Hydroponics System to Reduce Armenian Food Scarcity

An Interactive Qualifying Project Report Submitted to the faculty of Worcester Polytechnic Institute in partial fulfillment of the requirements for the Degree of Bachelor of Science in cooperation with the Armenia Tree Project. Submitted [05.03.2022]

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Abstract

Hydroponics is a flexible and sustainable agricultural practice providing efficient, high quality yields of essential produce. In collaboration with the Armenia Tree Project (ATP)'s goal to combat food scarcity across Armenia, we have developed a design and manual for an inexpensive and adaptable hydroponic gardening system. After researching preexisting designs compatible with highly nutritional crops relevant to the average Armenian diet, we began collaborative work with the American University of Armenia developing a guide providing additional insight supporting the design.

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Executive Summary

Armenia is a mountainous country located in the Transcaucasia region, landlocked and surrounded by Georgia, Turkey, Iran, and Azerbaijan. Domestically known as ‘Hayastan’, Armenia has been faced with both a pandemic and a war plaguing its people and its economy, particularly damaging the agricultural sector. An increased need to import food as well as spiking unemployment rates have led to both food scarcity and insecurity becoming alarmingly widespread.

Due to the increased cost of produce and an identified need for ease of access to fresh produce among impoverished Armenians, there is an unmet need for an alternate solution to relying on the typical agricultural supply chain to adequately provide food for all Armenian communities domestically. In times of food scarcity, it is vital to take advantage of what resources and agencies are available to the people and fashion them to fit existing needs. The design of an economically efficient hydroponic system to give the average Armenian household access to the ability to grow essential foods would greatly reduce food insecurity and the strain it puts on both the people and the economy.

Hydroponics is a revolutionary, innovative tool in small-scale agriculture that can greatly improve yields as well as extend the growing season, even more so when included inside a greenhouse. The use of hydroponics can improve not only general food availability in impacted communities that lack arable land but also the variety of available foods. As large portions of Armenia are rocky and arid, the majority of Armenia’s agricultural land is dedicated to cattle herding and the dairy industry. The low nutrient density of the soil discourages conventional farming but declines in the dairy industry as a result of the dramatically reduced number of dairy exports as farmers struggle to even meet domestic demands. Hydroponics is a cost-effective solution to the recent economic volatility of the dairy industry, as the cost associated with developing a single system is minuscule compared to that of raising cattle.

Our multifaceted goal involved intense research detailing the desires and capabilities of the average Armenian when it comes to food and home agriculture. One of our key objectives was to identify high value crops that are notably desired, nutritionally practical, and economically favorable; most critically, these crops must also thrive in hydroponic growing systems within Armenia’s climate. Furthermore, the largest challenges arise when aiming to design a system that can be easily constructed by a layperson with low-cost materials and simple instructions. Gaining a firm knowledge of a reasonable budget from the sponsor was important so that the system can be implemented repeatedly, with an emphasis on the use of sustainable, widely available, and cheap materials. The system must be scalable in size, as in communication with Armenia Tree Project (ATP) was specified that the system will be advertised and hopefully used by both Armenian schools to supply student meals and Armenian families relying on small-scale agriculture for income. After completing the design itself, we worked collaboratively with ATP to create instructional material on how to implement and maintain the system.

While developing the design for the hydroponic system, we consulted specialists from the ATP periodically to gain insight into Armenia’s climate and the appropriate systems best suited

for some of the crops the specialist noted as being particularly of interest, mainly greens, broccoli, and brussels sprouts. After identifying the crops that were highly nutritious, widely desirable, and suitable for hydroponics, a further discussion took place with the ATP about what materials specifically may be unexpectedly scarce. Additionally, following the creation of basic visual instructions, we worked collaboratively with students from the American University of Armenia to create an instruction manual and troubleshooting guide.

Food insecurity is a byproduct of the increased cost of basic goods including fresh produce, which is, in turn, a byproduct of food scarcity. By providing simple instruction on how to construct and use a hydroponic gardening system, Armenian families can have direct access to low-cost, readily available fresh produce year-round, with excess to sell as a means of generating income. Armenian schools can instruct young students on the importance of agriculture and home-grown food while providing healthy meals with fresh ingredients that the children had a hand in caring for themselves. The project seeks to make a lasting change in the accessibility and attraction to small-scale agriculture for the average Armenian.

Introduction

Food insecurity is one of the major global challenges made worse by Covid-19 and increases in global conflict. As supply chains are recovering from the global shutdown and borders between countries continue to be disputed, the accessibility of nutritious food consistently continues to decrease. For the 55 countries and 88 million people experiencing food scarcity in 2019, this means depleting essential household resources to meet basic needs or suffering the life-threatening side effects of malnutrition (IMF, 2020). With the severity of the issue continuing to worsen, the need for innovative solutions that bring efficient and affordable means of food production to those in need is essential. Acquiring improved means of agricultural production is the main focus of the Armenian government and the Armenian Tree Project.

In Armenia, man-made conflict and naturally occurring environmental hardships have made food security a significant challenge. The border conflict in the Artsakh region has contributed to the destruction of agricultural land, decreasing the presence of domestically sourced food and increasing reliance on neighboring countries. This reliance on imported goods has increased the cost of food significantly, hitting poor families in rural areas touched by conflict the hardest. The current system also failed to provide a reliable supply of food when international supply chains were affected during Covid-19. For Armenians, the lack of workable land for agricultural growth and unreliable food systems results in malnutrition and economic hardship. To help alleviate pressure organizations ATP and other organizations have committed time and money into innovative solutions to create more efficient year-round fruit and vegetable growth for families.

The ATP currently offers programs on agricultural techniques at its two community centers and its mobile classroom to create a more knowledgeable and self-sufficient Armenian population. By providing education, ATP helps empower Armenian families to take ownership of their own fruit and vegetable growth, and therefore alleviate some of the reliance on other countries. However, the natural seasons of Armenia and the poor soil conditions make conventional growing methods challenging and expensive to sustain.

A low-cost hydroponics system that could be easily replicated with simple instructions would make it possible for efficient plant growth independent of soil conditions. A hydroponics system designed to be used at home or a school would increase food production by increasing the control over the growing conditions of plants. By controlling factors like pH, water, and temperature, fruits and vegetables can be grown more efficiently. Keeping the design easy to use and low cost will help ensure that its benefits can be experienced by the most Armenians possible.

Armenia is not the only country that can benefit from low-cost hydroponics systems. Around the world drought, natural disaster, conflict, and climate change negatively impact the ability to access nutritious food. The ability for individuals to efficiently and cost-effectively grow their own food independent of surrounding conditions is an essential challenge that requires modern innovations to create.

Background

This section focuses on the historical context that is necessary for understanding the origins of food scarcity in rural Armenia. We first focus on the current state of food scarcity and agricultural production in Armenia with emphasis on its effects on the population. Moving on, we have provided an overview of current improvement efforts and an introduction of Armenia Tree Project (ATP), the sponsor of this project. Finally, we conclude with an overview of hydroponics systems that could be used to meet the needs of this project.

Historical Context

Armenia, locally known as 'Hayastan', is a landlocked, mountainous country that is located in the debatable 'middle east', sharing borders with Georgia, Turkey, Iran, and Azerbaijan (Fig. 1). Armenia currently faces unresolved border disputes with Azerbaijan near the southern region of the country, where a narrow strip of Armenian land separates Azerbaijani states and the self-proclaimed independent region of Artsakh. Although internationally recognized as part of Azerbaijan, Artsakh has a predominantly Armenian population and the area is disputed by both countries (Nations Online Project, 2022).

Figure 1: Map of Armenia & Boarding Countries (Nations Online Project, 2022)

The current fight for land in the Artsakh region has a long, bloody history with the neighboring countries that once participated in a brutal genocide of the Armenian people. The casualties associated with most recent conflicts have been disproportionately Armenian, but ethnic Armenians backed by the Armenian government continue to defend their ancestral land in the name of the ancestors lost to genocide and conflict.

The conflict in Artsakh has forced many Armenians to search for new homes in less tumultuous areas, but job stability in the context of the global COVID-19 pandemic is severely lacking. The unemployment rate has spiked to over 20% due to economic volatility. Fortunately, thanks to measures to reinforce key industries taken by the government to mitigate the economic damages Armenia has experienced as a result of the conflict and the pandemic, unemployment has dropped to 15% as of January 2022, and continues to fall (Trading Economics, 2022).

Armenia's agricultural sector is one of the most crucial to the country's domestic economy. Still, agriculture's contribution to Armenia's GDP has fallen by 3% since 2017, and continues to decline as a result of the ongoing conflict. Approximately 30% of Armenians are employed in agriculture when accounting for agriculture and agricultural processing. Agriculture has severely downsized as an industry since the late 2010s due to unfavorable weather conditions that continue to jeopardize the stability of conventional produce farming, leading to about 55% of the 70% of Armenia's land that is classified as agricultural to be used for cattle farming. The ATP, in light of these circumstances, has identified a need for an economically favorable, innovative solution to the stagnation in growth of the produce industry.

After the war with Azerbaijan, displaced Armenian families have struggled to make a living in the wake of losing their farmlands and primary sources of income. Furthermore, as a result of the war and climate change, there is a notable lack of readily available arable land for displaced Armenians. ATP hopes to improve the overall environment of Armenia while providing young Armenians with resources to more easily grow and potentially sell their own fresh produce. One of ATPs solutions is to help construct 50 greenhouses in the backyard of families, these would be about 9 m^2 (30 ft^2) in size. Not only would this provide food for Armenian families, but economic relief if they can sell the surplus of fruits and vegetables that they grow (The Armenian Mirror-Spectator, 2021).

Food Scarcity in Armenia

Armenian conflicts and disruption of national agriculture have had many impacts on the country, one of the greatest of which is limited food security. Food security can be defined as "all people, at all times, having physical, social, and economic access to sufficient, safe, and nutritious food that meets their food preferences and dietary needs for an active and healthy life" (International Food Policy Institute, 2020). Unfortunately, due to the reliance on food imports, poverty in rural regions, and additional uncertainties brought on by Covid-19, food scarcity has been perpetuated in Armenia.

