Aquaponic Systems in Puerto Rico:

Assessing Their Economic Viability

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Submitted to:
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Abstract

Puerto Rico’s lack of natural resources has led to an insufficient domestic food supply and large amounts of imports. One possible solution for increasing the food supply may be aquaponic systems. We focused on the economic viability of aquaponics in Puerto Rico and investigated the system of our sponsor, Agroponicos, Cosecha de Puerto Rico, Incorporated. We conducted a case study, financial analysis, an assessment of expansion opportunities, and researched resources and programs. We provided our sponsor with suggestions for improving their business and concluded that aquaponics can be economically viable in Puerto Rico.

Executive Summary

Problems and Methods

Approximately 67% of countries rely on food imports (Ng & Ataman, 2008), making maintaining a stable, safe and sufficient food supply a global challenge. Despite being a relatively small island, Puerto Rico relies heavily on foreign food imports. However, Puerto Rico was able to produce a large portion of its food supply, until the late 1950s, when the economy shifted from agriculture to industry. In addition, a lack of natural resources, such as farmable land and clean water; and natural disasters, such as hurricanes, may make traditional farming methods not viable on the island.

One potential solution may be aquaponic systems. Aquaponic systems combine recirculating aquaculture systems and hydroponics to create a symbiotic relationship that is beneficial to both plants and fish. Aquaponics may be a viable farming method for Puerto Rico because the systems do not require arable lands and utilize water efficiently. Our sponsor, Agroponicos, Cosecha de Puerto Rico, Incorporated ("Agroponicos"), has built and operates the only commercial aquaponic system on the island. Their mission is to expand aquaponics throughout Puerto Rico as a means of promoting local food production.

Agroponicos owns a 1.2 acre farm located near San Juan, Puerto Rico. The farm was constructed in 2011 and is owned and operated by a father and his two sons. The focuses of their business are on growing and selling produce and expanding to other municipalities. In the future, the company also plans to promote and teach educational programs for expanding the knowledge of aquaponic systems in Puerto Rico.

The goals of our project were to assess the economic viability of our sponsor's system and investigate opportunities for expansion. We achieved our project goals by completing the following objectives:

1. Investigate the process, from conception to production, to establish and operate a commercial aquaponic system by conducting a case study of Agroponicos' system,
2. Investigate the financial records of Agroponicos to conduct a financial analysis, and
3. Find resources and programs for establishing, operating, improving and expanding aquaponics through an online search and interviews with public officials and our sponsor.

After completing our literature review, we were unable to find information on aquaponics in Puerto Rico. Although there are case studies on systems located in other locations, we learned that aquaponics need to be evaluated on a case-by-case basis. Thus, it was important for us to understand our sponsor's system and the conditions of Puerto Rico.

Completion of our project objectives involved extensive data collection through interviews. We conducted a case study by interviewing our sponsor to fully understand the process, from conception to production, to establish an aquaponic system. In addition, we conducted a financial analysis of our sponsor's system to determine if the company is profitable. We conducted interviews with public officials and program directors to understand how aquaponic systems could play a role in the nearby municipalities of Caguas and Juncos. Finally, we investigated potential resources and programs with an online search and interviews.

Results and Recommendations

Using our case study, interviews and web-based research, we were able to address our three objectives. We then analyzed our data to provide recommendations and suggestions to Agroponicos for improving and expanding their business.

Case Study of Agroponicos, Cosecha de Puerto Rico, Inc.

First, we gained an understanding of our sponsor's conception phase by investigating the motives and skills required to establish a commercial aquaponics system. We investigated their background in aquaponics and the legal process used to establish their company and build their system. We learned that the legal process was time consuming, level surfaces are beneficial and background knowledge of aquaponics and business is helpful. We formulated recommendations to minimize costs by purchasing or renting land that is conducive to aquaponics and considering building with government entities to reduce the time it takes to receive approved permits.

Second, we addressed the construction phase of the system by investigating materials, labor and the upfront costs. We learned systems can be expensive, but quality materials should be purchased to reduce potential losses. In addition, we found that individuals should minimize the construction phase to save time and to start production sooner.

Finally, an analysis of the production phase allowed us to understand the steps taken by Agroponicos to evaluate whether their system is operating efficiently. We compared the data we collected on Agroponicos' water quality test and compared their values with the values we found in our research. We found no major issues with the quality of the water. We did, however, discover problems with the utilizations of labor and the temperature of the water. We found that the labor force of Agroponicos is not sufficient for expanding their business and operating their farm. We provided resources and suggestions for hiring subsidized labor. In addition, we found the temperature of the water is 5-10 °F too warm and provided recommendations for decreasing the water temperature. We suggested increasing the use of insulation on plumbing, improving ventilation, using natural heat exchangers and moving machinery.

Financial Analysis of Agroponicos, Cosecha de Puerto Rico, Inc.

After conducting a financial analysis, we were able to determine Agroponicos is not profitable with their current combination of five beds of lettuce and one bed of chives. Currently, they gross roughly $100,000 annually, but are unable to pay salaries, pay back the system or invest in new opportunities. We provided recommendations for increasing production and revenue, reducing expenses, and diversifying profits by selling tomatoes, fertilizer and services. We also assessed the economic viability of similar aquaponic systems by using data provided by Agroponicos to construct an Excel spreadsheet for estimating profits. We found certain systems could gross almost $300,000 annually.

After taking into account a number of important aspects of our sponsor's business, a SWOT (Strength, Weaknesses, Opportunities and Threats) analysis was conducted. From the analysis, we concluded that our sponsor has access to many resources, such as education in aquaponics, and a variety of opportunities to expand and diversify their business. However, they must contend with risks, such as hurricanes, competition with imported food and meeting the demand of consumers.

Opportunities for Expansion

Current opportunities for expansion include locations in Caguas and Juncos. The locations were identified by our sponsor. In addition, we identified possible resources and programs to support the establishment, operation, improvement and expansion of aquaponic systems.

Caguas

The establishment of aquaponic systems at the Caguas Botanical Gardens would benefit Agroponicos, the Botanical Gardens and the community of Caguas. Agroponicos could benefit from having space to host educational presentations and a greenhouse to build a series of smaller aquaponic systems. The Botanical Gardens may benefit from renting land to Agroponicos, providing an additional attraction to the Gardens, providing educational workshops to individuals interested in building aquaponic systems, and making a profit from the sales of the produce grown in the systems.

Building in Caguas would also allow Agroponicos to participate in the Sustainable Food Initiative and receive additional benefits from the municipality. The Initiative was developed by the mayor's Strategic Planning staff to address unemployment, food quality and production and poverty within the municipality. As part of the Initiative, the municipal distribution center is being expanded, which may provide Agroponicos with additional markets and resources. In addition, there is a lab with packaging machinery that may reduce packaging time and costs. One major risk associated with expansion into Caguas is that neither the Botanical Gardens nor the Sustainable Food Initiative have formal agreements with Agroponicos.

Juncos

The expansion of aquaponic systems in Juncos would incorporate several large-scale systems into the mayor of Juncos' plans for expanding the municipal Rehabilitation and Empowerment Center. The Center aims to address the social issues of drug addiction, crime, unemployment and housing. Aquaponics could provide employment opportunities for rehabilitated patients and help them regain power and control of their lives. Due to the size of the proposed extensive aquaponic system, the fresh produce may be sold to schools, nursing homes, prisons and the community. Agroponicos could benefit from land provided by the Center, the supply of subsidized labor, tax exemptions and the sale of produce. One major risk associated with expansion is that the performance of the Center will impact Agroponicos' ability to obtain sufficient grant money for the construction of the systems.

Resources and Programs

We identified resources and programs that could be used to establish, operate, improve and expand aquaponic businesses. We investigated the Small Business Administration (SBA), the USDA Farm Service Agency (FSA), the USDA Natural Resources Conservation Service (NRCS), the USDA Rural Development (RD) and the Puerto Rico Department of Agriculture (PRDA) for business and agricultural related programs and resources. The SBA recommended the Puerto Rico Small Business and Technology Development Center (PR-SBTDC) as a resource for helping beginning businesses develop a business plan and manage their business. Aquaponic businesses can utilize loans from the SBA or FSA as potential sources of funding. Additionally, aquaponic businesses can use NRCS grants and incentives to improve energy, water, or soil conservation; or use RD grants to help with expansion into rural areas. Furthermore, aquaponic businesses can apply for the PRDA Bona Fide Program which includes a variety of benefits.

We also investigated the USDA Organic Certification application process and analyzed the costs and benefits of attaining the certification. Additionally, we determined that the cost of the Certification should be affordable to Agroponicos and similarly-sized farms.

Risk management is critical for the economic viability of aquaponics because it allows individuals to contend with losses from crops and facilities caused by natural disasters or other threats. We investigated the USDA to find potential programs for crop losses. We recommended that farmers purchase the Federal Crop Insurance (FCI) for all insurable crops and then register the noninsured crops with the Noninsured Crop Disaster Assistance Program (NAP). If the FCI or NAP cannot provide enough support for a severe loss, farmers could apply for Emergency Loans from the Farm Service Agency.

Conclusion

The case study and financial analysis determined that the employees of Agroponicos have the skills and knowledge to successfully maintain and operate their aquaponic system, but lack the profitability to pay employees, pay back the system and invest in new opportunities. Potential solutions include changing the combination of crops grown, investing in new markets or utilizing outside resources and programs. Another limitation is that the company has not defined their mission and goals. We recommend Agroponicos consider their short and long-term goals and develop a business model.

Although Agroponicos is currently limited by their profitability, they are working to establish themselves as the central aquaponic organization on the island and as a resource for education, supplies and consulting. With this project, we learned that being able to operate a profitable aquaponic system depends on the type of crops grown, the size of the market and the ability to expand to new locations and markets. Thus, from our projections and research we conclude that aquaponic systems can be economically viable in Puerto Rico.

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Contributions

Chelsea Bunyaviroch contributed to “Potential Business Structures” portions of the background and the initial “SWOT Analysis” portion of the Results and Discussion.

Xinxin Ding actively contributed to “History of Agriculture in Puerto Rico” and “Assessing Different Types of Agriculture” portions of the background and associated sections for “Support Programs and Resources” in Methodology and Results and Discussion.

Siena Mamayek actively contributed to “Current Governmental Policies” portion of the background, the associated “Conception” and “Construction” portions of the “Case study of Agroponicos, Cosecha de Puerto Rico, Inc.,” as well as associated sections for “Opportunities for Expansion” in Methodology and Results and Discussion.

Bryan Manning actively contributed to “Aquaponic System Technology” and “Case Studies” portion of the background, as well as the “Production” portion of the “Case study of Agroponicos, Cosecha de Puerto Rico, Inc.” and the “Financial Analysis of Agroponicos, Cosecha de Puerto Rico, Inc.” in Methodology and Results and Discussion.

The Executive Summary and Conclusion were written together. All group members contributed to additional thoughts and edits to the paper, while **Bryan Manning** acted as the chief editor.

Table of Contents

Table of Tables

Table of Figures

Introduction

Having readily available, safe, and reasonably priced food is imperative to the well-being of society (Sibbel, 2006). Although some countries are able to domestically produce a sufficient food supply, nearly 67% of countries require food imports (Ng & Ataman, 2008). Therefore, maintaining a stable, safe and sufficient food supply is an issue on a global scale.

Puerto Rico has historically relied on food imports due to a lack of natural resources. Ideally, Puerto Rico would be able to domestically produce enough food, but urbanization, lack of farmable land and clean water, and hurricanes have made it difficult. Currently, Puerto Rico imports a large quantity of food. Spending on imports amounted to $148 million in 2008 and increased to $200 million in 2011 (United States Census Bureau, 2011). As a result, the increase in spending has led to a rise in food prices, as illustrated in Figure 1. With 45.6% (Bishaw, 2012) of the population living below the poverty line and with 14% unemployment (Bureau of Labor Statistics, 2013) high food prices are directly felt by the consumers of Puerto Rico.

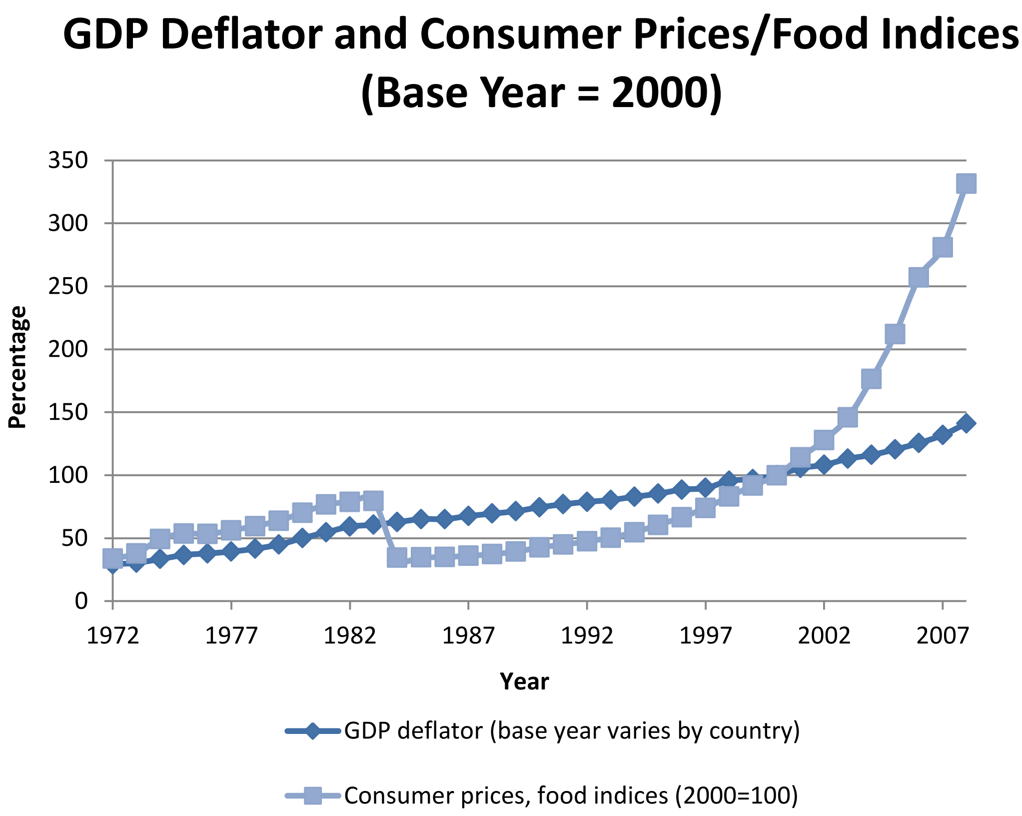

Figure 1: The consumer prices, food indices of Puerto Rico from 1972 to 2008 ("FAO Food Price Index," 2013; The World Bank, 2013).

Figure 1 illustrates the gross domestic product (GDP) deflators of Puerto Rico, which adjusts for inflation, and the consumer prices indices (CPI), which compares food prices. The index is 100 in the year 2000. The difference between the two functions, from 1972 to 1983 and 2000 to 2010, indicates that the increase in food prices is not entirely caused by inflation.

Puerto Rico could increase domestic food production by efficiently utilizing natural resources. Potential solutions may include conventional soil agriculture, organic soil agriculture, genetically modified (GM) crops, and aquaponics. However, due to limited arable land and issues with water resources in Puerto Rico, effective solutions should be environmentally friendly and efficiently utilize land and water resources. Therefore, aquaponic systems are one potential solution to Puerto Rico's insufficient food production because the systems utilize water efficiently and do not require arable lands.

Although aquaponics is a developing technology, there are successful systems in operation. Scholarly research on aquaponic systems is limited and most information is linked to Dr. Wilson Lennard, from the Royal Melbourne Institute of Technology (AU); Dr. James Rakocy, from the University of the Virgin Islands; the *Aquaponics Journal* and case studies pertaining to systems at the University of the Virgin Islands (UVI) and Growing Power, Incorporated (Wisconsin, USA). Although it is possible to find data on aquaponic systems, most is specific to individual systems and cannot directly apply to Puerto Rico.

The goals of our project were to assess the economic viability of our sponsor's system and expand aquaponics in Puerto Rico. Since Agroponicos, Cosecha de Puerto Rico, Incorporated, operates the only commercial aquaponic system in Puerto Rico, it served as a base model for research and analysis. First, we conducted a case study of Agroponicos to investigate the process, from conception to production, to establish and operate their commercial aquaponic system. Second, we investigated the financial records of Agroponicos to conduct a financial analysis and determine if the system is profitable. Lastly, we found sources of support through an online search and interviews with public officials and our sponsor to understand the economic viability of establishing, operating, improving and expanding aquaponic systems in Puerto Rico.

From our results, we were able to provide Agroponicos with a delineated process for establishing new commercial aquaponic systems, an analysis of initial costs and possible cost reductions for future systems, an analysis of the finances to increase profits and decrease expenses, an Excel spreadsheet for calculating projections, a SWOT (Strengths, Weaknesses, Opportunities and Threats) analysis of Agroponicos, an analysis of the benefits and risks of expanding to Caguas and Juncos, and information on resources and programs for establishing, operating, improving and expanding aquaponics.

Background and Literature Review

To understand the challenges of Puerto Rico's food production, it is necessary to understand the history of the island's agriculture, governmental policies, agricultural labor and farmlands. Understanding the challenges will help us assess which agricultural methods could be potential solutions for increasing Puerto Rico's food production and complying with the limitations of the island.

2.1 The History of Agriculture in Puerto Rico

When Puerto Rico became a territory of the United States in 1898, the island was already dependent on food imports (Carro-Figueroa, 2002; Rudel, Perez-Lugo, & Zichal, 2000). The dependency worsened as the population increased and small-scale farmers focused on growing cash crops for export (such as sugarcane, coffee and tobacco), instead of food crops (Carro-Figueroa, 2002; Rudel, Perez-Lugo, et al., 2000).The focus on cash crop agriculture continued into the 20th century. In 1934, for example, agriculture contributed to about 43% of the gross national product (GNP) and to 45% of employment (del Mar López, Aide, & Thomlinson, 2001). Then, in 1941, the U.S government enacted the Land Reform Law in an attempt to increase income for family farmers and increase food production (Carro-Figueroa, 2002). However, only a few farmers benefited and a majority of the impoverished farmers received little government support (Rudel, Perez - Lugo, & Zichal, 2000). Up until the 1950s, most of Puerto Rico's arable land was still being used for growing cash crops for exportation to the European and North American markets (Grau et al., 2003). Later in the 1950s, post-war policies shifted the economic focus from agriculture to industry (Grau et al., 2003).

With the beginning of industrialization and urbanization in the 1950s, the amount of farms and labor began decreasing. From 1940 to 1980, for example, Puerto Rico's farmlands decreased from 85% to 37% (Grau et al., 2003). Additionally, in 1940 45% of employment was based on agriculture, but by 2010 agricultural employment decreased to less than 2% (Thomlinson, Serrano, Lopez, Aide, & Zimmerman, 1996; U.S. Bureau of Labor Statistics, 2013). Figure 2 depicts the trend of agricultural employment from 1980 to 2010.

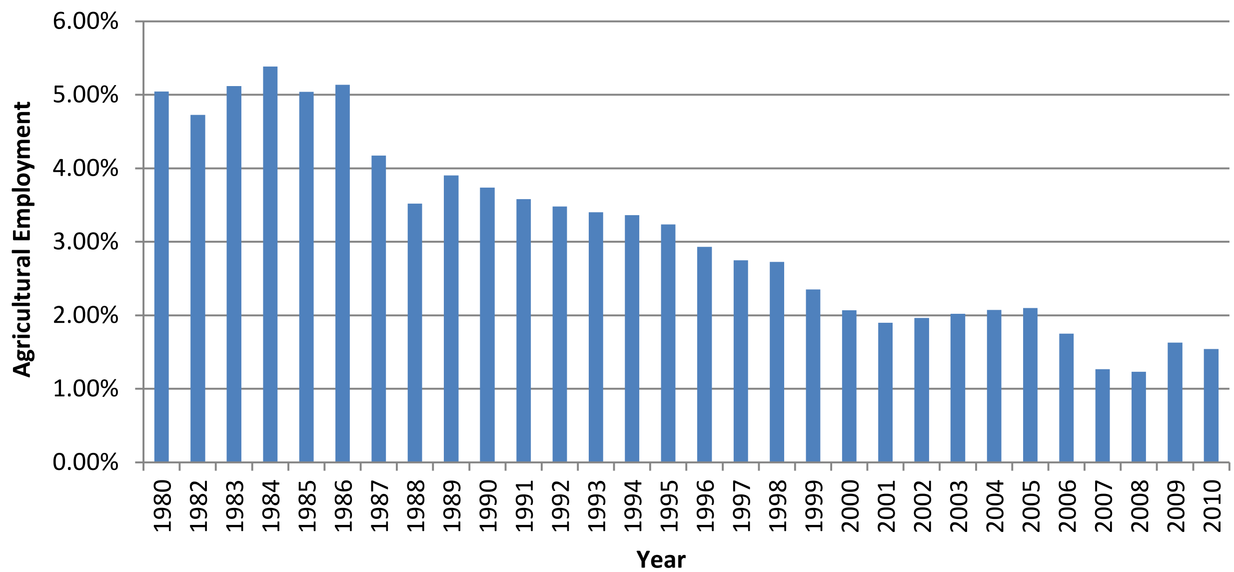

Figure 2: Agricultural employment as a percent of total employment in Puerto Rico, by year (U.S. Bureau of Labor Statistics, 2013).

The decrease in agricultural employment was partially caused by migration to cities, due to decreasing interest in agriculture and higher wages offered by lucrative, American industries (Carro-Figueroa, 2002). The decreasing interest in agriculture was caused by a lack of modernization in technology and high costs of land and labor (Carro-Figueroa, 2002; Rudel, Perez-Lugo, et al., 2000). Furthermore, globalization brought challenges to Puerto Rico's agriculture as a number of imported foods were supplied at lower prices than local farms could compete (Carro-Figueroa, 2002). As a result, farmers could not sustain a living and may have turned to cities for better opportunities.

The decrease in farmland was not only caused by lack of labor and abandonment of farms caused by urban migration, but also from encroachment of urban areas (del Mar López et al., 2001). An analysis of satellite imagery from 1977 to 1994 shows that urban lands increased from 11.3% to 27.4%, and that 41.6% of new urban lands were built on potential farm lands (Rudel, Perez-Lugo, et al., 2000). In the same study, the contribution of agriculture to Puerto Rico's GNP decreased from 43% (1930s) to 1.2% (1996), while the contribution of industry increased from 7% (1934) to 41% (1996). As a result, four major urban centers arose: San Juan in the northeast, Caguas in the central-east, Ponce in the south, and Mayaguez in the west (Carro-Figueroa, 2002). Except for Caguas, these centers are all located on some of the most fertile land in Puerto Rico (Lugo López, Bartelli, & Abruña, 2010).

2.1.1 Natural Factors Impacting Agriculture

Two additional issues that impact agriculture in Puerto Rico are hurricanes and water pollution. We researched the extent by which these issues threaten Puerto Rico to understand additional challenges to the island's agriculture.

Hurricanes

As a Caribbean island, Puerto Rico is prone to tropical storms and hurricanes. Most hurricanes make landfall on the eastern and southeastern parts of Puerto Rico (Boose, Serrano, & Foster, 2004). Hurricanes are capable of causing widespread destruction, loss of revenue, power and life. In Puerto Rico, small-scale hurricanes, which are given a F0 rating on the Fujita scale, occur roughly every four years, while larger hurricanes, greater than F0 on the Fujita scale, occur less frequently (Boose et al., 2004). The frequency and severity can be seen in Table 1.

Table 1: Frequencies of different-scale hurricanes in Puerto Rico (Boose et al., 2004; Theodore Fujita, 1971).

Scales of Hurricane	Damages	Frequency (years)
F0	Loss of leaves and branches, crop blow downs (Light)	4
F1	Scattered trees and signs, damage of houses and buildings (Moderate)	6
F2	Extensive blow downs of houses, destruction of buildings (Considerable)	15-33
F3	Forests leveled (Severe)	50-150

To combat the impacts of hurricanes in the past, small mountain farmers would grow tobacco. Due to the short four-month growth cycle, farmers were able to recuperate from hurricane losses (Carro-Figueroa, 2002). More recently, when hurricane Georges struck Puerto Rico in 1998, it caused the loss of 75% of the coffee crop, 95% of the plantain and banana crops, and 65% of live poultry. In addition, 96% of the island lost power. (Bennett & Mojica, 1999) Thus, hurricanes can be a threat not only to individuals, but also to crops and the economy of the island.

Water Quality

Although maximizing crop yields would be advantageous for increasing the domestic food supply of Puerto Rico, it may come at an environmental cost. The water quality in Puerto Rico is such a problem that in 2012 the EPA appropriated $46 million to the island to improve sewage plants and drinking water systems (Martin, 2012). Figures 3 and 4 outline the extent and causes of the water pollution in Puerto Rico.

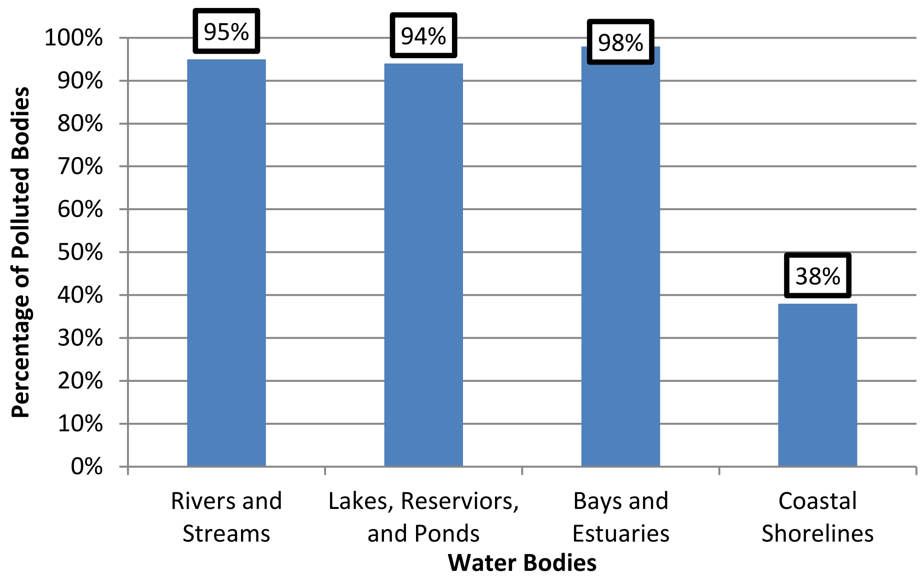

Figure 3: Pollution by percent of total water bodies (Environmental Protection Agency, 2010).

