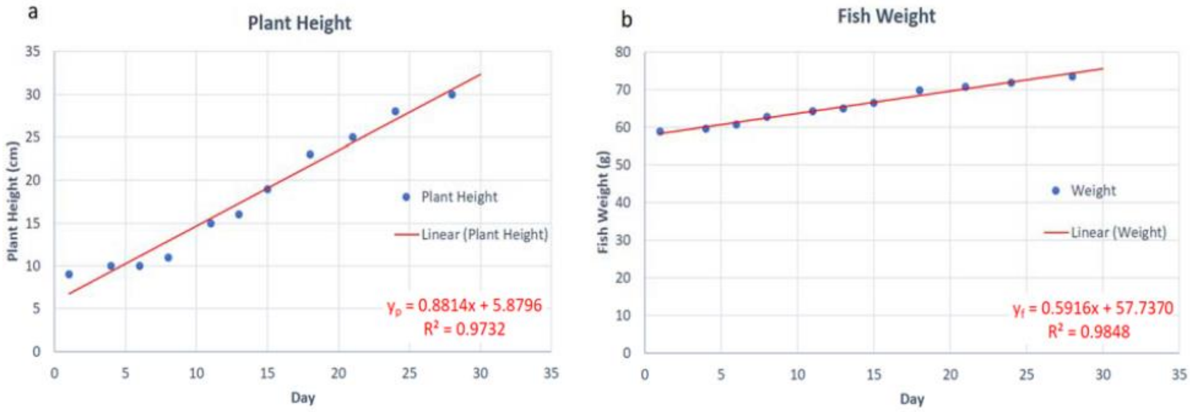
When the temperature become normal in the surrounded area the system sends the notification to the user about the system become normal. They have used different language to support the system i.e. python, PHP, java script, etc. It's also used some open source library that is circular gauge view for the android, bootstrap front-end frame works. They have also used some notification service like amazon SNS, google firebase to support mobile application.

For the web application as mentioned in Fig 9 (a) shows all the values of sensor, actuator status and threshold values that can be modified as the user requirement.

As it's mentioned in the dashboard user can setup the timer for the fish feeder. This count down timer can be setup as the characteristic of the fish and help to set up the timer to feed the fish.

3.5.5 Summary

The Designed intelligent aquaponics system has been continuously tested for 28 days. All sensor values for water temperature, water flow, and light intensity, PH and system height have been recorded. In addition, manual measurement of plant height and weight of fish was carried out to investigate and analyses data. The plants are Chinese water spinach, also called kangkong, and the fish is tilapia. Linear regression models were developed and the corresponding values of R2 (quality of fit) were calculated. The linear regression Model YP = 0.8814 x + 5.8796, with an R2 value of 0.9732, was formulated over time for the height of the plant as shown in Figure 3.1 (a), with YP being the height of the plant (cm) and X number of days. Likewise, YF = 0.5916 x + 57, 7370 with a value of R2 0.9848 for the weight of the fish over time as shown in Figure 3 (b), where YF is the weight of the fish (g) and X is the number of days. Since the two levels of R2 are very close to 1, which perfectly fits, the two models proposed can describe the link between plant growth and fish growth over time.



Day	1	4	6	8	11	13	15	18	21	24	28
Plant Height (cm)	9	10	10	11	15	16	19	23	25	28	30
Average Fish Weight (g)	58.75	59.50	60.75	62.75	64.25	65.00	66.50	69.75	70.75	71.75	73.50

Table 3. 1 (a) analysis for plant height; (b) analysis for fish weight.

4 Practical Part

In this part, we will discuss about company Thorilex is in Prague and research done by at me, created small aquaponics system at my place. This company is known for design and supplying aquaponics farm. The research gives the basic idea about the farm about the construction and how things originally work. We will also discuss experienced low-cost solution developed through the case study. The research paper will also indicate factors affecting and supporting the low-cost solution analysis based on the case study of selected company Thorilex and low-cost system developed by me

Research Questions

1. What are the advantages of the Aquaponics technology in current farming sector?
2. What are the limitations / challenges pertaining to Aquaponics technology?
3. What is the possible future development of Aquaponics technology in farming business / sector?