In February of 2021, the World Food Program (WFP) completed its Food Security and Vulnerability Assessment in Armenia. The WFP revealed that in a representative sample of approximately 4,240 Armenians an average of 9.2% fall below the acceptable food consumption score. While the definition of acceptable food consumption varies between organizations, there are some similarities. The WFP uses the Food Consumption Score to quantify the extent of food scarcity. To calculate this score WFP tracks how often families consume food groups every week. The values are then weighted by the nutritional significance of each food group, with main staples such as fresh produce being valued higher than fats, oils, and sugar. Using this system, acceptable food security scores are above 35, borderline security scores between 21 and 35, and poor security scores fall below 21.

As a representation of the whole of Armenia, this would translate to about 270,000 Armenians (WFP, 2021). Depending on factors like region and household income, the presence of food scarcity may vary. In Yerevan, the capital of Armenia, 10.2% of the population has below acceptable food consumption (WFP, 2021). In the lowest brackets of household income, the below acceptable food consumption can be as high as 30%, suggesting a clear correlation between wealth and food security in Armenia. Other factors that increase food insecurity or risk for food insecurity include having a female head of household, more than four children, and living in temporary housing. The most significant of which is the gender of the head of the household; houses with female heads experience 20% greater food scarcity.

Conflict and Covid-19 affect the severity of food scarcity as well, with about 41.5% of WFP survey respondents stating that the conflict in Artsakh somehow impacted their food security. The effects of Covid-19 in combination with the Artsakh conflict worsen the severity of any food insecurity by making the reliability and accessibility of food harder.

In many cases, even if food can be reliably sourced it does not always provide the necessary nutritional value (Fig. 2).

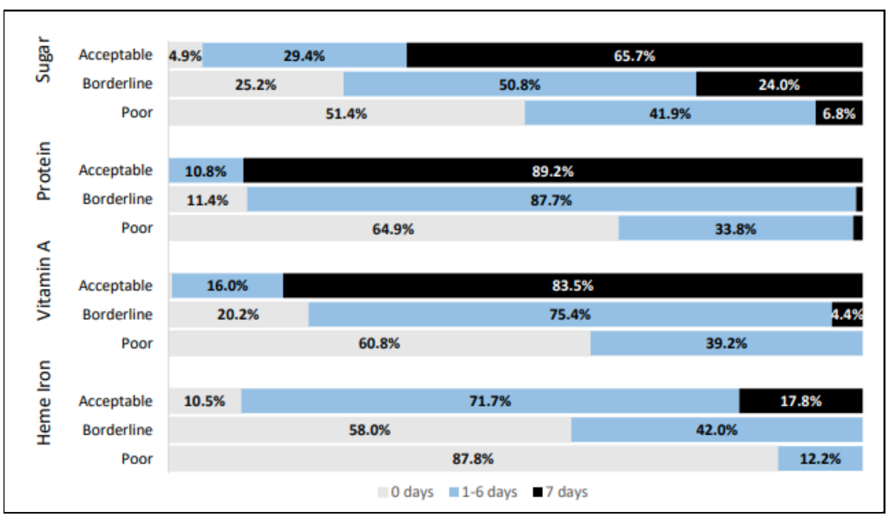

Figure 2: Nutrition by Food Consumption Score Groups (WFP, 2021)

The high percentage of Food Security Poor and Food Security Borderline respondents who do not have significant Heme Iron, Protein, or Vitamin A represents the majority of the sample. Their lack of nutrition can create a long list of negative health effects including asthma, depression, tooth decay, and anemia (Gunderson & Ziliak, 2015). Even in instances where there is access to food the balance of healthy foods isn't equally present. The WFP reported the "average Armenian consumes four times more staple foods (i.e. baked goods and potatoes)" and "two times less fruits and vegetables as compared to recommended optimal intake" (WFP, 2019). This ratio can also create negative health effects for Armenians.

Current Food Stability Effort

As food insecurity has been a long-standing issue in Armenia, there are a few programs that are helping ease the issue by providing different ways to supply, market, and distribute food.

One of the major foreign programs assisting Armenia is the WFP. The WFP has provided emergency food assistance and some medical assistance to Armenia since becoming an independent country in the 1990's. They currently provide schools with nutritious meals for school children and help relieve some of their families' struggles by sourcing food from local suppliers rather than imported foods. Having locally sourced food in schools promotes a healthier lifestyle by having freshly grown foods available for the students and helps the local market. They also support and supply machinery to local food value chains to promote and increase nutritious food production and output in many areas. Food value chains are partnerships between farms, other agribusinesses, and supply distributors that ensure an equal distribution of food throughout a certain area. By increasing Armenian farmers' access to farming technology and making machinery and farming equipment more available throughout different impoverished areas of Armenia, the WFP is trying to make food more attainable and affordable for everyone.

The WFP has helped steady the declining rate of food security as the percentage of the population suffering from this issue has remained at a constant of approximately 15% between 2013 and 2017, based on their food security report from 2019 (World Food Program [WFP], 2019). However, since the COVID-19 pandemic and the recent war, those numbers have increased from 17% to 19% between June-July of 2020 and November-December of 2020, respectively, according to their most recent food security report published in February of 2021 (World Food Program [WFP], 2021). There is a large percentage of people without food security and there is expected to be an increase in percentages based on the recent pattern. Even though they are contributing to a slower progression in this issue in Armenia, their efforts are not enough to completely stop the uptick in food scarcity.

The Food and Agriculture Organization (FAO) also has programs in Armenia to help communities with food security issues. The FAO is the United Nations agency dedicated to fighting hunger internationally. Currently helping over 130 countries, the FAO is an active source in providing funding and machinery for existing farms across the country as well as promoting relationships between local schools and local farms (Food and Agricultural Organization [FAO], 2022).

The FAO is helping communities through pilot stages between the years of 2015 and 2025. These pilot stages will consist of waves of efforts and funds with different goals all connecting to increasing food security. According to their website, their first pilot, called the 'School Food and Nutrition Program linked to the Agricultural Sector', "aims to better connect schools and farmers, and to build their capacities in the areas of nutrition and sustainable agriculture" (FAO, 2022). It is important to implement a way for farmers to optimize the output of their farms, which is what the first stage of the program aims to do. The second pilot is intended to strengthen food systems by linking "social protection programs to livelihood support and sustainable agricultural practices" (FAO, 2022). The final step of the program to be implemented is "focusing on coordination and advocacy" (FAO, 2022). These programs focus on helping conventional farming in Armenia, but as there is a lack of ideal farming land, alternative methods that focus on growing food without the use of cultured farmland are becoming increasingly crucial. The results from this project have not been formally published yet, as the project ends in 2025; however, it has been noted by the FAO that their progress and presence has been helpful thus far.

The ATP shares the goal to address reforestation and food production efforts with FAO. The ATP was founded in 1994 with the mission of assisting the Armenian people in using trees to improve their quality of life. This mission expanded into a focus on self-sufficient planting and education. The ATP has used its resources to educate over 57,000 students in over 500 schools across the country. The early education efforts target the more vulnerable population of children in the country with the hope that early education in agriculture and nutrition will help create a more knowledgeable and self-sufficient population.

The ATP accomplishes this mission primarily through clubs pioneered by passionate students, teacher education, and community-based environmental projects. In this segment of the organization, ATP provides resources and training to schools to run their own environmental education. The organization also has educational centers for environmental studies located in Karin and Margahovit. These centers provide additional homes for education and training which has been helpful to over 40,000 students and teachers (ATP, 2020). This is unique as ATP focuses on providing food for Armenians through local clubs and educational programs giving them alternative ways to produce nutritious foods themselves.

While education on agriculture and nutrition are having a positive impact on Armenian communities, there is a gap between theory and practice. More efficient and reliable growing methods are required to meet the needs of the schools and villages with which the ATP has been working. They have already made an effort to increase growth through more optimal growing conditions year-round, however, there is still a need for improvement.

Hydroponic Systems

Hydroponics is a growing segment of horticulture that can provide improved crop growth through the use of nutrient solutions rather than soil. The ability to grow crops efficiently without the need for nutrient-rich soil, an increasingly scarce resource in Armenia, is in part why it has been selected as the area of focus for research by the ATP.

Hydroponics has been used as long as agriculture has existed, although over the years hydroponics has progressed and become more advanced. Hydroponics first took off in the United States around 1900 when conventional soil-based agriculture began to become challenging due to the overuse of the soil depleting key nutrients. Over the years hydroponics have progressed, with NASA working on developing a hydroponic system in space (Pattillo, 2017).

The roots of a plant are the essential part of the plant fulfilling three main purposes: absorbing water and nutrients required for growth, the storage of nutrients, and providing support for the plant above ground. When submerged in water a plant develops water roots as opposed to the air roots that plants grow in soil in an attempt to steer growth towards water (Fig. 3).

Figure 3: Roots Grown in Water V.S. Roots Grown in Air (How to Hydroponics, 2020)

The ATP requested that we design a low-cost and efficient hydroponic system. They chose this system because conventional soil-based agriculture faces challenges such as poor soil fertility due to continuous cultivation over the years, or in our case the soil was toxic and not suitable for farming after the war. ATP would also like us to include low-cost materials that are readily available in Armenia. There are three major benefits to the hydroponic system: temperature control, reduced water loss due to evaporation, and protection against the weather. With a hydroponic system, one can build a system that is vertical rather than horizontal, optimizing the total yield. We will also conduct research on the necessary nutrients (pH and electric conductivity are crucial in nutrient composition) for each crop that can be put in the water and delivered directly to the plants (Majid, 2021).

Multiple system designs come into consideration while trying to maximize design capability while minimizing design cost. Specifically, Nutrition-Film Technique (NFT) is an attractive system design that offers flexibility when searching for construction materials, adding convenience for builders with fewer resources. NFT systems are circulatory, meaning that the water is constantly flowing in a closed system. Most successful NFT systems include the use of water and air pumps, but there are passive hydroponic systems that require similar nutrient solutions and rely on capillary action to move water to the plant such as the Kratky method (Science in Hydroponics, 2021). An exploratory analysis of the existing functional hydroponic designs and their key strengths and weaknesses is a critical factor in the creation of our model design.

Methodology

Our goal is to implement a complete hydroponics design that will increase crop yield and help alleviate food scarcity in Armenia. The hydroponics system must be affordable and easily built to accommodate our target users, students, and farmers. To achieve this goal, we set the following objectives:

1. Identify high-value crops
2. Identify ideal model designs
3. Adapting a Hydroponics System to Fit ATP's Needs
4. Building the System
5. Create Instructional Material

Objective 1: Identify High-Value Crops

The subsequent design and implementation of a hydroponics system is determined by the constraints of our project, mainly consisting of the specific types of crops the system is intended to grow. In order to provide the most effective solution, a well-researched list of crops must be gathered. The specific needs of each crop will then be used to select or design the hydroponics system.