Throughout the island, there are water quality issues with lakes, reservoirs, estuaries and bays. Some of the biggest contributors to the water pollution include metals, such as mercury, arsenic, cadmium, copper, lead, selenium and silver; toxic inorganics, which include cyanides; and pathogens, which include enterococcus bacteria and fecal coliform (Environmental Protection Agency, 2010). Conventional forms of agriculture in Puerto Rico, with the use of synthetic fertilizers and pesticides, have contributed to the water pollution.

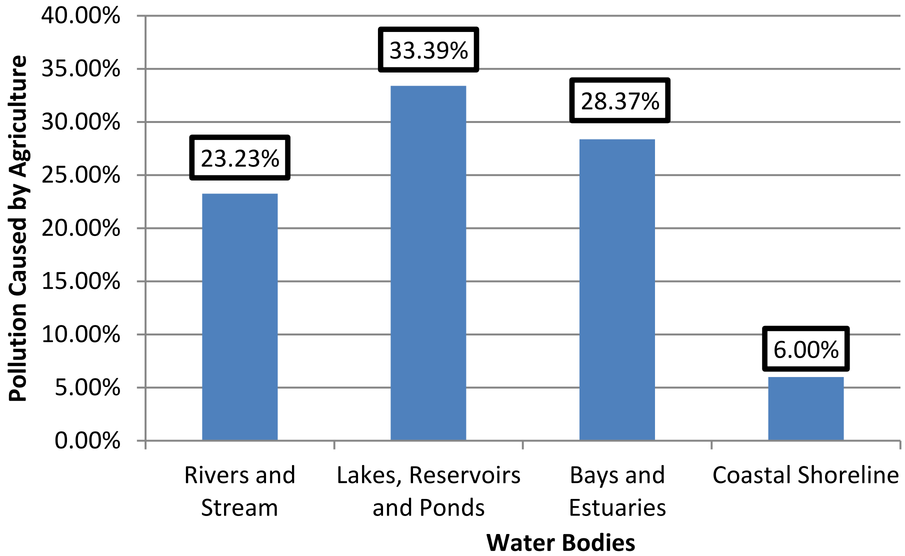

Figure 4: Percentage of polluted water bodies caused by agricultural pollution (Environmental Protection Agency, 2010).

Figure 4 shows pollution from agriculture, as a percentage of total pollution, is highest in lakes, reservoirs and ponds. Pollution from agricultural activities is considered NPS (Nonpoint Source) pollution since the pollution comes from many different sources (Environmental Protection Agency, 2010). Specifically, these pollutants are caused by poorly located or managed animal feeding operations, overgrazing, plowing too often or at the wrong time, and improper, excessive or poorly timed application of pesticides, irrigation water and fertilizer (Environmental Protection Agency, 2010). Because of the detrimental effects of current agricultural techniques on Puerto Rico's environment, it is advisable that future agriculture should not rely on wide-spread use of chemicals and, since clean water may be limited, should also be water efficient. Thus, using extensive amounts of chemicals and water to create bountiful crops may increase the domestic supply of food, but could lead to further environmental issues in the future.

Summary

Puerto Rico's agricultural history shows the island has a history of food dependency, which stemmed from a focus on growing cash crops, governmental policies, an increase in population and urbanization, a decrease in farmland and farmhands, and hazards such as hurricanes and water pollution. With this understanding, it is now possible to research agricultural techniques that may help increase the supply of domestic food, whilst abiding by the constraints of Puerto Rico’s resources.

2.2 Assessing Different Types of Agriculture

This section provides comparisons between conventional agriculture, organic soil agriculture, genetically modified (GM) crops and aquaponic systems. The strengths and weaknesses of each method are evaluated in regard to the challenges identified in the previous section.

We analyzed the yields, energy consumption, pollution, water and land use, and effects on human health to determine which methods of agriculture could comply with Puerto Rico's needs and limitations. The following types of agricultural are assessed:

1. Conventional soil agriculture uses agrochemicals, such as synthetic fertilizers, pesticides, and herbicides, to protect crops from pests and to increase yields.
2. Organic soil agriculture uses mechanical and biological techniques to protect crops from pests and organic animal manure to increase yields.
3. GM crops rely less on agrochemicals, and instead are genetically modified to be resistant to pests and to increase yields.
4. Non-Conventional agriculture, such as hydroponic and aquaponic systems, do not rely on the use of pesticides and fertilizers and are generally organic.

2.2.1 Soil Agriculture

The introduction of synthetic chemical fertilizers, herbicides and pesticides began in the 1940s and started a new age of agriculture. Since the 1960s, the use of agrochemicals has increased worldwide (Ferry, 2009). Fertilizers improve plant growth, while pesticides and herbicides protect crops from weeds and insects (Pimentel, Hepperly, Hanson, Douds, & Seidel, 2005). The increase of agrochemicals and the extension of irrigated areas have helped global production of cereals and meat increase by about 2% a year, from 1950 to 2005, and outpace the demand of an increasing world population (Kiers et al., 2008). Figure 5 shows the trend of food production, use of fertilizer and irrigation from 1960 to 1995.

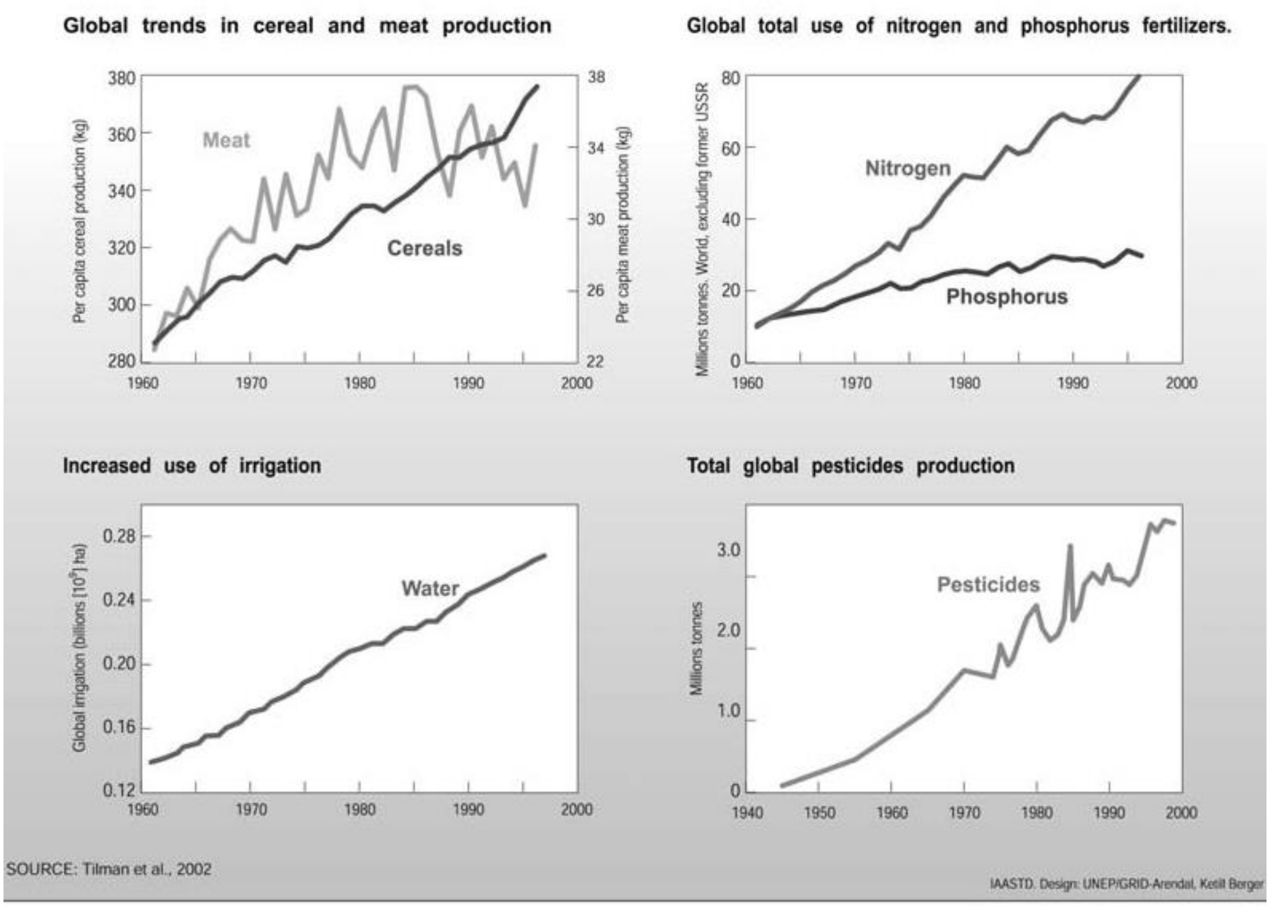

Figure 5: Global trends in cereal and meat production, nitrogen and phosphorus fertilizer use, irrigation and pesticide production (Kiers et al., 2008, p7).

However, large-scale use of agrochemicals has had detrimental side-effects on the environment and consumers. One critical issue with synthetic fertilizers, pesticides and herbicides is that they may affect the biodiversity of the soil (Ferry, 2009). Earthworms, for example, create holes which aid in the absorption and conservation of water, but may be killed by pesticides (Pimentel et al., 2005). Additionally, conventional agriculture leads to issues with nitrate and herbicide leaching, which is caused by fertilizers and herbicides seeping into the soil and water, that may contaminate water sources (Pimentel et al., 2005; Sotomayor-Ramirez & Martinez, 2006). Although conventional agriculture will increase food production, it comes at an environmental cost due to a heavy reliance on synthetic fertilizers, herbicides and pesticides.

2.2.2 Organic Soil Agriculture

Organic soil agriculture uses animal manure as fertilizer, and does not rely on herbicides and pesticides (Pimentel et al., 2005). To deal with pests, biological approaches, which include pest predators like ladybugs, are used. In addition, mechanical approaches, such as cropping techniques and seed timing, are used to prevent the growth of weeds and harmful insects (Gomiero, Paoletti, & Pimentel, 2008). Because organic soil agriculture does not rely on synthetic chemicals, they are more environmentally friendly than conventional agriculture.

Two major issues of organic soil agriculture are nitrate leaching and pest and weed control (Pimentel et al., 2005). Nitrate leaching may contaminate vicinal bodies of water (Pimentel et al., 2005) and may worsen water pollution. Also, mechanical and biological pest and weed control are affected by the weather and may not be as effective as pesticides and herbicides (Pimentel et al., 2005).

Comparison of Conventional and Organic Agriculture

Energy consumption and yields are important focuses of agriculture. Usually, conventional agriculture requires a large amount of energy, due to the use of farm machinery, fertilizers, and pesticides (Kiers et al., 2008). Energy consumption not only contributes to pollution, but may increase food prices due to the cost of fuel (Kiers et al., 2008). In terms of energy consumption (Gigajoules per hectare and Gigajoules per ton), in non-extreme climates, organic soil agriculture (Table 2) generally uses less energy than conventional agriculture (Gomiero, Paoletti, & Pimentel, 2008).

Table 2: Fossil energy consumption for different crops in organic and conventional agriculture (Gomiero, et al, 2008, p246).

Product and reference	Energy consumption (GJ/ha)			Energy consumption (GJ/t)		
	Conv.	Organic	Org. as % of conv.	Conv.	Organic	Org. as % of conv.
Winter wheat						
Alföldi *et al.* (1995)	18.3	10.8	−41	4.21	2.84	−33
Haas & Köpke (1994)	17.2	6.1	−65	2.70	1.52	−43
Reitmayr (1995)	16.5	8.2	−51	2.38	1.89	−21
Potatoes						
Haas and Köpke (1994)	24.0	13.1	−46	0.80	0.07	−18
Alföldi *et al.* (1995)	38.2	27.5	−28	0.07	0.08	+7
Reitmayr (1995)	19.7	14.3	−27	0.05	0.07	+29
Mäder *et al.* (2002)[som]	28.42	40.69	−30	3.70	3.98	−7
Citrus						
Barbera and La Mantia (1995)	43.3	24.9	−43	1.24	0.83	−33
Olive						
Barbera and La Mantia (1995)	23.8	10.4	−56	23.84	13.0	−45
Apple						
Geier *et al.* (2001)	37.35	33.8	−9.5	1.73	2.13	+23
Milk						
Cederberg and Mattsson (1998)	22.2	17.2	−23	2.85	2.41	−15
Refsgaard et al. (1998)*	—	—	—	3.34	2.16/2.88	−35/−13
Cederberg and Mattsson (1998) in Haas *et al.* (2001)*	—	—	—	2.85	2.4	−8
Haas *et al.* (1995) in Haas *et al.* (2001) *	19.4	6.8	−65	—	—	—
Haas *et al.* (2001)*	19.1	5.9	−69	2.7	1.2	−54

(som): Supporting Online Material (data from)

However, if working time and crop yields are also taken into account, organic soil agriculture usually requires roughly 20% more labor than conventional agriculture and typically has lower yields than conventional agriculture (Pimentel et al., 2005). Table 3 compares four key indicators, yield, labor, energy, and output verses input energy ratio, in a 20-year experiment (Gomiero et al., 2008). Table 3 demonstrates that organic agriculture generally has lower energy consumption, but relatively high labor costs. In terms of crop yields, although organic agriculture crop yields are generally lower than those of conventional agriculture, the difference depends on a variety of factors such as soil nitrogen components, soil pH, water quality, crop types, and management techniques (Seufert, Ramankutty, & Foley, 2012).

Table 3: A comparison of the rate of return in calories per fossil fuel invested (Gomiero, et al, 2008, p244).

Crop	Technology	Yield (t/ha)	Labor (hrs/ha)	Energy (kcal × 10^6)	kcal output/ (input)
Corn	Organic[1]	7.7	14	3.6	7.7
Corn	Conventional[2]	7.4	12	5.2	5.1
Corn	Conventional[3]	8.7	11.4	8.1	4.0
Soybean	Organic[4]	2.4	14	2.3	3.8
Soybean	Conventional[5]	2.7	12	2.1	4.6
Soybean	Conventional[6]	2.7	7.1	3.7	3.2

1) Average of two organic systems over 20 years in Pennsylvania.
2) Average of conventional corn system over 20 years in Pennsylvania.
3) Average U.S. corn.
4) Average of two organic systems over 20 years in Pennsylvania.
5) Average conventional soybean system over 20 years in Pennsylvania.
6) Average of U.S. soybean system.

Overall, conventional agriculture produces higher crop yields with higher energy cost, while organic agriculture produces lower yields with higher energy efficiency, but requires more management. Additionally, both organic and conventional agriculture require large amounts of farmland to produce high crop yields.

2.2.3 Genetically Modified (GM) Crops

GM crops are modified with genes of other organisms to help counter biotic constraints, such as weeds, pests, diseases, and abiotic constraints, such as drought, salinity, cold and flooding (Ferry, 2009). Two of the main reasons for developing GM crops were to reduce the use of agrochemicals and to protect the crops from insects. Many GM crops, such as maize, potato and cotton, are modified to produce Bt toxin proteins to kill the insects (Ferry, 2009).

The deployment of GM crops is still a controversy. Although GM crops help increase food production and reduce the use of synthetic agrochemicals, they also have several negative side-effects. Such side effects include the development of field-evolved insects, which have adapted to the insecticidal proteins, the evolution of herbicide-resistant weeds, the killing of beneficial arthropods, and potential risks to human health (Ferry, 2009). The resistance of the field-evolved insects reduces the effectiveness of Bt toxins. Figure 6 shows on a global scale that three species of major pests have developed a resistance to Bt crops after only ten years.

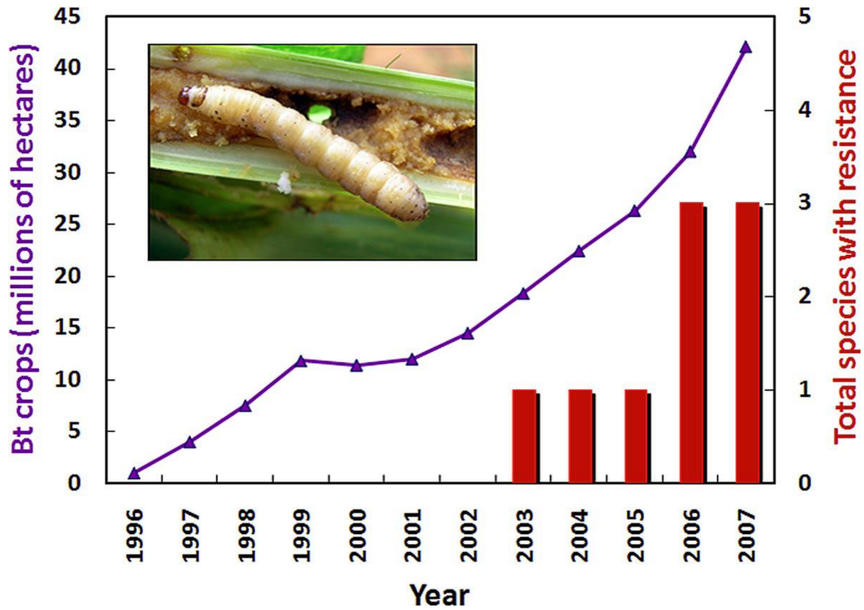

Figure 6: Global adoption of Bt crops and the number species of field-evolved Bt-resistant insects (Tabashnik, 2008, p19029).

Field-evolved insect resistance has been reported in Puerto Rico. In 2006, commercial farms and seed companies reported unexpected damage to GM corn caused by *S. frugiperda*, even though the pest should have been killed by the Bt toxins (Storer et al., 2010). The damage forced Dow AgroSciences and Pioneer Hi-Bred to withdraw GM corn from the market (Storer et al., 2010; Tabashnik et al., 2009). In addition, the field-evolved resistance of *S. frugiperda* in Puerto Rico was the fastest documented case of field-evolved resistance to a Bt crop (Storer et al., 2010). Although no statistics on Puerto Rico's GM crop production are currently available, several scholars have stated that the crops have been deployed on a large scale due to their high effectiveness against pests (Storer et al., 2010; Tabashnik, Van Rensburg, & Carrière, 2009).

2.2.4 Aquaponics

Aquaponic systems combine RAS (recirculating aquaculture systems) and hydroponics to create a symbiotic relationship that is beneficial to both the plants and fish. Unlike hydroponics, which rely on expensive nutrient supplements, aquaponics use organic, nitrogen-rich fish waste as an organic fertilizer (Blidariu & Grozea, 2011; Diver, 2006). The fish waste, which includes ammonia excreted by the gills and solid waste, are broken down and oxidized into nitrate before the plants can absorb the nutrients. The decomposition is called mineralization and is carried out by two types of beneficial bacteria, *Nitrosomonas sp.* and *Nitrobacter sp.,* which convert the toxic ammonia into nitrite, and nitrite to nitrate, respectively (Blidariu & Grozea, 2011; Graber & Junge, 2009). The nitrogen cycle of an aquaponic system is diagrammed in Figure 7.

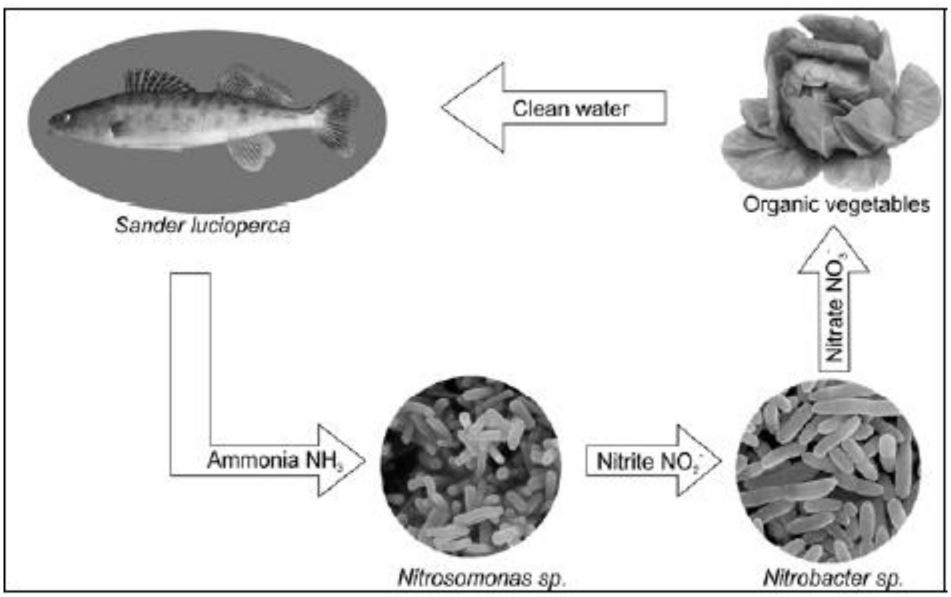

Figure 7: The nitrogen cycle in aquaponic systems (F. Blidariu, Grozea, A., 2011, p3).

Compared to soil agriculture, where generally less than 1% of the total water consumption is absorbed by plants, aquaponic systems continuously recirculate the water to the plants (Blidariu & Grozea, 2011; Diver, 2006; Jensen, 1968). Aquaponics is also a land saving approach since they could be built in buildings or on rooftops (Blidariu & Grozea, 2011).

In addition to saving water and land, aquaponic systems are also pesticide-free and therapeutant-free. Pesticides are toxic to fish while most therapeutants, such as antibiotics for treating fish parasites, may harm beneficial bacteria and can be absorbed by the plants (Turkmen, 2010). Although different systems may vary tremendously, according to some model studies, aquaponics can generate a yield comparable to that of hydroponics and soil agriculture (Blidariu & Grozea, 2011; Graber & Junge, 2009). Figure 8 compares the yields of tomatoes, aubergines and cucumbers in a study of different agricultural systems. It can be seen that the aquaponic system generated yields similar to that of the hydroponic and soil culture systems. The unit $gFWm^{-2}d^{-1}$ represents a gram formula weight per square meter per day. A gram formula weight measures the amount of a specific chemical element in one unit volume of solution. For energy consumption, since very few studies analyze the economic aspects of aquaponic systems, the statistics on energy consumption are not available. According to one study on economic analysis of aquaponic systems by Rakocy and Bailey, aquaponic systems require "moderate energy input" but no quantitative energy consumption information is available (Rakocy & Bailey, 2003).

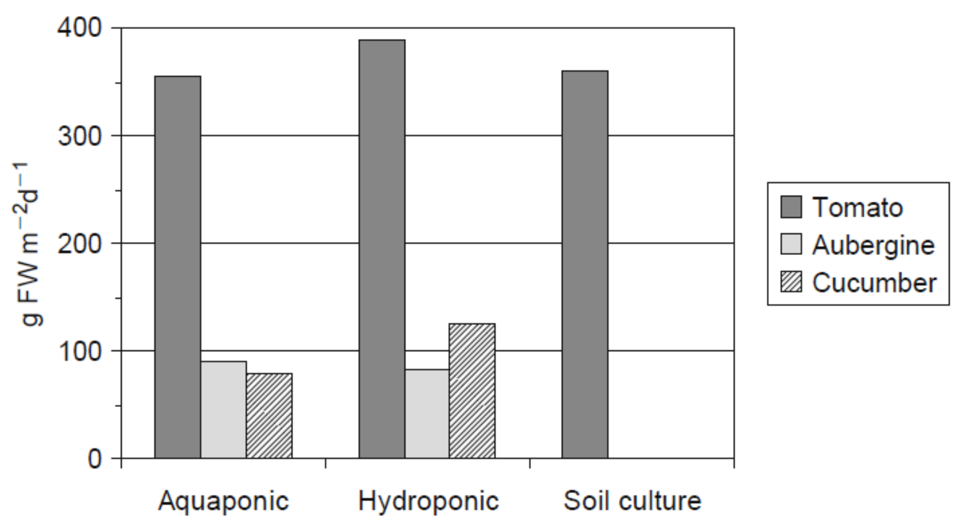

Figure 8: Yields of tomatoes, aubergines and cucumbers in different agricultural systems (Graber & Junge, 2009, p153).

There are some challenges and potential problems with aquaponics. First, aquaponics and organic soil agriculture are both limited by the effectiveness of pest control. Only organic pesticides, biological and mechanical controls, such as physical barriers and traps, can be used to protect the crops from pests. The effectiveness of biological and mechanical controls depends on the weather (Turkmen, 2010). Secondly, careful operations must be taken in order to keep the aquaponic system from being contaminated by harmful bacteria, such as *E. coli*, which affect bring the health of the fish and crops (Hollyer et al., 2009). If ground soil is used in the system, it should be sterilized by UV radiation to prevent contamination (Graber & Junge, 2009). In addition, the system must be kept away from animal manure because the manure may contain harmful bacteria. In short, aquaponic systems can reduce the amount of wasted water and nutrients, and synthetic chemicals, but may require elaborate operation and maintenance.

2.2.5 Comparison of Aquaponics to Other Agriculture Techniques

In summary, the strengths and weaknesses of conventional soil agriculture, organic soil agriculture, GM crops and aquaponics can be compared in terms of the yields, energy consumption, pollution, water and land use, and human health. Table 4 compares the agrochemicals use, water consumption, water pollution, yields, energy consumption and labor requirements among conventional soil agriculture, organic soil agriculture, GM crops, and aquaponics. All descriptions are relative to different agricultural methods mentioned in previous sections of this chapter.

Table 4: Comparison of conventional, organic, GM and aquaponic agriculture.

	Conventional Soil Agriculture	Organic Soil Agriculture	GM Crops	Aquaponics
Agrochemicals: Fertilizer & Pesticides	Relies on synthetic fertilizer, pesticides	Uses animal manure and rarely uses pesticides	May use less fertilizers and pesticides	No use of fertilizer and only use organic pesticides
Water Consumption & Possible Pollution	High consumption. Water pollution caused by agrochemical run-off	Lower consumption. Water pollution caused by animal manure run-off	Variable consumption. May have water pollution caused by run-off	Lower consumption than conventional and organic soil agriculture. Minimal water pollution.
Yields	High	Lower	High	Lower
Energy Consumption	High	Lower	May be Lower	Moderate
Labor and Management Skills	Lower	High	Lower	High

Therefore, considering the limited land and water resources in Puerto Rico, aquaponics may be a viable solution to the inadequate food production and may be safer and more sustainable than conventional soil agriculture, organic soil agriculture and GM crops.

2.3 Aquaponic System Technology

Aquaponic systems exist in different shapes and sizes, and function by creating a symbiotic relationship between fish and agriculture. Systems may be commercially purchased from companies such as Nelson & Pade (US), Portable Farms (US), or Background Aquaponics (AU). In addition, the internet contains plenty of non-scholarly websites, forums, and information that make it possible to construct a do-it-yourself system. Though there are many ways to construct an aquaponic system, there are three common techniques used: Media-filled Growth Bed method (MFG), the Deep Water Channel (DWC or Raft Method) and the Nutrient Film Technique (NFT).

