International Journal of Science and Research (IJSR)
ISSN: 2319-7064
ResearchGate Impact Factor (2018): 0.28 | SJIF (2018): 7.426

"Aquaponics"- Self Sustainable Ecosystem'

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Abstract: ***Aquaponics combines hydroponics with aquaculture. Hydroponics is the science of growing plants without soil in nutrient-rich water. The nutrients are exactly tailored to nourish and meet the growth requirements of the plants. Plants need nitrogen, phosphorus, potassium, and a variety of other micronutrients to thrive. Aquaculture is the breeding and farming of aquatic organisms, such as fish, shellfish, and aquatic plants, usually for human consumption. In an aquaponics system, the fish provide nutrients in the form of their "waste," or excrement. This waste contains nitrogen in the form of ammonia, along with a variety of nutrients like phosphorus and potassium. Nitrifying bacteria that live in the hydrotol in the fish tank and on the tank walls convert the ammonia first into nitrites and then to nitrates which the plants can use. The water in the tank, which contains ammonia, nitrites, nitrates, phosphorus, potassium, and other micronutrients, is continuously pumped into a grow bed where the plants are located. The plants remove the nutrients from this water, and nitrifying bacteria in the grow bed, clean the water by converting excess ammonia into nitrates, which plants use to grow. The clean water is then sent back into the fish tank. The grow bed and plants act as a biofilter, cleansing the water so that the fish remain healthy.***

1. Introduction

The sustainability of human race is a major concern for sustainability of our world. It's a big problem, considering that in the next 35 years we will be adding 1.5 billion people and need 20% more food. Linked to this problem of producing enough food is having enough land, water, and other natural resources to make that happen.

Aquaponics is a food production system that combines intensive aquaculture with hydroponics. The nutrient rich effluents from the aquaculture component are circulated through the hydroponic component where a proportion of these nutrients are taken up by the plants before the water is returned to the fish tanks.In the last 20 years nitrogen use in chemical fertilizers has exceeded by 20 times the nitrogen content in the oceans and brought severe eutrophication to water bodies. Closing the loop between crops and animals is therefore seen as the only way to improve water and nutrient efficiency and reduce wastes. Reducing land use would make a further contribution to sustainability.

Aquaponics, by combining fish and vegetable production and maximizing land, water and nutrient use efficiency, appears to offer a possible way forward in this regard, and has advantages in locations where water is scarce or soil is poor, and where there is strong demand for both fish and vegetables.

Hydroponics systems require a means of supplementing essential nutrients and aquaculture systems require some mode of waste removal. By incorporating these two farming systems into one symbiotic environment, the demands of each respective system are ideally met. Such dual crop systems drastically reduce the need for external interaction by recirculating system water while simultaneously removing toxic waste products.

Aquaponic systems use around 5% of the water used in traditional farming methods because water is filtered and cycled. With agriculture using around 70% of global water supplies, the future farming industry will be in increased competition with urban populations for water. Aquaponics has the potential to help lessen agricultural water usage.

There are many additional benefits to aquaponic systems. Plants grown in such systems have faster growth rates than soil farming leading to faster crop maturity and higher yields. Because aquatic animals cannot tolerate fertilizers and pesticides, customers are guaranteed that produce grown in aquaponic systems is completely organic. Such crops can be grown on land that is undesirable or in urban environments. Because the grow bed media is soil free, aquaponic systems are also able to avoid many soil diseases and pest issues.

A productive aquaponic system relies on the symbiotic interaction of plants and animals as a means of filtration and fertilization facilitated through the nitrogen cycle. The nitrogen cycle plays a vital role in aquaponic systems, as it provides nourishment for the plants and converts ammonia into useful chemical compounds. Fish produce waste through both their breathing and their feces production. The solid organic waste, which is primarily ammonia, is inherently toxic to fish if system levels are allowed to build. In the aquatic nitrogen cycle, bacteria known as nitrosomonas convert the ammonia into nitrites. The nitrites are then broken down by additional bacteria, known as nitrobacterium, into nitrates, which serve as a fertilizer when absorbed by the plants in the grow bed.

A successful aquaponic system maintains a chemical balance that allows system functions which are critical to stability and productivity to be optimized. Special attention should be given to system nutrient and acidity levels in the design process.

Plants need 16 essential nutrients for optimal growth. Three of the most common nutrients required are carbon (C), oxygen (O) and hydrogen (H). These macronutrients are supplied mainly by water and carbon dioxide gas. Other important macronutrients include: nitrogen (N), potassium (K), calcium (Ca), magnesium (Mg), phosphorus (P) and sulfur (S). Some of the less abundant micronutrients that aquaponic plant crops require are: chlorine (Cl), iron (Fe), manganese (Mn), boron (B), zinc (Zn), copper (Cu) and molybdenum (Mo). In order for plants to be successful, the aforementioned macro and micronutrients need to be balanced properly. Excess of one nutrient can inhibit the uptake of another. For example, excess of potassium may reduce the uptake of magnesium or calcium or visa-versa.

The method of determining the system plant to animal ratio has a big role in determining how the system nutrient dynamics will be. The Rakocy UVI approach which supplements plant nutrients by increasing feed rates and fish densities as compared to plant components, allows an excess of nitrogen to build within the system to allow for the mineralization of other nutrients. The advantages of this system are that most or all of plant essential nutrients are supplied by the fish component. This eliminates the need for an excess of buffers and nutrient supplements. The disadvantage to the UVI approach is that nutrient levels can fluctuate. High levels of nutrients can lead to phytotoxicity (an excessive buildup of nutrient salts), which will kill plant growth. While the majority of essential nutrients for healthy plant growth are supplied by the fish component in the UVI approach, potassium and calcium levels are usually insufficient. Potassium is often added to the system in the form of potassium hydroxide (KOH) and calcium is added as calcium hydroxide ($Ca(OH)_2$). The addition of these bases serves the dual purpose of raising pH levels that are often lowered by nitrification, while also supplementing deficient nutrients.