We used three major factors to determine the list of crops we included: local demand, nutritional value, and success in existing hydroponics systems. Then using that list we had ATP pick the crops they are most interested in growing. To obtain information on the most consumed fruits and vegetables in Armenia, we used existing survey and research data that outlined the consumer habits of Armenians. These data gave us the most popular Armenian foods and seasonal grocery spending habits. It also gave us insight into the frequency with which vegetables are used and helped determine the quantity of each type of crop required to fill the gap between supply and demand per household.

We then moved on to quantifying the nutritional value of the identified fruits and vegetables in order to select crops that would make the largest impact. To accomplish this, we researched each crop's nutritional value per servings using data on vitamins, calories, fats, carbohydrates, and proteins. This allowed us to compare all possible crops and choose the ones that were most likely to be enjoyed while providing high value for the user of the hydroponics system. The resulting list of fruits, vegetables, and herbs was then used to determine the requirements of the hydroponics system and guide research on existing systems known to have high success with the crops we had selected.

Herbs were also generally included despite being of little nutritional value, as they're particularly easy to grow hydroponically due to their small size. They still provide a large yield with typically fast growth times, further, they are highly desirable both to home growers and the average consumer for their flavor and easy preservation.

Objective 2: Identify Ideal Model Designs

Elaborating on why hydroponics was selected as a cost-effective method of growth, a variety of comparative data can be examined to show the long-term benefits of establishing a hydroponic growing system. A comparative study of strawberries being grown in conventional soil and a hydroponic setup detailed below implies that although a hydroponic system is more expensive up-front to produce, its long-term increased yield, improved quality control, and reduction in overall water use is a financially sound long-term investment.

Table 1. Fixed and Variable Costs for Hydroponic Grown Strawberries.

Fixed Costs			
Item	N	Price	Sub Total
5-gallon paint bucket	15	$2.97	$44.55
Hydroton	50 L bag	$87.00	$87.00
pH and ppm meter	2	$55.00	$110.00
8-inch netting	15	2.25	$33.75
Drip ring	15	5.95	$89.25
Pumping column	15	5.95	$89.25
Air pump	4	$20	$80
Electric cords and power strips	MISC	$60	$60
Total	-	-	$593.80
Variable costs			
Item	N	Price	Sub Total
Nutrientsa	2 liters	$4.20/liter	$8.40
pH adjuster	0.1/liter	$8.20/liter	$0.82
Bare root plants	30	$11.99/25 plants	$14.39
Electricityb	201.48 kWh	$0.118/kWh	$23.77
Waterc	360 gallons	-	-
Heat	Unknown	-	-
Total	-	-	$47.38

[a]Amount estimated from General Hydroponic Nutrients, Flora series
bEnergy cost was estimated by the following equation Cost($/day) = E(kWh/day) × Cost(cent/kWh), where E= .552 kWh/day (4 air pumps operating at 6 watts/air pump) and Cost= Northern Nevada is about $0.118 kWh/hour. Electricity was estimated at 24 watts (6 watts/air pump) operating at 23 hours/day for a total energy usage of 0.552 kWh/day. 0.552 kwH/day x 365 days/year x $0.118 kWh = $23.77.
[c]Water was calculated by adding 2 gallons/bucket x 15 buckets, replacing water 12 times yearly.

Figure 7: Comparison Between Hydroponics and Soil Systems for Growing Strawberries in a Greenhouse (Treftz & Omaye, 2017)

A significant portion of time was dedicated to researching and comparing pre-existing low-cost hydroponic systems and communicating our findings with the sponsor to determine a base design specific to ATP’s needs. We investigated the necessary components of hydroponic systems such as hydroponic grow boxes and Nutrition-Film Technique (NFT) systems.

We chose to focus on these designs as both offer the most flexibility in terms of the materials that may be used to construct and maintain the system which is a critical factor in keeping the estimated cost of the system low. A hydroponic grow box requires no pump or filtration system but requires longer periods of light exposure and larger units to produce a significant field. Conversely, NFT systems rely on pumps and carbon filtration in order to circulate nutrient-rich liquid throughout the growing chamber of the system, implying a higher base construction cost. The overall size of the system was determined by how much space the ATP could use towards the system we created but could be made larger or smaller by the user as the system was made to be scalable. A comparative analysis of these systems highlighting their estimated base cost of construction, yield, efficiency, and overall quality was presented to the representatives of ATP to finalize the simple mechanics of our ideal system.

After determining the ideal model system in a meeting with the ATP, we generated a spreadsheet of expected budget tables in order to create a list of recommendations for construction materials as well as the expected unit cost of each item. We compared the prices of the items by researching average prices on Amazon.com and in stores.

We talked with ATP about what size is ideal. We designed the system to be easily sizable so that users can make the system smaller or larger to fit their needs or to fit in the space that they have available.

Objective 3: Adapting a Hydroponics System to Fit ATP's Needs

One of the key challenges involved in completing the project was ensuring that the proposed hydroponics system successfully addressed the issues we had identified while keeping the materials and scope of the system feasible, so that it may be implemented and reproduced. This was a multifaceted issue culminating in the cost of the materials involved in constructing a hydroponics system, as well as the systems' need to be able to be easily scaled up. It was discussed at length with the sponsor that the hydroponics system developed would be used not only to educate school children on the use of hydroponic growing methods but also be advertised to farmers as a way to grow crops in unfavorable conditions and to extend their growing seasons.

When designing the system, it was important to keep in mind that this would not be a manufactured product, but rather a do-it-yourself set of instructions, informing and educating the reader on how to assemble a hydroponic system. While many of the same materials for construction that are readily available in the United States are accessible in Armenia, it was important to note that the relative cost of materials can be much higher; and that this project is meant to address food insecurity, which is an economically sensitive issue further encouraging prioritization of a low-cost design. This limited the materials available to develop a system and highlighted what aspects of pre-existing hydroponics designs were realistic and beneficial to our own. We suggested optional materials to be used to assemble the system, whether that be recycled household items or purchased items. That eliminated some financial stress placed on acquiring the materials needed for the system, which allowed a wider range of users as there would be cheaper material options and made the project more accessible to those with lower income. For users that are willing to spend more, a monitoring system might be a good addition to the system. We had a group of American University of Armenia (AUA) students work on researching a monitoring system that can be added. This would be placed in the tank and would test the levels of nutrients in the water.

In the earliest stages of sketching designs, we brainstormed and sketched ideas on paper and in a digital program called SketchUp. We utilized the CAD program SolidWorks to create a 3D model design and test the structural integrity of functional designs of hydroponics systems. SolidWorks was specifically chosen as we were more acquainted with this CAD program compared to others such as AutoCAD or Creo. SolidWorks has many simulation functions and is a program that allows its users to easily make changes and adjust models without needing to restart or remove large portions of design with every design iteration created. We were easily able to create CAD drawings and lists of materials that included the amount of each material used per unit and layout the required dimensions and fittings of each part in the assembly.

Objective 4: Building the System

After researching and designing we moved to build a functional scale model. We first organized all the materials needed in Excel and created a bill of materials that outlined each material needed and the total costs in both US Dollars and Armenian Dram. Then using this list as a guide, we found the cheapest versions of each item that still meet the requirements of the system. In our case, we were able to source all the materials, except the water pump, through a local hardware store. While pumps can be found in person, we found it easiest to purchase the specific pump we needed online as it allowed us to get a pump that meets our requirements.

The sourcing of tools was an important consideration during this objective as the ability of end-users to build the design in their own home is essential to the success of the system. For this reason, we also reviewed all the tools that would be needed to complete the design. During this step, we confirmed that to build the system a saw, rotary tool, and drill are needed.

After sourcing the materials and tools we transitioned to the construction of the system itself. Based on our previous research of other effective instructional manuals we outlined the order of construction into like processes. We started by making all the necessary cuts and holes into the wood, PVC, and tubing. Then we combined all the wood pieces to make the frame making sure to complete repeated steps simultaneously. After the frame was constructed, the pipes were finished with the proper end caps, placed on the frame, and then fitted with tubing. Finally, the tub and pump were connected to the system and it was tested. During this process, we troubleshoot issues and make improvements to the final design.

Objective 5: Create Instructional Material

In order to be a practical and effective option for Armenian students and farmers, understanding how a hydroponics system works is essential. For this reason, we developed instructional material to show users how to assemble the product. To create effective instructional material, we decided to make sure the format and level of explanation met the existing understanding of our audience. The ATP will distribute the instructional material and eventually build models through its scholastic program to allow students to discover new ways to grow foods, therefore, the instructional material must be engaging and comprehensible for them to put our design together with ease. This is especially true because end users are supposed to acquire the materials and tools on their own before building the system. The instructional material needs to be simple and effective as it will be read by schoolchildren learning about agriculture and farming, but also be read by rural farmers in Armenia for future distribution. We created one instructional guide we had to accommodate both audiences. To make the most comprehensive document possible, we also looked into what information to include before the instructions themselves to give a base-level knowledge on hydroponics in general and the key components of the system we selected.

To accomplish this objective, we researched basic user experience (UX) concepts and different types of existing instructional material that are meant to be universal. Researching UX concepts involved studying the best ways to create meaningful and comprehensible experiences with our material. By considering color, contrast, and scale we were able to gauge effective techniques for instructional material. We focused our research on industry leaders in effective instructions like Lego and Ikea. Each company's instructional material is universally effective across ages. Each company has published general information for their methods on effective institutions and we studied them to bridge those ideas into our final instructional material. In addition to major companies, we also researched existing instructional and learning booklets from current hydroponic systems on the market to understand how they are received by mass consumers.

We used SolidWorks to create step-by-step images of the different parts being assembled and Fusion 360 to create more lifelike renders of the design. This was the first part of our instructional material. How to monitor the system and troubleshoot plant health issues were explained in the booklet by the AUA students after the construction section.