4.1 Case Study 1: Thorilex

A company did the research in automatic greenhouse with area of 500 m2. This farm produced fish -herbs and latus which is most consumable item locally. Here company provided basic personal investment and growth. As per the company "Project of aquaponics farm is business-investment project that uses modern technologies of food production. Hydroponic system is used to grow plants and recirculation aquaculture system (RAS) is used to breed fish. Fusion of these two technologies creates aquaponics."

Below graph shows the initial investment for the plant and revenues.

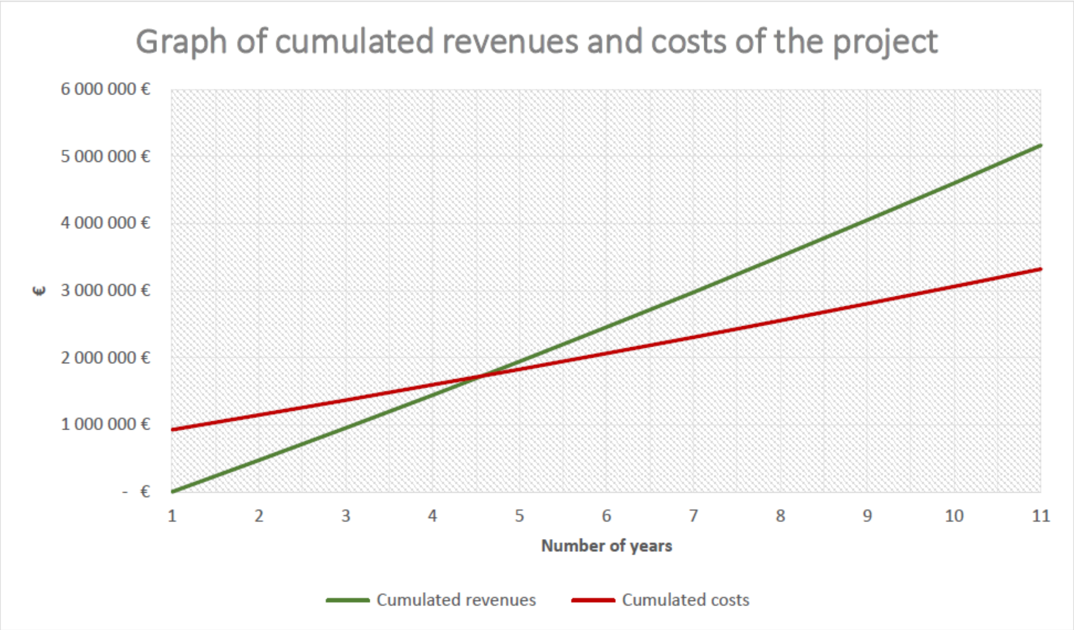


Figure 10 revenue vs investment

The graph shows the positive reward of the investment. As initial level investment is little high, but ~~you~~ will get back all that within 4.5 years.

4.1.1 Aquaponics Farm

They design farm that can be work 365 days. As we know the weather situation in Prague is varies. Their main aim is to produce local fresh healthy food and fish that will support society, environment and help to support cost of the project.

Aquaponics project from the company is the business investment project. They use latest tech which is used to good production of the food and fish. This system is used to grow plant and recirculation aquaculture system (RAS), which is used to breed the fish.