In practical terms, aquaponics is the integration of intensive recirculated aquaculture in tanks with hydroponic production of vegetables in nutrient solution. The history of both these technologies is therefore relevant to this analysis.

Hydroponics has a long history, and was an important element in agricultural systems throughout the world. In China it was reported that "frame fields" for growing water spinach were widespread in ancient times. The raft gardens were made with a frame of bamboo and a layer of soil and supplied leaf vegetables for home consumption. In Mexico and Bangladesh organic matter from plants was used to create rafts for floating agriculture. In Latin America in pre-Hispanic times Chinampas were probably the most intensive and productive agricultural system, and were part of a larger integrated agricultural system that supplied food for the local population. This form of agriculture was mainly carried out in swampy and flooded areas, wherever lack of land constrained more conventional agricultural production. Floating agriculture was also developed in Asian countries such as Kashmir, Nile Lake in Myanmar, and in the Tonle Sap lake of Cambodia. This type of agriculture is still in use, for example in Myanmar, Bangladesh and Cambodia.

Hydroponics first appears in the scientific literature in the 17th century and has been optimised for commercial operations in the first half of the 20th century. In Western countries, interest in soil-less culture for vegetable production started in 1925 when greenhouse vegetable production encountered chronic problems with soil-borne disease. During World War II hydroponic production was increased to supply the US army with fresh vegetables, and expanded further from the 50's and 60's all around the world. The further development of plastics and greenhouse technology created favourable conditions for the use of soilless production under any climate. Several media were used (sand, sawdust, peat etc.), but in the seventies the invention of the nutrient film technique (NFT) and rockwool as a growing medium led to increased efficiency. More recent advances include the use of fine mist spray of nutritive solution at root level (aeroponics), though adoption has been limited to date.

Hydroponics is now a well-established and fully commercial vegetable production system already widely applied in tropical and sub-tropical island nations, including for example The Cook Islands, Fiji, Mauritius, Hawaii, Jamaica and many others.

2. Purpose

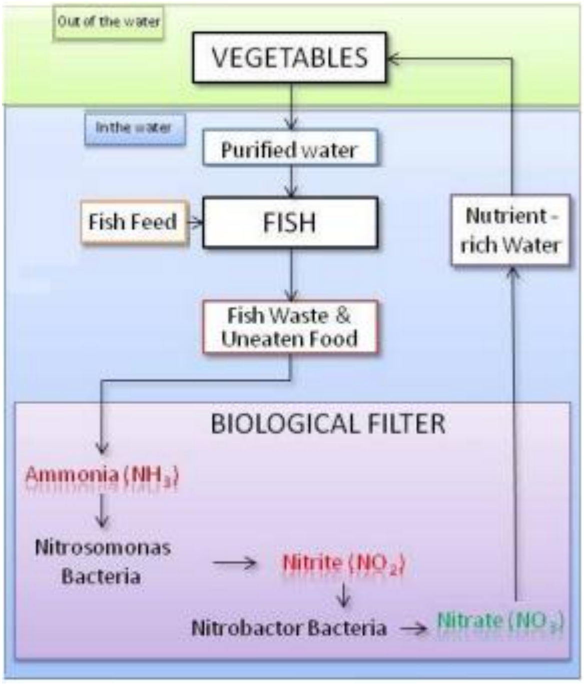
There is global concern about how future generations will produce more food sustainably. Agriculture has substantial environmental impact on natural resources: the conversion of natural land to agriculture, nutrient leaching and the use of chemicals are all serious issues. In the last 20 years nitrogen's use in chemical fertilizers has exceeded by 20 times the nitrogen content in the oceans and brought severe eutrophication to water bodies. Closing the loop between crops and animals is therefore seen as the only way to improve water and nutrient efficiency and reduce wastes. Reducing land use would make a further contribution to sustainability.

Aquaponics, by combining fish and vegetable production and maximizing land, water and nutrient use efficiency, appears to offer a possible way forward in this regard, and has particular attractions in locations where water is scarce and/or soil is poor, and where there is strong demand for both fish and vegetables.

In India too, since the Green Movement, and our modern methods of farming, comes the use of fertilizers and pesticides, which, along with water pollution, have been causing air pollution. Fumes from nitrogen-rich fertilizers and animal waste combine in the air with industrial emissions to form solid particles—a huge source of disease and death. Instead of the conventional method of agriculture, this innovative method (Aquaponics) can be adopted which does not depend on the fertilizers and pesticides.

3. Scientific Principle Involved

Plant growth in an Aquaponics is visually and systematically vastly different from a conventional growth, in farms, where natural requirements are in place. Although the actual science of Aquaponics is still in the early stages of its development, the biochemical cycle within it, cycling within the system, is quite well understood. The most important is the nitrogen cycle, which in an Aquaponics is the key element cycle as it symbiotically provides fertility to plants as well as cleans the water for the fish, removing the toxicity they would be subject to otherwise. The nitrogen cycle here occurs as the water flow through from fish tanks to biological filters containing bacteria situated on surface areas, to plants or a grow bed and back again.