While we worked on the instructional material, students from the AUA simultaneously worked on additional instructional material focused on monitoring and maintaining a hydroponics system. The AUA Environmental Monitoring Students were broken up into three groups to research different types of monitoring, recommended growing conditions, and troubleshoot issues with the system. The first team focused on what metrics are most important for monitoring the system and identifying how to acquire the necessary tools to monitor the system. The second team recommended a growing guide, providing information on the ideal levels of specific factors such as pH levels and temperature to best support the growth of the specific vegetables we had identified. The last group researched common issues and provided us with a guide that will allow a user of the system to troubleshoot potential issues. The format of this section provides a set of troubleshooting solutions to maintain ideal levels and a set of visuals can be used to diagnose common plant growth issues.

Results

The following section is an overview of the completed results for each objective of the project. In this section the final list of crops and materials are addressed, the final design in SolidWorks is shown and derived, the process of building a proof-of-concept prototype is explained and shown, and instructional material is presented.

Objective 1: Identify High-Value Crops

We used three major factors to determine the list of crops we included: local demand, nutritional value, and success in existing hydroponics systems. To obtain information on the most consumed fruits and vegetables in Armenia, we used existing survey and research data that outlined the consumer habits of Armenians. These pre-existing data gave us the most popular Armenian foods and seasonal grocery spending habits. They also gave us insight into the frequency with which vegetables are used and helped determine the quantity of each type of crop required to fill the gap between supply and demand per household.

We concluded the following crops based on the suggestions given to us by the ATP and our research. We selected the following crops based on their ability to thrive hydroponically, as well as their nutritional value and perceived popularity. These choices are shown in Table 1 below.

Table 1

Final Crop Choice

Herbs	Leafy Greens	Viny Vegetables
Dill	Kale	Tomato
Mint	Cabbage	Eggplant
Basil	Swiss Chard	Bell Pepper
Thyme	Collard Greens	Cucumber
		Green Beans

Undoubtedly, hydroponic systems best support crops that are fast-growing, high yielding, and water-loving. Particularly, most lettuces thrive hydroponically as a result of their short root systems and short, stable structure. However, many popular lettuces such as butter or iceberg are of little nutritional value and are not widely consumed by most Armenians. To balance this, we selected leafy greens such as kale, swiss chard, and collard greens, all of which provide a significant amount of dietary fiber as well as essential nutrients, mainly vitamins A, K, B6, and C, and the minerals calcium, potassium, copper, and manganese.

While viny plants must be trained and pruned when grown hydroponically, they can easily be supported in a hydroponic system with the addition of a trellis to the growing area. We felt it important to include a variety of vegetables providing different essential nutrients, as well as meeting general household demand to reduce the reliance on supermarket vegetables. Tomatoes and cucumbers are crops of particular interest for their wide variety, desirability, and hardiness. Tomatoes and cucumbers can also be easily converted to secondary handmade goods such as pickles and sauces, further increasing their potential economic value.

Objective 2: Identify Ideal Model Designs

We chose the NTF system because of its low cost, high effectiveness, and ATP's request for a water pump. The NTF system is an active hydroponics system that circulates the same water throughout the system to keep a constant flow going through the pipes as shown below in Figure 8.

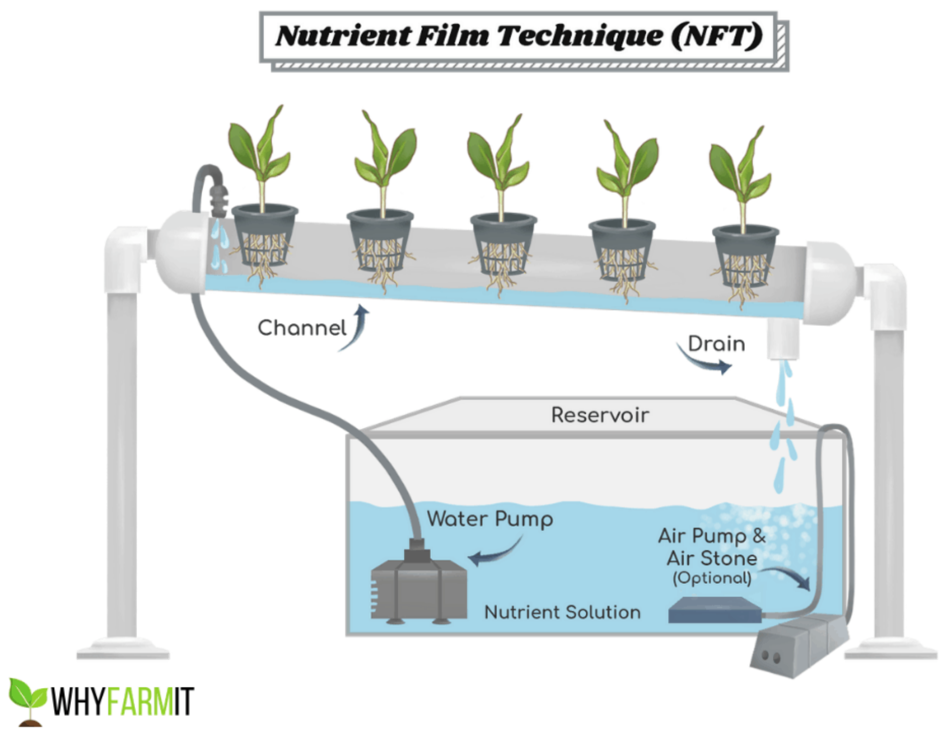

Figure 8: NFT Hydroponics Basic SetUp (Jamie, 2022)

The system has a tank that stores the water. A pump is used to pump the water up into the PVC pipes. The PVC pipes should have space for air in them to allow the air to get to the plant roots, as they would if they were to be planted in the ground. Figure 8 shows an air stone, a pump with a porous stone at the end, in the system. An air stone could be added to the tank to supply oxygen into the water that is flowing through the PVC pipes, but this is optional as the roots should get sufficient air intake from the gap they must cover to reach the water in the pipes. The water will flow through the tank, where the nutrient-solution will be mixed in with the water originally, and continue to circulate through the pipes allowing the plants to get the nutrients they need to grow. The user must add a portion of liquid plant food to the basin of water, and the type of nutrients that should be added depends on the plants the user chooses to grow. After that the water will flow through the tubing and back into the tank, closing the system, making it circulatory. Since the system has a pump, it will need a power source; however, this system can be modified so that a pump is not necessary. We did not make a model of a system without a pump, but the user could pour water into the top PVC pipe from the water tub to manually circulate the water. Circulating the water should be done once every few days to prevent algae and bacteria build-up.

The suggested material for the frame of the system is wood. We chose this because it is the most common and cheapest material that is strong enough to hold the system. Next, PVC pipes and vinyl tubing were chosen for the structural components that will have water run through them. These materials are not only readily available and cheap but are also suitable for the plants that are grown in the hydroponics system. Net pots will also have to be purchased to hold the seedlings and can be filled with stones or any natural rooting sponges. The materials we chose for the tank are a plastic storage bin, and a water pump. The water pump was placed and suction cupped onto the bottom of the plastic storage bin. The suction cups came with the pump, and seem to come with most water pumps. The plastic bin with the water pump is referred to as the tank. While a storage bin is suggested, any large object that is available and can hold about 10 gallons of water is also an option.

When determining what pump is suitable for the desired system size, the height of the system is the most important factor. For example, if the system is 5 ft (approximately 1.5 meters) a pump that can pump 6 ft (approximately 2 m) vertically is suitable. Pumps are typically measured in GPH (Gallons Per Hour) so the user should also keep in mind how fast the water is flowing through the PVC pipes. In an ideal situation, the inflow (the speed of the pump) matches the speed at which the water is exiting. The outflow speed is controlled by how big the user drills the exit tubing holes in the PVC piping which is reliant on the vinyl tubing sizing. In equilibrium, it will give a steady height of water in the PVC.

We purchased these materials to build a smaller version of the system. We chose to do this so that we could make our instructional material as we built it and we wanted to see if there were any flaws in our design that we were overlooking. Since the system was made for families to assemble at home, we wanted to make sure this was possible and within budget. A cost breakdown structure is displayed below:

Table 2

Price Breakdown of our design

Product	Quantity	Price (US)	Total (US)	Price (Armenian Dram)
2x4 (92 5/8")	5	$6.98	$34.90	16,454.30
PVC 4" x 10' (cut into 3 pieces)	1	$18.93	$18.93	8,924.93
PVC cap 4"	6	$3.67	$22.02	10,381.77
PVC Sealant	1	$12.63	$12.63	5,954.67
Chicken Wire (2'x25")	1	$15.95	$15.95	7,519.95
Screws (1 lb) (#10 x 2.5")	1	$9.47	$9.47	4,464.82
17 Gallon Tote w lid	1	$11.98	$11.98	5,648.21
Net Pots (30 count)	1	$11.49	$11.49	5,417.19
Hose (20ft)	1	$9.98	$9.98	4,705.27
Pump	1	$14.99	$14.99	7,067.34
Total			$162.34	76,538.44

Objective 3: Adapting a Hydroponics System to Fit ATP's Needs

We went through multiple design phases when developing a model for the hydroponics system. After doing research on NFT systems and verbally exchanging ideas, we began to brainstorm and sketch ideas. We then created a design in SketchUp, a 3D drawing program, as a base visual for our final design. The SketchUp drawing is shown below in Figure 9:

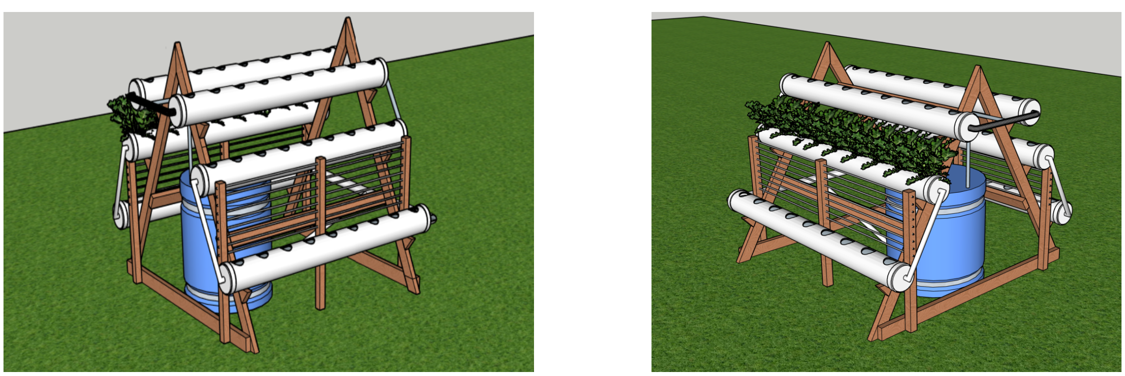

Figure 9: Initial SketchUp Design of Hydroponics System

The A-frame design is a common frame used for hydroponics systems as it is a sturdy structure and allows sunlight to hit each row of crops. We intended for the PVC pipes to be naturally sloped on the frame. The frame choice would allow for easy implementation for slanted positioning of PVC pipes that lets gravity naturally pull the water down the pipes. The SketchUp design does not show the angled pipes for simplicity, but we intended for that feature to be added in the final SolidWorks design to eliminate the need for a more powerful water pump. However, in the final design we found that we did not need to slant the pipes to increase the water flow and left the pipes horizontal. There is a trellis, a wooden structure with dowel rods, attached to the bottom of the A-frame that is only necessary when growing vine plants and can be added to the build at any time. The trellis is not necessary when growing non-vine plants. The trellis allows the vines to grow upward and maximize their yield. The tub in the center of the frame will be filled with nutrient-filled water and contain a small water pump that connects to the top two PVC pipes to start the flow of water.