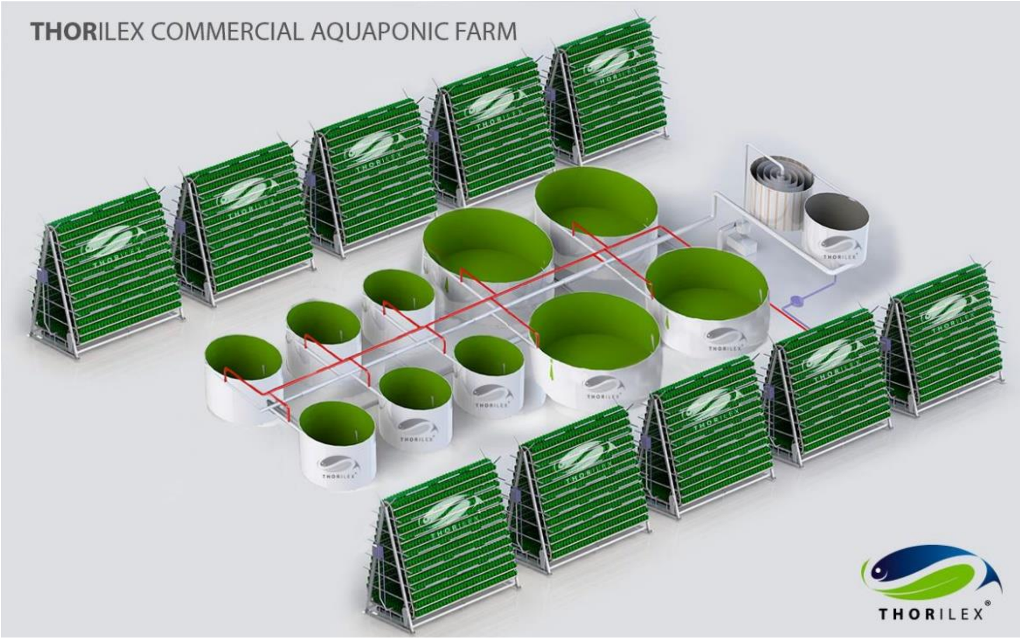


Figure 11 lay-out of farm

4.1.2 Fish breeding

Recirculating aquaculture system is used to breed the fish. This system is developed in the tank where it's easy to control the environment. Or easy to create environment according to require breeding fish. As this process done in the close tank, there is not risk of predator attack. The tank is safe and fully controlled to take care of fish. In case of illness or pest is possible to effectively protect the fish. As it is closed tank and it's easy to transfer or manipulate the fish.

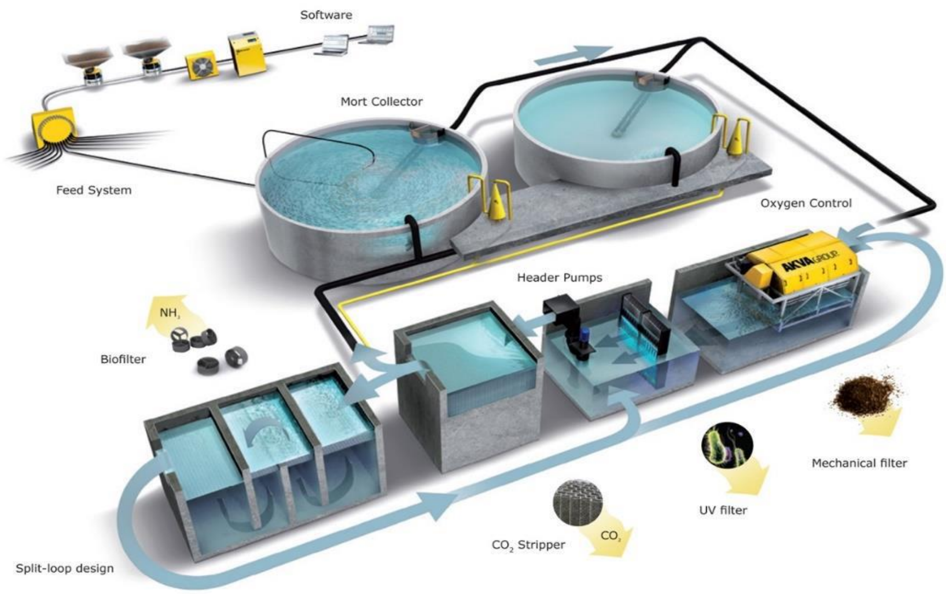


Figure 12 RAS system

4.1.3 Plant Growing

The systme is used to grow the plant without soil in the nutriant water. This water get the nutriant from the fish tank. The technology used to grow plant for 365 days production with minimum lost of plant with effictive production. As this systme is devloped for the indoor farming with all required element, minimum risk of pestisides as the most of the pest are devloped in the soil.

