AQUAPONICS: THE FUTURE OF SUSTAINABLE FOOD PRODUCTION

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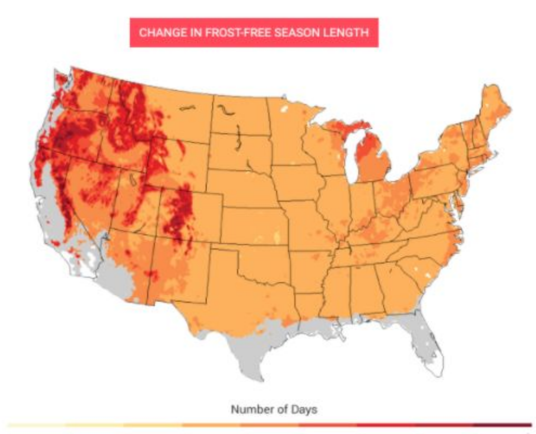
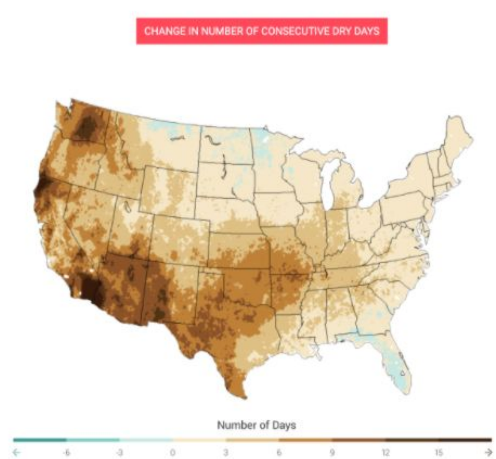
THE IMMINENT THREAT OF FOOD AND WATER SHORTAGE

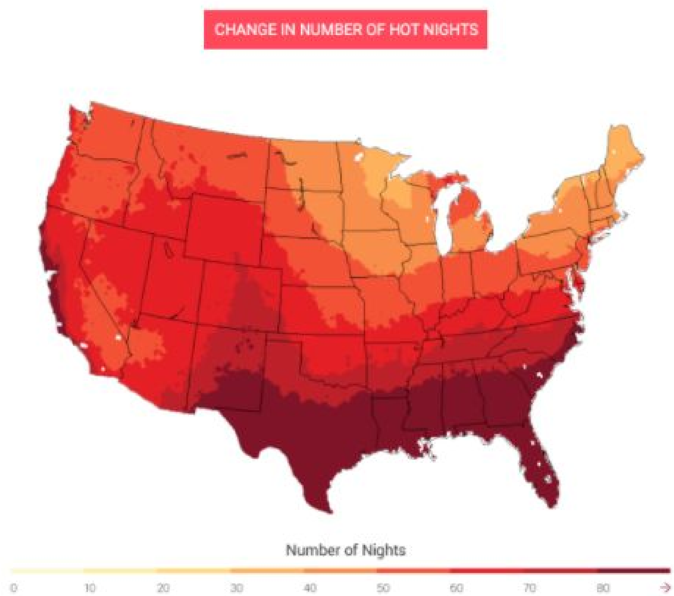
The exponential increase in the world's population will significantly affect global food distribution and security. The United Nations projects that by 2050, the global population will reach 10 billion people; this increase will proportionally affect the global food demand as it rises 70% [1]. In that same year, nearly 100% of major seafood species will be in a state of collapse: a species' population is 10% or less of what is considered to be a healthy yield [2]. Ultimately, current practices of fish farming are only exacerbating the problem; as fish are tightly packed into bodies of freshwater, high amounts of fish waste contaminate valuable freshwater systems, which creates toxic living conditions for sea life.

The United Nations' Food and Agriculture Organization approximates 33% of aquatic species are overfished while 60% are fished to their full potential. The FAO approximates that our expected population of 10 billion in 2050 will require 70% food, the ocean has the potential to provide resources to feed the world. However, in order for this to happen, fish stocks must be better managed as areas of the ocean must be better protected [3].