The major input into this nitrogen cycle – except for electricity which here is required for the pump to circulate the water – is fish food which is either in the shape of commercial fish feed or aquatic plants, depending on the type of fish and plants in a given situation. After the fish eats the food they produce waste. This fish waste, as well as any uneaten fish food, starts to break down and, from this, the majority of the nitrogen content form ammonia (NH_3) This ammonia is then, thereafter as it flows through the biological filter where Nitrosomonas bacteria is situated, converted to nitrite (NO_2^-) after which a second type of bacteria, Nitrobactor, converts nitrite into nitrate (NO_3^-) . It is this nitrate that then, as it flows through the growbed, serves as a fertilizer for the plants therein. The plants, in this hydroponic component of the system, take up the nitrate - that helps them grow - by removing it from the water and purifies it as it circulates back to the fish tank returning clean, fresh water for the fishes to thrive in.

Reactions

The chemical reaction equations for nitrification are given below: -

$$NH_3 + O_2 \rightarrow NO_2^- + 3H^+ + 2e^-$$
$$NO_2^- + H_2O \rightarrow NO_3^- + 2H^+ + 2e^-$$

Essentially these equations state that ammonia (NH_3) transforms into nitrite (NO_2^-), which then converts into nitrates (NO_3^-). Ammonia is converted to nitrite mainly by the bacteria Nitrosomonas as mentioned earlier, and is transformed into nitrate mostly by Nitrobacter.

Applying Law of Mass Action to the given elementary reactions:

$$Rate_1 = -\frac{d[NH_3]}{dt} = -\frac{d[O_2]}{dt} = k_1[NH_3][O_2] = k_1'[NH_3]$$
$$Rate_2 = -\frac{d[NO_2^-]}{dt} = -\frac{d[H_2O]}{dt} = k_2[NO_2^-][H_2O] = k_2'[NO_2^-]$$

However, we can assume that oxygen (O_2) and water (H_2O) are at much higher concentrations than ammonia and nitrite. This is reasonable because ammonia and nitrite are dissolved in a large amount of water in the plant bed. Also, the plant bed is well-oxygenated due to the flood and drain process. Hence, the percentages of oxygen and water consumed by the reaction will be negligible compared to their total concentrations. With minimal error, we can assume that the concentrations of oxygen and water remain constant throughout the reaction. Therefore, these concentrations can be absorbed into the constants of proportionality (Rate constant), such that –

$$k_1' = k_1[O_2]$$
$$k_2' = k_2[H_2O]$$

Thus, the reactions can be treated as pseudo-first order reactions, with the rate efficiency being controlled by the respective bacteria, i.e. Nitrosomonas and Nitrobacter.

4. Advantages of Aquaponics

- **Efficiency of water use**

Aquaponics systems use 10% or less of the water used inconventional soil based horticulture systems. Water use efficiency in hydroponic systems is probably comparable to that of Aquaponics, but more variable, depending on the frequency with which nutrient solution is discarded or dumped.

- **Independence from soil**

These systems can be established in urban or harsh rural environments where land is very limited or of very poor quality. This advantage applies also to hydroponics and recirculating aquaculture systems.

- **High levels of nutrient utilization**

This is the core rationale for Aquaponics and asignificant advantage in those countries or locations where nutrient enrichment is a problem (as for example in some Pacific lagoons). The fish and plants in most Aquaponics systems capture roughly 70% of the nutrients input in the form of fish feed; and the residual solid waste is relatively easy to manage and may be applied to fruit trees or conventional horticultural crops.

Although hydroponic systems also capture a high proportion of nutrients most operators dump the system water periodically to prevent the accumulation of salts and pathogens and allow for thorough cleaning and sterilization. In most cases this relatively dilute waste will not be a problem, and may be used for conventional crop irrigation.

- **Reduced labour & improved working conditions**

Labour inputs to conventionalhorticulture are hugely varied dependent on the degree of mechanization and chemical usage. Aquaponics systems usually use raised beds and do not need weeding. The work involved is of a higher quality than that required in more conventional systems and requires less labour.

- **Two for the price of one**

Aquaponics is a one-time investment. Although the initial money/capital may be somewhat higher than that of the traditional methods of irrigation, the output reimburses the cost by providing multiple benefits including plant growth and fish products.

Disadvantages of Aquaponics

It is unfortunate that the essential and desirable characteristic of Aquaponics – closely integrated production of plants and fish to maximize nutrient utilization – also introduces significant disadvantages from both production and marketing perspectives.

- **Compounding of risk**

Intensive aquaculture production may be subject to losses or reduced productivity related to water chemistry, temperature, lack of oxygen, and disease. Intensive horticulture (including hydroponics) may also be subject to losses from system failure (water supply), pests and diseases. Integration of intensive horticulture with intensive aquaculture compounds these risks since problems or failure of one component are likely to reduce performance of the other. Some risks may even be increased – biosecurity (exclusion of pathogens) is a key issue for intensive recirculating aquaculture systems and may be compromised by recirculation through a large outdoor vegetable production facility. Furthermore, the range of management responses (such as pest or disease management) for each component is constrained by the sensitivities of the other, and it may take some time to restore the whole system to optimal performance. These production risks are further compounded by high capital and fixed operating costs. Any break in production will have substantial cost implications.

- **Constraints on optimisation and economies of scale**

The drive towards efficiency inconventional food production has resulted in both specialisation and intensification. Specialist farmers or fish farmers are able to bring all their skills and effort to bear on optimisation of their production system for a particular product, and achieve economies of scale in sourcing, production and marketing. While the desirability of this may be questioned on many other levels, there is no doubt that existing economic incentives at both local and global levels continue to strongly favour this trend. Integration in Aquaponics not only flies in the face of these incentives, but the intimacy of the integration prevents optimisation of each component. Optimal water chemistry and temperature are slightly different for fish and plants in most cases.

- **Constraints on production and marketing**

Commercial producers adjust their rates ofproduction as far as possible to meet market demand for different products, and according to seasonality of demand. Maintaining (roughly) a fixed ratio of fish to plant production, and the long delays and high costs related to shutting down and restarting an Aquaponics system, significantly constrain flexibility to adjust production in line with demand.