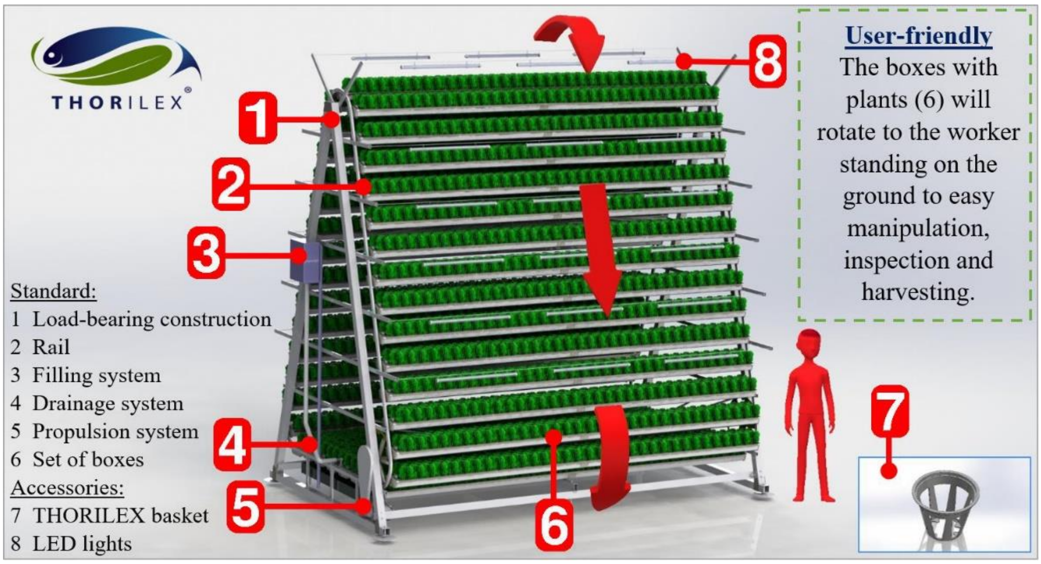


Figure 13 Plant Growing bed

4.1.4 **Technology Used**

They feed a special food to the fish and the ammonia form the waste of fish dissolved in the water. This ammonia become the nitrate with the help of bacteria. This nitrate is the nutrition for the plant. This nutrient water and other substance can be added in the nutrient water tank. This water reaches to the plant grow bed or plant zone. These plants take nutrition via root from the flow of water and this water reach back to the water tank.

These cycle repeats over and over.

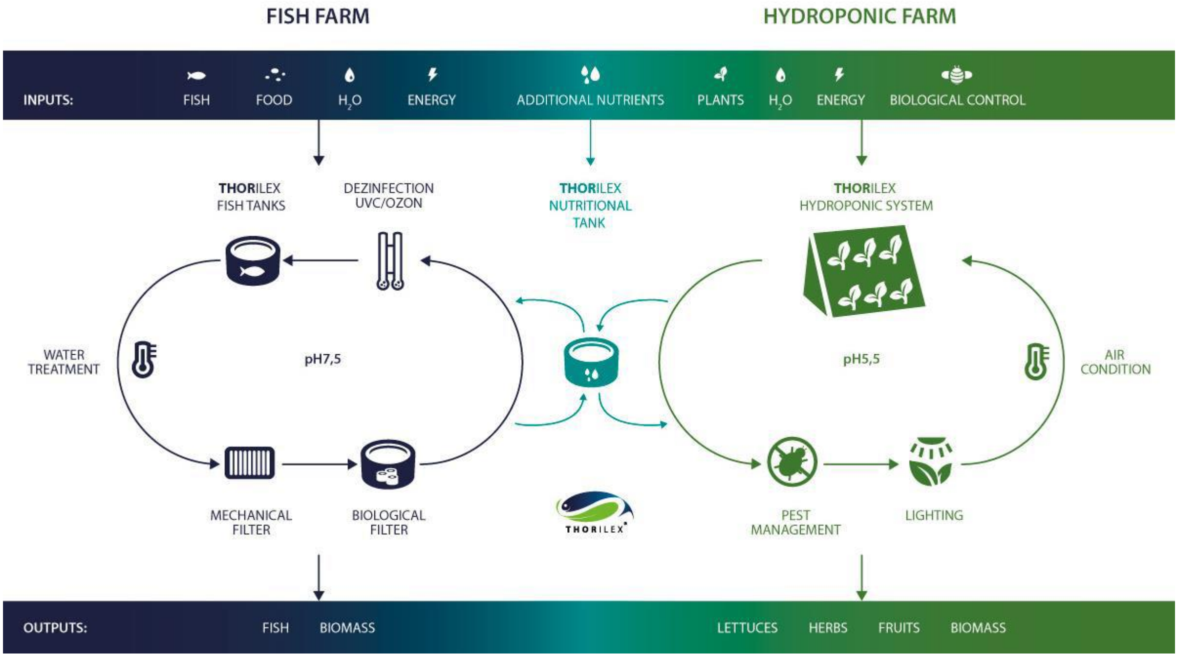


Figure 14 Overall system design

Here the company provided some list of the vegetables, herbs, fruit, and fish.