Phase two of our design process was creating a SolidWorks design. We changed a few aspects from the initial design in order to maximize the space on the frame for PVC pipes to increase crop yield. We wanted to cut the very top of the A-frame to add space for an additional PVC pipe on top to avoid buying an attachment that splits the water as it comes out of the pump. The PVC pipe on top has one input hole and two exit holes allowing for the water to flow down both sides of the frame.

A major change that was made was the placement of the bottom-most PVC pipe. In the initial design, we assumed that placing this lowest to the ground was optimal as it would maximize the amount of vertical space a trellis could be placed to support the growth of vine vegetables. When we built the system in SolidWorks, we found this became an issue as the midpoint of the bottom PVC pipe fell below the water level in the tank. To fix this issue we simply brought up the bottom pipe above the top of the tank so the water can continue to flow through the entire system. This change had to be reflected in the final full-scale design. Our final SolidWorks design is shown below in Figure 10.

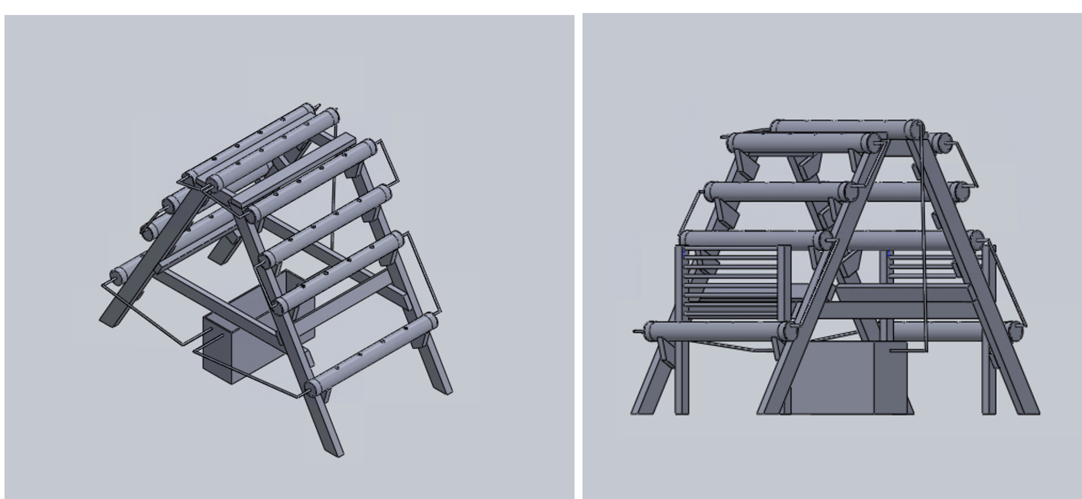

Figure 10: Final Design of Hydroponics Design

The design is meant to be scaled in height and length so the measurements of each part are only suggestions for a starter design. Each part of the build can be replaced with any other item that meets the functional requirements of the suggested material. For example, PVC pipes can be replaced with recycled gutters or pool noodles. The vinyl tubing can be replaced with a garden hose or any other item that the user may have that allows water to run through without any leaks and is long enough to connect the PVC pipes. We intend for users to use some recycled material as it will lessen the cost of the build. This is showcased by comparing the final design and the smaller-scale design that we built. There will also be a monitoring system placed in the design in order to keep the crops alive and healthy. The students from AUA assisted us by designing the monitoring system for our final product and also created a guide on how to use it. The monitoring system will be placed in the design to measure different aspects of the system, such as pH level, water temperature, light, and oxygen levels to ensure the plants are healthy. The AUA students decided where to put all the monitoring system components.

Objective 4: Building the System

The completion of a scale model resulted in a definitive list of materials, a complete list of tools, and a set of improvements to the system that were not fully realized until we had the opportunity to build it ourselves. Firstly, the materials and quantities of materials we estimated during the design process were sufficient to construct our scaled design with minimal leftover material. This was an important discovery to confirm as the instructional material relied on accurate estimates to build a full-scale model. The accurate material estimates help to keep costs down, a main focus of this project, by reducing the amount of money spent on leftover material.

Building the scale model also produced a complete list of tools that would be needed for an end-user to build our design. The list of tools did not vary significantly from our initial assumptions but completing the construction allowed us to prove that our design can be made with common tools. It also allowed us to specifically outline the tools we used and would be needed to build our system exactly how we did and later include this information in the final instructional material. We used a 12” miter saw, cordless drill, orbital jigsaw, industrial stapler, rotary tool (Dremel), speed square, tape measure, level, ½” drill bit, Phillips head power bit, plumber’s cement, and sandpaper/file to build the entire system. We used power tools to make cuts and drill holes; however, we are confident that without power tools the hand tool counterparts would be sufficient at the cost of additional time.

The completion of the design itself was crucial in creating the most concise model and easy-to-understand instructions, and revealed a handful of improvements that had to be made to the final design. The first major discovery was finding a method for setting the net pots into the pipe without specialized drilling tools that matched the diameter of the net pots. To do this, we first traced the outside diameter of the net pot onto a piece of paper and marked the center point. The circle was then cut out and placed onto the marked spots along the PVC pipe. With the paper template placed, we then marked eight points along the circle's edge on the pipe, each mark corresponding to a drill hole that was made using the ½” drill bit and the cordless drill. Then using a jigsaw, we connected the holes to create a rough circle in the pipe. Finally using either a rotary tool, file, or sandpaper, we smoothed the edges so the net pots fit tightly.

The second major change that was made was the overall shape and placement of the pipe support pieces. In the initial design, the pipes were supported by two wooden triangles placed on the outside edge of the vertical lengths of the frame. However, when we attempted to drill them into place, we found that driving screws through the narrowest side of 2 x 4 caused the wood to split. At that point, we brainstormed the simplest way to change the design of the supports using the materials we already had. In the end, we moved the supports to the inside edge of the frame and added the equivalent width of the 2 x 4 to the back edge of the support. With the support in that position, the screws could be drilled into the side instead of the front of the 2 x 4. The changes we made to the triangle supports are shown below in Figure 11. This change preserved as much of the original design as possible while making use of the materials we had to solve our problem. The change does require more wood; however, the scrap wood from cutting the 2 x 4s used to make the A-Frame was still enough to make all the supports with no additional wood purchase.

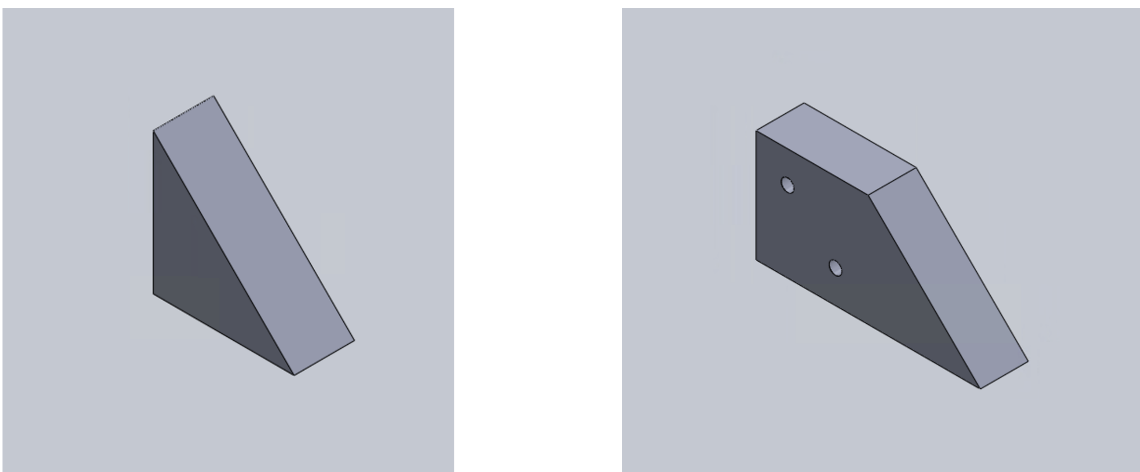

Figure 11: Change in Support Triangles, Before and After

The third result of building the scale model was a water estimation formula that can be used to find the minimum tank size and total water needed for any scale of our design. The key constraints in estimating the minimum water needed are the length of PVC pipe, the amount of PVC pipe filled, and the size of the pump. The size of the pump is important because it must remain fully submerged while the water is being circulated. Therefore, the total water needed is equal to a fourth of the volume of the pipes plus the amount of additional water needed to leave the pump submerged. The formula is based on the standard volume formula for a cylinder and for a cube. The variables are taken in meters then converted to liters by multiplying by 1000. Our estimated water formula is as follows:

$$\text{Estimated Total Liters of Water} = 1000 * (1/4 * \pi * r^2 * m) + (l * w * h)$$

r = Radius of pipe in meters
m = Total meters of pipe
l = Total length of the tub in meters
w = Total width of the tub in meters
h = Total height of pump

The estimated water formula is important for the instructional material as it allows an end-user to be confident that the container size they have will be sufficient for their system. Having the formula is another measure that makes understanding the requirements of our design easier and therefore more likely to be widely used. The formula is an estimate as it does not account for the amount of water in the flexible black tubes carrying water from pipe to pipe, therefore, the actual amount will be slightly greater. With all of these problems addressed, we completed building our final scale model which is shown below in Figure 12.