The demands for a population of 10 billion people does not just come with widespread food insecurity; rather, water shortages will also be a prevalent challenge. Due to the effects of climate change coupled with exponential population growth, the United Nations projects that 700 million people in 43 countries will have a scarce water supply by 2025. [4].







The maps above demonstrate how climate change will negatively affect farming practices in many regions of the United States. With more dry days, hot nights, and frost-free seasons, the climate will be too hot for agriculture to grow efficiently on a traditional farm setting [5].

However, a solution of more sustainable and low water-intensity farming does exist. Aquaponics uses 90% less water than a traditional farm [5]. Additionally, it can be grown indoors, making it independent of climate and weather conditions. Aquaponics is not only a tool used to prevent the most severe effects of food insecurity and water shortages, it is a method of farming that can lead the world into a future of sustainable farming.

AN INTRODUCTION TO AQUAPONICS

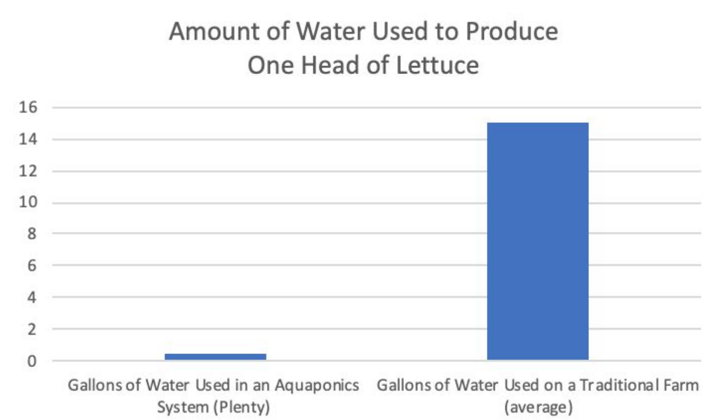
Aquaponics is the combination of aquaculture (indoor fish farming) and hydroponics (soilless farming). Essentially, a basic aquaponics system consists of fish, plants, and water. The fish produce waste, which is converted by bacteria into a compound used to fertilize the plants. The water is then led to the plants. The plants intake water concentrated with the fertilizer and return clean water back to the tank. Aquaponics is a demonstration of the symbiotic relationship between plants and fish.

BENEFITS OF AQUAPONICS COMPARED TO TRADITIONAL FARMING PRACTICES

WATER SUSTAINABILITY

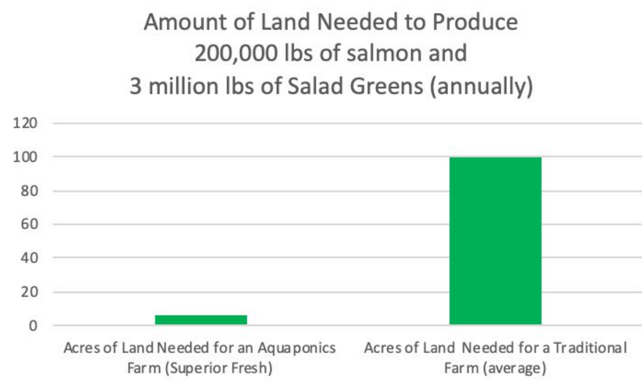
As water becomes more scarce and food demand rises, the sustainability of traditional farming practices are being questioned. Currently, agriculture accounts for 70% of global water usage, with an expected 5% increase by 2050 [7]. Essentially, as more water is used to maintain livestock, crops, and systems of agriculture, less water will be available to the general public. The solution to this particular problem is quite simple: popularize methods of farming that are less water intensive. This usage is mostly due to the widespread use of sprinkler systems to irrigate crops; however, a large majority of the water that is used to irrigate plants is not actually absorbed by the plants - it is simply wasted. Aquaponics allows for the bare minimum of water to be used in growing crops as it uses 90% less water than the traditional farm [6].

Plenty, a hydroponics company based in San Francisco, is able to produce one head of lettuce using ⅕ gallon of water; typically, a single head of lettuce requires 15 gallons of water to produce [1].