Vegetables	**Fruit**	**Herbs**	**Fish**	**Special**
Lettuce Crispy	Strawberries	Basil	Nile Tilapia	Prawns
Lettuce Salanova	Raspberries	Mint	Common Carp	
Head Lettuce	Blueberries	Rucola	African Catfish	
Romain Lettuce		Oregano	Tench	
Oak Lettuce		Coriander	Ornamental Fish	
Lamb's Lettuce				
Spinach				
Bay leaves				
Chilli papers				

Table 4 1 list of crops and fish you grow

Company still offer or invite people if they need to grow something different than they are providing. They are still doing some experiment for the new vegetables, herbs and fruit.

4.1.5 **Project realization.**

As per the company they took around the 6 to 14 month to establish the project and make to work. It will be divided in 4 stage

- Pre-investigation
- Investment phase
- evaluation phase
- Operation phase

4.1.5.1 Pre-investigation

As their first stage to investigate the site and prepare the document and feasibility study. Which is including the size of open area, weather availability of water and its condition. Also, the region for an example if the region is remote location. It will cost more for transportation.

4.1.5.2 Investment or Installation phase

After preparing all the documentation they are starting to construct the hall. After the construction they are implementation the indoor hardware i.e. including tank for fish and water. Start to prepare growing bed that can be vertical or horizontal as per the requirement. They also provide training for the staff. In this phase they make the system live.

4.1.5.3 Operation phase

This is the final phase here they will help the owner, how to evaluate and control system? Food production and how to sell production? That is depend on the owner how soon they react on it. Here company will help to set up the market for owner by research requirement of the food and fish. Based on that owner can start production accordingly.