- **Energy costs**

Most Aquaponics systems will require more energy than conventionalhorticulture or hydroponics systems, primarily related to the oxygen demand of both fish and bacteria, and the corresponding need for intensive aeration as well as pumping.

- **Management costs and demands**

Routine maintenance, water quality monitoring andmanagement can be demanding, requiring both skills and dedication. Furthermore, in order to cover the relatively high capital and operating costs, production from these systems must be maximized, requiring high levels of organisation and management in production scheduling, and highly effective sales and marketing.

- **Limited range of suitable fish species**

Tilapia is by far the preferred fish for Aquaponicssystems, especially in the tropics and sub-tropics. This is because it is extremely easy to breed, adapts well to high density, is tolerant of low oxygen concentrations (and therefore less susceptible to temporary power failure of system blockage) and tolerant of high nutrient concentrations. Flesh quality is also generally good. However, it is non-native to the Pacific region, and introductions of such a robust species in some countries (such as Australia) has had negative impact on native fauna. While such impacts are unlikely to be as severe in biodiversity limited small islands, there may be issues in some countries. Dependence on highly tolerant species also restricts market opportunity.

- **Nutrient utilization efficiency is not specifically recognised in sustainable food certifications** such as organic, and the apparent advantage of Aquaponics andhydroponics over conventional agriculture in this regard cannot be readily translated into a price premium on the open market. Indeed organic certification of soilless cultivation is still not possible for many organic labels.

5. Current Examples

- Aquaponics systems at home, called the Aquaponics Machine, with revenue generated by selling produce to tourists is an effort to reduce growing dependence on imported food.
- Dakota College at Bottineau, North Dakota has an Aquaponics program that gives students the ability to obtain a certificate or an AAS degree in Aquaponics.
- In Bangladesh, the world's most densely populated country, most farmers use agrochemicals to enhance food production and storage life, though the country lacks oversight on safe levels of chemicals in foods for human consumption.

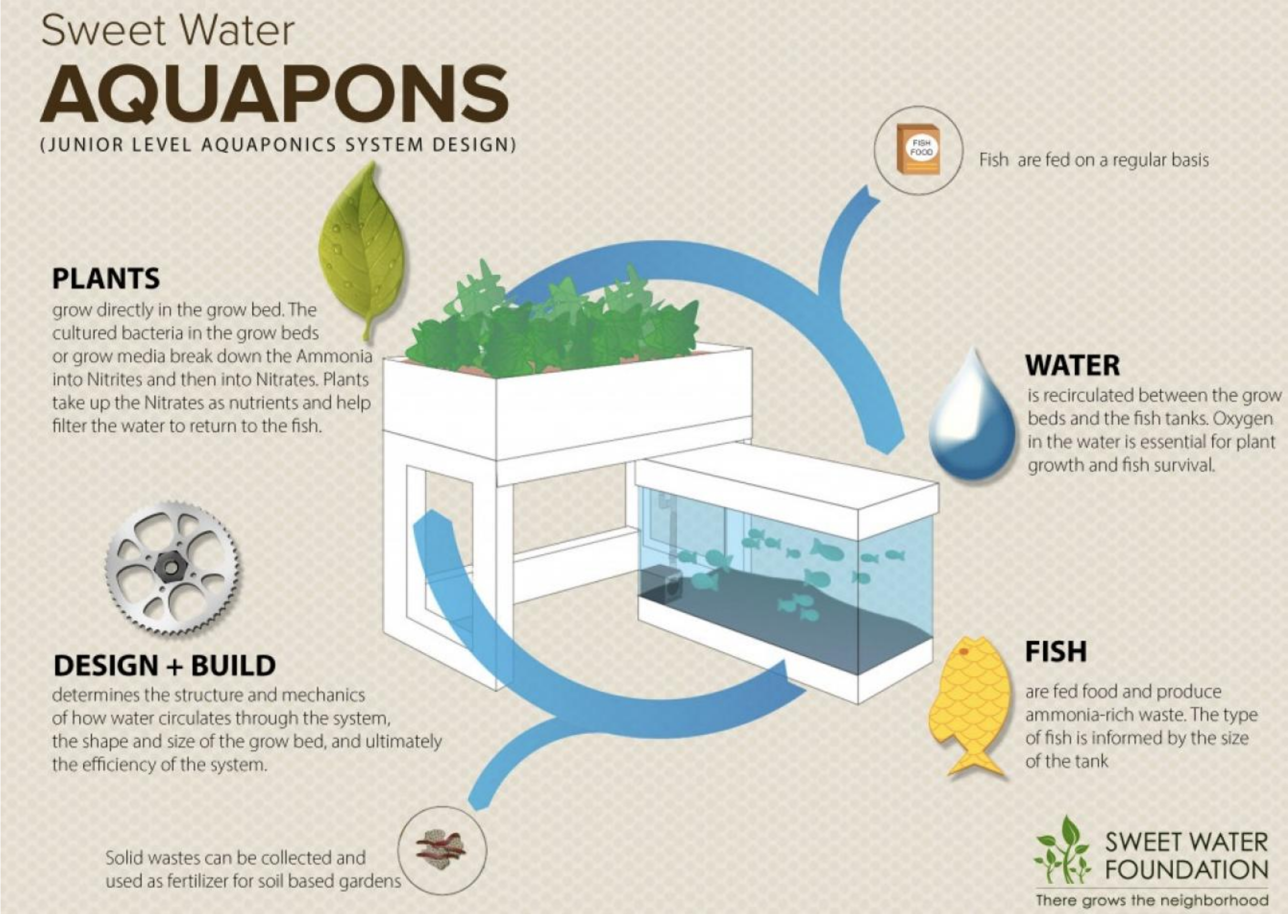
To combat this issue, a team led by M.A. Salam at the Department of Aquaculture of Bangladesh, Agricultural University has created plans for a low-cost Aquaponics system to provide organic produce and fish for people living in adverse climatic conditions such as the salinity-prone southern area and the flood-prone haor area in the eastern region. Salam's work innovates a form of subsistence farming for micro-production goals at the community and personal levels

- With more than a third of Palestinian agricultural lands in the Gaza Strip turned into a buffer zone by Israel, an Aquaponics gardening system is developed appropriate for use on rooftops in Gaza City.
- The Smith Road facility in Denver started pilot program of Aquaponics to feed 800 to 1000 inmates at Denver Jail

and neighboring downtown facility which consist of 1,500 inmates and 700 officers.