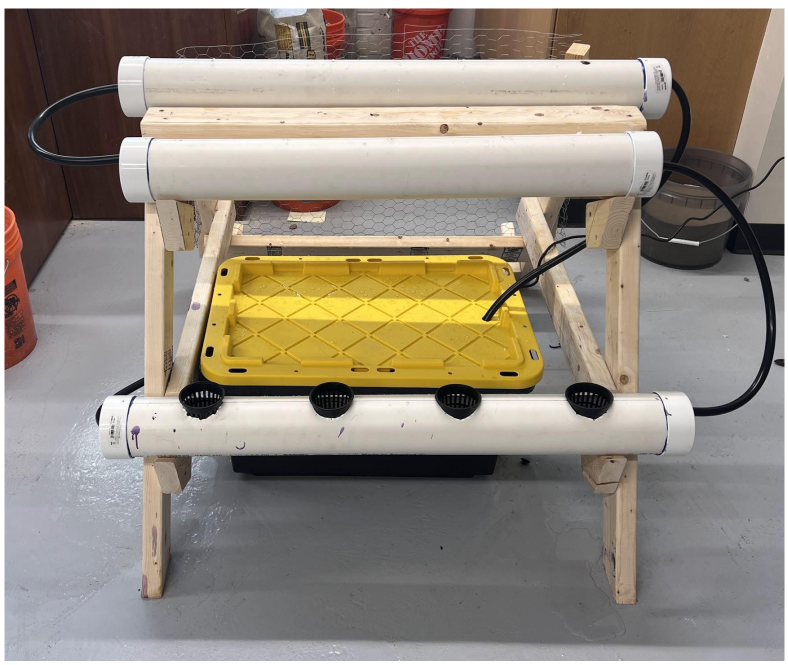

Figure 12: Final Built Scale Model

Objective 5: Create Instructional Material

After completing the design and physical construction we transitioned to the instructional material. The instructional material is a comprehensive document that explains the basics of hydroponics, how to construct our specific design, and how to monitor and maintain the system after construction. The final document uses the effective strategies we observed in existing instructional material. These methods were then used in our final instructions. The final instructions were organized into an introduction, recommended vegetables, explanation of major components, construction, and monitoring.

We studied different instructional booklets that were targeted toward kids or were advertised as easy to follow and picture-based. We decided that this booklet was meant to be educational and needed brief explanations of what each part of the system accomplished and what the benefits of hydroponics are. Picture-based instructions seemed to be the most popular type of instructions among children and young adults, based on toy and furniture company instructional assembly booklets that we had found. We began to look into Ikea instructions and Lego instructions as we all had hands-on experience with building items from those specific companies. They had all the materials used and minimal wording associated with each picture, often with a tool used and the number of screws and materials per step. We decided that this method was the most universal and was the most effective while taking into consideration that our booklet would have to be translated into a different language. We had some experience with a program called Piktochart which allowed us to easily add images and format our booklet the way we desired. By using some screenshots from the final SolidWorks design and renders from Fusion 360, we put together a guide for the construction of the final design. This deliverable is attached to this document along with another document added by the AUA students that explains how to use the monitoring system and how to identify and troubleshoot specific plant problems. This material is attached in Appendix A. Below in Figure 13 are two pages of the instructional material. The first page on the left is the materials and intro page which outlines all the tools and materials needed for building the system. This page uses checkboxes to give an active component to the checklist and has images of each material for reference. The second page on the right is the first instruction page. This page highlights an image of the work needed to be completed on each step. This page also shows what tools and materials are needed for each step along with a description of the actions that are needed to execute.

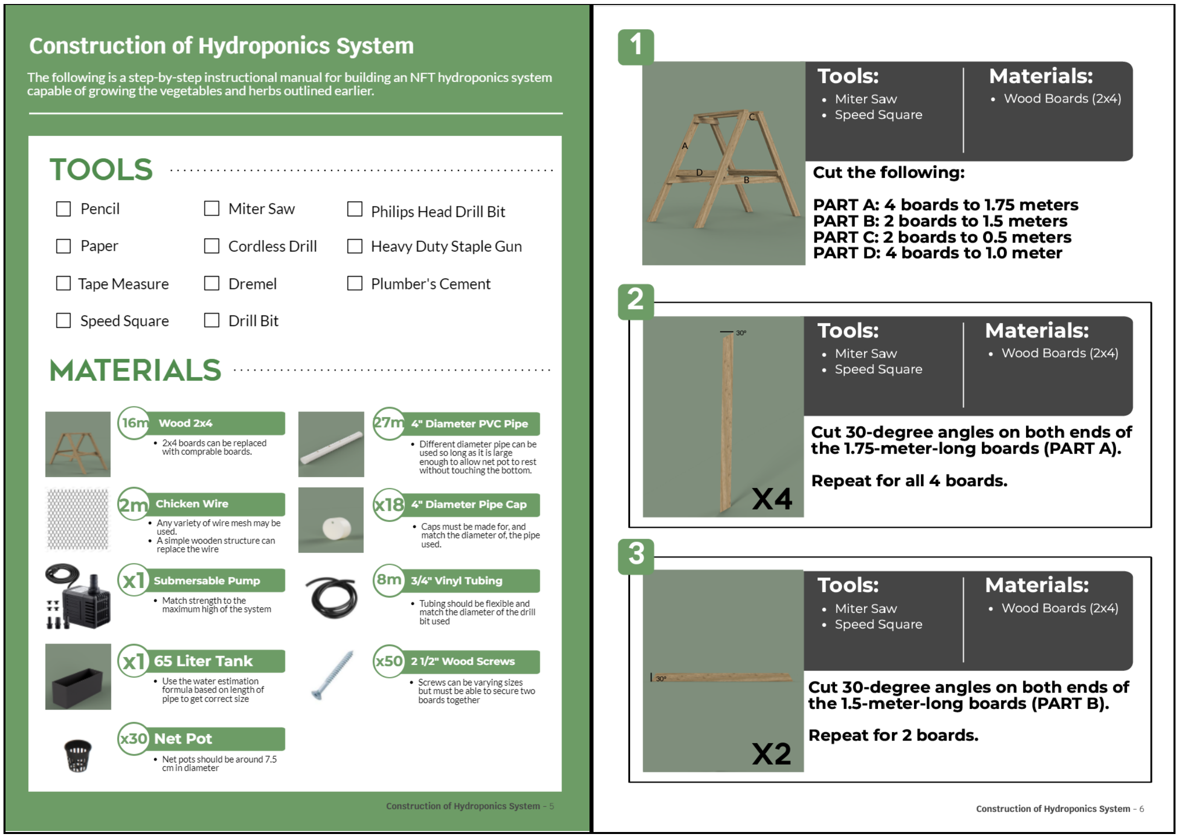

Figure 13: Final Instructional Booklet

Recommendations

This section is divided into three sections, each focusing on recommendations and implementation guidelines for the final hydroponics system, additional plants, and the instructional material.

Recommendations For System

We recommend that the Armenia Tree Project (ATP) adopts the Nutrient Film Technique system designed in the project to help address current food insecurity in Armenia. The system we designed combines low cost and ease of use to make a solution for growing produce at home or at a school. It should be noted that our system is designed to work effectively in a greenhouse as requested by ATP. While the system could be used outdoors, its design as of now only accounts for its functionality in a greenhouse. A greenhouse will help to keep the air temperatures stable and evenly distribute light across the entire system. If there is a case where placing the system in a greenhouse is not an option, we recommend that further research be completed to ensure the system's success regardless of exposure to sun, rain, or other elements. A key difference we recommend researching further is the effect of sunlight on the system and the potential integration of a built-in light source. The use of an integrated grow light may be one potential change that will increase the yield of the system by stabilizing the lighting conditions. This could be especially helpful during seasons with less sunlight or shorter days.

A similar addition not addressed in the final system is the use of timers and air stones. Primarily for cost reasons, these two elements were not included in the final design; however, if an end-user had a high budget, they could be added to the system with ease. We suggest proper research on the cheapest choice of a sufficient air stone and timer if desired. An air pump and air stone could be added directly into the tub on the opposite side of the water pump and would help reduce bacteria growth, and a timer could be added at the outlet and allow for greater control of the system's water flow making it more efficient. Another important element of the final design that warrants further research is the type of hydroponic growing media used in the net pots. While there are a variety of options to choose from, the effectiveness of each option was not tested in this project. We recommend that the ATP complete a cost-benefit analysis comparing different types of growing media before recommending the best option to the end-user.

The long-term effectiveness of the system was not captured in the scope of this project due to time constraints. We recommend that the ATP build the system themselves in Armenia to test it with the targeted vegetables. We suggest that the ATP simultaneously tests the system for its ability to grow the recommended plants and for the effectiveness of the troubleshooting manual. By testing the plant growth over multiple months, the ATP can ensure that the system designed in this project is a practical solution before sending it to an audience. This will also give them the opportunity to test the troubleshooting recommendations for plant health provided by AUA should any issues with plant growth come up.

It is strongly recommended that all users review the provided guide in its entirety before attempting to recreate this hydroponic system and to ensure a total understanding of the required tools, materials, and techniques. Furthermore, this guide assumes a basic knowledge of tools such as saws, drills, and other potentially dangerous objects. Users should take basic safety precautions while constructing their system, including but not limited to, tying back long hair, wearing eye protection, and having proper supervision for younger audiences.

We would like to emphasize that the system is meant to be easily scalable and adaptable. Users may build the frame using the proportions provided on a larger scale to provide a higher potential yield, being only limited by the strength of the pump acquired. Users should inspect the specifications on the pump they intend to use in order to determine the maximum system size it may be able to support, keeping in mind both the gallons per hour (gph) and maximum pump height.

The materials listed for assembly were chosen based on relative accessibility in our scenario but can be substituted by most materials serving the same purpose. Using recycled materials would be an excellent way to reduce the cost and waste associated with the system if they are easily accessed. For example, instead of PVC piping, gutters can be used to house the plants and nutrient solution if they are not rusted or have existing holes. As a note, changing the materials used may change some of the tools needed to assemble the design, but we encourage users to use whatever they have available. Additionally, hydroponics is a widespread agricultural practice, with countless adaptations that can be found online. When contemplating the use of alternative materials, cross-referencing the provided guide with open-source information could serve to improve the overall understanding of the construction and function of the system.