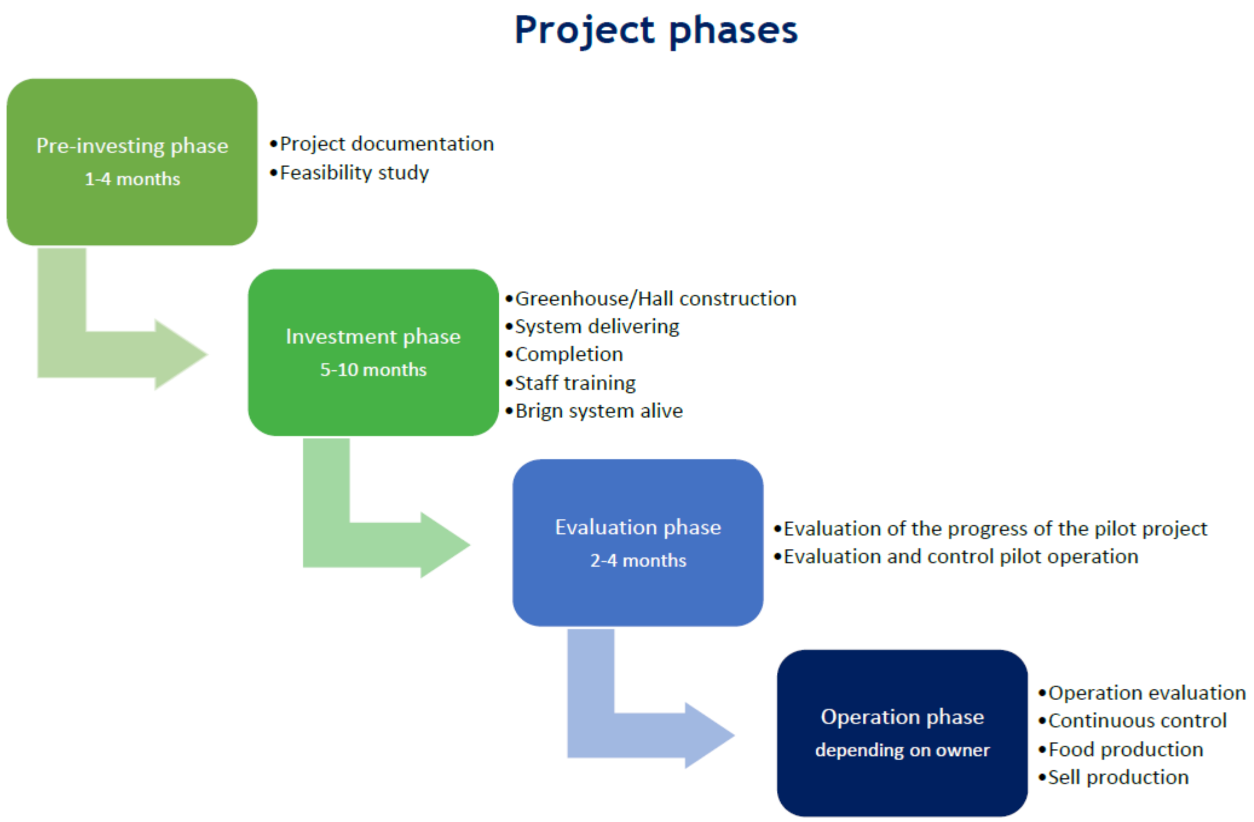


Table 4 2 Operation phase

4.1.6 **Project cost**

The initial cost for the project as per the company is divided in 4 unit. That is automatic green house, Recirculation system, Engineering and hydroponics for the area of 1000m2. More detailed shows in the below graphs, this graph is divided in to 2 graphs showed in below. These graph in divided two parts operation cost and investment cost.

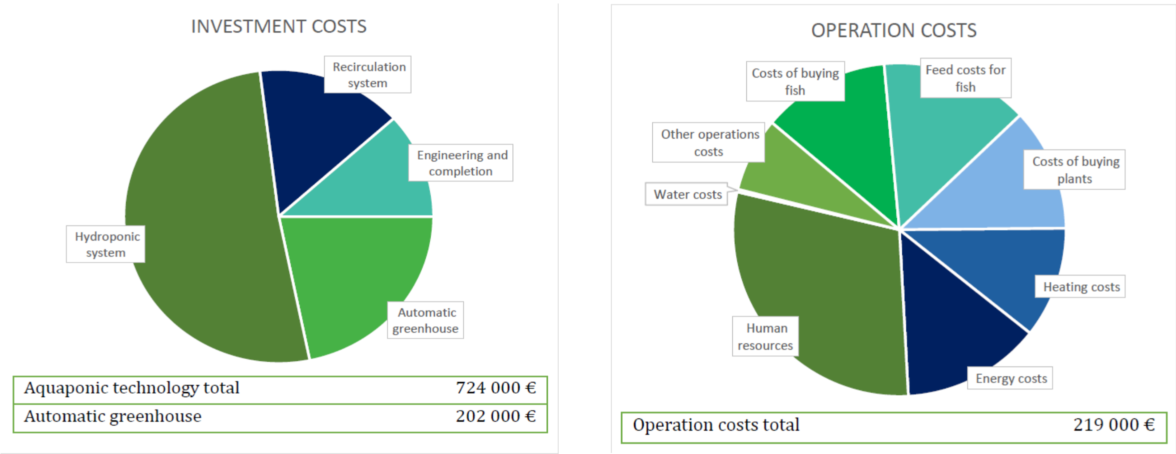


Figure 15 Investment and operation cost.

4.1.7 **Project realization**

The company design their farm for the 1000m2 where one third of the space used for recirculation system and two third space is for hydroponics system. In the RAS they grow the fish and hydroponics system they grow the plant. Consumer wants to buy high quality product that are produced locally. As these products produced locally it can be cheaper than the imported product as it includes transportation cost. But once it was produced locally that cost will be removed from the gross price.

Company claims their farm can produce fresh food locally for 365 days. From financial side company claims payback period will 3.88 year and the yearly internal rate is 22%. Results

Every farm has their own specification and so THORILEX farm has too. THORILEX farm do not work exactly for the concept of aquaponics but they have mixed aquaculture and hydroponics. They have built separate recirculation aquaculture system for the fish grow and hydroponics to grow plant. They have created separate water tank between hydroponics and RAS. The data provided by the company for commercial is not obligatory as it will varies by the location. The main of the company is to create local production unit for the fish and vegetable so it will help to get fresh and hygienic food for the consumer.

4.1.8 Overall assessment

Project of aquaponics farm is business-investment project that uses modern technologies of food production. Hydroponic system is used to grow plants and recirculation aquaculture system (RAS) is used to breed fish. Fusion of these two technologies creates aquaponics."

Initial investment would start from €1,000,000 and might cross €3,000,000 based on the project stages and material cost. However, the aquaponics farm project would reach breakeven point within 4.5 years as discussed in Figure 12 revenue vs investment. 4.1.1. Aquaponics Farm by selected company Thorilex is designed to work 365 days within Prague's climate.