2.3.1 Media-filled Growth Bed (MFG)

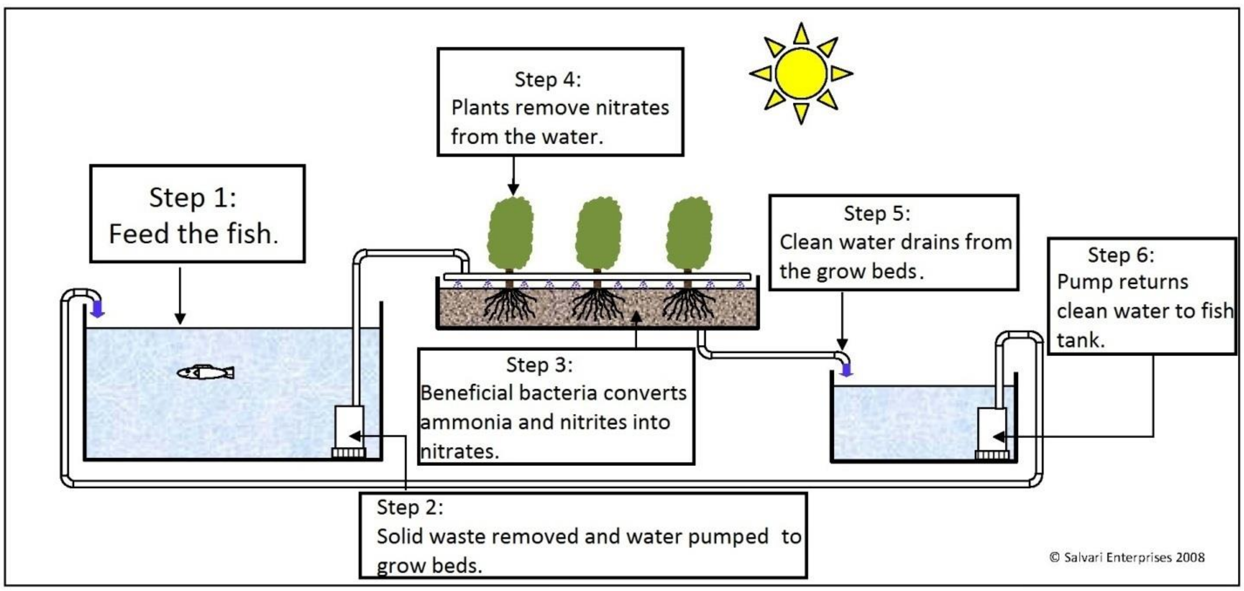

Figure 9: Schematic of Media-filled Growth Bed (Salvari Enterprises)

Figure 9 illustrates a media-filled growth bed (MFG) system. Fish are kept in a separate tank where they are fed and allowed to grow. As the water becomes soiled with fish waste, uneaten food, bacteria, fungi and algae, the water is either mechanically filtered or pumped directly into the growth beds. The growth beds contain the plants and medium, which may include: lightweight expanded clay aggregate, lava rock, river gravel, pea gravel, perlite, vermiculite, sand, coir, glass beads or gravel (St. Charles, 2013). The medium not only contains the plants, but filters the solid waste and provides a location for the waste to mineralize into plant nutrients (Nelson, 2008). The nutrients are absorbed by the plants, and the water returns to the fish tank. Although the process is relatively simple, there are nuances that must be described in detail.

Removal of Solid Waste and Biofiltration (Mineralization)

Fish waste is a source of nutrients for plants, but is only useful once converted into nitrate (Nelson, 2008). For MFG systems, Dr. Lennard explained that there are two ways of filtering and reusing solids (Lennard, 2012):

1. Use additional equipment, like a mechanical filter and clarifier, to quickly remove, separate, treat and mineralize all solids before returning them back into the system, or
2. Use media growth beds for mechanical and biological filtration. In other words, the beds are the only source of filtration and the solid waste is never physically removed from the system.

Dr. James E. Rakocy, a leading aquaponics scientist at the University of the Virgin Islands (UVI), echoes the advice of Dr. Lennard and states most of the fecal waste fish generate should be removed before the water enters the hydroponic tanks (Rakocy, Masser, & Losordo, 2006). If the solids are not removed and are broken down aerobically, the water may have reduced oxygen levels and an increase in ammonia and carbon dioxide. If the solids are broken down anaerobically, methane and hydrogen sulfide will be produced, which are toxic to fish (Lennard, 2012; Rakocy et al., 2006). Although Dr. Lennard called the filtering of solids the "Golden Rule" of aquaponic systems, it is not entirely necessary for MFG systems (Lennard, 2012).

Filtering solids is strongly encouraged, but is not pivotal in maintaining a balanced MFG system since the media growth bed may act as a sufficient mechanical and biological filter

(Lennard & Leonard, 2006). The idea is to balance the daily solids rate to the daily mineralization or breakdown rate to allow for natural filtration and mineralization (Lennard, 2013). If the bed is unable to contend with the daily solids influx, additional filters will need to be used. Much like a regular filter, the media beds will become clogged and will need to be cleaned. To help prevent clogging and to help increase mineralization, growth beds are sometimes filled and drained constantly, which is known as the "ebb and flow" cycle (Rakocy et al., 2006). This claim was refuted by Dr. Lennard and Leonard who concluded that the "ebb and flow" method showed no improvement over the continuous flow of water in their particular experiment (Lennard & Leonard, 2004).

2.3.2 Deep Water Channel (DWC) or Raft Bed Method

Unlike the media-filled growth (MFG) system, the DWC system relies on floating rafts to support the plants. Figure 10 shows the DWC system at the University of the Virgin Islands (UVI), which is similar to the design used by our sponsor.

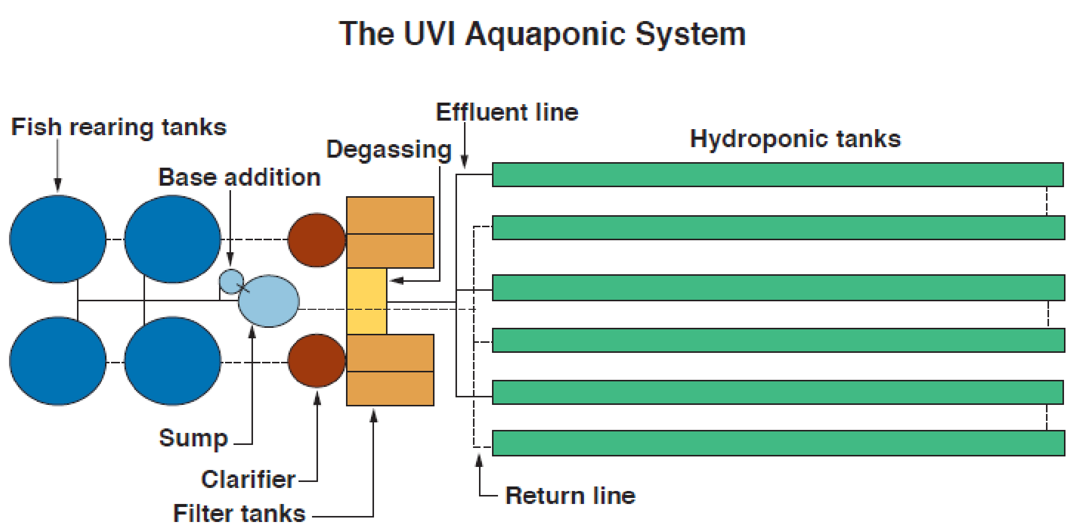

Figure 10: Schematic of UVI DWC system (Rakocy et al., 2006, p3).

The major components of a DWC system are the fish-rearing tank, a clarifier, a filter and floating rafts to support the plants (Rakocy et al., 2006). Before the water from the fish tank can be pumped into the growth beds, the clarifier and filter must remove the suspended and settleable solids. Failure to remove the solids may cause lower oxygen levels and an increase in ammonia, carbon dioxide, methane and hydrogen sulfide (Rakocy et al., 2006). Before passing into the growth beds, the water is pumped into the degassing station, where extensive air flow allows the removal of harmful gases, improves mineralization and helps separate potassium, phosphorous and magnesium from the waste (Lennard, 2013; Rakocy et al., 2006). In the Agroponicos system, water supplements are added into the degassing station, while the UVI system supplements are added into the base addition station (Casas, Casas, & Casas, 2013; Rakocy et al., 2006).

Removal of Solid Waste and Biofiltration (Mineralization)

DWC systems rely more on mechanical filtration than MFG systems. In the UVI system, the clarifiers are cleaned three times a day and the filters are cleaned once or twice a week to limit anaerobic mineralization (Rakocy et al., 2006). Although aerobic mineralization is important for creating plant nutrients, anaerobic mineralization can be used to raise or lower nitrate levels. If the filter is cleaned twice a week, for example, the system will have higher nitrate concentrations, which promotes the growth of leafy green vegetables. If the filter is cleaned once a week, for example, the system will have lower nitrate concentrations, which promotes fruit development in vegetables such as tomatoes. (Rakocy et al., 2006) This cleaning cycle is specific to the UVI and will depend on the system. Agroponicos, for instance, cleans their filters after two weeks of use (Casas et al., 2013). Despite the differences in filter cleaning, both systems produce healthy produce. If the waste is not completely filtered or mineralized, the waste will cause toxicities in the water, clogged plumbing, and allow fine solids to adhere to the roots of the plants causing reduced nutrient uptake (Nelson & Pade, 2007). An image of damaged roots can be seen in Figure 11.

Figure 11: Crops covered with fine waste caused by poor filtration (Andrew, 2009).

In DWC systems based off the UVI system, the fish tanks and growth beds are constantly aerated to improve dissolved oxygen (DO) levels and mineralization (Rakocy et al., 2006). In an ideal DWC system, most mineralization occurs on the underside of the rafts and on the bottom of the growth beds (Casas et al., 2013; Rakocy et al., 2006). A healthy DWC system may contain a layer of sludge on the grow bed, which can be seen in Figure 12.

Figure 12: Sludge on bottom of growth bed (Courtesy of Agroponicos).

The sludge is beneficial to the system providing it is thin enough to mineralize aerobically. Thus, the use of aeration in the growth beds is necessary (Casas et al., 2013; Rakocy et al., 2006).

When cleaning the system, the removed solids and sludge should be moved to a well-aerated mineralization tank to allow for further mineralization. This practice saves and produces nutrient-rich water, which can later be pumped back into the system, and produces fertilizer (Casas et al., 2013; Rakocy et al., 2006).

2.3.3 Nutrient Film Technique (NFT)

The last type of aquaponic system is the Nutrient Film Technique (NFT) method and it uses similar equipment as the DWC system. Unlike the DWC system, the NFT system relies on tubes to support the plants and to transport the water to the plants. The tubes can be seen in Figure 13.

Figure 13: NFT beds (AquaponicsEasy, 2011).

In the DWC system, the roots of the plants are almost entirely submerged, while in the NFT system only a small portion of the roots are submerged (Lennard & Leonard, 2006). Mineralization should primarily occur in the water channels and follows the same biofiltration techniques as the DWC system (Rakocy et al., 2006).

2.3.4 A Comparison of DWC, NFT and MFG Systems

To determine which type of aquaponics system is most effective, it is first necessary to understand the strengths and the weaknesses of each system.

Medium-Filled Growth Bed (MFG) Method

The following list outlines the strengths and weakness of MFG systems:

- MFG systems may not require mechanical filters, or special equipment for mineralization, making upfront costs and energy costs lower than other systems.
- Mediums are filters and may clog, leading to inefficient filtration, mineralization, and nutrient delivery to plants. To remedy the clogging, the entire bed must be replaced. Replacing the medium may be more time-consuming than cleaning a physical filter (Lennard, 2013).
- Medium may be heavy, and may require stronger materials and additional labor to construct the system (Rakocy et al., 2006).

NFT (Nutrient Film Technique) and DWC (Deep Water Channel) Systems

NFT and DWC systems are very similar and only differ in the amount and method of water being supplied to the plants. Dr. Lennard outlines the main differences between the NFT and DWC systems (Lennard, 2010):

- In the NFT system, the smaller amount of water may limit the uptake of nutrients by the plants and is less forgiving to nutrient and pH imbalances.
- NFT systems use smaller feed lines and may become easily blocked.

Aside from the slight differences in the systems, the strengths and weaknesses of the NFT and DWC systems can together be compared to the MFG system:

- The NFT and DWC systems have physical filters, which may be easier to clean than a MFG system.
- The additional use of mechanical filtration and mineralization equipment may lead to higher upfront and energy costs than a MFG system.

- Since the DWC and NFT systems rely on rafts and tubes, they may be less expensive than a MFG system.

Quantitative Metrics to Compare MFG, DWC and NFT Systems

To determine the success of a system in terms of the limitations of Puerto Rico, the wet fish weight, crop yields and water use are compared (Lennard & Leonard, 2006). The wet fish weight and crop yields are underlined in Table 5.

Table 5: Statistics on comparison of MFG, DWC and NFT systems (Lennard & Leonard, 2006, p5).

Parameter	Control	Gravel	Floating	NFT
Fish				
Wet weight[1] (g/rep.)	$220.0^{a} \pm 16.1$	$206.7^{a} \pm 13.3$	$266.7^{a} \pm 29.6$	$250.0^{a} \pm 25.2$
SGR[1] (%/rep./day)	$0.90^{a} \pm 0.05$	$0.89^{a} \pm 0.06$	$1.13^{a} \pm 0.13$	$1.09^{a} \pm 0.10$
FCR[1]	$1.01^{a} \pm 0.08$	$1.07^{a} \pm 0.07$	$0.85^{a} \pm 0.10$	$0.90^{a} \pm 0.08$
Feed fed (g/rep.)	220.0	220.0	220.0	220.0
Lettuce				
Biomass gain[1] (g/rep.)		$2639.4^{k} \pm 28.9$	$2338.1^{m} \pm 14.5$	$2159.0^{n} \pm 9.8$
Yield[1] (g plant^{-1}))		$131.97^{k} \pm 6.46$	$116.91^{m} \pm 3.24$	$107.95^{n} \pm 2.20$
Yield[1] (kg m^{-2})		$5.05^{k} \pm 0.25$	$4.47^{m} \pm 0.12$	$4.13^{n} \pm 0.08$
Nutrients				
Phosphate[1] (mg l^{-1})	$7.15^{a} \pm 1.03$	$3.42^{b} \pm 0.11$	$3.47^{b} \pm 0.94$	$3.91^{b} \pm 0.37$
Nitrate[1] (mg l^{-1})	$51.23^{a} \pm 1.58$	$4.63^{b} \pm 2.85$	$2.60^{b} \pm 1.84$	$15.70^{c} \pm 2.57$
Phosphate (g/rep.)[y]	0.80	0.38	0.51	0.40
Nitrate (g/rep.)[y]	5.74	0.52	0.39	1.62
Phosphate removal (%)[y]		52.5	36.3	50.3
Nitrate removal (%)[y]		90.9	93.2	71.8

[1]Values are means ± SE

k, m, n: values showing the same letter are not significantly different ($P > 0.05$, $n = 60$) (ANOVA)

a, b, c: values showing the same letter are not significantly different ($P > 0.05$, $n = 3$) (Mann–Whitney)

y: values are calculated from mean final nutrient concentration per unit volume of test system replicate

SGR: specific growth rate (% day^{-1}): [(ln final wt. − ln initial wt.)/(time (days))] × 100

FCR: food conversion ratio: feed fed/(wet weight gain)

In Table 5, the following types of systems are being tested:

- The Control System: Only includes fish and no plants are grown in a gravel-filled growth bed. This system compares nitrate and phosphate accumulation with the absence of plants.

- Gravel (MFG): Includes fish and plants being grown in the gravel-filed grow bed.
- Floating (DWC): Includes fish and plants being grown in floating rafts.
- NFT: Includes fish and plants being grown in a NFT system.

Fish

Aquaponics do not just depend on the produce being grown, but also on producing large, healthy fish. In Table 5, the "wet weight," which applies to the weight of a fresh fish, is a useful metric in determining which system produces the largest fish by mass. Although there were some variations, the authors concluded that the weights of the fish were generally equal across all systems (Lennard & Leonard, 2006).

Lettuce

To understand which system produced the most lettuce, the yield ($\frac{kg}{m^2}$) was considered. This measurement shows the amount of food produced in one unit of area. This metric is useful in regions where arable land is scarce, such as Puerto Rico. From Table 5, it is seen that the yields, ranked in descending order, are highest in the gravel MFG system, followed by the DWC system and NFT method (Lennard & Leonard, 2006). Dr. Lennard explains that the MFG and DWC methods may create better plant growth since the roots are more in contact with the water than the NFT method (Lennard & Leonard, 2006). The lack of root contact with the water in NFT systems may prevent the plants from effectively removing nitrates from the water, which may impede plant growth (Lennard & Leonard, 2006).

Water Use

Since Puerto Rico has issues with water quality, it is important to use water efficiently. Table 6 shows that most systems use roughly the same amount of daily water replacement (Lennard & Leonard, 2006). The abbreviation, D.O., stands for dissolved oxygen.

Table 6: Further data on system comparison (Lennard & Leonard, 2006, p7).

Parameter	Control	Gravel	Floating	NFT
D.O. Initial[1] (mg l^{-1})	$7.77^{a} \pm 0.07$	$7.84^{a} \pm 0.03$	$7.96^{a} \pm 0.06$	$7.93^{a} \pm 0.07$
D.O. Final[1] (mg l^{-1})	$7.23^{a} \pm 0.04$	$7.20^{a} \pm 0.01$	$7.28^{a} \pm 0.03$	$7.28^{a} \pm 0.01$
D.O. Difference (mg l^{-1})	0.54^{a}	0.64^{a}	0.68^{a}	0.65^{a}
Conductivity initial[1] (μS cm^{-1})	$212.3^{k} \pm 5.2$	$189.7^{m, p} \pm 3.2$	$171.7^{m, q} \pm 1.2$	$155.0^{m} \pm 1.0$
Conductivity Final[1] (μS cm^{-1})	$857.0^{k} \pm 20.8$	$360.0^{m, p} \pm 22.6$	$416.3^{m, q} \pm 34.0$	$377.7^{m} \pm 13.3$
Conductivity Difference (μS cm^{-1})	644.7^{k}	$170.3^{m, p}$	$244.7^{m, q}$	222.7^{m}
Daily Water Use[1] (L $replicate^{-1}$)	$1.83^{a} \pm 0.10$	$1.73^{a} \pm 0.10$	$1.83^{a} \pm 0.10$	$1.97^{a} \pm 0.10$

[1] Values are means ± SE

a, b: values showing the same letter are not significantly different ($P > 0.05$, $n = 54$) (ANOVA)

k, m: values showing the same letter are not significantly different ($P > 0.05$, $n = 54$) (ANOVA)

p, q: values showing the same letter are not significantly different ($P > 0.05$, $n = 54$) (ANOVA)

In conclusion, Dr. Lennard and Leonard concludes that the NFT hydroponic sub-systems are less efficient at both removing nutrients from fish culture water and producing plant biomass than MFG or DWC systems in an aquaponic context (Lennard & Leonard, 2006). Still, the study does not rule out NFT as a viable aquaponic method and Dr. Lennard reevaluates the system in *A New Look at NFT Aquaponics* (Lennard, 2010).

2.3.5 Maintaining an Aquaponic System

Maintaining an aquaponic system requires trial and error, but the following tips may help ensure the system is operating efficiently. The following information is adopted from various sources on ensuring systems are operating efficiently.

- Maintain dissolved oxygen (DO) levels that meet the requirements of the fish. Lettuce needs roughly more than 2.1 mg/L, mineralization bacteria generally need more than 2.0 mg/L and warm water fish need at least 5.0 mg/L. (Lennard & Leonard, 2006)
- The optimal mineralization occurs at temperatures ranging from 77 to 86 °F, a pH ranging from 7.0 to 9.0 (with 7.0 being the most effective), saturated dissolved oxygen, low biochemical oxygen demand (<20 mg/liter) and a total alkalinity of 100 mg/liter or

more. Mineralization increases the acidity of the water and buffers such as calcium hydroxide and potassium hydroxide, may be needed to balance the pH (Rakocy, 2007; Rakocy et al., 2006).

- Maintain a constant food supply at a constant feeding rate ratio. A DWC system usually requires 60 – 100 g/(m^2 · day), while NFT systems require generally 25% less (Rakocy, 2007).
- Potassium, calcium and iron must be supplemented to the system because fish waste does not contain these elements which are necessary for plant growth. The supplements can be added in the form of Potassium hydroxide and Calcium hydroxide to act as bases to balance the pH (Lennard, 2013; Lennard & Leonard, 2006).
- Although the removal of solids is not necessary in MFG systems, the removal of solids is encouraged. Solids decrease the dissolved oxygen (DO) levels, adhere to the roots of plants and prevent the uptake of nutrients. Additionally, MFG systems can become clogged (Rakocy, 2007).
- Do not use pesticides because they will kill the fish. Instead, the user must look into organic herbicides or other forms of pest control. (Rakocy, 2007)

2.3.6 The Costs of an Aquaponic System

Aquaponic systems come in a variety of shapes and sizes, and can be built by a user or purchased. To understand the estimated upfront costs of buying a DWC aquaponic system, the product catalogue of Nelson & Pade was used (Nelson & Pade, 2012). The following chart plots the footprint, or the surface area occupied by the entire system, and the cost. The costs do not include optional equipment, freight, installation or sales tax (Nelson & Pade, 2012).

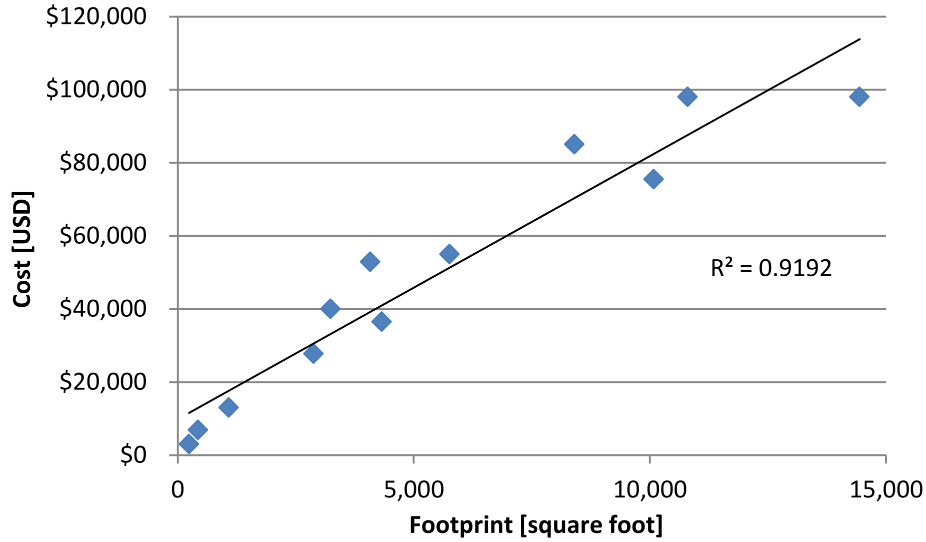

Figure 14: Cost of Nelson & Pade systems (Nelson & Pade, 2012).

As seen in Figure 14, there is a relationship between the size of the system and the price. The smaller, less expensive systems are for home use, while the large, more expensive systems, which are bigger than 2,880 ft^2, are for commercial use (Nelson & Pade, 2012). In addition to startup costs, which include the system and the equipment, the user should take into account the costs associated with labor; construction and cost related to building and permitting, maintenance, energy use, fish and fish feed, crops and transportation. As such, the only way to accurately calculate these costs would be to analyze a specific system.

2.4 Case Studies

Since no literature exists on the economic viability of aquaponic systems in Puerto Rico, case studies from other locations were evaluated. The first case study is an analysis of the aquaponic system at the University of the Virgin Islands (UVI) and explains why the system achieved economic success (Bailey, Rakocy, Cole, & Shultz, 1997). The second case study was conducted by Elisha R. Goodman (MIT) and analyzed Growing Power, Inc.'s system in order to develop economically successful business models for future aquaponic systems (Goodman, 2011).

2.4.1 University of the Virgin Islands (UVI) Case Study

This study includes an early analysis of the aquaponics system located at the University of the Virgin Islands (UVI), which is where much of the aquaponics research is conducted under the guidance of Dr. James E. Rakocy. In addition, the UVI system is a similar design and operates in a similar climate as our sponsor's system making the study relevant to our project. In Dr. Rakocy's system, profits from the tilapia and lettuce represented two-thirds of the revenue and covered operational losses from fish food, purchasing fish and fish production. Recovering from these costs was possible because of the high price of tilapia, lettuce and basil in the Virgin Islands. Lettuce, for example, that is shipped from California can be expensive due to costs associated with transportation and may not be as fresh as locally grown produce. (Bailey et al., 1997)

Within this case study, the author mentioned Bioshelters Inc., located in Amherst, Massachusetts, which produces basil for the Boston area. This facility has found success in this market since the demand for basil is high and its shelf life is short, which means the basil would have to be shipped quickly to ensure freshness. This example was mentioned in the UVI case study because it highlights the importance of finding a market that is looking for fresh, organic goods. (Bailey et al., 1997)

The success of the UVI system may be attributed to the following points:

1. Developing a profitable, niche market despite competition.
2. Creating a continuous supply of products that can be sold weekly.
3. Building in temperate conditions to reduce the energy demand for heating the system.
4. Reducing the costs of construction materials, electricity use, water use, labor and land, which are very high in the U.S. Virgin Islands. (Bailey et al., 1997)

2.4.2 Growing Power, Inc. Case Study

The second case study involves an aquaponic company called Growing Power, Inc., located in Milwaukee, Wisconsin, which incorporates several MFG systems. It employs 60 employees, has 3,000 volunteers and annually hosts 100,000 people on tours or attending workshops. The system is capable of growing microgreens, lettuce, basil, tomatoes, green tomatoes, peppers and watercress. The company uses small and large MFGs systems, on the order of 65', and uses 15,000 gallon fish tanks to produce batches of 10,000 fish. The study goes into great detail about maintenance, the labor commitment, and a means of creating an educated labor force. (Goodman, 2011)

Since the company is located in Wisconsin, the temperature of the system has to be regulated to ensure the fish and the plants do not freeze. To do so, the system relies on heaters to keep the ambient greenhouse temperature between 60 – 65 °F and the water of the fish, depending on the type, between 68 – 85 °F. The company raises tilapia, yellow perch and blue gills. To aid in insulation, the system uses compost piles and embeds part of their system in the ground. In addition, the author also notes that the large growth beds are replanted incrementally to maintain filtering capacity and production, while the smaller systems are cleaned at once. (Goodman, 2011)

The case study notes that having an educated staff that is willing to go above and beyond is necessary in maintaining a system. In this particular company, one person is always on call to deal with issues like heater malfunctions, pump breakages, clogging, stopped water flow or issues with the fish. The ideal employee should be knowledgeable in plumbing, flow of water, mechanical systems, construction and have an aptitude for learning. In addition, there should exist a leader "who will champion the system and has the overall picture" (Goodman, 2011). To create educated employees, the company expects a five year commitment and states it takes two years to train an individual. In conjunction with the training, an intern receives $100/week plus food and shelter, while an apprentice will start at $10/hr. and after six months will make $15/hr. The average salary of the company is $35,000, but professional employees may make closer to $45,000. (Goodman, 2011)

To create a profit, the company relies on three pillars: selling to a niche market, hosting paid workshops, and relying on donations and grants. Their green tomatoes are a niche crop since they are hard to find on the commercial market. In addition, they are able to sell their fish at a premium price because their marketing efforts promote their fish as fresher, cleaner and having a better taste and texture that other fish. A shortcoming of the company, however, is that they are only licensed to sell live fish, which reduces their market. (Goodman, 2011)

To create additional profit and to educate people, the company hosts workshops to teach urban farming techniques. The breakdown of the attendees includes those who want to setup systems in their hometowns and those who have run into issues finding startup capital. However, the majority of attendees focus on creating compost piles, growing sprouts and greens, and on creating a business plan. They also offer a two-day workshop entitled "From The Ground Up," which enrolls between 100 – 150 attendees and is geared towards growing sprouts, constructing aquaponic systems, and building hoop houses. The events are open to everyone and even offer financial scholarships. (Goodman, 2011)

The company relies on income, grants, and donations to achieve a positive cash flow. In addition, the author mentions how another aquaponic company, Sweet Water Organics, has yet to break even from sales of produce and fish. To remedy this situation, Growing Power, Inc., has created a not-for-profit arm to take advantage of grants, donations and to get non-profit tax exemptions. (Goodman, 2011)

Further analysis from the author explained that three of the four aquaponic systems she projected were not profitable unless they were all on a large scale. To remedy these issues, the author suggests potential business models (Figure 15).