LAND CONSERVATION

In addition to water conservation, land conservation is another environmental benefit of aquaponic farming. Superior Fresh, an aquaponics company in Wisconsin, grows salmon and lettuce year round despite the cold Midwest winter. The company is able to produce 200,000 lbs. of salmon and 3 million lbs. of salad greens annually. A traditional farm would need 100 acres of land to achieve this level of production; however, Superior Fresh only used six acres [6].



Since aquaponics requires less land, an aquaponics system can exist in any environment: urban, rural, or suburban. Therefore, aquaponics crops are locally grown and sold, leading to a decrease in one's carbon footprint. This is a stark contrast from factory farms that grow their crops on one side of the world and sell them on the other. Food production currently makes up 29% of greenhouse emission [8]; an increase in local distribution would have an impact on lowering that footprint.

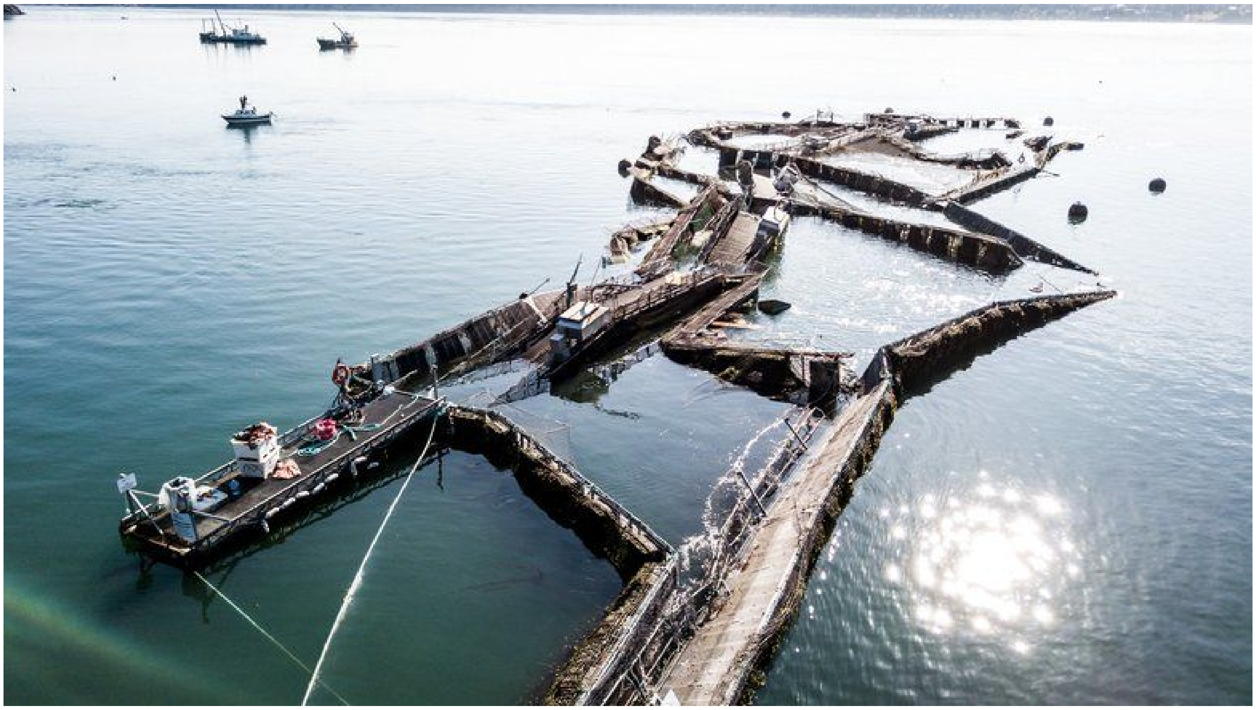
Aquaponics also leads to a higher crop yield. Since aquaponics can be done indoors, crops can be grown year round due to their independence of weather and climate. Additionally, plants can grow twice as fast due to the natural fortification of the water and the nutrients obtained from fish waste [9, 10].

A SUSTAINABLE ALTERNATIVE TO HARMFUL FISH FARMING PRACTICES

Aquaponics also provides a sustainable alternative to common practices in the fish farming industry. Currently, fish farming raises the concerns of farmed fish escape and fish waste discharge [6].