Recirculating aquaculture system is an excellent design by Thorilex to breed fish without any risk of predators and easy to transfer another tank.

Nutrient water is used to grow plants without soil and improves fertility of plans naturally.

Special food is used to feed fish which helps to produce more ammonia resulting in nitrate with help of bacteria present in the water. The complete process creates nutrient water for grow bed.

To conclude the case study, aquaponics farm project produces highly organic food in any challenging climate condition. Initial project investment would be high comparing ordinary farming process. This could be considered as negative side of the project as normal farmer may not afford or meet initial project investment requirements. However, production capacity could be modified based on this concept which would result in high profit margin in long run.

Overall, aquaponics farming concept is recommended in unstable climate regions to produce organic fresh edibles.

4.2 Case Study 2: Experimental

The main aim of doing this experiment is to compare the product or the process developed by company in manner of lower down the cost with same or similar output and make or develop system affordable for the small farmer or the farmer in non-developed country, where they are struggling with weather and some water challenges.

4.2.1 Introduction

For rapid urbanization, land devoted to agriculture has fallen. The rapid growth of the human population has also increased the demand for food. Traditional farming methods for growing plants require a lot of soil, time and labor. As a result, concerns about safe and sustainable food sources are growing, leading to the need for new farming methods. Here we will discuss about the aquaponics system to develop at my place. The main of aim of doing experiment is to compare and try to provide proposed solution with lower price.

Figure 16 Source Owner

Figure 17 Source owner

4.2.2 Technology used

Here we are using some basic devises to create the aquaponics system is based on unit smart power control.

In this smart control unit consist and manage the power supply for whole system. We can distribute this power control unit in 3 phase that is include voltage generator, voltage convertor and voltage supplier.

Voltage generator consist of 2 mini hydro turbine which connected at the beginning of the water flow or end of the water flow, which supply water from aquarium to the grow bed and from grow bad to aquarium. As soon as water flow started its start to generate the electricity. And we can use the same electricity to run the water pump later after trigger the pump very first time.

This way more electricity can be generated with placing more number of hydro turbine. This is also known free source of electricity.

Voltage convertor unit help us to convert incoming electricity to the desired or required form that can be AC and DC.

As we are using most of the AC power to run the pump and Led grow light for the grow bed. We are using DC to AC voltage convertor.

Voltage supplier unit help to control all the device connected to the system. This unit help us switch the main power source generated power unit. In this way we are not using any external power supply. Here we can use the battery to remove the need of first time to turn on the water pump to turn on the water flow. But once the flow is started and as it is continues we do not required if after that. But still we can use battery as a backup.

Water pumps: this submersible pumps are one of the main part of the whole system, its main application to circulate the water from the aquarium to the grow bed and grow bed to aquarium below is the specification of pumps that used in system.

Figure 18 DC pump

Feature:

- Super long working life (more than 30000 hours).
- Submersible installation and entirely waterproof.
- Low consumption.
- Low noise(less than35db).

Specification:

- Working temperature: 0 ~ 75.
- Power consumption: 4.2W.
- Rated voltage: 12V DC.
- Max rated current: 350mA.

Mini Turbine: the idea of using this device is generate the electricity as discussed earlier the whole process is based on the nutrition's and the water circulation, as adding this device to the water flow resulting free electricity. That can make whole system more independent.

Figure 19 Mini turbine.

Specification:

- The output Voltage: 12V
- between the wire resistance 10.5 ± 0.5Ω
- Insulation resistance 10MΩ (DC100 megger)
- the maximum pressure 0.6Mpa outlet closed
- the outlet opening maximum pressure 1.2Mpa
- Start pressure 0.05Mpa

4.2.3 Implementation costs

This include the price of whole set up that include the aquarium, seeds, growbed, etc.

Name	Unit	Price(kc)
Aquarium	1	350
Grow bed pot	1	25
Seeds	1	45
Gravels	2 bags	100
Hydro turbine	2	250
Power control unit	1	495
Grow light	1	50
Filter pumps	2	500
Pipes	2	50
Air pump	1	100
Connector for turbine	4	140
Water heater	1	300
Total		**2505 kc**

Table 4.2-1 Item list. Source: own

4.2.4 Overall assessment

Strength:

The system developed by author is cheaper compare to the other market option, also its modular to purchase. The user has freedom to get an advantage of free electricity with his requirement.