Add-on To An Existing Business	Owner operated	Cooperative ownership	Not-for-profit	Equity Financing
Reduced capitalization costs Reduced operating costs	Minimal or no labor costs	Shared capitalization costs Shared operating costs Minimal or no labor costs	No taxes Grants, donations, volunteers	No interest charges
1	**2**	**3**	**4**	**5**

Figure 15: Examples of business models (Goodman, 2011, p75).

1. Adding an aquaponic system to an already existing business would reduce marketing, website, insurance, accounting and tax filing costs. The author is clear that while incorporating an aquaponic system with a business that already has the necessary agriculture and aquaculture is a bonus, incorporating one on the roof of a building or where there is extra space would also help reduce building costs.

2. Expenses can be reduced if the system is owner-operated since the owner would be doing most of the work leading to lower labor costs. This may or may not create sufficient income.
3. Another plan involves a cooperative business model in which an aquaponic system is added to an existing business to help reduce startup and operating costs and is owner-operated to help reduce labor costs. To fund the system, this business model only requires small amounts of start-up capital from each owner of the cooperative and allows for small growers to enjoy the benefits of economics of scale, while remaining small producers. In this model, costs such as marketing, transportation, and insurance are shared expenses.
4. Another business model involves creating a not-for-profit business model which has no tax liability. This means the company has more access to grants, donations, and volunteers.
5. Instead of using debt, the company can rely on equity to fund the business. (Goodman, 2011)

In conclusion, the author states that aquaponic systems are risky because they rely on the prices of food and niche markets. As seen from Figure 16, one could explore different business models, explore donations and grants, diversify revenue streams, diversify crops or rely on volunteers. Still, the author admits that an aquaponic system that is based in a temperate location, such as the Virgin Islands or Puerto Rico, will have different financial prospects. Regardless of temperature, the author included some examples of ways to increase income and reduce expenses. (Goodman, 2011)

Vertically Integrate - Produce It on the Farm	Get Things For Free
Compost to create soil fertility	Compost inputs from industrial waste streams
Worms, worm castings	Pots from landscapers
Water catchment	Donated or low cost land
Solar power	Volunteer labor
Wind power	Woodchips from tree trimmers
Solar hot water	Tap into waste heat - cogeneration
Biodigesters	
Raise fish fry	

Diversify Revenue Streams
Workshops and trainings
Tours and agri-tourism
Merchandising
Fundraising
Speaking engagements
Consulting
Workforce training programs
Partnerships with universities
Education programs with local schools
Grow ornamentals eg: Koi, fish for fish stores
Experiment with mushroom, shrimp and algae production

Figure 16: Examples of diversifying profit from an aquaponic system (Goodman, 2011, p77).

2.5 Current Governmental Policies

The current government of Puerto Rico is attempting to revitalize agriculture on the island. However, there is no direct identification of aquaponics in the legal system.

2.5.1 Government Platform for 2012-2016

The Puerto Rican government has identified and is attempting to ameliorate the economic issues with agriculture. The current Governor of the Commonwealth of Puerto Rico, Alejandro Garcia Padilla (2012 – 2016) has goals to restore the island's social welfare and develop projects to create a prosperous economy. He intends to transform and promote agriculture to create more jobs to boost economic development. In compliance with Law 1 of 2013, Employment Now, Padilla aims to create 50,000 jobs in 18 months. Pertaining to agriculture, Padilla's objectives are to invest in technological advances for innovative agriculture development and establish financial programs specifically for controlled, environmental business. Padilla mentions hydroponics and aquaculture as areas of interest for the financial programs. An overview of Padilla's government platform can be found in Appendix B. (Padilla, 2012)

2.5.2 Sustainable Development

To coincide with Governor Padilla's goals, alternative forms of agriculture are needed for boosting economic development. Sustainable development is an important aspect that encourages a prosperous economy. Hishamunda and Ridler define four key socio-economic and environmental keys for sustainability. First, the system should not only yield positive returns, but more importantly, equal or higher values when compared to similar industries. In such cases that profits are less than competitive rates, there may be more incentive for individuals to leave for better opportunities. Second, their rate of return must remain stable. Returns that fluctuate significantly have higher risks associated with them. Third, the farmed species, whether fish from aquaculture systems or combined fish and plants from aquaponic systems, must be grown and cultivated by acceptable methods that comply with social norms. Last, agriculture must be environmentally compatible over a long time frame. Sustainable operations should not only serve a purpose for present generations, but also for future generations (Hishamunda & Ridler, 2003).

Aquaponic systems may be in agreement with the four keys. If returns are positive and equal or higher than similar industries, a stable rate of return is established, the fish and crops are grown and cultivated in a socially acceptable way, and the farm is environmentally friendly and built to last, then the business may by sustainable.

2.6 Potential Business Structures

Considering different governance structures is one of the first steps needed to create new aquaponics business ventures. To help evaluate which governance structures are most appropriate, we considered the ease of obtaining start-up capital and resources, the process in which the business makes decisions and who is responsible for paying for liabilities, including taxes, for the company as a whole. The following business structures were considered:

1. Sole Proprietorship,
2. Partnership,
3. Cooperative System (Co-op),
4. Corporation,
5. S Corporation, and
6. Limited Liability Company (LLC).

2.6.1 Sole Proprietorship

A sole proprietorship is an unincorporated business that is owned and operated by a single person. The owner keeps the profits and is responsible for any debts, losses or liabilities. The only action that the owner must take is to obtain the necessary licenses and permits for their business. (U.S. Small Business Administration)

As the sole owner, one also has complete control of the business and can make their own decisions. However, since there is no legal separation between the owner and their business, the owner can be held personally liable for the debts and obligations incurred from the business. In addition, a sole proprietorship may face difficulties with raising money for their business. Since stocks in the business cannot be sold, very often investors will not invest in the business. It is also a challenge to receive loans because banks are hesitant to lend to a sole proprietorship due to a perceived lack of credibility to repay loans if the business fails. (U.S. Small Business Administration)

Since the income received from the sole-proprietorship is considered to be the same as the owner's income, the business itself is not taxed separately from the owner. It's also easy to prepare tax reports and tax rates are the lowest in comparison to most business structures. (U.S. Small Business Administration)

2.6.2 Partnership

A single business owned by two or more people is known as a partnership. In the business, each partner contributes money, property, labor or skill in exchange for a share of the profits and losses in the business. If two or more people wish to start a partnership, it is highly recommended to discuss a wide variety of issues beforehand and develop a legal partnership agreement. This agreement should include how future business decisions will be made, including how profits will be distributed between partners, how to resolve disputes, how to change ownership (whether bringing in new partners or buying out current partners) and how to dissolve the partnership. The business must be registered with the state generally through the Secretary of State's Office. Once the business is registered, business licenses and permits will need to be obtained. (U.S. Small Business Administration)

There are three different types of partnership arrangements such as general partnerships, limited partnerships and joint ventures. In general partnerships, profits, liabilities and management duties are split between partners. If there is an unequal distribution, the percentages assigned to each partner must be documented in the partnership agreement. In limited partnerships, partners are allowed to have limited liability and limited input with management decisions depending on the extent of each partner's investment percentage. Joint ventures are treated as a general partnership, but only last for a limited amount of time or for a single project. (U.S. Small Business Administration)

Partners must share all of the liabilities including business debts and decisions made. They can use personal assets of all partners to satisfy the partnership debt. Each partner can pool their resources to obtain capital especially to secure credit or seed money. The business itself does not pay income tax and instead the partners must include their share of the partnership's income or loss on their personal tax returns (U.S. Small Business Administration).

2.6.3 Cooperative System

Another way to expand an aquaponic business is to set up a cooperative. A cooperative, also known as co-op, is a business or organization owned and operated by a group of people to split the costs and share the benefits of the business (U.S. Small Business Administration).

To start a cooperative system, a group of individuals must agree on a common goal and a plan for how to attain it. If the members and committee choose to do so, they can incorporate the cooperative by registering with state agencies. (U.S. Small Business Administration)

When using this type of business, each member has the power to vote on what route the cooperative will take and usually there is an elected board of directors and officers who run the business. Members can also routinely join or leave without causing dissolution of the cooperative. Members can also purchase shares to become part of the cooperative. However, the democratic structure of the co-op ensures that the organization reflects the needs of its members as opposed to the needs of a few wealthy members. Since the members contribute their resources to the company, they are legally liable for any debts they must settle. The way in which they settle liabilities can be determined amongst the members.

In addition to their individual investments, members also might have access to a variety of government-sponsored grant programs to help start the business, depending on the type of cooperative. Unfortunately there is a slower cash flow which might make the cooperative difficult to maintain or start-up. The cooperative does not pay federal income taxes as a business entity. (U.S. Small Business Administration)

2.6.4 Corporation

A corporation is a business that is owned by shareholders but is considered an independent legal entity. These businesses are generally larger and better established. Corporations are formed based on the laws of the state in which they are registered. To register the business as a corporation, articles of incorporation must be filed with the respective Secretary of State's Office. Directors may need to be established and stock certificates may need to be issued in the registration process depending on the state. Once the business is registered, business licenses and permits must be obtained. (U.S. Small Business Administration)

Due to their size, corporations have the ability to sell ownership shares in the business through stock offerings. However, they have less access to grants. Typically, a board of directors is chosen by stockholders to run the corporation. Corporations have limited liability where the corporation is legally liable for the actions and debts the business incurs as opposed to the shareholders. Corporations file federal income taxes separately from their owners. (U.S. Small Business Administration)

2.6.5 S Corporation

One special type of corporation created through an IRS tax election is an S corporation (S corp). In a traditional corporation, the company is double taxed where the corporation is taxed and the shareholders' shares are taxed. As an S corp, only the shareholders are taxed as opposed to both the business and the shareholders. (U.S. Small Business Administration)

To qualify as an S corporation, a business must be first chartered as a corporation in the state where it is headquartered. The business must also qualify under the IRS stipulations and all shareholders must elect their corporation to become an S corporation. Similar to most businesses, S corps also need to register with the IRS, state and local agencies and obtain a tax ID number. Once the business is registered, all important business licenses and permits must be obtained. (U.S. Small Business Administration)

S Corps make decisions based on their initial business structure. The financial liability for which the owner or "shareholder" is responsible is reduced in comparison to a C corporation. In general, start-up capital depends on which type of business structure existed before the S corp designation. In addition, S corps are not taxed the same in each state. (U.S. Small Business Administration)

2.6.6 Limited Liability Company

A limited liability company (LLC) is a business that has a legal structure that combines the limited liability features of a corporation and the tax efficiencies and operational flexibility of a partnership. Depending on the state, there can be one member (who is considered the owner), two or more members, corporations or other limited liability companies. ("Limited Liability Company," 2007)

The governing structure of an LLC depends on which laws regulate the business. Most of the time, members can appoint one or more manager or directly manage an LLC themselves. In an LLC, members are protected from personal liability for an LLC's business decisions or actions. Since an LLC is not recognized as a separate tax entity by the federal government, the business itself is not taxed. Instead, LLC members pay federal income taxes through their personal income tax. ("Limited Liability Company," 2007)

2.6.7 Summary

The way companies are organized affect their ease of obtaining start-up capital and resources, the process in which the business makes decisions, who is responsible for paying for liabilities for the company as a whole and how owners and the firm are taxed. Thus, the selection of an organization structure is highly dependent on the goals of the entrepreneur. Depending on how an individual wants to run their business in the future, they can pick and choose which business structure best suits their needs. Overall, the aforementioned business structures can be summarized in Table 7.

Table 7: Overview of business structures.

	Decision Making	Liability	Start-up Capital	Tax Treatment
Sole Proprietorship	Owner	Full	Loans	Owner
Partnership	Partners	Shared	Loans	Shared
Cooperative System	Elected Board of Directors	Distributed among members	Access to Grants and loans	Members only
Corporation	Appointed Board of Directors	Just the business	Stocks	Stockholders and Business
S. Corporation	Depends on the Business it was originally	Just the business	Stocks	Only stockholders
Limited Liability Company	Board of Directors appointed by members	Just the business	Loans	Members only

2.7 Conclusion

From a thorough analysis of the history of Puerto Rico's agriculture, the island has not been capable of producing a stable domestic food supply. Although governmental policies have attempted to improve the agricultural sector, the lack of arable lands and clean water still makes many forms of agriculture not feasible. One viable technology is aquaponics because it is environmentally friendly, does not require soil and uses water efficiently. Because no literature exists on the financial and business aspects of aquaponic systems in Puerto Rico, we must explorer the system currently utilized by Agroponicos, Cosecha de Puerto Rico, Incorporated.

Methodology

In order to assess the economic viability of aquaponic systems in Puerto Rico, we formulated the following research questions:

1. What is the process, from conception to production, to establish and operate a commercial aquaponic system?
2. Can an aquaponics business be profitable in Puerto Rico?
3. What available resources and programs are there for the establishment, operation improvement and expansion of aquaponic systems?

In order to answer the research questions, we identified the following objectives and methods:

1. Investigate the process, from conception to production, to establish and operate a commercial aquaponic system by conducting a case study of Agroponicos' system,
2. Investigate the financial records of Agroponicos to conduct a financial analysis, and
3. Find resources and programs through an online search and interviews with public officials and our sponsor.

Since Agroponicos operates the only commercial aquaponic system in Puerto Rico, a case study of their system was conducted to investigate the process, from conception to production, on how to establish and operate an aquaponic system (Specific information and terminology on the system may be found in Appendix P). We developed our initial questions from gaps in the literature research and adapted questions from existing case studies. We expanded our questions over the course of our two months in Puerto Rico. A financial analysis was also conducted using financial information provided by our sponsor. We separated and analyzed the upfront costs, profits and estimated the breakeven point, the payback period, and projections for future systems.

We investigated potential sites for expansion based on recommendations from our sponsor. The site director of the Botanical Gardens at Caguas was interviewed to understand the mission statement of the Gardens, the availability of land, the conditions of the unoccupied greenhouses and if Agroponicos' goals for education and expansion would be beneficial to the Gardens. The mayor of Caguas' staff was interviewed to determine the economic goals of the municipality, available resources for businesses and individuals, the needs of the businesses and individuals, the necessity for a sustainable food supply and the benefits of aquaponics. The mayor of Juncos manages the Rehabilitation and Empowerment Center and was interviewed to understand the goals of the Center, the tax exemptions offered to businesses, the land provided to Agroponicos, the supply of labor and the potential for a new market.

After conducting an initial internet search, we conducted interviews with some support programs to further investigate funding, business and risk management resources that could be applied to establishing, operating, improving or expanding an aquaponic business. We interviewed personnel at the U.S. Department of Agriculture (USDA) Farm Service Agency (FSA), the Small Business Administration (SBA) and the Puerto Rico Department of Agriculture (PRDA). We then analyzed our interviews and documentation to understand the eligibility requirements, the specific uses of the support and if the support could be applied to aquaponics.

3.1 Case Study of Agroponicos, Cosecha de Puerto Rico, Inc.

Figure 17 is a pictorial representation of what we researched in order to conduct the case study and financial analysis of Agroponicos and a list of our deliverables.

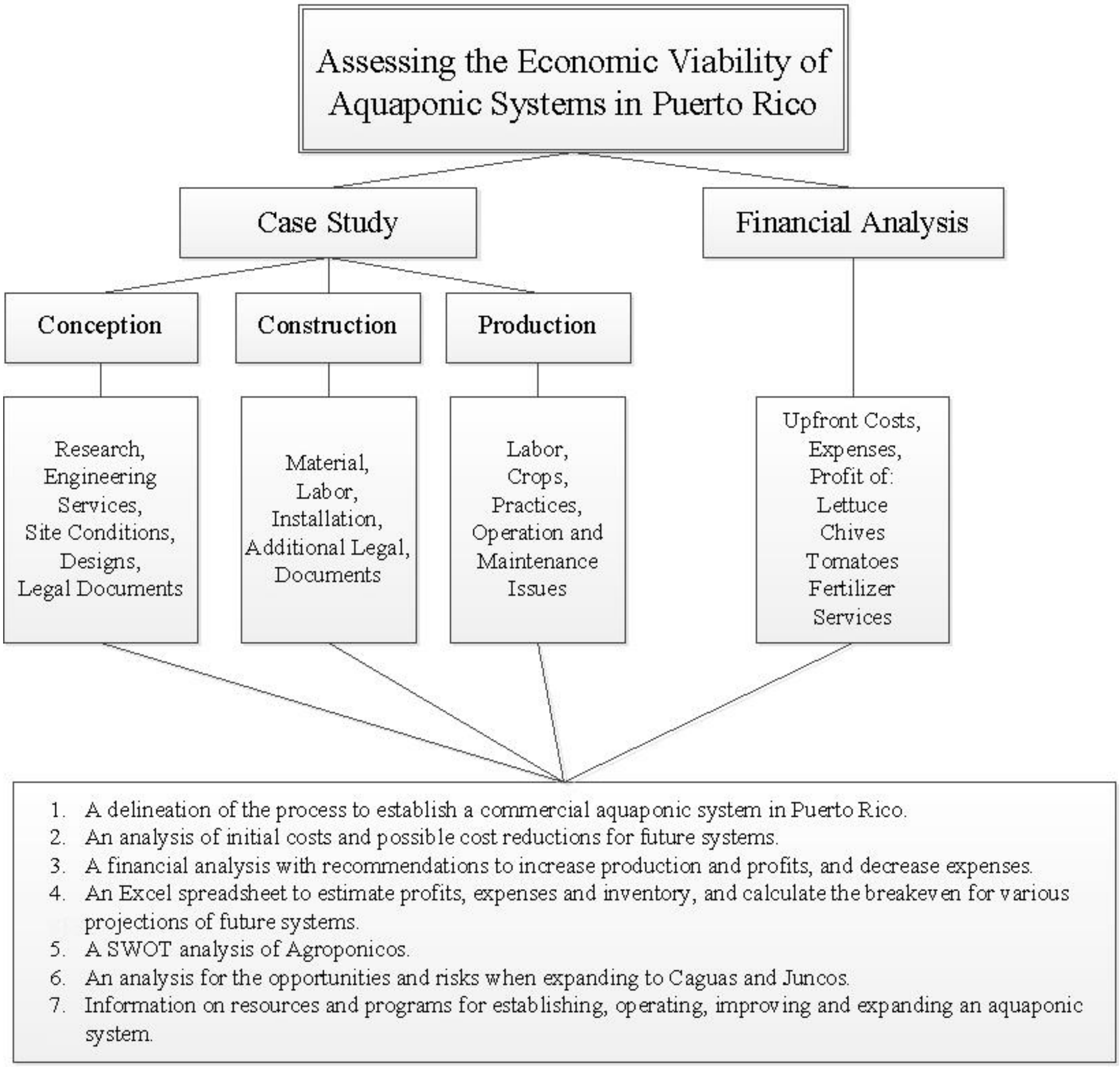

Figure 17: Concept map for the case study and financial analysis of Agroponicos.

To delineate the process, from conception to production, to establish a commercial aquaponic system in Puerto Rico, we carried out a series of formal and informal interviews with the staff of Agroponicos and completed a day of harvesting and packaging on the farm (Figure 17). We developed our initial questions from gaps in the literature research and from existing case studies since no literature exists on aquaponic systems in Puerto Rico. We then expanded the questions over the course of two months to address new concerns or issues. After each interview, the notes of all group members present were compiled and typed into a single document. The list of interview questions can be found in Appendix C. Exploring the conception, construction and production phases of the system allowed us to learn how to establish a commercial aquaponic system in Puerto Rico.

The conception phase helped us understand the background research and the steps taken to establish a commercial aquaponic business. The construction phase helped us understand the difficulties in building a system and determine the specific types of material and labor used. The production phase helped us understand whether the system is operating efficiency, the required skills of the employees and how and what kinds of crops are harvested. Operational and maintenance practices, which heavily focused on water quality tests, were checked against the literature to determine if the tests are being administered properly and if the various test results are acceptable. In addition, we provided recommendations for issues that have not yet been resolved by consulting the literature and engineering principles. Our case study helped us develop questions for our interviews with government and public officials (See 3.3 Opportunities for Expansion).

The major limitation of the case study is that the data were collected on only one farm and can only be validated in the literature. Since literature is scarce, some of our claims cannot be validated and are just observations. In addition, some steps of the process were completed by third parties making it difficult to obtain accurate and precise answers from our sponsor. Thirdly, some documents only exist in Spanish, which made them difficult to analyze, but translations were provided by our sponsor and interviewees.

3.2 Financial Analysis of Agroponicos, Cosecha de Puerto Rico, Inc.

To determine if Agroponicos is an economically viable company, the upfront costs, estimated margins, and operational expenses were provided by our sponsor. Most data were collected while the system was producing two beds of lettuce and an assortment of other produce, and were estimated and scaled to the full production level of five beds of lettuce and one bed of chives. At full production, each weekly harvest will include 20 rafts of lettuce and three rafts of chives. We first calculated the payback period of the current system and then examined profitability. The major sources of income come from the primary crops of lettuce and chives.

To calculate the contribution margin of lettuce, the bags of lettuce produced were counted, multiplied by the selling price and the various direct variable expenses were subtracted. A similar process was followed to estimate the contribution margin of chives, except the direct costs of the seeds and plant food were considered negligible due to the continuous growth of the produce.

Fixed operating costs were deducted from these contribution margins to determine the profitability of the system, the breakeven point and the maximum salaries the business could pay while remaining profitable. The study also examined how to increase the profitability of Agroponicos by investigating how expenses could be reduced and by searching for other potential sources of revenue.

The financial analysis enabled us to assess the economic viability of building similar aquaponic systems in Puerto Rico by using the data provided by Agroponicos to construct an Excel spreadsheet. The spreadsheet estimates the total expenses and profits of similar systems as a function of beds. Operation and fixed costs remained the same for lettuce and chives.

Agroponicos' DWC system, which utilizes six beds and 72 rafts, was used to create projections of different arrangements of crops. Some data used for the analysis can be found in Appendix J.

Combining the information found from the financial analysis and interviews with our sponsor, a SWOT (Strengths, Weaknesses, Opportunities and Threats) analysis was conducted to give our sponsor an objective view on the current status of their business. The analysis allowed us to determine recommendations on how to improve Agroponicos as a business.

The first limitation of the analysis is that the electricity cost is a high estimate because it accounts for the air-conditioner in the office, which is operated all day to refrigerate produce, and not just the machinery needed to run the primary pumping systems. Secondly, the estimation of the cost to produce chives is not as detailed as the cost to produce lettuce. While we were able to estimate the amount of wasted lettuce, we were unable to estimate for chives and assumed 100% of chives were sold. Thirdly, most costs are based on estimations and assumptions and are not averaged values. Fourthly, the weight of the lettuce, which is used in the projections, is based on the weight of the lettuce after it is dunked in water. Still, we were able to estimate the amount of revenue from one bed (See Appendix P) of lettuce within $5 of Agroponicos' estimate. The estimated revenue was on the order of a few hundred dollars. Lastly, these values may change if the company begins receiving profit from other products, services or changes the price of their goods.

3.3 Opportunities for Expansion

After outlining the process to develop an aquaponic system and assessing its economic viability in Puerto Rico, we conducted interviews with the mayors of Caguas and Juncos and the director of the Botanical Gardens in Caguas. The interviewees were suggested by our sponsor because of their goal of expanding to Caguas and Juncos. The initial interviewee questions reflected information provided by our sponsor, but were subject to change during the interviews. Interviews focused on understanding social issues, mission statements, types of support, potential locations, and the risks and benefits of expanding an aquaponic business to other municipalities. After each interview, the results of all group members present were compiled and typed into a single document.

Caguas

The Botanical Gardens are a venue where visitors can appreciate exotic foliage, learn about the history of Puerto Rico, eat food, attend programs and events, and buy plants. The Gardens have several vacant greenhouses and facilities for conducting educational programs. Questions were formulated after meeting with our sponsor to discuss their goals and the resources available at the Gardens. An interview was conducted with the site director of the Botanical Gardens and we investigated the mission statement of the Gardens, his goals for expansion, his support for hydroponics and aquaponics, why a previous hydroponics system failed and if the services provided by Agroponicos – especially education and hands-on experiences – would be beneficial to the Gardens. Interview questions can be found in Appendix F.

Interviews were carried out with the mayor of Caguas' staff for Strategic Planning to understand the issues of the entire municipality and how the government is helping. Initial questions were derived from the interview carried out with the mayor of Juncos and were expanded upon during the interview. The revised questions addressed the economic goals of the municipality, the available resources for businesses and individuals, the needs of the businesses and individuals, the Sustainable Food Initiative and the role of Agroponicos in Caguas. To supplement the interview, the staff provided us with sections of their Sustainable Food Initiative proposal that included the goals and mission statements. Appendix E includes the interview questions.