- In Malaysia Alor Gajah, Melaka, Organization 'PersatuanAkuakutur' Malaysia' takes innovative approach in Aquaponics by growing Lobster in Aquaponics.
- Windy Drumlins Farm in Wisconsin redesigns Aquaponics-solar greenhouse for extreme weather conditions which can endure extremely cold climate.
- Volunteer operation in Nicaragua "Amigos for Christ" manages its plantation for feeding 900+ poverty-stricken school children by using nutrients from Aquaponics method.
- Aquaponics in India aims to provide aspiring farmers with Aquaponics solutions for commercial and backyard operation.
- Verticulture in Bedstuy utilizes old Pfizer manufacturing plant for producing basil in commercial scale through Aquaponics, yielding 30-40 pounds of basil a week.
- Aquaponics startup Edenworks in New York expands to full-scale commercial facility, which will generate 130,000 pounds of greens and 50,000 pounds of fish a year.
- There has been a shift towards community integration of Aquaponics, such as the nonprofit foundation Growing Power that offers youth job opportunities and training while growing food for their community. The model has spawned several satellite projects in other cities, such as New Orleans where the Vietnamese fisherman community has suffered from the Deepwater Horizon oil spill, and in the South Bronx in New York City.
- Whispering Roots is a non-profit organization in Omaha, Nebraska that provides fresh, locally grown, healthy food for socially and economically disadvantaged communities by using Aquaponics.
- In addition, Aquaponics gardeners from all around the world are gathering in online community sites and forums to share their experiences and promote the development of this form of gardeningas well as creating extensive resources on how to build home systems.
- Recently, Aquaponics has been moving towards indoor production systems. In cities like Chicago, entrepreneurs are utilizing vertical designs to grow food year round. These systems can be used to grow food year round with minimal to no waste.

- Superior Fresh in Hixton, Wisconsin, produces 1.8 million pounds of lettuce and leafy greens — and 40,000 pounds of fish — within 123,000 square feet of production space.
- Very unique greens are growing in greenhouses in Hixton, Wisconsin. These greens are distinctive in several ways and they float on a large water tank of 850,000 gallons. Indeed, it is one of the largest Aquaponics facility in the world and utilizes salmon waste in their growth.
- AQUAPONS



Sweet Water AQUAPONS is an online platform where students gain digital badges as they learn the skills needed in Aquaponics. The Sweet Water Foundation (SWF) developed AQUAPONS to provide self-directed learning opportunities to future sustainable agriculture practitioners and expand the field of Aquaponics by creating a replicable model for urban agriculture education.

6. Case Presentation

A) Identification and Analysis of Problem

India is a country with a vast diversity in people, cultures, religion, food, agriculture etc. In today`s scenario, the main problem faced by us is overpopulation, due to which food and land availability is scarce. Various problems faced are:

1) **Instability:** Agriculture in India is largely depends on monsoon. As a result, production of food-grains fluctuates year after year. A year of abundant output of cereals is often followed by a year of acute shortage.
2) **Cropping Pattern:** The crops that are grown in India are divided into two broad categories: food crops and non-food crops. While the former comprise food-grains, sugarcane and other beverages, the latter includes different kinds of fibres and oilseeds. In recent years there has occurred a fall in agricultural production mainly due to fall in the output of non-food articles
3) **Land Ownership**: Although the ownership of agricultural land in India is fairly widely distributed, there is some degree of concentration of land holding. Inequality in land distribution is also due to the fact that there are frequent changes in land ownership in India. It is believed that large parcels of land in India are owned by a- relatively small section of the rich farmers, landlords and money-lenders, while the vast majority of farmers own very little amount of land, or no land at all. Moreover, most holdings are small and uneconomic. So the advantages of large-scale farming cannot be derived and cost per unit with 'uneconomic' holdings is high, output per hectare is hectare is low. As a result peasants cannot generate sufficient marketable surplus. So they are not only poor but are often in debt.
4) **Sub-Division and Fragmentation of Holding:** Due to the growth of population and breakdown of the joint family system, there has occurred continuous sub-division of agricultural land into smaller and smaller plots. At times small farmers are forced to sell a portion of their land to repay their debt. This creates further sub-division of land.Sub-division, in its turn, leads to fragmentation of holdings. When the size of holdings become smaller and smaller, cultivation becomes un-economic. As a result a major portion of land is not brought under the plough.
5) **Land Tenure**: The land tenure system of India is also far from perfect. In the pre-independence period, most tenants suffered from insecurity of tenancy. They could be evicted any time. However, various steps have been taken after Independence to provide security of tenancy.
6) **Conditions of Agricultural Laborers:** The conditions of most agricultural laborers in India are far from satisfactory. There is also the problem of surplus labor or disguised unemployment. This pushes the wage rates below the subsistence levels.
7) **Neglect of crop rotation:** Successful conduct of agricultural operations depends upon a proper rotation

of crops.-If cereals are grown on a plot of land its fertility is reduced to some extent. This can be restored if other crops such as pulses are grown on the same plot on a rotational basis. Most farmers in India are illiterate and do not understand this important point. Since they are not aware of the need for crop rotation they use the same type of crop and, consequently, the land loses its fertility considerably.