As it is made from the scratch or some used item, user can lower down price.

It's produced completely organic food. And required less land and water with more production compare to regular farming.

Weakness:

The system implemented with selected number of crops thus its need to be tried out with other crops in different weather conditions or can be grown with some traditional farming process.

System is designed considering some low or no technological educated farmer, thus no more advanced technology used like AI or Cloud but that can be modified and implemented.

For using as commercial base to generate extra electricity it's required more turbine as this system tested with only two turbine. As the aim of system is not to generate electricity this should not be sole purpose of the system.

Opportunity

System developed on a base of very scalable model. It can use as hobby or it be can deployed as commercial base. Still there are some developing country farmers who are still struggling with the lack technology with advanced farming techniques. As this model requires little resources which reward very good results in manner of farming production and fulfill the basic needs.

Threat

As the system is exclusively developed and tested by the parameters set by the author, there is slight possibility that the outcome may not be favorable according to the other users' preferences. Also it requires regular maintenance with solid waste.

5 Results and Discussion

In comparison, the project costs of Thorilex solution are higher than the costs of the solution proposed by the author. The equipment of the project can be found as a part and install them together which is going to be cheaper than Thorilex providing to the consumer.

The new thing that project have is the multifunction system with smartness that consumer get more benefit in which is that consumer do not need to invest money on electricity after first start of the aquarium.

The aquaponics has built-in mini turbine system which works with water flow that need for farming and it save the electricity in battery that generate from mini turbine which is connected with system. The mini-turbine, according to the knowledge of the author, was used in an aquaponics systems for the first time and that is one of the good advantage to generate electicity, There for it makes model different than other available model in market. The main advantages of the project are, it's by product, i.e. electricity. The designed model gives the similar output with low cost and more flexibility to expand and reduce the size as per the requirement of user.

The disadvantages are as it was not tested as a large scale. Also, as it was tested just indoor and not to the outdoor the result may be varying. The main aim of the project was to develop a model that can be stable in challenging weather conditions that can be negotiable.

As the project work on the main principal of nutrition supply for the fish and the vegetable or the corps that can be grown.

Above mentioned factor strictly needs special attention, because some production parameters still need to be determined and optimized to prepare aquaponics for commercial use as some components and their interactions are not technically mature yet. To achieve a success in the desired field, need to focus on combining field of scientific and International framework. The importance of this field is not restricted for certain internal or external condition, but the approach should be universal and has to be used globally. This implies resource–economic (i.e., resource-saving) production systems that can be run in any weather condition or any region that can be hot, cold, dry or combination thereof.

Vermeulen and Kamstra [09] report only a marginal cost reduction for environmental benefits of nutrient reuse and energy efficiency when aquaponics is compared to RAS and hydroponics run separately. However, this study included some part of commercial and social factors into account, such as operating in a resource limited world. Due to sort of land as the population increasing and changes in climate increase the usage of Energy and there for the prices of land and energy are constantly rising, and governmental policies encourage reduction of emitted pollution (e.g., tax incentive schemes), so this cost margin benefit of aquaponics is expected to rise. As discussed earlier about not enough data provided by the existing company who is involved in smart aquaponics business more research needed form the government to available this system uses for the farmer who are not financially strong, it is still necessary to determine the purpose and the scale of the respective systems before building them; the needs on a microeconomic level in terms of food self-sufficiency or local food supply might differ from profit-oriented approaches and from country to country.

6 Conclusion

To conclude the thesis, it is seen that both case study project and experimental project gave excellent production outcome in multiple climate regions.

Linking the conclusion with objective to o develop a case study of using smart devices for crop production in challenging weather conditions. This was also designed to for the developing countries or the farmers who are less technically educated.

Practical part of the thesis contains comparison of an existing commercial aquaponics solution and a new prototype proposed by the author. A low-cost aquaponics model was proposed as a prototype that was tested, verified and evaluated in practice. The SWOT analysis was conducted in order to indicated opportunities and threats posed by the external environment, and also weaknesses of having certain limitations that was the model tested at indoor only and not outside or other location.

At the end of the practical part there is a case study which tells about the aquaponics system has lower costs than the Thorilex solution. Despite the lower costs, the proposed system works on the same fundaments, also the designed system has the byproduct of generating electricity which makes model more independent.

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