Juncos

Interviews were conducted with the mayor of Juncos and his staff. Translations were provided by our sponsor and the mayor's financial advisor. The mayor is hoping to improve the municipal Rehabilitation and Empowerment Center by incorporating outside businesses, like Agroponicos, to provide employment opportunities and a sense of community between the municipality and the rehabilitated members of the Center. The questions were formulated after interviews with our sponsor and targeted the purpose of the Rehabilitation and Empowerment Center and how the mayor wants to employ the rehabilitated drug addicts, expand the Center, provide healthy food to Puerto Rico, build a large-scale aquaponic system and create a sense of community between Juncos and the rehabilitated drug addicts. Additionally, we asked the mayor about the land and tax incentives he will provide to businesses that build at the Center, how he intends to pay the employees and how he intends to sell the produce produced from the aquaponic system. Interview questions can be found in Appendix D.

The major limitation of the interviews was that not much of the information has been published or is readily available for validation. Thus, we are unable to cite specifics or validate any claims made during the interviews. Additionally, the interest in aquaponics may change with the leadership of Caguas, the Botanical Gardens or Juncos.

3.4 Resources and Programs

Initially, an online search was conducted to investigate resources and programs that could be applied to business or agriculture. Due to the lack or complexity of the information available online, we decided to conduct interviews with some of the respective agencies in Puerto Rico. Our initial questions investigated the types of support, eligibility requirements, the specific uses of the support and if the support could be applied to aquaponics. Further questions were developed to reflect our sponsor's goals of expanding their business into other sectors, such as education and consulting. We investigated the U.S. Department of Agriculture (USDA) Farm Service Agency (FSA), the Small Business Administration (SBA) and the Puerto Rico Department of Agriculture (PRDA). After each interview, the results of all group members present were compiled and typed into a single document. A full list of questions and responses can be found in Appendices G - I, respectively.

Sources of Monetary Support

We interviewed officials from the USDA Rural Development office to investigate the availability of loans and grants and if the loans and grants applied to aquaponic systems. However, the Rural Development office instead referred us to the USDA Farm Service Agency (FSA) which offers loan programs more pertinent to agriculture. We then interviewed the loan manager of the FSA to learn about the specific sources of support.

We interviewed officials from the SBA office to investigate loans, grants and resources for starting a business. In addition, we investigated whether the resources could be applied to aquaponic systems. During the interview, we learned that the SBA loan amounts were too large and the interest rates were too high, which made them not suitable for our sponsor's business. We then shifted our focus towards other available resources for helping our sponsor formulate a business model.

We interviewed an official from the Puerto Rico Department of Agriculture (PRDA) to investigate the benefits of the Bona Fide Program to understand the application process, the benefits and the eligibility requirements. We asked questions about tax incentives and subsidized labor costs for farmhands.

Organic Certification

We interviewed an official from the Puerto Rico Department of Agriculture (PRDA) to investigate the benefits the USDA Organic Certification, understand the application process, determine the costs and explore subsidies. Additionally, we obtained information on labeling regulations in Puerto Rico to understand how produce can be labeled as organic or GMO-free.

Risk Management Programs

We conducted additional online research for crop insurance and risk management programs after our sponsor informed us of the risk of losing their crops to hurricanes. We first investigated the Federal Crop Insurance (FCI) in Puerto Rico, but found that the crops our sponsor grew were not covered. We then investigated the FSA website and found the Noninsured Crop Disaster Assistance Program (NAP), the Supplemental Revenue Assistance Payments Program (SURE), the Emergency Farm Loans and the Disaster Debt Set-Aside Program (DSA). We read the pertinent documentation to find the eligibility requirements and the amount of losses covered by each program.

We were limited by the amount of time we had to investigate the programs, resources or incentives offered by the USDA agencies, SBA and PRDA. These programs do not include all federal or local governmental agencies. We also did not investigate sources of donations or private support. In addition, a large amount of our data came from interviews and there is a chance of missing, inaccurate or conflicting information. To minimize inaccurate information during interviews, we made sure to conduct research before the interviews and follow-up on interviews to ask addition questions so as to verify the information we obtained. Lastly, since aquaponics is not a common form of agriculture, some agencies did not understand the technology or know if the systems would be completely covered by the programs, resources or incentives.

Results and Discussion

The results are organized to reflect the order of our research questions. First, we discuss the results from the case study and the necessary process to establish a commercial aquaponic system in Puerto Rico. Second, we compile and analyze the financial data to determine if the business is profitable and provide suggestions to improve profitability. Third, we discuss opportunities for expansion to sites located in Caguas and Juncos. Last, we provide and analyze sources of support that may be used to establish, operate, improve and expand aquaponic systems.

4.1 Case Study of Agroponicos, Cosecha de Puerto Rico, Inc.

What is the process, from conception to production, to establish and operate a commercial aquaponic system?

Agroponicos, Cosecha de Puerto Rico, Incorporated owns a 1.2 acre farm located near San Juan, Puerto Rico. Constructed in 2011, the farm is owned and operated by a father and his two sons and is currently the only commercial aquaponic system in Puerto Rico. The focuses of the business are on growing and selling produce and expanding to other municipalities. In the near future, the family plans to promote and teach educational programs to expand the knowledge of aquaponic systems in Puerto Rico.

4.1.1 Overview of the Farm

Agroponicos currently utilizes a large Deep Water Channel (DWC) aquaponic system, two smaller Media-filled Growth beds (MFG) systems and a sludge tank.

Deep Water Channel

The DWC system encompasses over 2,400 m^2 and is comprised of six 4'x 100' growth beds with twelve 4' x 8' floating rafts in each bed. The system is based on the system at the

University of the Virgin Islands, except Agroponicos focuses primarily on the sale of produce and not fish. The entire apparatus is covered by a greenhouse to keep out pests.

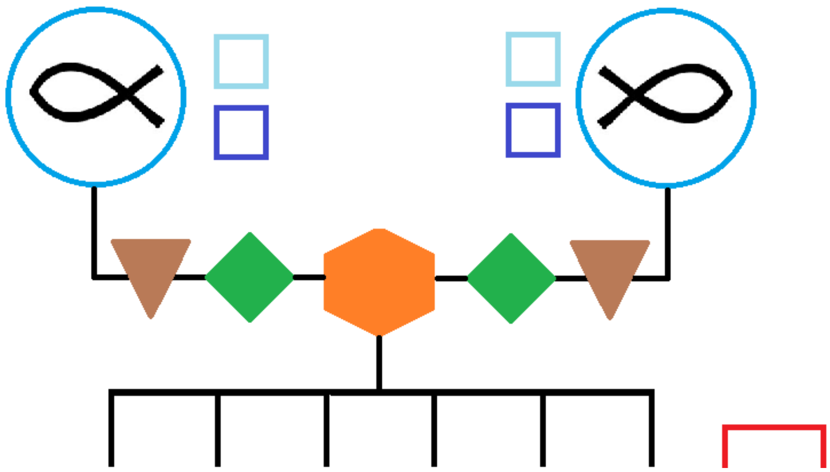

Figure 18: Schematic of Agroponicos' DWC system.

The system, as diagrammed in Figure 18, consists of two 4, 500 gallon pools (blue circles) containing 1,200 tilapia in total, two clarifiers (brown triangles), two filters made of orchard netting (green diamonds) and one degassing station (orange octagon). To reduce the need for additional water pumps (dark blue squares), the nutrient rich water is gravity fed into the clarifiers, filters, degassing station (orange octagon) and the growth beds (black lines). After circulating through the growth beds, the water is pumped back into the pools. The sludge tank is only used when the system (twice a year) or filters (once every two weeks) need to be cleaned and is not always connected to the DWC system. The air pumps (light blue squares) provide aeration to the fish tanks, the degassing station, the growth beds and the sludge tank (red lines). Large amounts of aeration are required for the fish and to promote mineralization throughout the entire system.

Medium-filled Growth Beds (MFGs) System

To supplement the main DWC system, two smaller gravel MFG systems were added to the farm. One system is being used to grow lettuce seedlings and the other, containing three growth beds, is being used to grow tomatoes.

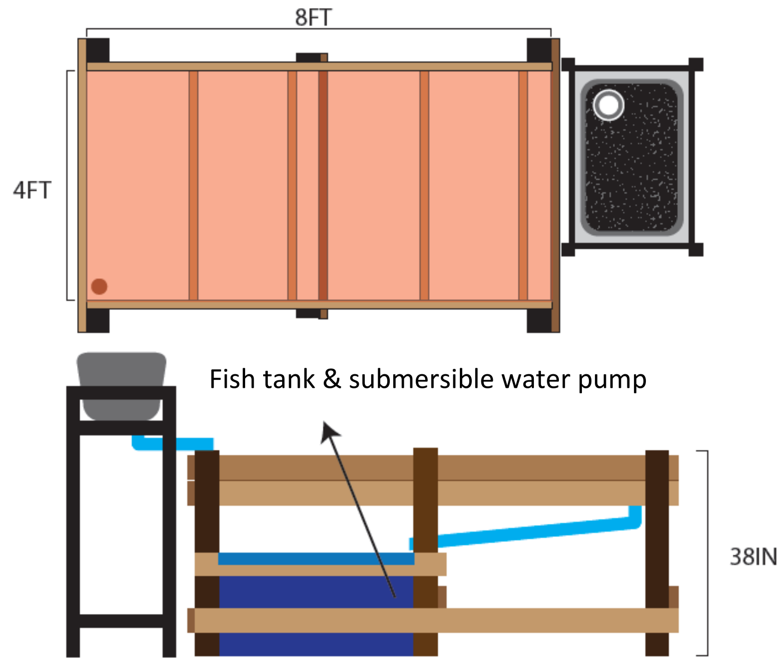

Figure 19: Wicking bed MFG system for seedlings (Courtesy of Agroponicos).

One of the MFG systems, also known as a wicking bed (Figure 19), was built by Agroponicos to improve the quality of the seedlings before planting them into the DWC system. The technique was learned at an aquaponics conference by one of the employees. The system is not connected to the DWC system, incorporates a separate pump and 12 tilapias, and is covered by a greenhouse. Initially, seedlings were grown in conventional soil, but there were issues with germination and damage to the crops caused by transferring the seedlings into the net pots (See Appendix P for terminology on Agroponicos' system). In addition, the process was time consuming. The seedlings grow in the wicking bed for three weeks. The estimated cost of this MFG system is $600 – $700.

Figure 20: MFG system for growing tomatoes (Courtesy of Agroponicos).

The other MFG system (Figure 20) is located outside the greenhouse and is constructed differently than the wicking bed. This system is constructed to grow tomatoes since the greenhouse over the DWC system prevented bees from pollenating the crop. Artificial pollination was attempted with toothbrushes, when the crops were grown in the DWC system, but the practice was time consuming. The estimated cost of this MFG system was $200 because it was built from materials found on the farm. The system is not incorporated into the DWC system's water supply.

The Sludge Tank

The sludge tank measures 3'x 40' and 3'deep and stores water and solid waste from the system during cleaning. When cleaning the filters, 800 gallons of water and solids are drained from the filter and clarifier tanks into the sludge tank. Moving the water allows the filters to be washed. The sludge tank is aerated and creates nutrient-rich water that can be pumped back into the system. Additionally, the remaining sludge can be sold as fertilizer.

4.1.2 Conception to Production: Establishing a Commercial Aquaponic System

The steps outlined below delineate the process our sponsor took, from conception to production, to establish and operate their commercial aquaponic system.

Conception

Our sponsor's aquaponic system is based on the UVI system and was financed by the family. Pedro Casas Jr. has an extensive background with aquaponics, five years of research in agriculture, recently become a member of the Aquaponics Institute, taken courses at UVI and constructed small-scale aquaponic systems.

To establish their business, Agroponicos had to register their company name and brand name, Bohiti, with the State Department of Puerto Rico to receive their Certificate of Merchant. The Certificate of Merchant is renewed every year to ensure the legal validity of the company. In addition, our sponsor applied for an employer identification number (EIN) with the U.S. Internal Revenue Service (IRS) at the Puerto Rico Treasury Department. Unemployment and disability account numbers were requested from the Puerto Rico Department of Labor and Human Resources. Lastly, our sponsor obtained workers' compensation insurance from the State Insurance Fund Corporation. These steps established Agroponicos as a business.

Before construction, a surveyor must mark the property lines and elevations. Next, our sponsor hired an engineering firm to produce the necessary CADD (Computer Aided Design and Drafting) drawings for the main DWC system and the office. The drawings included the main system and the necessary drainage and infrastructure installations. The initial site conditions can be seen on the right side of the road in Figure 21.

Figure 21: Initial site conditions (Courtesy of Agroponicos).

Permits were required before starting the construction and operation of the farm. To begin the permitting process, our sponsor obtained a letter of endorsement from the Puerto Rico Department of Agriculture to legally classify aquaponic systems in Puerto Rico as agriculture. Afterwards, they could start obtaining the necessary legal documents. The legal documents for permitting that were obtained before construction included the Permit of Construction and the Permit for Clearing the Land.

Applications and requirements for these permits can be found online at the Integrated System of Permits which can be filled out individually or by an engineering firm. The Integrated System of Permits only provides general requirements, while the specific requirements must be obtained from the municipality. Additionally, we learned that because our sponsor is a private company, and not working with a governmental agency, it takes longer to obtain the necessary permits.

Construction

The entire construction phase of the project lasted 11 months and included pouring the concrete beds and installing the bed liners, piping, equipment, roof structure over the fish tanks and the trailer office. The construction of the roof over the fish tank and the office was subcontracted, while the rest of the system was constructed by Agroponicos with the help of three friends and family. Leveling the land; constructing the drainage, electrical and water infrastructure; and obtaining permits required five months. Figure 22 shows the concrete beds (middle) and the office (in the stacked trailers, top right) during the early phases of construction.

Figure 22: Concrete beds with trailers on site (Courtesy of Agroponicos).

Equipment was purchased domestically and from the continental United States. Most of the materials were bought from Aqua Eco-Systems in Florida or bought locally from HQJ Plumbing Supplies. The fish tanks were swimming pools ordered from eBay. The liners for the concrete beds were expensive, but quality is important to ensure that they are durable, able to last wear and tear, and safe to use in an aquaponic system. The overview of the nearly complete system can be seen in Figure 23.

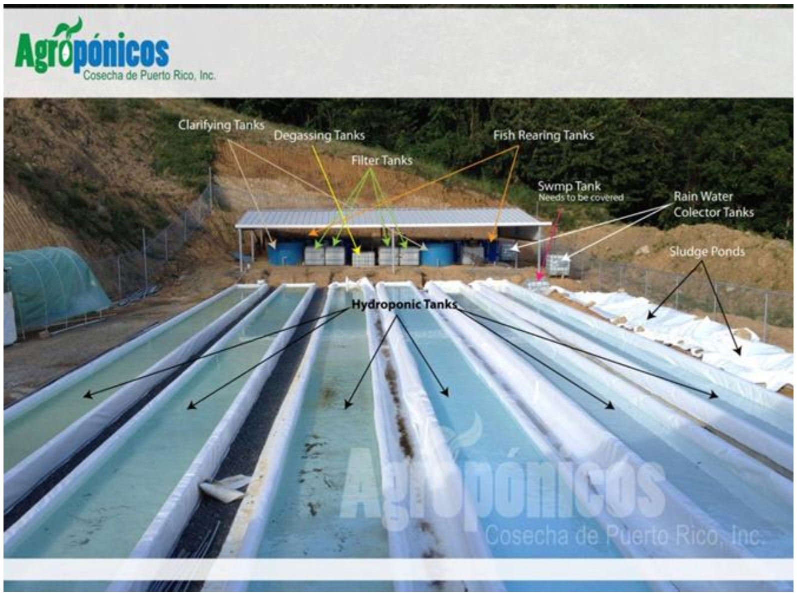

Figure 23: Overview of system (Courtesy of Agroponicos).

The final stages of construction involved installing the greenhouse and the office. Additional construction included a seedling area and two MFG systems. To complete the construction phase of the project, our sponsor had to obtain a Permit of Use and obtain fire safety and plumbing inspections before the farm could operate.

Upfront Costs

Breakdowns of the upfront costs for the conception and construction phases of the project are listed below. Agroponicos' aquaponic system was privately funded and cost less than $200,000. No salaries were taken by Agroponicos or paid to the friends and family who helped construct the system. The upfront costs of the farm are broken down in Figure 24. These costs include the DWC system, the office and the greenhouse.

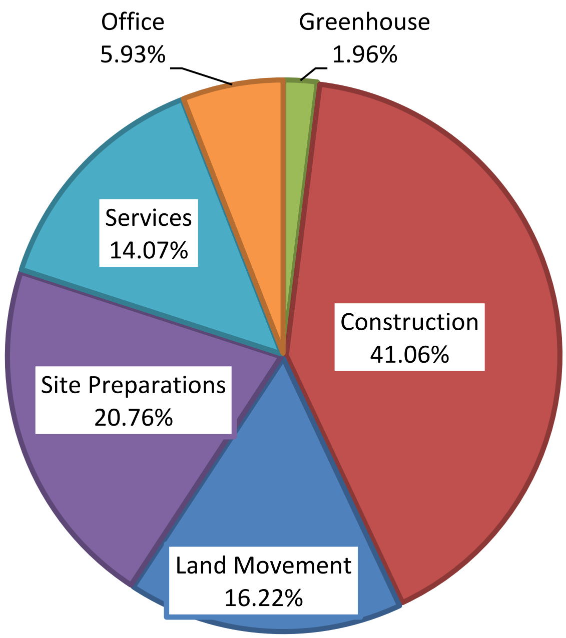

Figure 24: Breakdown of Agroponicos' initial costs.

The specifics of each cost are represented below:

- **Construction** includes pouring the concrete beds, construction of the fish roof and construction of the plumbing.
- **Site Preparations** includes the down payment plus 11 months of rent on the land, the electrical and water connections, draining, fencing and metering devices.
- **Land Movement** includes the costs of moving the land before any construction occurred.
- **Services** includes the cost of having an agronomist survey the land and an engineering firm prepare CADD documents, purchase permits and sign permits.
- **Office** includes the cost of purchasing and installing two trailers and an air-conditioning unit.
- **Greenhouse** includes the cost of purchasing and installing the greenhouse over the aquaponic system.

This break down of the initial expenses allows for a better understanding of the costs associated with establishing a commercial aquaponic system in Puerto Rico. This understanding also makes it easier to estimate the approximate costs of building future systems.

Production

Before reaching production, the system was tested with different crops to determine if they could be successfully grown. The testing allowed the company to diversify their crops and learn how to operate the system smoothly. As of March 2013, the plans for the system include five beds of lettuce and one bed of chives. Lettuce is grown in the system due to a high demand; they are easy to grow and have a short growth cycle. Chives are grown in the system because they are highly profitable and require relatively low labor. To ensure clients would purchase the produce, a portion of the beds was pre-sold before production. The company currently sells to almost a dozen establishments, including restaurants and grocery stores in the San Juan area. Table 8 outlines the types of crops tested in the system and the reasons for continuing or discontinuing production. The experimental phase lasted for roughly one year. Currently, the primary harvest of Agroponicos is green lettuce and chives.

Table 8: Experimented crops and status in the system.

Produce	Status	Reason
Tomatoes	Testing	Moved to MFG system for pollination purposes
Basil	Discontinued	Lack of market
Mesclun	Discontinued	Lack of market
Parsley	Discontinued	Lack of market
Culantro	Discontinued	Lack of market
Cilantro	Discontinued	Lack of market
Mustard	Testing	Available market
Mint	Discontinued	Lack of market
Chives	Production	Profitable market, low maintenance
Lettuce	Production	Available market, easy to grow
Watercress	Discontinued	Lack of market

The lettuce is grown for three weeks in the wicking bed (Figure 19) and for three weeks in the DWC system before harvesting. Each weekly harvest of lettuce produces approximately 80 lbs.

Chives are grown on a slightly different schedule and are harvested on a 4-week growth cycle. Each weekly harvest of chives produces approximately 120 lbs. The chives can be plucked and will regrow without additional seeding. The chives remain permanently in the DWC system.

Labor and Skills

The division of labor for harvesting lettuce typically includes one individual harvesting, seeding and maintaining the system and one individual packaging and delivering the produce. With two employees, it takes roughly three days to harvest and package the six beds.

The skills and experiences of the employees are provided below:

- **Pedro Casas, Sr**. is the CEO of the company, has experience in business, aquaponics and sometimes aids with packaging the produce.
- **Pedro Casas, Jr**. has over five years of agriculture experience including soil agriculture, hydroponics and aquaponic systems. He designs small-scale and large-scale aquaponic systems and performs the graphic design of all marketing materials for the company. He is primarily responsible for harvesting, seeding, and daily maintenance of the system. In addition, he is a certified Aquaponics Institute instructor.
- **Jorge Casas** has an educational background in business and oversees marketing and distribution of the produce. He is primarily responsible for developing relationships with clients, packaging, quality control and ensuring all goods are sold and transported to clients. He actively seeks new clients and opportunities for the business.

Table 9 shows the major tasks related to harvesting a system at full production. Typically, harvesting begins at 6 a.m. and continues until noon, while packaging continues until 2 p.m. Harvesting must be completed before noon or the heat will negatively impact the quality of the lettuce. Table 9 is an idealized schedule and in reality produce may take more than one day to be completely sold since Agroponicos receives orders on a weekly basis.

Table 9: Harvesting and packaging schedule of 5 beds of lettuce and 1 bed of chives.

<table>
<tr><th>Beds</th><th>Monday</th><th>Tuesday</th><th>Wednesday</th><th>Thursday</th><th>Friday</th></tr>
<tr><td>1 – Lettuce</td><td>Harvest, Plant & Package</td><td></td><td rowspan="4">Delivery</td><td rowspan="6">Seedlings
Visitors
Cleaning
Invoicing
Maintenance
Delivery</td><td rowspan="6">Maintenance
Delivery</td></tr>
<tr><td>2 – Lettuce</td><td>Harvest, Plant & Package</td><td></td></tr>
<tr><td>3 – Lettuce</td><td></td><td>Harvest, Plant & Package</td></tr>
<tr><td>4 – Lettuce</td><td></td><td>Harvest, Plant & Package</td></tr>
<tr><td>5 – Lettuce</td><td></td><td></td><td>Harvest, Plant & Package</td></tr>
<tr><td>6 – Chives</td><td></td><td></td><td>Harvest & Package</td></tr>
</table>

The following narrative is representative of one day of harvesting lettuce. Harvesting of the system is typically completed on Monday, Tuesday and Wednesday, with two beds being harvest each day. Each harvest includes two beds of produce. To make harvesting easier, a raft of lettuce is removed and placed atop a pair of sawhorses outside the greenhouse. A full raft may weigh up to 20 lbs. and will require two persons to move without damaging the raft.

The lettuce is cut at the head, dunked in water for pest control and improved packaging, and then moved inside the air-conditioned office. Care must be taken since the lettuce is fragile from being in the rafts. The remaining plant soil, which consists of a Coco-Tek and vermiculite mixture, and the lettuce roots are removed from the net pots and composted (See Appendix P for terminology on Agroponicos' system). The net pots are left to soak and reused for future seedlings. The tops of the rafts are cleaned and the bottoms are untouched as to not remove the beneficial bacteria required for mineralization. Although the order of rafts is unimportant for growth, the more developed produce is moved closer to the harvesting area for ease of access and aesthetics (Figure 25).

Figure 25: The last 3 stages of lettuce growth, seen on left (Courtesy of Agroponicos).

The lettuce is packaged inside an air-conditioned office to reduce wilting. The heads of lettuce are separated, checked for insects or browning, and then manually packaged into 10 oz. bags. Careful attention must be paid to removing broken or browning lettuce to improve shelf life and appearance. The final step of packaging is adding the Agroponicos' logo to the bag and stacking the produce in reusable boxes.

Once the packaging is done, the clients are called and their orders are taken. Although the beds are generally reserved for specific clients, the amount of produce will vary and must be confirmed on the day of delivery. In reality, it may take more than one day to complete all the deliveries scheduled for that day.

After harvesting, the rafts are placed into the beds and filled with new seedlings. To replace the harvested lettuce, 20 rafts with 960 net pots are filled with a mixture of vermiculite, Coco-Tek, and three or four seeds. The net pots are assembled in the same area of the wicking system, which is located next to the DWC growth beds. The entire process, with two persons, takes approximately 1-2 hours. Table 10 outlines the approximate duration and duties expected from the two employees for one day of harvesting and packaging. The same process occurs on Monday, Tuesday and Wednesday, and would require a total of 51 hours per week. Harvesting and maintenance is covered by the same employee, while packaging, marketing and transportation is covered by the other.

Table 10: Duties and time commitment of harvesting 2 beds of lettuce (Mon., Tue. and Wed.).

Job Title	Duties	Time Commitment
Harvesting	Cutting lettuce, cleaning, refilling, replacing net pots, removing dead fish, restocking fish, seedlings	5 hours
Maintenance	Checking and recording water quality, ensuring crops are growing, understand how to maintain system, feed fish, on call for seven days a week	1 hour
Packaging	Quality control, separating bunches, packaging bags, adding logo, packing transit crates	8 hours
Marketing	Confirming orders, expanding clients, selling produce	1 hour
Transportation	Delivering produce to clients	2 hours
Total		**17 hours**

Without skilled staff, running an aquaponic system can be a daunting task. Knowing how to quickly regulate, troubleshoot and adjust pivotal parameters, including pH and ammonia, can be the difference between a healthy harvest and a poor harvest. Although the skills needed to harvest and package the produce may be simple, the marketing and maintenance skills come with experience. The breakdown of labor is used to provide recommendations to Agroponicos for addressing issues with the amount and utilization of labor (See 4.2 Financial Analysis of Agroponicos, Cosecha de Puerto Rico, Inc.).

Maintenance and Operation

Water quality is the life of the system and affects the fish and plants. To ensure that the system is balanced, pH, ammonia, nitrites, nitrates, dissolved oxygen (DO), calcium and iron levels are monitored. Most tests are completed with a simple pool kit, but electronic pH and temperature meters may be used to verify the measurements. Table 11 highlights the types, frequencies and level of water quality metrics.

Table 11: Type, frequency and level of water quality test metrics.

Type of Test	Frequency	Level	Notes
pH	Daily	7.0	Measured in degassing station
Temperature	Daily	70 - 82°F	Measured in fish tanks
Nitrite	Weekly/Bi-	0	Measured in degassing station
Nitrate	Weekly/Bi-	> 10ppm	Measured in degassing station
Ammonia	Weekly/Bi-	0	Measured in fish tank (not during feeding)
Chlorine	Varies	0	Measured when rainwater is added
Dissolved Oxygen (DO)	Monthly/Bi-	5 mg/liter	Required for plants, fish, mineralization
Iron	No test	Low	Added for plant growth, yellowing of plants indicates low levels
Calcium	No test	High	Required for plant growth, used to raise pH, deficiency indicated by plant health
Potassium	Weekly	High	Required for plant growth, used to raise pH, deficiency indicated by plant health

Measuring the pH of the system is rather simple, but being able to adjust the value is the real challenge. As discussed in section 2.3.5 Maintaining an Aquaponic System, the ideal level of pH is 7.0 because it accommodates the plants, fish and mineralization of the system. To maintain the pH of the system, Agroponicos uses several techniques. If pH needs to be raised, rain water (pH ≈ 7.5), calcium hydroxide or potassium hydroxide can be added to the system. Conversely, if the pH needs to be lowered, the fish can be fed a more food. Although the employees conduct tests on the water quality, it takes a certain amount of intuition to understand the deficiency in the system. For instance, a yellowing of the lettuce levels is usually an indication of an iron deficiency. Additional precautions may be taken when water is added to the system.