8) **Inadequate use of manures and fertilisers:** Inadequate use of manures like cow-dung or vegetable refuge and chemical fertilisers makes Indian agriculture much less productive than Japanese or Chinese agriculture.
9) **The use of poor quality seeds:** In India, not much use has been made of improved varieties of seeds. The main cereals (rice, millets and pulses) are still grown chiefly with unimproved seeds.
10) **Inadequate water supply:** Farmers also suffer due to lack of irrigation facilities. Moreover, ordinary varieties of seed can be replaced by better varieties if there is an assured supply of water. The need for the construction of minor irrigation works of a local nature is both urgent and pressing. In fact, the total water potential in the country is more than adequate to irrigate the whole areas under cultivation. However, the present problem is one of discovering cheap and easy methods of utilising these vast supplies of water.

B) Objectives:

To Design a cost efficient self-sustaining ecosystem – 'Miniature Aquaponics System' that can be easily setup and managed by groups consisting of two to three families in rural areas , which can demonstrate the principle of recycling and reuse, thus emphasizing on the need of eco-sustainability.

C) Planning Done:

Choose the tank carefully: Fish tanks are a crucial component in every aquaponic unit. Any fish tank will work, but round tanks with flat or conical bottoms are recommended because they are easier to keep clean. Use strong inert plastic or fibreglass tanks, because of their durability and long life span.

Ensure adequate aeration and water circulation: This means you should use water and air pumps to make sure that the water has high levels of dissolved oxygen and good water movement so that your animals, bacteria and plants are healthy. Electricity costs are a significant portion of the system budget so choose the pumps and power source wisely, and consider photovoltaic power, if possible.

Maintain good water quality: Water is the life-blood of an aquaponic system. It is the medium through which all essential nutrients are transported to the plants, and it is where the fish live. Five key water quality parameters are important to monitor and control: dissolved oxygen (5 mg/litre), pH (6–7), temperature (18–30 °C), total nitrogen, and water alkalinity. The water chemistry may seem complicated, but the actual management is relatively simple with the help of common test kits.

Do not overcrowd the tanks: Your aquaponic system will be easier to manage and will be insulated against shocks and collapse if the stocking density is kept low. The recommended stocking density is 20 kg/1000 litres, which will still allow for substantial plant growing area. Higher stocking densities can produce more food in the same space, but will require much more active management.

Avoid overfeeding, and remove any uneaten food: Wastes and uneaten food are very harmful for aquatic animals because they can rot inside the system. Rotting food can cause disease and can use up all of the dissolved oxygen. Feed the animals every day, but remove any uneaten food after some time and adjust the next day's portion accordingly.

Choose and space the plants wisely: Plant vegetables with short grow-out periods (salad greens) between plants with longer-term crops (eggplant). Continued replanting of tender vegetables such as lettuce in between large fruiting plants provides naturally shaded conditions. In general, leafy green plants do extremely well in aquaponics

D) Successive Criteria and Possible Alternatives

1) In order to be successful, aquaponic crops need around 10 hours of sunlight. If you must use artificial lights, it is recommended to use high intensity discharged light. The fish, however, do better in shade and blocking sunlight will help prevent algae from forming in the tank.
2) If your area gets enough rainwater, you may be able to harvest all the water you need from the rain. Whatever water is used, make sure it is covered so that harmful materials like bird waste don't get into the water.
3) For the average freshwater fish, the pH level of the water will need to be between 6 and7.Having the right pH is so critical for the health of the fish and crops.
4) Both the fish and plants need oxygen in the water. The oxygen, in fact, is the reason that plants can survive and thrive while their roots are continuously immersed in water. An air pump will take care of the system's oxygen needs.
5) Nutrients should be added continuously to the water on a very low level**. I**ron, potassium and calcium are usually needed. Calcium builds stronger stems in plants and prevents blossom rot. And both potassium and calcium combat acidity, assisting with your pH balancing.

E) Implementation

Aquaponic systems may include the following components

- A fishtank
- Plant seeds
- A growbed
- Any soil substitute (hydrotol)
- Few fishes
- A pipe
- A small pump

The procedure involves setting up of a grow bed on top of an aquarium consisting of any edible, medicinal or air purifier plants like lettuce, tomato, cucumber, leafy green vegetables, peas, fenugreek, other herbs . It makes the use of soil substitute Hydrotol which contains nitrifying bacteria which directly convert Ammonia, excreted by fishes (Rohu

,Catla, Carp, Koi, Goldfish, Catfish etc.) into nitrate which act as a natural fertilizer

F) Challenges Faced in Implementation

1) **Bug Problems**
Aquaponics can experience a problem of bugs which destroy the plants. After you notice the bugs, you should take necessary steps and look for ways of getting rid of them before they feed on all your plants. They spread very fast hence you need to act fast if you will like to save your plants.The method which you will use to get rid of the bugs should not poison the water. This is necessary to note because poisoning the water will lead to the death of your fish..
2) **Allowing the Tank Water to Get Too Hot**The tank should not get too hot. You should know the optimum temperature for your fish to do well. When the water will get too hot, it will reduce oxygen concentration. This can harm the fish hence you should install your system in such a way it will not heat to an extent where it will inconvenience your fish.
3) **Having Too Many Fish in the Tank**Too much fish in your system will make the system less efficient. Bigger fish can start feeding on smaller fish. This will result in a loss. Too much fish will release a lot of waste at a given period of time which will be more than what the plants can filter. The ideal condition should be one fish for every 20 liters of water.
4) **Not Frequently Testing Ammonia**
Ammonia is produced by the fish through their respiratory system. It is released through their gills. It is very toxic hence it should not be left to reach levels where it will kill the fish. You will know about the concentration of ammonium in your system through carrying out tests at least once a week. If the levels will be high, you should dilute the water so that the concentration will reach acceptable levels.
5) **Restricting Access to Fish Tanks**
When designing your system you should have the fish tank in a location where you can easily access it. This is necessary so that you will easily know what is going on in the fish tank each time you will visit your system. Restricting the access of your fish tank can result in several problems.
6) **Iron Deficiency**
Iron deficiency will lead to chlorosis of plant leaves. Plants will need iron for photosynthesis and the uptake of phosphorus and nitrogen through their leaves. You will confirm whether your system is low in iron after carrying out iron tests. The iron can be added through use of iron supplement.