Farmed fish escape is a particularly concerning issue due to its potential negative impact on aquatic ecosystems. In fish farming, fish are kept in pens which are connected to bodies of water. Oftentimes, these fish are being held in an ecosystem that they are not native to. The possible escape of these non-native fish can have adverse effects on natural populations; ultimately, this out-of-place species will compete with the natural populations for food, habitat, and mating partners - destroying the functionality of the ecosystem. If these fish were to breed with other species of completely different genetic makeup, their offspring will have genetic deficiencies, making it more difficult to survive.

However, one of the most prominent threats of farmed fish escape is the spread of diseases and parasites; these epidemics could have catastrophic effects on fish populations [6]. In aquaponics, on the other hand, the threat of fish escape is completely eliminated as fish are not held adjacent to a natural body of water.



Farmed Fish Escape is a major threat to aquatic ecosystems. As shown in the photograph above, the barrier in a fish holding site collapsing, allowing for tens of thousands of salmon to escape into the Pacific Ocean [11].

The waste that fish discharge in these fish farming pens can damage the well-being of an aquatic ecosystem. Essentially, in many forms of fish farming, the fish will discharge their waste into an adjacent waterbody, damaging the hydrology of the water [6].

A SUSTAINABLE ALTERNATIVE TO COMMON FARMING PRACTICES

Furthermore, chemical pesticides are not used in aquaponic farming; the use of any harmful chemicals would create toxic conditions for the fish. Therefore, aquaponics produces a more organic and non-processed crop when compared to the traditional practices of farming.

Farms that use pesticides and other nitrogenous chemicals can contaminate nearby bodies of water as a result of stormwater runoff. However, in aquaponics, a well-maintained system will have no effect from stormwater runoff.

HEALTH BENEFITS

There are health concerns regarding pesticide residue on crops and hormones in processed meats [5]. However, since an aquaponics system simply is incapable of using pesticides, the produced crops will have no nitrogenous additives: a healthier and more organic outcome.

OUTLINE OF AN AQUAPONICS SYSTEM

FISH TANK

The fish tank is the backbone of the aquaponics system. The fish are held and fed in this tank, allowing for the production of ammonia: a compound that is later converted into fertilizer for the plants. The fish tank has specific condition requirements that must be maintained; these conditions include temperature, water quality, fish density, and oxygen levels.

The fish tank of an aquaponics serves as the backbone of the aquaponics system. It is in this tank where ammonia is produced, the compound that is later converted into fertilizer for the plants [12].

The temperature of the fish tank can vary depending upon the organism type. The ideal temperature for warm water fish, such as tilapia, range between 22-32 degrees Celsius. The ideal temperature for cold water fish, such as trout, range between 10-18 degrees Celsius [13]. The temperature should be consistently monitored to assure that the fish's environment is ideal.

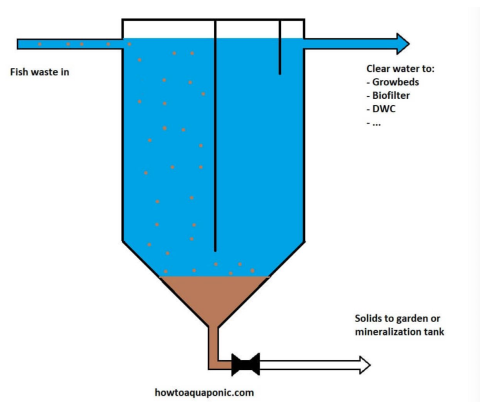
The pH - the measurement of the acidity or basicity of the water - is ideally within the range of 6.6 to 7.6 [14]. The typical pH of water is 7. If the pH is out of this range, a buildup of ammonia - a toxic compound found in fish waste - in the fish tank is imminent. If the pH were to exceed 7.6, adding nitric acid or phosphoric acid would effectively lower the pH; weak acids such as vinegar or strong acids like hydrochloric acid and sulfuric acid will also do the trick. If the pH were to drop below 6.6, calcium hydroxide in the form of hydrated lime can raise the pH [14].