Recommendations For Additional Plants

We recommend that the ATP and all potential users experiment with additional plants to expand the list of crops that can produce high yields. There are a variety of options not individually explored during this project that could potentially thrive within a hydroponic system. Generally speaking, most leafy greens, herbs, and fruit-bearing vine plants are capable of successful hydroponic growth. It’s important to note that while hydroponics offers wide flexibility, the hydroponics systems explored in this project are unable to sustain root plants such as potatoes, beets, and other starchy vegetables. We recommend that users research and consider the needs of any alternative crop they are planting to ensure its success within our system.

The recommended crops listed in the first objective of the results focused on high nutritional value as well as high resale value in the context of the needs of ATP, leading to a heavy focus on vegetables and some herbs. Fruits were mainly not included as they generally are of lower caloric and nutritional value and many desirable fruits like pome and stone fruits must be grown on trees. However, there are some fruits that are possible to grow in a hydroponic system such as strawberries, grapes, and blueberries. These typically take more time to grow, and the yield is comparatively low to other crops grown hydroponically. However, there is still value in growing some fruits as the antioxidants and fibers they provide are important for a healthy diet. We recommend that if fruits are going to be grown hydroponically, it be attempted by those who already have experience in agriculture. To expand the availability of fruits grown hydroponically, further research on the best systems and ideal conditions for those systems should be completed by ATP.

Recommendations For Improving Instructional Material

We recommend that the ATP use the instructional material completed in the project as it provides a complete overview of hydroponics and step-by-step instructions on how to build the NFT system we designed. We first recommend that the ATP translate the instructional material into Armenian so that it can be understood by a wider audience in their region. This can be completed using a variety of PDF editors which allow an end user to edit the text field and image of the document. After the document is translated, we recommend ATP test the effectiveness of the material with different user groups. During this process, ATP should target the effectiveness of the instructional material across a variety of different age demographics and experience levels to ensure the material is easy to comprehend. ATP can accomplish this by monitoring different groups while they try to build the system using the instruction and then ask for feedback.

The value of the instructional material can be expanded through the use of different forms of media. We recommend ATP take video recordings of building the system to serve as a more dynamic and “real world” reference for those looking to build the system. The recordings make many of the steps more easily understood by showing the actual process instead of describing it in text and still pictures. The video recordings should then be edited together and placed as a link in the PDF document. A video of this sort would also offer a more engaging and concise set of instructions that can be accessed anywhere with an internet connection. The video and the instructional material should be uploaded to ATP’s website to give the largest audience possible access to the material.

Conclusion

Food scarcity is an issue that's become increasingly prevalent in not only Armenia but worldwide. There's an identified, overwhelming need for an overhaul of the agricultural industry given the current heavy reliance on imported goods impacting the price of food. While many activist groups are exploring plans to address food insecurity, we've determined that a low-cost hydroponic system would be immensely impactful for the average Armenian. Designing a scalable hydroponic system capable of growing highly valued crops would not only address the food scarcity rampant among farmers and schools, but it may also provide opportunities for additional income. While hydroponics offers the benefit of extending the growing season and allowing for more diverse produce, challenges are expected such as supply while adding limiting factors like portability, the optimal size for the desired use, cost, and powering the system using renewable energy sources. However, when faced with a sub-optimal climate and increasingly abundant food insecurity, we assert a low-cost, scalable hydroponic growth system would be a groundbreaking development for Armenia.

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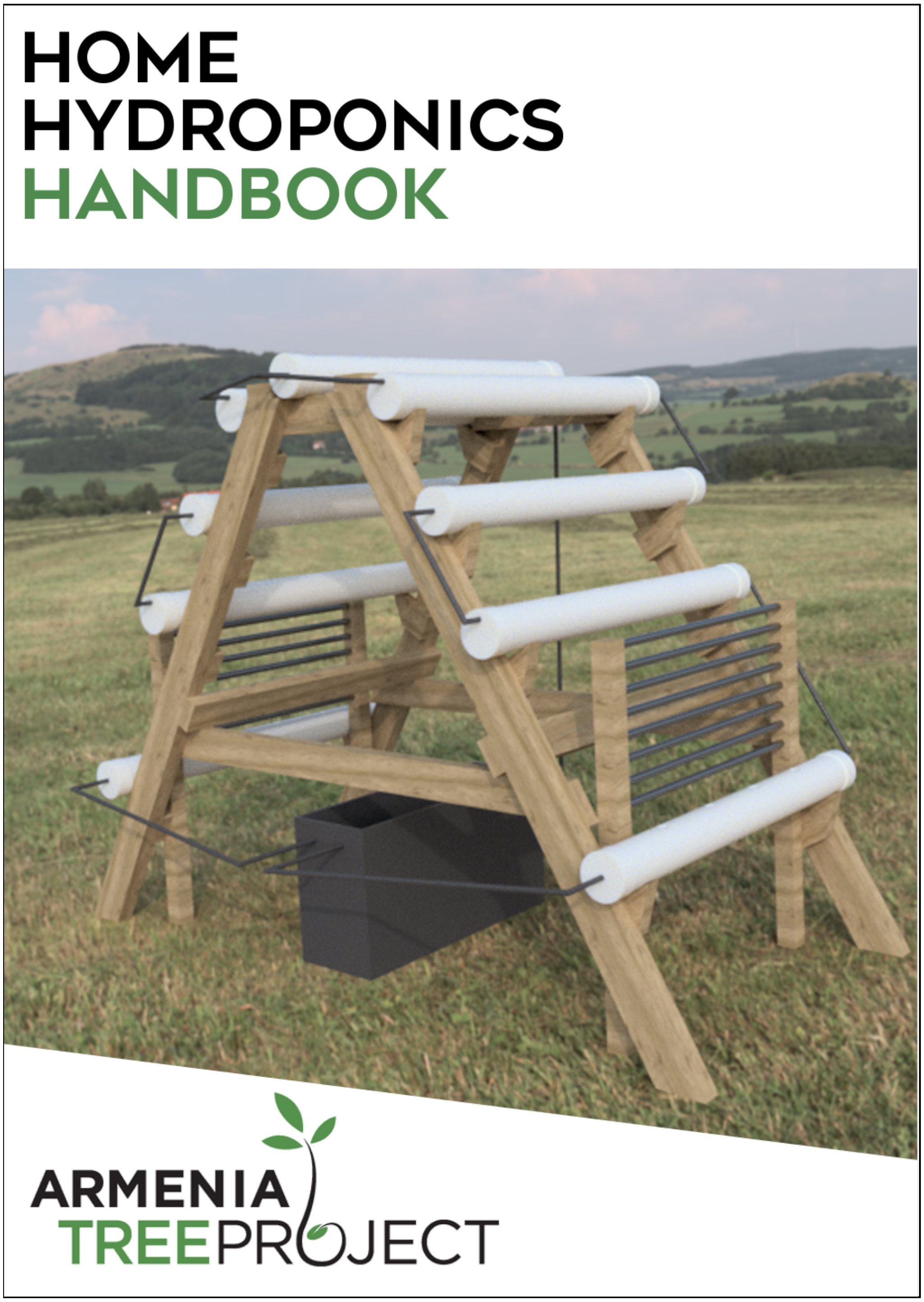
Appendix A



Contents

Introduction to Hydroponics

What is hydroponics?

Hydroponics is a broad term used to describe a non-traditional method of gardening, where plants are grown in clay, pebbles, liquid, and other non-soil grow medium. Our system focuses on nutrient film technique hydroponics, which uses a solid growth medium to support the plants placed in a constantly flowing, water based nutrient solution. Hydroponics systems can take many forms but are most commonly broken down into active and passive systems. A passive system is one that does not rely on the movement of water through pumps while an active system does. Both types can be effective and serve a purpose depending on location and budget. In most cases, however, an active system more consistently produces high yields as the circulation of water and nutrients keeps the plants in a healthier state.

Why is it important?

Hydroponic horticulture supports consistent and more frequent yields for a variety of crops. Small-scale hydroponics provides potential growers with much more flexibility than traditional gardening in being adaptable to a smaller space, limiting consumption of water, and facilitating a microclimate to extend the growing season. By making small-scale agriculture more accessible, overall waste and supply chain costs are reduced by hydroponic gardening, promoting a healthier economy and environment.

What is Nutrient Film Technique?

Nutrition film technique, or NFT for short, is a flexible subsection of hydroponic horticulture that focuses on the use of a submersible pump to provide a nutrient-rich, water-based solution to immature plants that are in smaller pots filled with solid growing medium, housed in a long tray or pipe. NFT systems are active systems, meaning there is constantly a moving part supplying power to the system so that water will continue to flow. An NFT system constantly provides oxygenated water to the roots of each plant by allowing the water to then flow down through the system via gravity, where the unused solution is then collected in the tank to be pumped through the system again.

Recommended Vegetables

The graphic below shows the intended vegetables the NFT system was designed to accommodate and their intended positions. The system is designed such that all vine vegetables should be placed on the bottom-most pipe with the trellis, moving up the side, the next three pipes can house a variety of leafy greens, and on top smaller herbs should be placed.

TOP

HERBS

- Dill
- Mint
- Basil
- Thyme

MIDDLE

LEAFY GREENS

- Kale
- Cabbage
- Swiss Chard
- Collard Greens

BOTTOM

VINE VEGETABLES

- Tomato
- Eggplant
- Bell Pepper
- Cucumber
- Green Beans

Major Components Overview

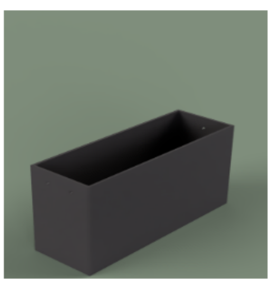
The following are brief explanations of each major component of an NFT system. In each section the requirements and important details to consider when sourcing the material are mentioned.

FRAME

The frame holds the piping for an NFT system. This particular design uses wood 2x4s and is in an A-frame shape. This shape helps expose as many lengths of piping as possible to the sun while also being stacked vertically, making the system efficient on floor space. A variety of wood can be used if the system will be inside a greenhouse, however, if the system is going to be outside or exposed to the elements, treated wood should be used to ensure the frame lasts. This design relies on wood, as it is common and cheap but other materials can be used so long as they are stable and support the weight of the system.

PIPING

The piping in an NFT system is used to carry the water and house the net pots. Most often a form of PVC pipe is used because it is cheap and designed for moving water, however, other similar materials can be used such as gutters, so long as they can be fitted to hold the net pots. In many cases, rectangular gutters or troughs are used. The piping must also be sealable. In this design we use end caps specifically designed for the pipes. Whatever you choose, you must make sure it can be sealed on both ends.