7. Beneficiary Satisfaction

- No artificial fertilizers are required.
- Prevents the formation of harmful aerosol particles.
- Decreases agriculture based air pollution
- The system can be placed in houses with indoor plants to purify air.
- Added benefits of ready-made fertilizer available
- Plants are able to maintain the oxygen to carbon-dioxide ratio very efficiently, and is thereby able to reduce the carbon footprint from other sources.
- Recycling of nutrient-rich Non-toxic water continuously.
- It uses only 1/10th of the water of soil-based gardening .
- No harmful petro chemicals, pesticides or herbicides can be used.
- This system can be put anywhere- outside, in a greenhouse, in your basement, or in your living room

It uses the plants, naturally occurring bacteria, and the media in which they grow in to clean and purify the water, after which it is returned to the fish tank and water can be reused indefinitely .use as biological filtration (conversion of ammonia to nitrates)

8. Learning Outcomes

- Identify innovative ways to build an aquaponics system
- Identify available resources that can be used to build an aquaponic system.
- Compare and Contrast available resources/technologies in terms of functionality, availability and cost
- Apply knowledge gained from the interaction to build a working prototype of an aquaponic system that can be used in school or homes
- Apply learning from the working prototype to build an actual Aquaponic System
- Showcase Aquaponic System to an international audience
- To Identify, define, and solve problems associated with many aspects of aquaponics production (operations, economics, policy, communication).
- Critical evaluation of aquaponics information from diverse sources in order to enhance integrated practice (research, management, policy).
- Effectively and economically produce aquaponics products, understand regulations, manipulate and control environmental factors for plant/fish growth, and integrate social/cultural aspects across the distribution chain.
- Understand and be sensitive to the juxtaposition of unique contributions from diverse knowledge systems with distinct values in relation to aquaponics.
- Learn through aquaponics experiences, create a foundation for producing applied research to outreach outcomes, enhance your ability to express findings and societal deliberation in written and oral formats.
- Deliberate and work with aquaponics practitioners and the broader community to identify shared values and address societal problems.
- Exploration of biology through observations of animal and plant life cycles,
- Investigation of chemistry while analyzing water quality, employing math skills to calculate water flow rates, and practice finance by selling harvested products
- Aquaponics in education allows students to have a tactile connection with living plants and animals, and hands-on learning through system care exposes them to the natural processes of ecosystems.

9. Conclusions

- By recirculating aquaculture systems, hydroponic systems and (integrated) aquaponic systems all share the advantage of reduced water use per unit production, and are therefore of interest for development in water deficient areas.
- From a purely commercial, or economic development perspective, in almost all circumstances, the disadvantages of aquaponics would outweigh the advantages. However integrating recirculating aquaculture with hydroponic plant production increases complexity, compounds risk, compromises system optimisation for either product, restricts management responses – especially in relation to pest, disease and water quality - and constrains marketing.
- From a sustainability perspective there are substantial questions related to use of high quality fish feeds as the nutrient source for systems focused primarily on plant production, and energy use is also relatively high. Solar or wind driven systems would usually be required to make them both economically viable and environmentally sustainable. From a food security perspective, especially in water constrained areas, it would appear that hydroponics and aquaculture undertaken as independent activities according to local market need would normally be more attractive, although it is possible that if both became successful, the advantages of integration might then be explored.
- Household scale production may have some potential in water/soil deficient areas, or where people are sufficiently wealthy that investment in backyard gardening becomes a worthwhile hobby activity in its own right. Relatively simple "2 bucket" backyard designs may be fairly robust and resilient, so long as feed inputs are kept below some basic operating thresholds, and so long as Tilapia (or possibly catfish) are available. The main constraint here will be energy cost and energy/equipment reliability. Operating costs may be reduced through investment in solar panels/wind turbines and batteries, and reliability can be addressed through investment in monitoring systems and backup. In most cases however small scale hydroponic systems are likely to serve this need better at least in the first instance. These may be upgraded to aquaponic systems once skills have been developed, and if there is demand for fish and a ready supply of high quality fish feed and seed.