Regarding fish density, one pound of *mature* fish per five to seven gallons of tank is a helpful ratio to follow regarding fish density [14].

Additionally, oxygen is a key component of assuring the health of your fish. Oxygen is delivered to the tank using an aeration device. It is advised that a lot of oxygen is present in the tank; very rarely can you overdo oxygen [14].

CLARIFIER

The clarifier consists of a separator that allows for particles to sink and clean water to rise. This process directly follows the fish tank. Once the water is cleansed, it flows directly into the biological filter [15].



BIOLOGICAL FILTRATION TANK

Water flows directly from the clairfier into the biological filtration tank. In order to efficiently filter out the remaining toxic ammonia, a biological filter is essential. A biological filter consists of many kinds of bacteria that will convert the ammonia into compounds that plants have the ability to safely absorb. A T-shape is recommended for the pipe that leads into the biofilter. It is beneficial since it allows for an increase in the water's exposure to oxygen and the removal of carbon dioxide from the water [16]. The biological filter medium creates enough surface arrow to allow nitrifying bacteria and ammonia oxidizing bacteria to gather and convert NH_3 into a less toxic compound [17].

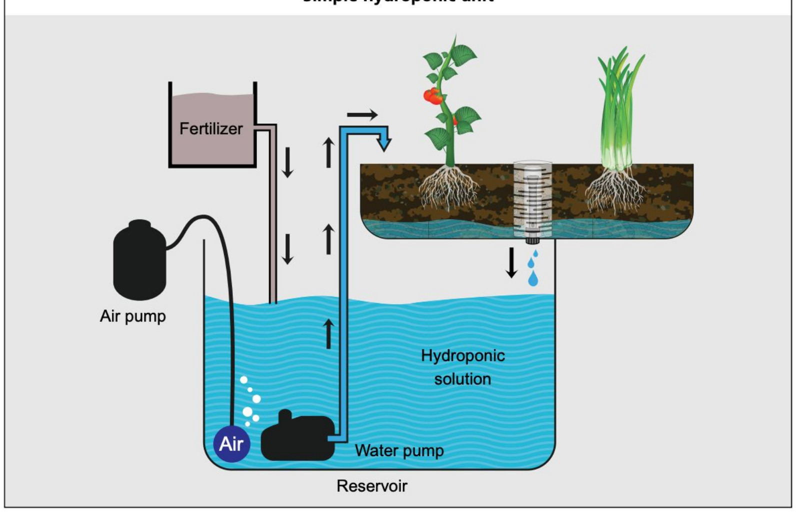
HYDROPONICS SYSTEM

Once the fish waste is converted into fertilizer, the water is safe to enter the hydroponics system. The hydroponics system comes in a variety of designs; however, every hydroponics system features crops planted in substrates as well as a flow of water directed back into the fish tank. Substrates are various inert growing media that take the place of soil in aquaponics or hydroponics [12].

Essentially, substrates are more sustainable than soil since they are able to be reused and they have the ability to hold more water. Additionally, substrates, also known as growing media, allow for physical stability of the plants. Growing media can have varying water holding capacity (WHC): a measurement of how absorbent or restrictive the growing media material is. Mother Earth Coco Coir and Grodan Gro-Wool are examples of media with high absorption rates (hold on to a lot of solution) - leading to little irrigation. Other examples on the other end are Mother Earth Hydroton Expanded Clay Pebbles which hold little water and require a lot of irrigation [18].

Essentially, once the water flows from the biological filter, the water is directed to the hydroponics system, often in the form of a grow bed. The water is led to the plants, either through PVC pipes or grow beds. The plants are able to remove the nitrate - a main compound found in the fertilizer - through the process of bioremediation - and the output is purified water. Once, the process of bioremediation is complete, the water is safe to return to the main fish tank, where the cycle begins again.