Each month, 800 gallons of water is added to the system because an equal amount is moved to the sludge tank when cleaning the filters. To supplement these water losses, Agroponicos uses municipal water and collects rain water for use in the system. With municipality water, Agroponicos takes an extra precaution and aerates the water to remove harmful gases. With rain water may, chlorine tests are conducted. In addition to municipal and rain water, water from the sludge tank can be pumped back into the system, providing the aeration is turned off and the solids have sunk to the bottom. Thereafter, the sludge can be harvested as fertilizer.

Regulating the temperature in an aquaponic system is an economic challenge mentioned in the case studies (See 2.4.2 Growing Power, Inc. Case Study). The only methods used to regulate temperature at Agroponicos are the greenhouse over the crops and the roof over the fish tanks. The roof maintains the water temperature in the fish tanks between 70° - 82° F, depending on the season, and the rafts help insulate the water in the growth beds. Ideally, the ambient temperatures should not exceed 75 °F, as higher temperatures may cause reduced growth, decreased quality, and a bitter or off flavor in the lettuce (Drost, 2010). The tilapia is not as sensitive as the lettuce, but live best at temperatures between 55° - 75 °F (Goodman, 2011).

Table 12: Period of monthly temperatures (°F) in Río Piedras (Southeast Regional Climate Center, 1959-2012).

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.
Avg. Max.	83.9	84.2	85.1	86.4	87.6	89.1	88.9	89.1	89.3	88.8	86.5	84.4	87
Avg. Min.	65.9	65.6	66.4	68.1	70.4	71.7	72.3	72.5	72.2	71.4	69.5	67.4	69.5

The values shown in Table 12 are average monthly temperatures of an area near Agroponicos. The actual values observed at the farm may vary due to elevation, winds and location. The average high temperatures are higher than 75 °F, but the average minimums show the temperature is not consistently high. To reduce the water temperature in the future, the company is considering using cool water from a nearby river as a heat exchanger, opening the roofs of the greenhouse, using fans near the bottom of the crops, adding insulation to the fish tanks, and adding solar panels to the roof to absorb some of the sunlight. Another concern was that the pumping equipment was causing additional heating of the water in the fish tanks. To counteract the temperature increase, the company is considering using the ground as a heat exchanger by burying the pipes leading from the machinery into the ground.

The concentration of nitrate, nitrite and ammonia are a function of the amount of fish waste created and the rate of mineralization. The fish tanks have a low stocking density system (measured in $\frac{kg\ of\ fish}{m^3\ \ of\ water}$) due to the small number of fish in the fish tanks. The current amount of fish food used for each tank is 4 lbs. per day and was decided upon from experimentation. The amount of feed given to the fish should remain constant, but raising the amount can be used to lower the pH. In addition, there are no equations to calculate the precise amount of fish and fish feed needed in the system; it comes down to trial and error.

Pest Control

The greenhouse was constructed to keep out pests, but the farm still has issues with caterpillars, stink bugs, spider mites, aphids, and grasshoppers. The biggest pests are reportedly stink bugs. To contend with pests, Agroponicos applies an organic pesticide called DiPel from Valent BioSciences, weekly. In addition, the company has invested in praying mantises and lady bugs to contend with the pests, but they may leave the farm or die.

4.1.3 Recommendations

The following recommendations address each section of the case study and were identified after interviews and working with the staff of Agroponicos. The recommendations were influenced or supported by the literature review and engineering principles.

Conception

In the interviews, Agroponicos stated that site conditions and obtaining necessary legal documents were their biggest difficulties. Although Agroponicos' system has already been constructed, the following recommendations could be used by others to facilitate the conception phase.

- **Purchase or rent land that is conducive for aquaponic systems.** Land that is already flat and level will eliminate land movement costs. Also if the area is already clear, meaning without any tress or plants, individuals would not have to obtain a land clearing permit. Additionally, since aquaponics do not use the soil from the land, they can be built in areas that are non-conducive to agriculture such as roofs, or abandoned or polluted land.
- **Build with government entities.** Through interviews we learned that working on projects with public officials or government entities reduces the time it takes to receive approved permits.

Construction

An aquaponic system may be expensive to construct, but should be built to last. Through interviews, we learned it is important to invest in quality machinery and materials. It may be advisable for individuals to construct quickly to allocate less time and money during construction.

- **Construct system quickly.** Time spent constructing the system is money wasted on renting the land. To reduce construction time, individuals should have the materials and labor ready to quickly construct the system. Our sponsor identified that the permitting process can be time consuming. To ensure the permitting process is quicker and done properly, Agroponicos suggests using qualified, professional engineering services.
- **Invest in quality materials.** Materials, such as liners, need to be durable and not harmful to plants and fish. Although the liner may be costly, it is best to invest in the early stages so as to not risk damage in the future: a tear in a liner will stop production and may lead to losses and further damages.
- **Invest in sufficient machinery.** All machinery of the system should be powerful enough to complete the task without being so powerful that the potential of the machinery is being wasted. In addition, devices should be energy efficient as to not increase utility costs. Agroponicos uses a 1.5 hp. water pump and two air pumps rated at 1.5 hp. and 1 hp.

Production

The process Agroponicos takes to maintain their system is in agreement with the literature review (See 2.3.5 Maintaining an Aquaponic System). The main improvement to the health of the system would be to reduce the temperatures of the water in the system by 5-10 °F. As discussed in section 2.4.2 Growing Power, Inc. Case Study and shown in section 4.2 Financial Analysis of Agroponicos, Cosecha de Puerto Rico, Inc., it may be expensive to regulate the temperature of an aquaponic system. Thus, any methods used to regulate the temperature should not require a large amount of electricity consumption. Insulation is one method for reducing the temperature. The growth beds, for example, are already slightly insulated, due to the concrete and rafts, but the fish tanks are not insulated. Both the suggestions provided by Agroponicos to regulate the temperature and our own suggestions are assessed below.

- **Using a nearby river as a heat exchanger.** The cooler river water could be used to remove heat from the water in the system. No net water from the river would be used in the system. To use the water from the river would require the permission of the DRNA (Departamento de Recursos Naturales y Ambientales) and would require additional construction and pumping equipment. The benefits of this project would depend on the construction and operating costs of the new machinery, and the effectiveness of the heat exchanger.
- **Opening the greenhouse.** Opening the greenhouse can reduce the temperature by improving convectional heat transfer (Manitoba Agriculture). Care should be taken to ensure that large amounts of pests are not entering the greenhouse. In addition, the heat can be further dispersed by utilizing fans, which are already owned by the company, near the growth beds. Care should be taken to use the fans sparingly as to reduce the amount of electricity consumption.
- **Adding insulation to the fish tanks.** Adding insulation to the fish tanks would be a relatively affordable way to regulate the temperature of the water. In addition, if a cover were to be installed on top of the fish tanks, it could be removed during the night to allow the water to cool, and added in the morning when the temperature rises. Additionally, increasing the reflectivity of the roof would help reflect sunlight from the tanks.
- **Adding insulation to the growth beds.** The only insulation offered by the growth beds are the rafts and the concrete beds. Concrete is not a strong insulator. The ground could

be used as a heat exchanger, but would require the beds to be surrounded by earth. There would be costs associated with moving the land. Care would have to be taken so production is not impacted, the land is not a danger for the employees and the beds are high enough so soil is not kicked into the system.

- **Adding insulation to piping.** Insulating piping ensures the water is kept at a more constant temperature. A suggestion would be to add insulation to above ground pipes. Burying the pipes may provide better insulation, but there would be additional costs and production may be impacted during construction.
- **Reducing impacts of machinery.** Due to the close proximity of the machinery and the fish tanks, additional heat may be transferred to the water. One method would be to move the pumping equipment farther away from the fish tanks. The movement of the machinery would have to be performed quickly as to not jeopardize the production of the system.

4.2 Financial Analysis of Agroponicos, Cosecha de Puerto Rico, Inc.

Can an aquaponics business be profitable in Puerto Rico?

The financial analysis includes the estimated profits of Agroponicos, expenses and projections of hypothetical future systems. The calculations did not include the cost of labor or taxation. Afterwards, a list of recommendations was compiled to improve the profitability of Agroponicos by increasing profits and decreasing expenses.

4.2.1 Profitability of Agroponicos

The income of Agroponicos is mostly derived from five beds of lettuce and one bed of chives. Other smaller and less frequent sources of income include tomatoes, tilapia, fertilizer and services, but were not included in the financial analysis. Figure 26 is a breakdown of the money made from selling lettuce and chives, assuming all produce are sold. The percentages include the direct and operating expenses. The operating expenses were dispersed, with lettuce receiving $\frac{5}{6}$ the expenses and chives receiving $\frac{1}{6}$.

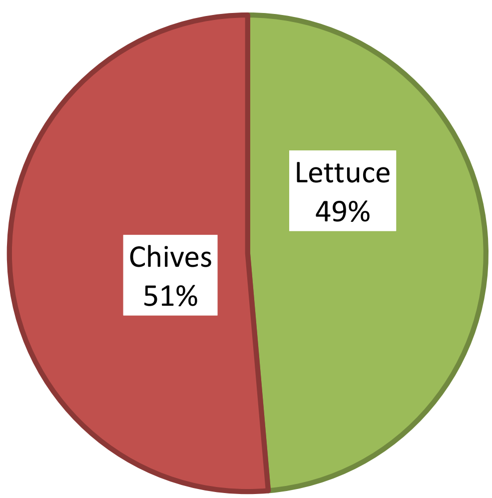

Figure 26: Weighted margins of lettuce and chives.

As seen from Figure 26, the current configuration of crops, 49% of the margins are from lettuce and 51% are from chives. Although selling chives produce higher margins, Agroponicos has chosen lettuce as the primary crop because of the larger market. In addition, the contribution margin ratio $\left(\frac{sales - direct\ expenses}{sales}\right)$ for lettuce is 90%, and for chives is 98%. The contribution margin ratio is higher for chives since there no costs associated with seedlings.

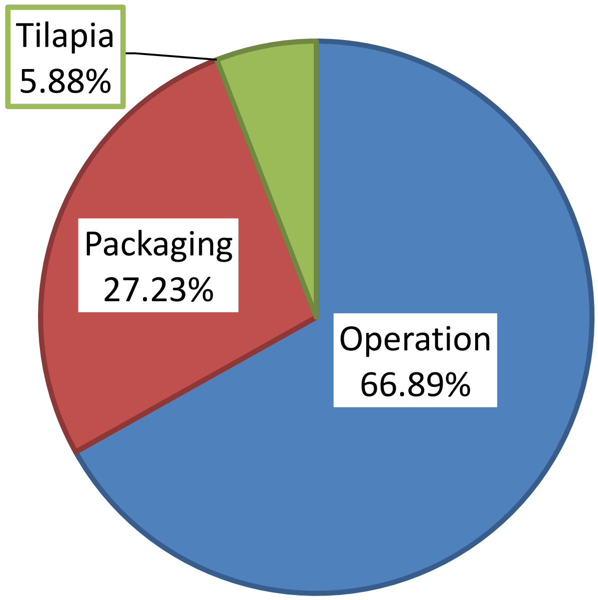

Figure 27: Annual expenses of Agroponicos.

The estimated yearly expenses account for approximately 25% of the yearly sales of lettuce and chives. The tilapia costs include fish feed and an estimated annual replacement of 500 tilapia. The packing costs include the costs of packaging the lettuce and chives. The operating costs include water, electricity, water and supplements, and transportation. The fixed costs include insurance, permitting and water quality costs. The largest operating expense is electricity and accounts for 41% of the total yearly expenses.

Although the company generates profit, employees are not taking a salary and all money is invested into the business. At the current rate, there would be a payback period of less than two years. Conversely, if the company used their sales to pay the employees, the salary would amount to roughly $50,000 annually. Since Agroponicos is looking to expand their business, the company must be able to pay its employees, pay back on initial investments and have funds to invest in new opportunities.

4.2.2 Additional Sources of Revenue

Profits from tilapia, sludge, tomatoes and services were not accounted for in any of the profit calculations. Explanations for why each good is not a large contribution of profits are assessed in each subsection below.

Tilapia

Agroponics offers tilapia twice a year to the local community. In total, the system will produce between 80 - 100 lbs. of tilapia annually. To supplement the sold fish, approximately 400 fingerlings are needed. The expenses of the fish, which include fish feed and fingerlings, account for an estimated $2,128 in annual costs and were included in the expenses. The annual profits from the fish amount to approximately $400 and were not incorporated into the profits. From fish, the company is annually losing almost $1,728 due to feeding and replacing the fish. If the company chooses to break even on the fish, which is not a goal of the company, each tilapia would have to be sold for $17.28 per pound.

Sludge

Every two weeks, the sludge tank is filled with 800 gallons of water and an assortment of solid waste, which eventually settles as sludge. This sludge can be used as a fertilizer since it is filled with high levels of nitrates. The company has the logos and containers to sell fertilizer, but has not had time to locate a strong market.

Tomatoes

Tomatoes were tested in the DWC system before being planted in the MFG system. The costs of the systems were approximately $200 and were not considered in the expenses since they are not part of the DWC system. Agroponicos has experimented with tomatoes and intends to further explore the market in the future.

Services

The staff of Agroponics has a diverse set of skills and talents. They are able to design systems, provide resources, give advice on materials, consult and maintain systems, and educate. Since the employees are responsible for working on the farm, they are generally not able to actively pursue or promote other avenues of income. Table 13 outlines potential services that could be sold based of the skills on the employees.

Table 13: Potential services offered by Agroponicos.

Education	• Knowledge from conferences, UVI and Aquaponics Institute • Ability to teach courses on aquaponics • Experience in running and starting up an aquaponic business
Consulting	• Ability to design and scale systems • Knowledge in constructing systems • Have skills to maintain and troubleshoot systems
Resources	• Information on sources of funding • Resources from Aquaponic Institute and local agencies • Understanding the market of organic foods in Puerto Rico

Although Agroponicos has conducted a few courses on aquaponic education, the company may not have enough labor to maintain the farm and to invest time in promoting or expanding their services.

4.2.3 Projections for Future Systems

By using data collected from Agroponicos, it was possible to develop an Excel spreadsheet to estimate the expenses and profits of different sized systems as a function of beds. This section focuses on creating projections to calculate expenses and profits of systems producing different combinations of lettuce and chives. No projections include the cost of labor or taxation.

Lettuce Production

Table 14 estimates the expenses associated with operating a one, two or five bed system of lettuce on a system identical to Agroponicos. The tilapia costs include fish feed and an estimated annual replacement of 400 tilapia. The lettuce costs include bags, logos, replacement seeds and soil. The operating costs include water, electricity, chemical supplements and transportation. The fixed costs include insurance, permitting and water quality test costs.

Table 14: Projected weekly expenses of lettuce.

	Bed 1	**Bed 2**	**Bed 5**
Variable			
Tilapia	$20	$20	$41
Lettuce	$32	$65	$162
Operating	$166	$176	$361
Fixed	$11	$11	$11
Total	**$229**	**$272**	**$575**

The big gap in costs from running two beds to five is primarily caused by packaging, fish costs and operating costs. When operating less than three beds, only half of the machinery and fish tanks are used. To account for less than three beds, it was assumed that the system ran on one fish tank, one air pump and one water pump. Operating costs for five beds rises drastically since there are more expenses from the additional fish and machinery needed to operate the system. Additionally, the increase in beds leads to an increase in lettuce production and the costs to grow and package the goods. The difference between running one bed versus two is very small. Thus, it is advisable to run a system with all beds being utilized since the utility costs increase as a step function of three beds.

To cover the costs of operation, the farm must produce a minimum amount of lettuce. The breakeven of the system was calculated with one, two and five beds of lettuce. The number of bags to break even is shown in Table 15. A range of bags is provided to estimate the maximum amount of bags that could be produced and a realistic amount of bags that could produced after accounting for non-packable lettuce. The values were computed based on production yield statistics provided by Agroponicos (See Appendix J).

Table 15: Weekly breakeven of 1, 2 and 5 beds of lettuce.

	Bags to Breakeven	Total Bags	% of Total Bags
1 Bed	119	120 - 138	86% - 100%
2 Beds	135	240 - 276	49% - 56%
5 Beds	248	600 - 690	36% - 41%

As seen in Figure 15, growing one bed of lettuce is not profitable because the bed may not produce enough bags to break even. Two beds are able to cover the costs since the only increases in expenses are transportation, supplements and packaging. Five bed systems are capable of breaking even based on the amount of bags produced from a harvest. Table 16 indicates the estimated weekly, monthly and yearly margins, as well as the payback time in years, needed to pay back the initial investment without any salaries being paid.

Table 16: Weekly, monthly, yearly margins and payback of lettuce.

	Weekly	Monthly	Yearly	Payback
5 Beds	$947	$4,734	$49,400	2.7 years
2 Beds	$282	$1,409	$14,704	9 years
1 Bed	$1	$7	$78	36.7 years

A commercial aquaponic system running five beds of lettuce will have a quicker payback period than one or two beds of lettuce (Table 16). If salaries are paid, the payback period would take longer. On the other hand, if all margins are distributed as salaries, then the two main employees would each gross $24,700 (5 beds), $7,352 (2 beds) or $39 (1 bed) annually at most.

Lettuce was selected by the company as the main crop because it could be harvested weekly, has a huge market, and is relatively easy to grow. Agroponicos stated the lettuce was produced to cover the costs of the system and not to make a large profit. Thus, changing the types of produce grown may make the system more profitable.

Chive Production

Table 17 estimates the amount of expenses associated with operating a one, two or five bed system of chives on a system identical to Agroponicos. The tilapia costs include fish feed and an estimated annual replacement of 400 tilapia. The chive costs include bags and logos. The operating costs include water, electricity, chemical supplements and transportation. The fixed costs include insurance, permitting and water quality test costs.

Table 17: Projected weekly expenses of chives.

	1 Bed	2 Beds	5 Beds
Variable			
Tilapia	$20	$20	$41
Chives	$27	$53	$133
Operating	$166	$176	$361
Fixed	$11	$11	$11
Total	**$223**	**$260**	**$545**

The difference in expenses to operate one, two and five beds of chives follows the exact same logic of operating one, two and five beds of lettuce (Table 14). The only difference is the direct cost of the chives.

To cover the costs of operation, the farm must produce a minimum amount of chives. The breakeven of the system was calculated with one, two and five beds of chives. Table 18 shows the breakeven amount needed in bags of chives.

Table 18: Weekly breakeven of 1, 2 and 5 beds of chives.

	Bags to Breakeven	Total Bags	% of Total Bags
1 Bed	32	40	79%
2 Beds	35	80	44%
5 Beds	67	200	33%

As seen in Figure 18, each projected system is capable of breaking even based on the amount of bags produced from a harvest. Table 19 indicates the estimated weekly, monthly and yearly margins, as well as, the payback time, in years, needed to pay back the initial investment without any salaries being paid.

Table 19: Weekly, monthly, yearly margins and payback of chives.

	Weekly	Monthly	Yearly	Payback
5 Beds	$5,867	$29,337	$306,146	0.6 years
2 Bed	$2,347	$11,735	$122,458	1.4 years
1 Bed	$1,173	$5,867	$61,229	2.9 years

A commercial aquaponic system running five beds of chives will have a quicker payback period than one or two beds of chives and one, two or five beds of lettuce (Table 19). If salaries are taken, the payback period would take longer. On the other hand, if all margins are distributed as salaries, then the two main employees would gross $153,073 (5 beds), $61,229 (2 beds) or $30,615 (1 bed) annually at most. The money generated by growing five beds of chives may be sufficient for paying salaries, paying back the system and investing in new opportunities. Thus, growing chives may be one method of creating an economically viable aquaponic system.

As discussed in section 2.4.1 University of the Virgin Islands (UVI) Case Study, being able to sell produce to a niche market may be more difficult than growing it. With one bed of chives, Agroponicos could produce annually 6,200 lbs. of chives and with five beds they could produce 31,200 lbs. of chives. The grower has to be certain there is a market for the produce in order for producing more chives to increase profits.

4.2.4 Strength Weakness Opportunities Threats (SWOT) Analysis

A SWOT analysis stands for strengths, weaknesses, opportunities and threats for a business. Strengths and weaknesses look at how a business is currently operating, while opportunities are potential ways for a business to expand and threats are internal and external forces which may hinder progress (Osterwalder & Pigneur, 2010).

A SWOT analysis looks at all aspects of a business to determine which areas can be improved, which ventures can be investigated and how to minimize threats. The knowledge gained from the SWOT analysis will help the business develop strategies to expand or improve the organization (Osterwalder & Pigneur, 2010). A SWOT analysis for Agroponicos can be seen in Figure 28.

<table>
<tr>
<td>Strengths
▪ Availability of start-up funds
▪ Employees have training and experience in aquaponic systems
▪ Have some knowledge of which produce maximizes profits, and which have strong markets
▪ Do not need to heat system since climate is conducive for plant growth
▪ Do not need specialized skills to harvest the system. Have the specialized skills required for overseeing or managing system</td>
<td>Weaknesses
▪ No balance between providing salaries, paying back system or investing in new opportunities
▪ Low profitability on current system
▪ Skilled employees doing unskilled work
▪ Huge time commitment to harvest and package
▪ Large energy and utilities costs
▪ Packing costs are high
▪ Improper handling of lettuce causes wasted profits
▪ Might need to cool system in the summer</td>
</tr>
<tr>
<td>Opportunities
▪ Support programs:
  • Can get loans from FSA at a low interest rate
  • Bona Fide
▪ Diversified products (i.e. tomatoes, fish, fertilizer, education, consulting)
▪ New incentive from the governor of Puerto Rico to buy locally as opposed to imported food
▪ Expansion to Caguas and Juncos</td>
<td>Threats
▪ Permitting and licensing time
▪ Hurricanes may cause huge loss of profits and will need to restart production
▪ Competition with markets selling imported food
▪ Inability to sell produce
▪ Demand for organic and/or GMO crops</td>
</tr>
</table>

Figure 28: SWOT analysis of Agroponicos.

Some of Agroponicos' strengths are our sponsor's background knowledge and training in aquaponics and business, and the ability to design, finance and operate their own aquaponic business. In addition, Agroponicos had knowledge of which crops could grow in the system and yield a profit. The company struck a balance between the large and non-profitable lettuce market, and the small and profitable chives market. Another benefit is that Agroponicos is in a warm climate that is conducive to agriculture. Before the company can expand, they will have to overcome their weaknesses.

Agroponicos mentioned they have issues operating the system while attempting to expand the business. Difficulties with expanding the business are partially caused by the amount of time employees are spending harvesting and packaging the produce. The skilled employees are performing unskilled labor, such as harvesting and packaging, instead of attempting to expand the business. One potential solution would be to hire farmhands to help harvest and package. Paying for additional farmhands would require the business to start paying salaries and would reduce the profits of the business. Still, the farmhands would allow the employees to utilize their time to find new clients, future opportunities for expansion and markets for tomatoes, fertilizer and services. Another method for increasing profits would be to reduce waste with better handling of the produce and reducing the variable and fixed costs. Future opportunities are necessary for the current employees to start taking salaries, paying back the system and expanding the business.

Two opportunities for expansion are Caguas and Juncos. At Caguas, Agroponicos intends to start an educational program and construct aquaponics systems at the Botanical Gardens. Expansion to Caguas may allow the company to gain benefits from education, consulting and selling produce at the Gardens (See 4.3.1 Caguas). At Juncos, Agroponicos intends to build a large-scale aquaponic system at the Rehabilitation and Empowerment Center. The system will provide employment opportunities and training to the rehabilitated drug addicts. Most of the profits would be derived from selling the produce to schools, prisons, nursing homes and the community. The mayor of Juncos, having served for over 16 years, has suggested using his prominence in the municipality to promote the produce and seek governmental support from the governor (See 4.3.2 Juncos). To finance the projects, Agroponicos has access to additional programs and resources, such as the U.S. Department of Agriculture (USDA) Farm Service Agency (FSA), the Small Business Administration (SBA), and the Puerto Rico Department of Agriculture (PRDA). More information on resources and programs can be found in section 4.3.3 Resources and Programs. Although financing the system is one major obstacle, Agroponicos has additional internal and external threats.

One of the first threats experienced by Agroponicos was the permitting and licensing process because of the time needed for approval. For future expansion, it is imperative to complete the paperwork quickly and correctly and ensure all guidelines are followed. Although it might take longer to start producing goods, the system or business will not run into legal issues or penalties. Once the system begins operating, there are additional threats that may arise.

Another threat is that Agroponicos might not be able to sell all of their produce. This inability could be caused by the employees not having enough time to sell the produce, competition offering better prices or a lack of interest in organic or GMO-free produce. Lastly, hurricanes or other natural disasters could destroy crops and the farm. Agroponicos currently has no insurance or resources to cope with damages caused by natural disasters.

4.2.5 Recommendations

In order to improve the profitability of Agroponicos, revenue has to be increased and expenses have to be reduced. All recommendations are based on numbers provided by Agroponicos and are based on five beds of lettuce and one bed of chives.

Reducing Utility Costs

The biggest expense for the farm is the cost of electricity since all machinery is electrically driven for all hours of the week (24/7). The machinery includes two air pumps, two water pumps and an air-conditioner unit. The list of recommendations includes:

- The office currently operates as a walk-in refrigerator and is large enough for packaging, storing and office space. The room is insulated, but the double-doors of the trailer are not sealed properly. To improve energy efficiency a divider should be installed between the double doors and the interior to ensure a better seal and a smaller cooling space. No extensive work should be done on the office if a packaging center can be found in Caguas (See 4.3.1 Caguas).
- The air-conditioner should not be in use if there is no produce or employees at the farm. The quicker the produce is sold, the quicker the air-conditioner can be turned off. The air-conditioner should be set to a temperature and should be set to shut off at said temperature.
- Puerto Rico Green Energy Fund has funds available for individuals, governmental or private, who seek renewable energies. Small-scale projects, considered Tier 1 projects, cover solar panels and small wind turbines. Specific details on the pricing are included in Appendix O. Before pursuing this investment, an engineering firm should be consulted to determine the power requirements of the farm and if solar

panels, wind turbines, or some combination of the two, is the best means to reduce energy costs (See 4.3.3 Resources and Programs for more support for green energy).

Increasing Profits from Lettuce

A weight measurement of one harvest found that 87.21% of the lettuce harvest could be packaged, while 12.79% was deemed unacceptable for packaging. During the harvest, the lettuce can become weakened due to the water and may be damaged during harvesting and packaging. If more care is taken with harvesting and packaging, then there is potential for an additional weekly profit of $237 or an annual profit of $12,352.