References

[1] Adams, R. E.W., (2005) Prehistoric Mesoamerica. University of Oklahoma press, Norman, OK, USA. 544 pp
[2] Adler P.R., Summerfelt S.T., Glenn D.M., Takeda F. 2003. Mechanistic Approach to Phytoremediation of Water. Ecological Engineering 20, 251-/264
[3] Ahmad, M.H. 2008. Response of African Catfish, Clariasgariepinus, to different dietary protein and lipid levels in practical diets. Journal of the World Aquaculture Society 39:541-548
[4] Al-Hafedh, Y.S., Alam, A. and Beltagi, M.S. 2008. Food Production and Water Conservation in a Recirculating Aquaponic System in Saudi Arabia at Different Ratios of Fish Feed to Plants. Journal of the World Aquaculture Society, Vol. 39,510:520
[5] Barnabé, G., 1990 Aquaculture, (II volume) 2nd edition. Ellis Horwood Limited, Chichester, England pp 1104
[6] Brix, H. and Schierup, H.H. 1989. The use of aquatic macrophytes in water pollution control. Ambio 18: 100-107
[7] Chamberlaine, G., Rosenthal, H., 1995. Aquaculture in the next century: opportunities for growth, challenges for stability. World Aquac. Soc. Mag. 26 (1), 21–25
[8] Costa-Pierce, B.A., 1996. Environmental impact of nutrients from aquaculture: towards the evolution of sustainable aquaculture systems. In: Baird, J.D., Beveridge, M.C.M., Kelly, L.A., Muir, J.F. (Eds.), Aquaculture and Water Resource Management, Blackwell, UK, pp. 81– 109
[9] Davidson, J. and Summerfelt, S.T. 2005. Solids removal from a coldwater recirculating system—comparison of a swirl separator and a radial-flow settler. Aquacultural Engineering 33:47–61
[10] Dediu L, Cristea V, Xiaoshuan. Z. 2012. Waste production and valorization in an integrated aquaponic system with bester and lettuce. African Journal of Biotechnology 11
[11] Degani, G., Ben-Zvi, Y. and Levanon D., 1988. The effect of different dietary protein sources and temperatures on growth and feed utilization of African catfish Clariasgariepinus (Burchell). The Israeli Journal of Aquaculture - Bamidgeh 40:113-117
[12] De Graaf, G. and Janssen, H., 1996. Artificial Reproduction and Pond Rearing of the African Catfish ClariasGariepinus in Sub-Saharan Africa - A Handbook. FAO Fisheries Technical Paper, 362. Food and Agriculture Organization of the United Nations.
[13] DeLong, D.P., Losordo, T.M., Rakocy, J.E. 2009. Tank Culture of Tilapia. SRAC PUbblication 282. South Regional Aquaculture Center
[14] Diana, J.S.,Szyper, J.P, Batterson, T.R., Boyd, C.E., Pedrahita, R.H. 1997. Water quality in ponds. In: Egna, H.S, Boyd, C.E. (eds) Dynamics of pond aquaculture. CRC press, Boca Raton, New York. 437 pp.
[15] Downing, J.A., Baker, J.L, Diaz, R.J., Prato, T., Rabalais, N.N. and Zimmerman, R.J. 1999. Gulf of Mexico Hypoxia: Land and Sea Interactions Task Force Report No. 134. Council for Agricultural Science and Technology, Ames, IA
[16] Diver, S. 2007. Aquaponics-integration of hydroponics with aquaculture. ATTRA - National Sustainable Agriculture Information Service. 46p
[17] Edwards, P. 1987. Use of terrestial vegetation and aquatic macrophytes in aquaculture. pp 311-315. In: Moriarty, DJW and Pullin RSV (eds) Detritus and microbial ecology in aquaculture. ICLARM conference prodeedings 14, 420 p
[18] El Sayed, A.F.M., 2006. tilapia culture. CABI Publishing, Wallingford, UK. Pag 70-94
[19] Endut, A., Jusoh, A., Ali, N., Wan Nik, W.B., Hassan, A. 2010. A study on the optimal hydraulic loading rate and plant ratios in recirculation aquaponic system. Bioresource Technology 101:1511–1517
[20] FAO. 2007. Profitability and sustainability of urban and peri-urban agriculture. Agricultural Management,

Marketing And Finance Occasional Paper 19. Food and Agriculture Organization of the United Nations

[21] Ghosh, BP, and Burris, RH 1950 Utilization of nitrogenous compounds by plants. Soil Sci. 70:

[22] Gloger, K.C., J.E. Rakocy, J.B. Cotner, D.S. Bailey, W.M. Cole and K.A. Shultz. 1995. Waste Treatment Capacity of Raft Hydroponics in a Closed Recirculating Fish Culture System. World Aquaculture Society, Book of Abstracts: 126-127.

[23] Goulden M. (2005) Production of a Variety of Plant Species in a Gravel Bed Aquaponic Test System with Murray Cod (Maccullochellapeelipeeli). MSc thesis. Institute of Aquaculture Stirling University, Stirling, Scotland

[24] Graber, A. and Junge, R. 2009. Aquaponic Systems: Nutrient recycling from fish wastewater by vegetable production. Desalination 246:147–156

[25] Hassall & Associates, 2001. Hydroponics as an Agricultural Production System. RIRDC Publication No 01/141 RIRDC Project No HAS-9A

[26] Henry-Silva, G.G. and Monteiro Camargo, A.F. 2006. Efficiency of aquatic macrophytes to treat Nile tilapia pond effluents. Sci. agric. (Piracicaba, Braz.) vol.63 (5)

[27] Homem de Carvalho, J.L. 2001. Prove: small agricultural production virtualization programme. Urban Agriculture Magazine, No 5. Appropriate methods for urban agriculture. Leusden, RUAF

[28] Jensen, M.H. 1981. New Developments in Hydroponics systems: Descriptions, Operating Charateristics, Evaluation. pp. 1-25. In: Proceedings: Hydroponics: Where Is It Growing? Hydroponics Society of America. Brentwood. CA.

[29] Jones, J.B, , 1997. Hydroponics, a practical guide for the soilles grower. St Lucie press, Boca Raton, FL USA

[30] Lennard W.A. 2004 Aquaponics the Theory Behind Integration. [Internet] Gippsland Aquaculture Industry Network – GAIN, Traralgon Victoria. Australia

Glossary and keywords

1. Ammonia
2. Aquaponics
3. Bio filter
4. Fibre glass
5. Hydrotol
6. P^H