TANK

The tank holds water for the system and houses the pump. A variety of containers can be used to hold water so long as they are watertight and can be covered to prevent evaporation. The height of the water level must also fall below the midpoint of the lowest PVC pipe this will ensure gravity is able to carry water back into the tank and continue circulation. The formula below can be used to estimate the amount of water needed for a system and therefore what size tank to use.

Estimated Total Liters of Water = 1000 * (1/4 π r2 m) + (l * w * h)

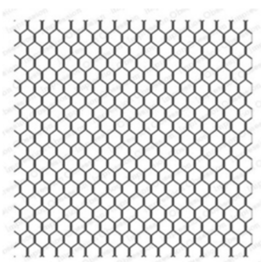
r = Radius of pipe in meters
m = Total meters of pipe
l = Total length of tub in meters
w = Total width of tub in meters
h = Total height of pump

Major Components Overview

The following are brief explanations of each major component of an NFT system. In each section the requirements and important details to consider when sourcing the material are mentioned.

PUMP

The pump is what drives water flow through the system. A typical aquarium pump is sufficient for a system of this size. To pick a pump you need to keep in mind the max pump height, gallons per hour, and the tube fitting size. This information can usually be found in the product detail section online or listed on the box. The max pump height should be above and as close to the actual height of the system, anything below will not work and anything above may be too much and cause overflow. The gallons per hour for the pump vary depending on the pump but does not need to be above 300 GPH for this system. Lastly, you must make sure whatever fittings the pump comes with match the interior diameter of the tubing that you use.



TRELLIS

The trellis will be used to support vine vegetables on the bottom-most layer of the hydroponics system. The trellis provides a structure for the plants to grow onto. For the plants we have selected, the trellis should be at least 45cm tall measuring from the center of the pipe and span the entire length of pipe. Many different options can be used so long as there is space for the vines to grow onto and the structure does not obstruct the other plants. Make sure if you are using a wire mesh, like chicken wire, the space between wires is large enough for the vines to grow fully.

NET POT

The net pot is a plastic structure that holds the plants. A net pot is designed so that a medium can be used inside to provide a structure for the roots but also has holes so that the roots can grow beyond the container. Different plant medium can be used including, perlite, clay pebbles, or rock wool. The roots must grow beyond the pot to come in contact with the nutrient-enriched water in the pipe.

Construction of Hydroponics System

The following is a step-by-step instructional manual for building an NFT hydroponics system capable of growing the vegetables and herbs outlined earlier.

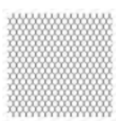
TOOLS

- ☐ Pencil
- ☐ Paper
- ☐ Tape Measure
- ☐ Speed Square
- ☐ Miter Saw
- ☐ Cordless Drill
- ☐ Dremel
- ☐ Drill Bit
- ☐ Philips Head Drill Bit
- ☐ Heavy Duty Staple Gun
- ☐ Plumber's Cement

MATERIALS

16m Wood 2x4

- 2x4 boards can be replaced with comprable boards.



2m Chicken Wire

- Any variety of wire mesh may be used.
- A simple wooden structure can replace the wire

x1 Submersable Pump

- Match strength to the maximum high of the system

x1 65 Liter Tank

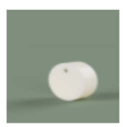
- Use the water estimation formula based on length of pipe to get correct size

x30 Net Pot

- Net pots should be around 7.5 cm in diameter

27m 4" Diameter PVC Pipe

- Different diameter pipe can be used so long as it is large enough to allow net pot to rest without touching the bottom.



x18 4" Diameter Pipe Cap

- Caps must be made for, and match the diameter of, the pipe used.

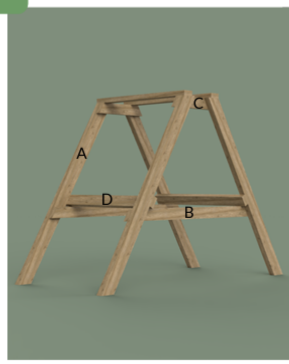
8m 3/4" Vinyl Tubing

- Tubing should be flexible and match the diameter of the drill bit used

x50 2 1/2" Wood Screws

- Screws can be varying sizes but must be able to secure two boards together

1



Tools:
- Miter Saw
- Speed Square

Materials:
- Wood Boards (2x4)

Cut the following:

PART A: 4 boards to 1.75 meters
PART B: 2 boards to 1.5 meters
PART C: 2 boards to 0.5 meters
PART D: 4 boards to 1.0 meter

2

Tools:
- Miter Saw
- Speed Square

Materials:
- Wood Boards (2x4)

Cut 30-degree angles on both ends of the 1.75-meter-long boards (PART A).

Repeat for all 4 boards.

3

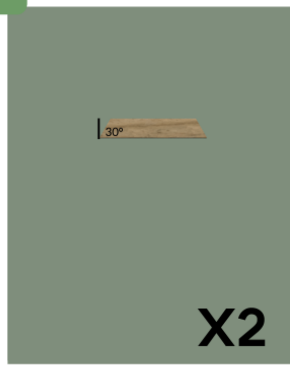
Tools:
- Miter Saw
- Speed Square

Materials:
- Wood Boards (2x4)

Cut 30-degree angles on both ends of the 1.5-meter-long boards (PART B).

Repeat for 2 boards.

4



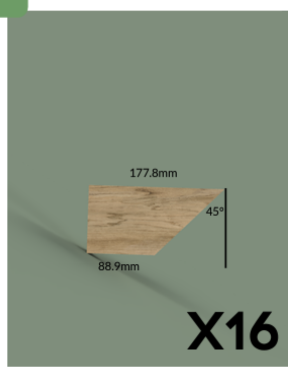
Tools:
- Miter Saw
- Speed Square

Materials:
- Wood Boards (2x4)

Cut 30-degree angles on both ends of the .45-meter-long boards (PART C).

Repeat for 2 boards.

5



Tools:
- Miter Saw
- Speed Square

Materials:
- Wood Boards (2x4)

Cut a square out of the 2x4 plus a 45° right triangle added to the end. Dimensions are shown on the left (PART E).

Repeat 16 times.

6

Tools:
- Cordless drill

Materials:
- 4 PART A
- 2 PART B
- 2 PART C
- 16 Screws

Align the boards on the floor as shown and use two screws to secure each place the boards meet.

Repeat 2 times.

7

Tools:

- Cordless drill

Materials:

- Wood Frame
- Part E
- 32 Screws

Attach Part E to hold the PVC using 2 screws for each piece place them as shown. Make sure the lowest PVC pipe will sit higher than the tub.

Repeat for both frames.

8

Tools:

- Cordless drill

Materials:

- Wood Frame
- 4 Part D
- 8 Screws

With the frame on the floor, place all 4 Part Ds as shown and use two screws to secure them to the frame.

9

Tools:

- Cordless drill

Materials:

- Wood Frame
- 8 Screws

Connect the remaining wood frame at the end of Part D as shown. Use two screws at each point to secure.

10

Tools:

- Cordless drill
- 3/4'' Drill Bit
- Jig Saw

Materials:

- PVC pipe
- Net Pot

Measure out equally spaced points on your PVC by drawing a straight line down the pipe.

To make the hole to hold the net pots, drill holes about ⅛" smaller than the diameter of the net pot.

Then use a saw to connect the holes to create a hole big enough to hold your net pot

File holes to fit the net pots snugly

11

Tools:

- Cordless drill
- 3/4" Drill Bit
- Dremel

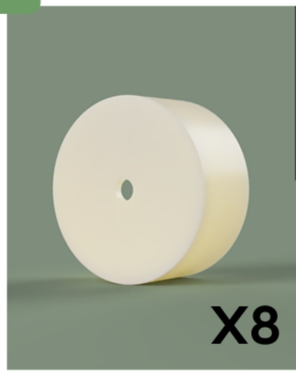
Materials:

- PVC End Cap

Drill a hole using the 3/4" drill bit. The center of the hole should approximately 3 cm from the outside edge of the cap.

Repeat on 9 end caps.

12



Tools:

- Cordless drill
- 3/4" Drill Bit
- Dremel

Materials:

- P PVC End Cap

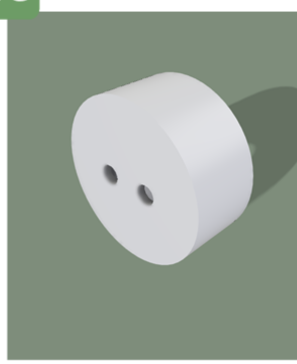
Drill a hole in an end cap using 3/4" drill bit.

The center of hole should be 5.715cm down from the top of the cap

This will be on the bottom half of the end caps which are used for the outflow of water.

Repeat on 8 end caps.

13



Tools:

- Cordless drill
- 3/4" Drill Bit
- Dremel

Materials:

- P PVC End Cap

Take one end cap that will be the outflow cap for the top pipe of the system.

Mark 2 holes that will be centered at 5.715cm down from the top of the cap and make sure they are on the same horizontal plane.

Drill holes with a ½" drill bit. This will create two outputs that will lead water down both sides of the A-frame design.

14

Tools:
- Plumber's Cement

Materials:
- PVC pipe
- End Caps

Place the end caps on the PVC pipes and seal using plumber's cement.

Make sure that each pipe has one input cap and one output cap.

Set aside the pipe with the end cap with two holes as the top.

15

Tools:

Materials:
- Wood Frame
- 9 PVC Pipes with end caps

Place all 9 PVC Pipes on the frame as shown.

Make sure the pipe with two holes in one end cap is on top.

16

Tools:
- Cordless drill

Materials:
- 2 x 2 Wood pieces or scrap
- 8 Screws

Using scrap wood attach the 2x2 wood posts to the outside side of the frame close to the PVC pipe that your plants will be growing in as shown.

Repeat for both sides

17

Tools:
- Heavy Duty Staple gun

Materials:
- Chicken Wire

Run the trellis material, such as dowels or chicken wire, across the two posts and staple it in place.

Repeat for both sides.

18

Tools:
- Scissors or knife

Materials:
- 8m of 3/4" tubing

Connect the tubing as shown by approximating the length needed to connect one hole to the next. Cut then fit into the pipe input or output hole.

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