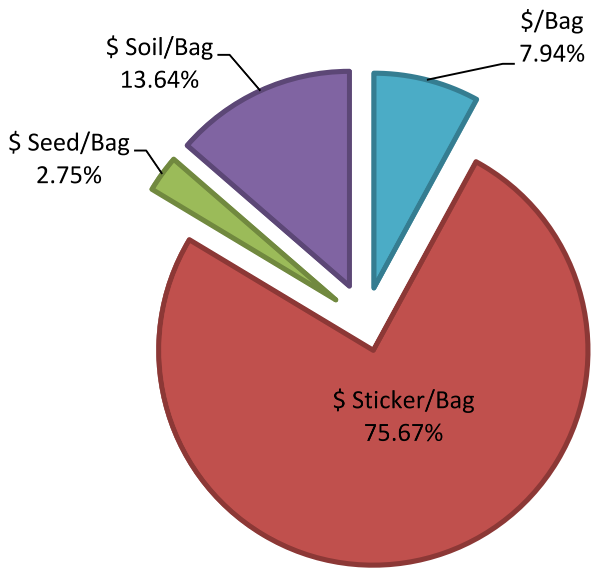

Figure 29: Breakdown of direct expenses for 1 bag of lettuce.

As production increases, so do the expenses of producing the lettuce. Figure 29 is the breakdown of the direct expenses for one bag of lettuce without including labor. The biggest contributor to the cost of packing is the cost of the sticker on the bag, which contains the company's name and brand logo. With five beds of lettuce, the weekly direct expenses for harvesting and packaging account for 32% of the total weekly expenses. One suggestion would be to get pre-printed bags that include all of the logos. For the pre-printed bags to be cost-competitive, the cost of the logos and bags must be less than $0.22 per bag. Another alternative would be to purchase cheaper stickers. In addition, to decrease the time to harvest can be accomplished by cutting the rafts into a zigzag pattern to allow for one person to perform the lifting.

Increasing Profits from Chives

Not much data were collected on harvesting the chives, but the same sticker and bag expenses as lettuce were applied. As shown in Figure 29, expenses can be reduced by reducing the cost of the logos and bags to less than $0.22 per bag.

Reducing Deficit from Tilapia

Currently, 8 lbs. of fish food are fed daily to the 1,200 tilapia to ensure the plants have enough nutrients. After considering the cost of purchasing fingerlings ($250 annually) and fish food ($1,879 annually) and the profit from the fish ($400 annually), the company has a deficit of $1,728 annually. To cut down on food costs, the Puerto Rico Department of Agriculture and the Aquaponics Institute have suggested supplementing the fish feed with lettuce. To ensure enough nutrients are making it into the system, a 50% mix of lettuce and fish food should be considered. The fish feed would require 4 lbs. of non-packable lettuce and could be supplemented by the 11 lbs. of wasted lettuce produced by four rafts. Nitrate levels, fish and plant quality should be checked more frequently to ensure the crops are not being damaged. The economic benefits of the mixed feed would lead to fish feed expenses being reduced by 50% and reduce the overall deficit caused by the fish to $789.

Increasing Profits from the Sludge Tank

A market and clients for the fertilizer should be found to more effectively use the by-products of the farm. Markets may include golf courses, hotels and landscaping businesses.

Increasing Profits from Services

The employees of Agroponicos have voiced concerns that they are having difficulties expanding their business due to the amount of time they spend harvesting. To better use the time of the current employees, it may be worthwhile to look into hiring farmhands to complete the unskilled labor work. Under the Bona Fide Program, the Commonwealth of Puerto Rico will absorb up to 75% of the costs of paying farmhands and provide a $200 Christmas bonus (See 4.3.3 Resources and Programs for more information about the Bona Fide Program). A farmhand can be employed for $5.75 per hour and the payments will be reimbursed to the company after three months. It was estimated that it would take 32.5 hours per week to harvest and package all six beds and would annually cost the company $2,438 after the subsidy. Hiring farm hands saves the skilled labor 32.5 hours per week, which can then be spent on expanding the amount of clients, investigating new markets for the tomatoes and fertilizer, expanding the company to other locations and pursing other opportunities.

4.3 Opportunities for Expansion

What available resources and programs are there for the establishment, operation, improvement and expansion of aquaponic systems?

Agroponicos is considering expanding to Caguas and Juncos. Expansion to Caguas may occur at the Botanical Gardens, while expansion to Juncos may occur at the Rehabilitation and Empowerment Center. Both sites have the potential to benefit Agroponicos and the municipalities.

4.3.1 Caguas

The mayor of Caguas has implemented a strategic planning unit to fulfill the growing aspirations of the municipality. Caguas' mission statement is to creatively and effectively provide the people of Caguas with quality service, through the optimal use of its resources and the active participation of its citizens. The strategic planning unit is proposing the Sustainable Food Initiative to help address unemployment, poverty and the food crisis faced by the community.

The mayor of Caguas believes in governing with the people, not for the people. To effectively provide for his community, the mayor has implemented a six-part sustainable development plan. The plan will focus on the culture of his people, the logistics of production and the transparency of his government. The sustainable development plan for Caguas is outlined on a plaque near the center of town (Figure 30).

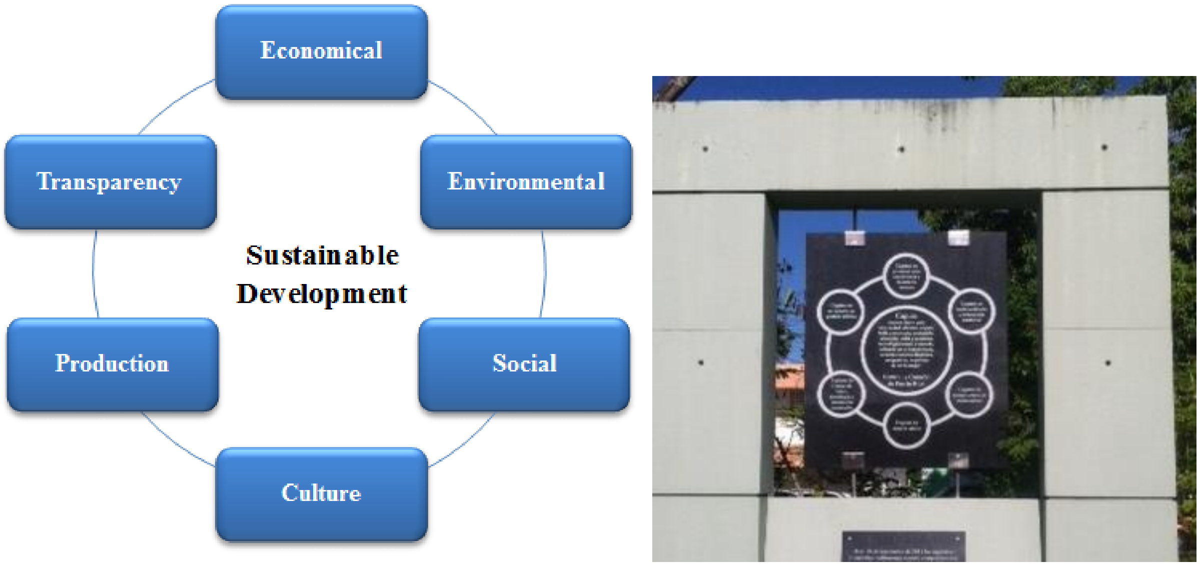

Figure 30: Sustainable development for Caguas (English translation and summary on left).

The Sustainable Food Initiative will incorporate all aspects seen in figure 30. The strategic planning staff believes that sustainable and innovative agricultural technologies can improve the economy, job creation, healthy eating and ecological restoration and preservation, of the municipality. To achieve these goals, the Sustainable Food Initiative will include several private and public stakeholders, and the community.

Botanical Gardens

Located in Caguas, Puerto Rico, the Botanical Gardens offer a potential site for the expansion of aquaponic systems and Agroponicos. The mission statement of the Botanical Gardens is to become internationally recognized as a center of education and natural, cultural and sustainable resources. To accomplish these goals, the current site director, Omarf Ortega, wishes to increase annual visitors, profits and attractions.

Background

The Botanical Gardens opened in 2007. Omarf Ortega, the current site director, has been managing the Gardens for almost two years. The Gardens were originally a sugar cane plantation and then evolved into a dairy farm, before being purchased by Caguas to prevent the construction of residential homes. The entire site consists of 60 acres with walking trails covering 32-33 acres. In the future, Ortega wishes to expand the amount of trails for walking, biking and horseback riding. In addition, the Gardens offer the Viva Program, where individuals can take part in yoga, photography, arts and crafts.

Currently, the site obtains most of its income from admission, but these profits are only sufficient for maintaining the grounds. Other income is derived from tours, private events, the restaurant and the rent from a small, privately-owned store located in the Gardens. In the past, the Gardens included a commercial hydroponic system. Ortega claims the system was unsuccessful, due to poor management and lack of contractual agreements.

Despite previous setbacks, the Gardens are looking to fill the vacant greenhouses with educational hydroponics system, contracted through Mech-Tech College. The Gardens would not invest capital in the system, but would gain revenue from the contract. However, no agreement has been reached, despite months of discussions. Thus, Agroponicos may have a chance of expanding to and within the Botanical Gardens.

Opportunities and Risks

The establishment of aquaponic systems at the Botanical Gardens may benefit Agroponicos, the Botanical Gardens and the community of Caguas.

Agroponicos

The Botanical Gardens have agreed to provide Agroponicos with space to give educational presentations and a greenhouse to build aquaponic systems. The primary goals are to offer hands-on education and produce to the community. To gauge community involvement, the company intends to offer short workshops on aquaponics and samples of their produce to visitors. The greenhouse will act as a practical classroom and will include DWC and MFG minisystems. The cost and size of these systems would be reduced, as compared to Agroponicos' DWC system, because they must fit inside the existing greenhouse. The greenhouse provides level land and is equipped with the necessary water and electrical infrastructure. If the company is successful, there are additional greenhouses that could be rented. The long-term goals would include an aquaponic store that would sell necessary materials, components and services for individuals to build their own systems. At the Botanical Gardens, Agroponicos have a new location to sell produce and offer services.

There are risks associated with starting an aquaponic system at the Botanical Gardens. One of the risks is that there are only verbal contracts. It was proposed that Agroponicos would rent the land from the Botanical Gardens and pay 5% of the sales from their produce to the Gardens. There are also no agreements on who will provide the labor to maintain the system when classes are using the systems. Additionally, Agroponicos must be able to invest time and capital into constructing the systems, ensuring the systems are running smoothly and the produce are being sold. Lastly, there must be a steady source of income from selling services and produce or else the project will not be economically viable.

Botanical Gardens

The benefits of housing Agroponicos in the greenhouses are that the Botanical Gardens are renting lands that would otherwise be vacant, providing an additional attraction to the garden, providing education and making profit from the produce. Although, the Gardens would not be investing money in the systems, they could lose prestige if the site fails. The Botanical Gardens and Agroponicos must create a written contract before pursuing the venture.

Caguas Community

An aquaponic system in Caguas has the potential for benefiting the entire community. Under the terms of the Sustainable Food, Agroponicos would qualify as innovate, sustainable form of agriculture and could produce healthy produce for the municipality. In the community, Agroponicos could utilize a lab and a distribution center. The lab contains packaging equipment, which could be used to reduce the time and cost of packaging produce. In addition, Agroponicos could utilize the distribution center to reach new markets and to reduce the time and cost of distributing goods. Also, the distribution center can dehydrate goods, such as chives. Another goal of the Initiative is to capitalize on the needs of the community. For instance, the Initiative could help connect Agroponicos with local businesses or individuals who need specific crops gown locally.

Summary

The major benefits and risks of expanding to the Botanical Gardens are shown in Figure 31. The list is comprised of information we obtained during our interviews in Caguas.

Benefits:	Risks:
▪ Botanical Gardens has existing greenhouse ▪ Will not have to pay for land movement ▪ Can sell produce to restaurant on site, to a farmers' market and use a distribution center in Caguas ▪ Can use lab in Caguas to package produce ▪ Opportunities with for education, consulting, vegetarian deli and aquaponic store ▪ Can easily get the licenses and permits ▪ Can get community involved and help the Botanical Gardens ▪ Advertisement from the Gardens in newspaper and television ▪ Located near Agroponicos	▪ History of rapid changes in management ▪ May have a limited number of customers ▪ Smaller system may decrease the construction costs, but may produce small amount of revenue from sales ▪ Will have to harvest, package and sell additional produce ▪ Failure of previous hydroponic system ▪ No agreement on rent, building or labor ▪ No tangible funding ▪ Requires manpower from Agroponicos

Figure 31: Benefits and risks of expanding to Caguas' Botanical Gardens.

4.3.2 Juncos

A few of the major problems faced by the municipality of Juncos are unemployment, housing, crime and drug addiction. The mayor of Juncos is attempting to address unemployment and drug addictions by expanding the municipal Rehabilitation Center.

Rehabilitation and Empowerment Center

The municipality has already invested $2.5 million into the Rehabilitation and Empowerment Center, and is investing an additional $150,000 grant to build offices and a $3 million loan for land, clinics and administration. The mayor explains he would admit any individual who is looking for help, even if the person cannot afford it.

Background

The mayor of Juncos claims that the standard 21-day treatment for drug addiction is not enough time to rehabilitate the patients. At his Center, the mayor intends to not only give patients treatment, but also give them the ability to remain at the Center to regain control of their lives. After completing the treatment, the individual would then decide if they want to remain in the Center, to live and work, or venture back into the world.

The Center is currently expanding its facilities by constructing additional housing and office space. In addition, the Center is encouraging additional companies to build on the site and may even offer tax emptions. The mayor hopes to appeal to outside bossiness and open a restaurant, bakery, horse stable, paddle boats, pasta factory and an extensive aquaponic system. He intends for the businesses to be open to both the public and the patients to help create a sense of community. The patients of the Center would then have the option to work at with the various businesses, learn skills and receive a subsidized amount of money.

For Agroponicos, the Center would provide land and tax exemptions, and could produce large amounts of produce. The main purpose of the systems would be on crop production. The proposed extensive aquaponic systems would incorporate eight of our sponsor's DWC system. Construction of the systems would progress in groups of two and continue until all eight are completed. Since a portion of the land will be provided for our sponsor, it is Agroponicos' responsibility to provide the funding for the actual construction of the extensive aquaponic system.

Funding for the extensive aquaponic system will require grants, which our sponsor's lawyer is investigating. One potential source of funding requires submitting a formal proposal under Law 1 of 2013, Employment Now. By proposing a project that complies with the goals of Employment Now, our sponsor has the potential of obtaining a letter of endorsement, which would provide funding and incentives for their project. In addition, the lawyer is investigating the Puerto Rico Science, Technology & Research Trust for additional funding. If the project proposal is approved, there will be money available for building at Juncos.

Opportunities and Risks

The benefits of expanding aquaponics to the Center are that labor would be provided and subsidized. Of the expected 150 patients the Center could serve, approximately 30 would be available to operate the aquaponic system. Although a supervisor with knowledge of the necessary operation and maintenance of the system would have to be present, all harvesting and packaging could be completed by the patients.

Aquaponic systems would provide another dimension to the Center. Although the systems are geared towards the commercial production of produce, the systems could provide a sense of community involvement, hands-on experience and education. Produce grown in the system could be marketed, with the support of the mayor, to the on-site establishments and to local schools, elderly centers, supermarkets and prisons in Juncos.

Risks associated with the expansion are determined by the performance of the Center and Agroponicos' ability to obtain sufficient grant money for the construction of the aquaponic systems. If the Center does not reach completion, the extensive aquaponic system may have no labor force and the systems may not be utilized. If no grant money is available, the physical aquaponic systems cannot be constructed.

Summary

The major benefits and risks of expanding to the Rehabilitation and Empowerment Center are shown in Figure 32. The list is comprised of information we obtained during our interviews in Juncos.

.Benefits:	Risks:
▪ Have employees that will be subsidized by Rehabilitation and Empowerment Center ▪ Permits and licenses can be approved quickly ▪ System will be used to fulfill a community need and provide jobs ▪ System will be built in pairs of two until all eight are completed ▪ Produce will be sold to new markets: schools, prisons and retirement homes ▪ Large profits if produce is sold ▪ No taxes, provided land and land movement ▪ Mayor can help promote the purchase of the produce ▪ More opportunities for Agroponicos to expand	▪ Need additional funding to build ▪ Rehabilitation and Empowerment Center must succeed for the aquaponic system to succeed ▪ Can potentially lose huge amounts of money if the system or Center fails ▪ Have to harvest, package and sell additional produce ▪ Requires manpower from Agroponicos

Figure 32: Benefits and risks of expanding to Juncos' Rehabilitation and Empowerment Center.

4.3.3 Resources and Programs

In addition to exploring opportunities for expansion in Caguas and Juncos, we investigated resources and programs for the establishment, operation, improvement or expansion of aquaponic systems and businesses in Puerto Rico. Potential sources of support were investigated at the U.S. Department of Agriculture (USDA), the Small Business Administration (SBA) and the Puerto Rico Department of Agriculture (PRDA). Business and management resources were investigated at the SBA. In summary, we found that the USDA offers loans, grants, incentives, organic certifications and risk management programs; the SBA offers loans for small businesses; the PRDA offers the Bona Fide Program to improve local agriculture and the Puerto Rico Small Business and Technology Development Center offers resources for businesses.

USDA Farm Service Agency (FSA) Loans

The USDA FSA's Farm Loan Programs offer direct loans and loan guarantees to farmers. Two loans that may be helpful to our sponsor and individuals looking to construct an aquaponic system are the Ownership Loans, which are used for purchasing lands or constructing farms, and the Operating Loans, which are used for buying materials, equipment, or paying operating bills. After conducting interviews with the FSA loan program manager, we learned aquaponic farms are covered by the program.

For both the Ownership Loans and Operating Loans, the FSA provides options for direct loans or guaranteed loans. The direct loans may be suitable for startup farms or small farms because the loans offer up to $300,000 at low interest rates. As of April 2013, the interest rates are 1.25% - 5%. The guaranteed loans may be applied to loans of more than $300,000 and are offered by commercial institutions at interest rates, as of April 2013, of about 5% - 10%.

To be eligible for the Ownership Loans and Operating Loans, the FSA requires applicants to currently own or lease a farm and to have at least three years of experience operating a farm. To prove the three years of experience, the applicant can provide farm records or training certifications. In addition, the FSA offers loans for beginner farmers and socially disadvantaged farmers that have fewer eligibility requirements.

Small Business Administration (SBA) Loans

In addition to loans offered by USDA Farm Service Agency, we investigated loans and resources of the SBA. The SBA offers loans and loan guarantees to small businesses and startup companies. In general, SBA loans are much larger than the loans of the FSA and have higher interest rates. Through our interview with the SBA, we learned their loans are not advisable for small, agricultural businesses. In addition, we learned a well-formulated business plan must be developed before an individual can apply for the loans. The SBA recommended the Puerto Rico Small Business and Technology Development Center as a resource for helping beginning businesses develop a business plan and manage their business.

USDA Natural Resources Conservation Service Incentives and Grants

In addition to the loans, we searched for grants and incentives specifically for agriculture. The USDA Natural Resources Conservation Service (NRCS) provides financial assistance and technical assistance to improve energy, water, and soil conservation and to preserve the surrounding environment of the farm. The four programs, which are not inclusive of all support programs, that may apply to aquaponics are the Environmental Quality Incentives Program (EQIP) National On-Farm Energy Initiative, EQIP Organic Initiative, NRCS Conservation Stewardship Program and NRCS Conservation Innovation Grant Program. Detailed information on eligibility, types and amounts of incentives and offering cycles of the programs can be found in Appendix K.

The EQIP National On-Farm Energy Initiative provides up to $450,000, over a six year period, and technical assistance to farmers who want to invest in energy conservation (U.S. Department of Agriculture Natural Resources Conservation Service, 2013a). The funds can be used to purchase green energy technologies, such as, solar panels or wind turbines.

The EQIP Organic Initiative provides annually up to $20,000 and technical assistance to farmers who need assistance in transitioning to organic farming or improving organic techniques (U.S. Department of Agriculture Natural Resources Conservation Service, 2013b). Farms can utilize this program to become organic, to improve pest control or to conserve water resources.

The NRCS Conservation Stewardship Program provides funds to help farms conserve natural resources, such as energy, water, and soil (U.S. Department of Agriculture Natural Resources Conservation Service, 2012). The funds may be used to increase conservation practices or technologies and the amount depends on the quality of the conservation effort. However, since the fund is provided after evaluating the performance of conservation, producers must make the initial investment with no guarantee for full reimbursement.

The NRCS Conservation Innovation Grant Program provides up to $30,000 for farmers who wish to adopt innovative conservation approaches or technologies to improve nutrient management practices or energy conservation (U.S. Department of Agriculture, 2013). The grant is awarded on a competitive basis and requires a full proposal.

USDA Rural Development

In addition to the grants and incentives from USDA Natural Resources Conservation Service, we also found grants offered from the USDA Rural Development. The USDA Rural Development provides loans and grants for support rural communities to improve economic opportunities, infrastructure, the environment and the sustainability of local agriculture (U.S. Department of Agriculture Rural Development, 2013). Most of the grants provide funds for companies and projects that promote employment, professional education, or business opportunities in rural areas. Thus, these grants can be a potential source of funding for expanding aquaponics into Puerto Rico's rural regions.

Puerto Rico Department of Agriculture Bona Fide Program

In addition to the monetary support provided by USDA and SBA, we were informed by our sponsor of the Bona Fide Program offered by the Puerto Rico Department of Agriculture. Bona Fide is granted to a farm as early as their first year of business and must be renewed after their first year with proof that the farm is in good economic standing. Bona Fide provides certified farmers a number of benefits, including a 90% exemption on the income tax, a 100% exemption on the property tax, a 100% exemption on the municipal tax, a 100% exemption on the excise on agricultural equipment, a 100% exemption on the sales tax on agricultural materials and an incentive for subsidized labor as mentioned in section 4.2.4 Strength Weakness Opportunities Threats (SWOT) Analysis. The benefits of the Bona Fide Program can be applied to Agroponicos and aquaponic farmers.

USDA Organic Certification

In addition to resources and programs, we researched the USDA Organic Certification for aquaponics, which may provide more opportunities and support. By interviewing Puerto Rico Department of Agriculture and searching online, we learned that any farm with more than $5,000 annual income is eligible to apply for USDA organic certification (Baier, 2012). By studying the application and fee structure, we learned that the USDA Organic Certification has a complicated and costly application process due to strict federal regulation of organic farming (Coleman, 2012).

Obtaining the USDA Organic Certification brings both costs and benefits for individual farms. The certification will allow the farm to label their certified products as organic, which may lead to improved marketing and access to resources such as the Environmental Quality Incentives Program Organic Initiative (See Appendix L), but may come with a large fee. After the first-time application, a certified farm has to provide an annual update and pay a fee for the certifying agent to renew the certification. The certification process and the cost depend on the complexity of the farm, which is determined by the certifying agent. To help reduce the cost of the certification, the USDA offers the National Organic Certification Cost-Share Program (NOCCSP) which reimburses 75%, or up to $750, of the certification fee.

As a result, a farm will need to weigh the costs and benefits before deciding to obtain the USDA Organic Certification. The cost can be estimated by consulting with a certifying agent and the benefits can be determined by if the certification will improve sales or access to resources. Still, if the process it too expensive for a farmer, they may instead opt to market their products as “pesticide-free,” “GMO-free,” or “Made in Puerto Rico.” Detailed information on the application process, labeling regulations, the National Organic Certification Cost-Share Program, and fee structure of a certifying agent can be found in Appendix L.

Risk Management Programs

Besides having resources and programs to fund a farm, a business must also be able to conquer risks. Risk management is critical to agricultural businesses, especially in regions where unexpected losses could be caused by natural hazards. As mentioned in section 2.1.1 Natural Factors Impacting Agriculture, hurricanes pose a threat to Puerto Rico's people, economy and agriculture (Boose et al., 2004).

To counter risks caused by natural hazards, a few risk management programs are available in Puerto Rico, including the Federal Crop Insurance (FCI), the Noninsured Crop Disaster Assistance Program (NAP), the Supplemental Revenue Assistance Payments Program (SURE), the Emergency Loan and the Disaster Set-Aside service. The FCI is the most basic risk management program for crops. The NAP and the SURE are offered by the Farm Service Agency to cover the loss of most uninsurable crops. In cases where the FCI, NAP, and SURE cannot provide sufficient support, farmers can consider the Emergency Loan offered by the Farm Service Agency. Additionally, if farmers who suffer losses from natural hazards cannot make payments to their FSA loans on time, the Disaster Set-Aside service can help producers reschedule their payments. Detailed information about the nature, eligible producers, eligible losses, coverage, and costs of the risk management programs can be found in Appendix M.

4.3.4 Suggestions and Recommendations for Utilizing Support Programs

General suggestions and recommendations were made after analyzing the resources, programs and case study. Further information on the resources and programs can be found in Appendix N.

General Suggestions and Recommendations

Business Plan, Management and Marketing:

- The Puerto Rico Small Business and Technology Development Center can be utilized by individuals who need help with business plans, management, marketing or general business advice. Since a business plan is required when applying for loans from Farm Service Agency and Small Business Administration, it is advisable for Agroponicos or individuals to develop a business plan.

Establishment, Operation and Improvement:

- The Farm Service Agency's loan programs offer monetary support for buying land or equipment, or paying for farm operating costs. This program can be applicable for individuals looking to establish, operate or improve an aquaponic system, but are unable to finance the system.
- The USDA Natural Resource Conservation Services (NRCS) offers grants and incentives for technologies and practices to improve the efficiency of using water and energy. These programs can provide help to individuals looking to reduce energy and water consumption.
- We recommend Bona Fide to aquaponic farmers because of the wide variety of benefits.
- The USDA Organic Certification may improve the economic viability of aquaponic businesses by providing access to more resources and improved marketing. Since the certification comes with variable fees, the benefits of the certifications may vary due to different locations and the demand for goods labeled "organic."

Expansion:

- For the expansion of aquaponic businesses, the Farm Service Agency direct loans may be utilized due to the moderate amounts and low interest rates.

- For the expansion of aquaponic businesses in rural areas, the USDA Rural Development grants may be utilized as a potential source of funding.
- For aquaponic businesses that have a well-formulated business plan, are financially stable and are looking to expand, the large loans with high interest rates offered by Small Business Administration may be utilized as a potential source of funding.