FIGURE 1.3
Simple hydroponic unit

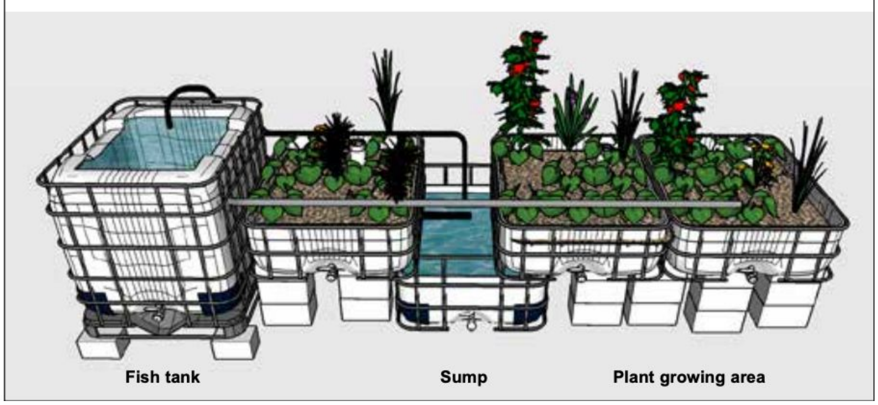


[12]

SUMP TANK

The sump tank is a water collection tank that should hold between a quarter and a third of the total volume of the fish tank. Not all aquaponics systems require a sump tank; if the water volume of the fish tank is greater than or equal to the volume of your empty grows beds, a sump tank is unnecessary. Typically, it is located at the lowest point of the aquaponic system in order for water to gravitate towards it [13]. The sump tank should also be located below the grow beds, allowing for easy circulation of the water [19].

FIGURE 4.1
Illustration of a small media bed unit



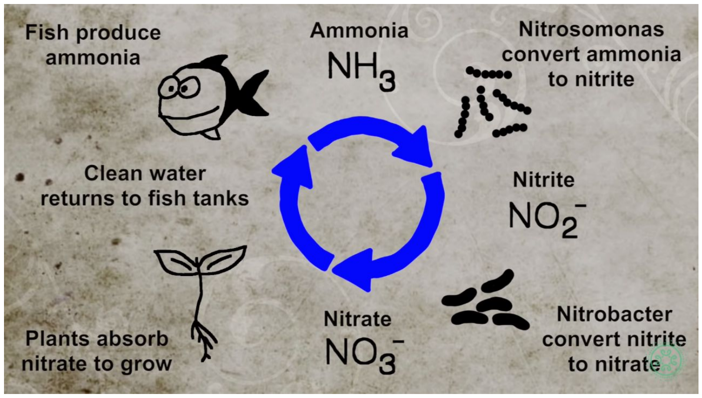
[13]

THE CHEMISTRY BEHIND AQUAPONICS

The success of aquaponics is entirely based on the process of nitrification. Fish waste creates a compound known as unionized ammonia (NH_3) which is toxic; it has the potential of destroying an aquaponic system by killing fish and plants. However, once NH_3 comes in contact with water, the compound ammonium (NH_4^+) is formed: a non-toxic compound.

Despite the majority of fish waste being converted into NH_4^+, a small concentration of NH_3 *does* exist; it must be removed before it creates deadly conditions for both the plants and the fish. The concentration of NH_3 is dependent on the pH of the water: a measurement of the acidity or basicity of the water. At a pH of 7 (the typical pH measurement of water), the concentration of NH_3 is typically below 0.5%; however, if the pH were to rise to 10 (a more basic measurement), the NH_3 concentration has the potential to rise to 80% [17].

First, the NH_3 is converted into nitrite (NO_2^-). However, nitrite is also toxic to both plants and fish. Therefore, other types of bacteria must convert nitrite into nitrate (NO_3^{-2}). NO_3^{-2} is safe for both plants and fish, and can serve as a fertilizer for plants. Therefore, the plants intake water concentrated with nitrate. Then, the plants intake the nitrate and return purified water back into the fish tank: a process known as bioremediation.



The process of nitrification, or the nitrogen cycle, is what converts the fish waste (ammonia) into plant fertilizer (nitrate) [20].

MAKE YOUR OWN AQUAPONICS SYSTEM

See the "Do-It Yourself Aquaponics" guide for more information about how to design, maintain, and care for a successful aquaponic system!

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