Risk Management:

- All aquaponic businesses in Puerto Rico should have a risk management plan, that addressees crop and facility losses caused by natural hazards. For crops, the producers should purchase the Federal Crop Insurance (FCI) for all insurable crops and register the noninsured crops with the Noninsured Crop Disaster Assistance Program (NAP). If the FCI or NAP does not provide enough monetary support during a disaster, the farmers can apply for the Emergency Loan offered Farm Service Agency. To be prepared for the disasters, the farmers should have an estimate of potential losses.

Suggestions and Recommendations Specifically for Agroponicos

Operation and Improvement:

- Agroponicos is currently renting the 1.2 acre farmland at a rate of $400 per month. The Farm Service Agency's direct Ownership Loan is one potential means to purchase the land since Agroponicos is eligible, the loan is large enough to buy the farmland and the interest rates are low. The loan would be economical if the monthly cost of paying back the loan is lower than the monthly cost of renting the land and if the loan is paid back quickly. The principle on the land would be reduced from the rent that is already been paid.
- The electricity expense is about 41% of the total expenses of Agroponicos. Therefore, the grants and incentives offered by USDA Natural Resources Conservation Service may be

used by Agroponicos to reduce electricity costs by adopting technologies, such as solar panels or wind turbines.

The USDA Organic Certification:

- To determine if the organic certification is affordable for Agroponicos, we estimated the certification fee per year for our sponsor's 1.2 acre farm using the fee structure of Quality Certification Services (QCS) (Appendix L). QCS is a certifying agent which provides UDSA organic certification in Puerto Rico. According to our interview with the Puerto Rico Department of Agriculture, the operation complexity of Agroponicos would be between simple and moderate. Since Puerto Rico is a small island, additional expenses, such as travel and lodgings for the certifier, were not included in the calculations. In addition, the $50 first-time application fee was not included. As illustrated in Table 20, the annual certification fee should be affordable to our sponsor and similarly small aquaponic businesses after 75% of the cost is recovered from the National Organic Certification Cost-Share Program.

Table 20: Annual fee estimation of Agroponicos' 1.2 acre farm.

Option	Annual Fees	Assessments	Inspection	Total Fee	After 75% Reimbursement
Grower Certification OPTION 1: Standard Grower Certification	$150 (0-20 acre)	$7300 (estimated monthly gross profit) *12*0.5% =$438	$275 (inspection fee) + $25 (processing fee)	$888	$888*0.25 =$222

Risk Management of Agroponicos:

- We estimated the losses of crops caused by a hurricane for Agroponicos based on an inventory of five beds of lettuce and one bed of chives, as illustrated in Figure 33. The lettuce is grown on a 6-week cycle, while the chives are grown on a 4-week cycle. As mentioned in section 4.2 Financial Analysis of Agroponicos, Cosecha de Puerto Rico, Inc., the revenue of a raft can be calculated for lettuce and chives. By knowing the revenue of a full raft, we can estimate revenue of the non-harvested beds by using a weighted fraction. For example, a bed of lettuce that has been growing for five weeks can be estimated as $\frac{5}{6}$ of a fully grown raft, while a bed of chives growing for two weeks can be estimated as $\frac{2}{4}$. Thus, the total revenue in the growth beds before a harvest is approximately $10,000. Considering the amount of loss and the frequency of hurricanes in Puerto Rico, we recommend our sponsor to register for the risk management programs introduced in section 4.3.3 Resources and Programs.

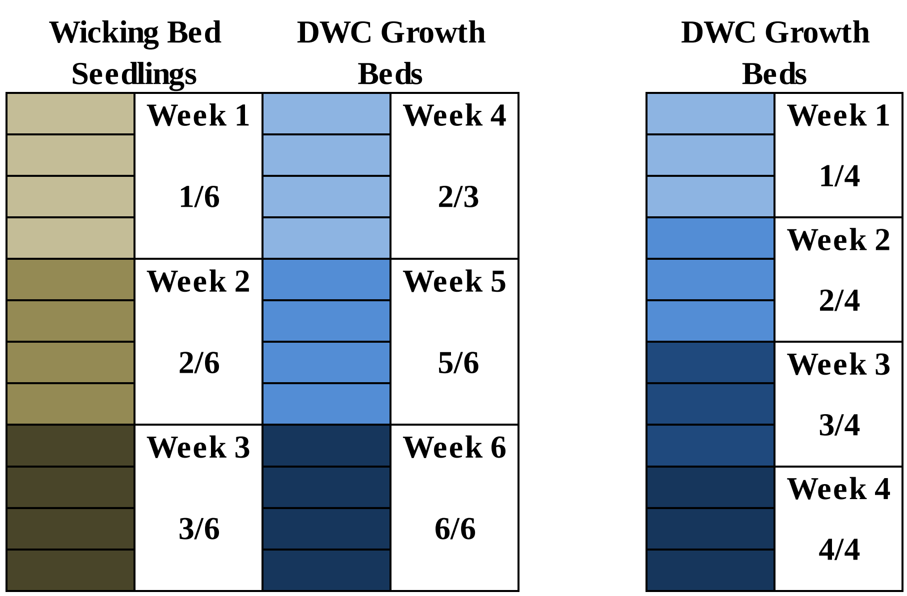

Figure 33: Pictorial description of revenue of lettuce and chives.

Conclusion

Profitand Labor Recommendations

The case study and financial analysis determined that Agroponicos has the skills and knowledge to successfully maintain and operate their aquaponic system, but are currently limited by its low profitability and lack of labor. One of the major hindrances to Agroponicos is that they can currently either pay salaries or pay off the initial investment; but not both. In order to expand, Agroponicos must be able to address their issues with profits and labor. Our following suggestions are a means to diversify profits and increase manpower:

Utilize incentives from the Puerto Rico Department of Agriculture. The Puerto Rico Department of Agriculture will subsidize up to 75% of the salaries of agricultural workers. By using this incentive, Agroponicos can hire part-time labor to reduce the time the current employees spend on harvesting and packaging produce. Although the salaries of the part-time labor will come at a cost, the time saved for the owners can be applied to other revenue-generating business ventures.

Utilize loans and grants from the USDA. Agroponicos may utilize the loans from the USDA Farm Service Agency for establishing, operating, improving or expanding their business. Specifically, the loans could be used for hiring part-time labor. In addition, Agroponicos may utilize grants from the USDA Rural Development if the company plans on establishing new farms or providing aquaponic education in rural areas, or processing their produce into other products.

Utilize opportunities at Caguas. Establishing aquaponic systems in Caguas provides opportunities for Agroponicos. The Botanical Gardens have offered land and one greenhouse for Agroponicos to host educational workshops. In addition, the Gardens may provide the manpower to maintain the systems when not utilized during the workshops.

The mayor of Caguas' Strategic Planning staff suggested Agroponicos utilize the distribution center and lab in Caguas. The Caguas' Sustainable Food Initiative may help find additional markets for Agroponicos, both domestically and in the continental United States. If the rates charged for the use of the packaging machinery in the lab are too high or the prices offered by the distribution center are too low, then Agroponicos may opt to hire their own workers and continue to independently sell their produce.

Utilize opportunities at Juncos. The proposed aquaponic systems in Juncos would incorporate several large systems into the Rehabilitation and Empowerment Center. Aquaponics may be used as employment opportunities for individuals with prior drug addictions and help them regain power and control of their lives. The labor to harvest the system would be provided and subsidized through the Center. Additional markets for the produce may include surrounding schools, nursing homes, prisons and other community facilities.

Adapt and expand to the demands of the market. Agroponicos should adjust the prices and types of crops with the market demand to improve profits. In addition to finding markets for tomatoes and fertilizer, the company may also consider searching for markets for crops previously tested in their system.

Agroponicos should continue expanding to new markets. The skills of the employees could be utilized to offer services, such as education and consulting. Although these services could increase the profits of the farm, Agroponicos must still be able to operate and maintain their system.

Business Recommendations

The owners of Agroponicos have proposed many ideas about the role of aquaponics and their business in Puerto Rico. Because the company is new, the owners have not been able to develop a unified direction for the business. Although the owners have the skills and may have the resources to pursue their ideas, they have not provided a clear method to achieve them. The following are suggestions for organizing the ideas and goals of the company:

Define the Mission and Goals of the Company. Before Agroponicos can move forward with their business, they must decide on a mission and goals for the company. The company has mentioned they are currently looking to expand to Caguas and Juncos, offer aquaponic training, open an aquaponic store, open a vegetarian deli, purchase a van and install solar panels. With three members of the business having potentially different goals in mind, the owners should sit down and discuss short-term and long-term goals for their business. The owners should establish goals to improve their farm and to expand to Caguas, Juncos or other locations.

Develop a Business Model. A business model is a written plan that a company utilizes to guide them in their effort to generate a profit and achieve their mission. It usually describes the reasoning behind how that organization creates and captures value in any product that is sold. It is important for businesses to have a business model, because they may otherwise invest more than they can afford. Conversely, they may under-invest and may not effectively utilize opportunities to expand. If a company does not evaluate what opportunities to take or what choices to make, their business will be less effective.

Our sponsor, Agroponicos, plans on expanding into Juncos and Caguas while providing services in education and consulting. In order to expand, the owners must choose a business structure that will help them obtain sufficient start-up capital and limit the amount of liability of each owner. Taking these two factors into account, the company could be split into two separate businesses. One of the two businesses could be for-profit while the other business, which could focus on education, could be a non-profit organization. A detailed analysis of different business structures can be found in Appendix Q.

Deliverables

This report and an additional Excel spreadsheet have been provided to Agroponicos. Within these documents, our sponsors will find the following:

1. A delineation of the process to establish a commercial aquaponic system in Puerto Rico.
2. An analysis of initial costs and possible cost reductions for future systems.
3. A financial analysis with recommendations to increase production and profits, and decrease expenses.
4. An Excel spreadsheet to estimate profits, expenses and inventory, and calculate the breakeven for various projections of future systems.
5. A SWOT analysis of Agroponicos.
6. An analysis for the opportunities and risks when expanding to Caguas and Juncos.
7. Information on resources and programs for establishing, operating, improving and expanding an aquaponic system.

The Economic Viability of Aquaponic Systems in Puerto Rico

Although Agroponicos is currently limited by their profitability, they are working to establish themselves as the central aquaponic organization on the island and as a resource for education, supplies and consulting. With this project, we learned that being able to operate a profitable aquaponic system depends on the type of crops grown, the size of the market and the ability to expand to new locations and markets. Thus, from our projections and research we conclude that aquaponic systems can be economically viable in Puerto Rico.

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Appendices

A. Our Sponsor: Agroponicos Cosecha de Puerto Rico, Inc.

Our Sponsor, Agroponicos, Cosecha de Puerto Rico, Incorporated owns a 1.2 acre farm located near San Juan, Puerto Rico. Constructed in 2011, the farm is owned and operated by a father and his two sons and is currently the only commercial aquaponic system in Puerto Rico. The focuses of the business are on growing and selling produce and expanding to other municipalities. In the near future, the family plans to promote and teach educational programs to expand the knowledge of aquaponic systems in Puerto Rico.

Our project, "Aquaponics in Puerto Rico: Assessing the Economic Viability", focused on delineating the process for the establishment and operation of Agroponicos, evaluating the profitability, and investigating opportunities and resources for the expansion of aquaponics in Puerto Rico. Therefore, the findings, suggestions and recommendations provided by our project may help the growth of Agroponicos and expansion of aquaponic systems in Puerto Rico.

Descriptions of how Agroponicos is divided amongst the family members with job details are listed below:

- **Pedro Casas, Sr**. is the CEO of the company, has experience in business, aquaponics and sometimes aids with packaging the produce.

- **Pedro Casas, Jr**. is the president of the company, has over 5 years of agriculture experience including soil agriculture, hydroponics and aquaponic systems. He designs small-scale and large-scale aquaponic systems and all marketing materials for the company. He is primarily responsible for harvesting, seeding, and daily maintenance of the system. In addition, he is a certified Aquaponics Institute instructor.

- **Jorge Casas** is the vice president of the company, has an educational background in business and oversees marketing and distribution of the produce. He is primarily responsible for developing relationships with clients, packaging and quality control and ensuring all goods are sold and transported to clients. He actively seeks new clients and opportunities for the business.

B. Government Platform

GOVERNMENT PLAN

GOVERNOR-ELECT

ALEJANDRO GARCÍA PADILLA

2012-2016

KEY POINTS

Learn about the plan the Governor-Elect Alejandro García Padilla will be carrying out during his term - from security measu that will restore the Island's social welfare, to projects that will bring back a prosperous economy.

The main priorities of his government will be:

- **Reactivating the economy.**
- **The creation of 50,000 jobs in 18 months.**
- **Giving back peace and safety to Puerto Rican families.**
- **Reducing crime.**

SECURITY

- Activate the National Guard to fight guns and illegal drugs.
- Use advanced technology to keep watch over our coasts.
- Create a new Rapid Force Police Team for immediate crime-fighting initiatives.
- Launch the "Tregua" (Truce) Program to mobilize religious and community leaders.
- Implement a continuous educational model from pre-kinder to university (K-16).

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ECONOMY

- Provide support for Puerto Rican business people and capital.
- Transform agriculture to create more jobs and promote economic development.
- Reduce and stabilize the cost of energy without manipulation or trickery.
- Through unique incentives, attract industries that can't operate outside of the United States because of security and tax reasons.
- Work hand-in-hand with the policies of President Obama and the Democrat administration.

AGRICULTURE

- Promote agriculture as an important part of job creation and economic development.
- School cafeterias will have trays filled with local produce.
- Invest in technologically advanced agricultural development.
- Create financial programs for controlled-environment businesses (E.g.: hydroponics, aquaculture)
- Transform the agrarian market, aligning resources with the needs of the farmers.

JOBS

- Create 50,000 jobs during the first 18 months of government.
- Enact the "Empleos Ahora" (Jobs Now) Law to facilitate and incentivize the creation of new business establishments and the expansion of existing ones.
- Establish an energy credit tied to job creation.
- Create "La Fuerza de Uno" Program (The Force of One) to encourage businesses to hire at least one unemployed person.

SUPPORT PUERTO RICAN PRODUCTS

- Provide support for Puerto Rican business people and capital.
- Establish an unprecedented collaboration between the government and the cooperative movement.
- Repurpose PRIDCO buildings, facilitating them to new local businesses or to those looking to expand.
- Accelerate government payments to suppliers by setting pre-established payment periods.
- Implement a new public policy for import substitutions.

ENERGY

- Develop an autonomous renewable energy industry for Puerto Rico.
- Encourage an energy conservation culture and incentivize efficient practices.
- Transform the Electric Power Authority with a new mandate to renovate its relevance for the country.
- Reduce the use of fossil fuels – petroleum, natural gas and coal – that pollute the environment.

Figure 34: Padilla's Plan.

C. Case Study with Agroponicos

Interviewers: Bryan Manning, Siena Mamayek, Xinxin Ding
Scribe: Chelsea Bunyaviroch
Interviewees: Pedro Sr. Casas, Pedro Jr. Casas, Jorge Casas

To facilitate the case study the following questions will be asked:

1) **What are the legal documents that you obtained for construction, operation, production or selling? What incentives or grants do you have now?**

   a) How did you know which permits you need and where did you find them?

      Sistema Integrado de Permisos (SIP) provides information on required permits to people who want to start a business. SIP provided the applicants with a list of permits.

   b) What is the entire process of application? Is there an order to obtain all the required documents? Is there an expiration date for any of the permit?

      The permits included :

      a. Permiso de limpieza de terreno (Permit of cleaning the land),
      b. Permiso de Construccion (Construction Permit),
      c. Permiso de Uso (Permit of Use),
      d. Fire Safety Certificate from Bomberos (Fire Department of local municipality)and
      e. Pluming certificate: form ARPE -16.9A (Rev).

      After measuring the topology of the land, it took about two months total for our sponsor to obtain all the permits required for their business. In applying for the permits, our sponsor had to provide the classification of their business. However, since Agroponicos was the first company trying to build a commercial aquaponic system in Puerto Rico, there was no classification for aquaponics yet. Thus, our sponsor contacted the Puerto Rico Department of Agriculture and obtained an endorsement which classified aquaponics as agriculture.

      After the classification, our sponsor applied for all the permits required to build and use their farm. They applied for the Permit of Clearing the Land (Permiso de limpieza de terreno) first to clear the land they used for construction. If any tree on the construction site needed to be moved away or cut down, the Permit of Land Movement would be required instead of the Permit of Clearing the Land. Our sponsor also applied for the Permit of Construction (Permiso de Construccion) which allowed them to start building the farm and the trailer. After construction, in order to start using the farm, our sponsor applied for the Permit of Use (Permiso de Uso). In addition, they also applied for the Fire Safety Certificate because the local Fire Department needed to make sure that *the construction had a functional bathroom, exit sign, and extinguisher. The local Fire Department would check the extinguisher every year and renew the certificate. Our sponsor also applied for a Plumbing Certificate.*

c) Where can people obtain application information and paper works?

The instruction and forms of Permit of Construction and Permit of Use could be found on the SIP website. To obtain the Permit of Clearing the Land, applicants needed to go to the local SIP office. As for the Firefighter Certificate and the Plumbing Certificate, applicants needed to go to pertinent departments of local government. Our sponsor also told us that the requirements of permits may be different in different municipalities and applicants needed to contact the municipal office to obtain relevant information.

d) How much did it cost to finish the whole application?
Less than $200,00.

e) Do you know if you need to reclassify your system if you are commercially producing fish? If not, do you know where we can obtain relevant information?

Yes, aquaponics needed to be reclassified if the system started to commercially produce fish. The classification was done by the Department of Agriculture of Puerto Rico.

f) What were the processes of application for the Certificate of Registered Merchant?

The Certificate of Registered Merchant (Certificado de Registro de Coerciante) was issued by the Department of Treasury of Puerto Rican Government (Departmento de Hacienda, Gobieno de Puerto Rico). Our sponsor stated that this certificate was required for selling their products and therefore could be applied after obtaining all the necessary permits for construction and operation. As long as their company did not change and was renewed every year, the Certificate of Registered Merchant would stay effective.

g) What is Bona Fide? How did you apply for the Bona Fide? Is the Bona Fide only for agriculture but not for aquaculture? Is it municipality-specific?

Our sponsor stated that Bona Fide provided local farmers with many financial benefits including tax exemptions. According to our sponsor, if a producer owned a farm of more than one acre, the producer could go to the Puerto Rico Department of Agriculture to apply for the Bona Fide with a farm operation proposal. The Department of Agriculture would grant the eligible farm owner the Bona Fide for the first year of farm operation without any other requirement. However, the Certificate of Bona Fide needed to be renewed every year, and the producer had to show proof of good standing in their business. Our sponsor *failed to obtain the Bona Fide for the second year because they were not clear about the requirements.*

2) **Whilst installing the system, what issues did you come across?**

   a) How much did it cost to buy the system? How much did it cost to install the system? Did you construct the system by yourself or did you do it with a kit? Where did you obtain the components?
   b) How did you fund or finance your system?
      i. *Out of the pocket*
   c) How much time and money was invested in making the area ready for installation? (Flattening the land, investing in infrastructure?)
      i. *2-3 months for leveling the land – 18,000 -2000 incentive*
      ii. *5 people helping to build the system*
      iii. *Some sub-contracting, mostly by self*
      iv. *AES (aqua ecosystems = Florida) or bought locally by HQJ (Water, air pumps, [In-Land Plastic = liner = expensive], air stones, tubing, green house…) = Puerto Rico (pools eBay) [HQJ]*
   d) How long did it take to get the system ready for operation?
      i. *4-5 years of research, MFG, Organic Soil, Hydroponics and Aquaponics (Padrin)*
      ii. *Understanding the bacteria and the agriculture*
      iii. *"Get your hands in the job," have to be farmers.*
      iv. *Construction: 2-3 months of land movement,(2 months of waiting for permitting: got a "Got go ahead"), = 11 months in total: 11 days for the concrete beds, tubing PVC, pipes pools.*
   e) What could you have done better?

3) **What issues did you have once you wanted to start production?**
   a) What additional costs are needed to getting the system running? How much does fish, fish food and crops cost?
   b) How easy is it to get these necessities?
      i. *Packaging, Boxes, Stickers, etc.*
      ii. *Started using plastic boxes, need to cut costs*
      iii. *Boxes are expensive*

Seedling issues, now they are using a MFG system (wicking bed)
Fish can be sensitive and must be handled with car. Timing to understand. NEED TO GO SMALL AND THEN GET LARGER.
Excellent seedling system
ADAPTION IS KEY
4-5 months outside. Sun, Rain, "2 full beds of lettuce in one week"
Learning from mistakes
400 - 500 tilapia in each tank, lower density
Rooftops, old warehouses – Repurposing lands: contaminated lands, broken down buildings

4) What kind of crops can you grow?

a) What are the limitations of the system regarding crop diversification?
   i. *Tomatoes for bumble bees limited by netting to stop*
   ii. *Lettuce good, basil was NOT moving*
   iii. *Lots of testing*
   iv. *Mesclum and Green Mix*
   v. *Have tried:*
      1. *Italian parsley*
      2. *Culantro*
      3. *Cilantro*
      4. *Green Mustard/Red Mustard*
      5. *Tomatoes: Black Cherry/ Yellow Pear/Jet Setter/BHN/Tye Dye/Roman (Indeterminate/Determinate)*
      6. *Mint*
      7. *Basil*
      8. *Chives*
      9. *Lettuce: Red/Green/Roman/Butter Heads*
      10. *Water Crest*
   vi. *Currently:*
      1. *Lettuce, Mustard Greens, Mesclun and Chives = Demand*

b) Have you experimented with other crops?

c) Did you notice issues with the roots of the plants becoming caked with particulates? How did you remedy this?
   i. *No rotation of crops, 500 raft to one acre*
   ii. *Gravity to bring the water down into grow beds*

5) What are the steps to maintain and operate an aquaponic system?

a) How do you monitor the system?
   i. *Electronic meters or pool kits pH and temperature every day, but other tests like alkalinity and chlorine are done when water is added to the system from local water supply*

b) How do you adjust the system? Adding buffers? Other chemicals, herbicides, bases? Contend with weeds and pests?
   i. *Organic Pesticide: Di-Pel – Bacteria to kill caterpillar*
   ii. *Only pest they can't control is stinkbug*
   iii. *Depends on crops*
   iv. *Ladybugs: Left /Praying Mantis*
   v. *Netting bad for tomatoes*
   vi. *Remove dead fish to not promote fungus*

c) What skill sets are necessary for laborers and/or managers of the system?
   i. *Walk the plants, got to love it, got to know the differences in sound*
   ii. *Hands on, like the system:*
      1. *Put pipes together and fish*
      2. *Interest in being outside and making food*
      3. *Juncos – Need labors, with qualified operators*

4. *Basic skills for harvesting and packaging*
5. *Control chemistry is more skilled*
6. *Education*
7. *Make one in municipalities in each area*
8. *Pay for gas on one side of the island*

d) Monitor noise of the system

e) Where and how much do you store filtered waste products of the system?

f) Collect quantitative data on the maintenance costs (restocking fish from selling and death, plants, water, paying for energy and repairing the system) on time spent on labor to keep the system running and harvesting produce

i. *Good liners are important*

ii. *Beginning: Materials for aquaponic/construction, Fish Food = $100)45-50 /lb for feed)/month, Energy and Water = Highest Expenses*

iii. *8 lbs/day*

iv. *Flexible*

v. *Know the chemistry of the water:*

1. *Water can be cold or too hot*
    a) *Need water quality*
    b) *Get hands on*
2. *Organic Fish Food:*
    a) *USDA does NOT certify organic fish even with ORGANIC feed (Expensive)*
3. *Buffers for pH/Supplements*
    a) *Calcium Hydroxide (no Potassium)*
    b) *Potassium*
    c) *Iron – NO VINEGAR*
    d) *NOT PRODUCED BY FISH AND PLANTS NEEDS THEM*
    e) *pH = 7 nutrients LESS available*
    f) *GET CHARTS ON ABSOPRTION of NUTRIENTS (Savador)*
    g) *20 kW*
    h) *pH, Nitrate/Nitrite (Once or twice a week, check during rain to see if it changes, Ammonia = 0) Trial and error*
    i) *Look at fish (Edge of water, need air!), Lettuce is yellowing need to look at it.*
    j) *Every day: Temperature and pH -> "Life of the system"*
    k) *Running almost a year: flush the system only once.*
    l) *Clean filters once every 2 weeks (2 months would be max)*
    m) *1200 fish – More nutrients than we are using (4 or 6 more beds) UVI – More fish*
    n) *Sludge: Fertilizer – turn off air pump and pump water into system and high in nutrients*
        i. *Sell the fertilizer – Market it!! (800 gallons every 2 weeks @ 5$ a gallon)*
        ii. *Golf Course*
        iii. *Soccer Academy*
    o) *Clean water by just moving it*

p) *Drops for everything*
q) *Where do you do the testing:*
   i. *Usually in degassing tanks (Would be used to decrease nitrogen for methane CO2 and anaerobic)*
   ii. *Buffers in the degassing tank, different from UVI*

6) How do we determine profitability?

a) Calculate weekly profit by taking inventory of sold goods and costs with running system (Transportation/Handling, energy use, water use, pesticides)
b) Calculate the consistency of the harvest, by calculating amount grown in either heads or pounds over 7 weeks
c) Calculate the number of businesses currently in operation and determine if that number deviates.
d) Determine the size of the growth beds and fish tanks to normalize production values
e) How do you sell your products? (Marketing, Facebook)
f) How did you make this market/discover this market?
g) If any, how much money do you make from educational programs?
h) What has been successful for you? (niche market, marketing as organics, tours)
i) Finally, we will use these data to determine if the overall system has or will break even
   i. *High return of investments 2-3*
   ii. *9 month producing (almost 170,000, but did not cut corners)*
   iii. *$10,000 to $11,000 in future at 3 going to 6 (2 beds produce enough money to pay off farm expenses EXCEPT salaries)*
   iv. *Other beds depend on marketing*
   v. *Goal: cannot do less than $320/week/bed to be safe (Not necessarily break even)*
   vi. *Chives potential for $800/week*

7) How do you want to expand your business?

a) Are you looking for a sole proprietorship, limited liability company, corporative, corporation, partnership and S corporations?
   i. *SERVICES*

CHECKS AT FOOD STORES TO GET PRICES.
NOT AS HIGH AS ORGANIC, AND NOT LOW AS REGULAR

Lettuce matches the U.S.
Catastrophe if anything goes wrong, aquaponics produce during storm
Hurricanes get crazy, fight for food
Hurricane seasons could be dangerous
Presale on the roof to test the system, loyal customers – 5 stores
2 weeks still green

D. Interview with Mayor of Juncos:

Wednesday March 20th, 2013

City Hall
Juncos, Puerto Rico

Interviewers: Siena Mamayek, Bryan Manning
Scribe: Xinxin Ding, Chelsea Bunyaviroch
Interviewee: Alfredo Alejandro Carrión (Mayor of Juncos)
Agroponicos Member: Pedro Jr. Casas
Translator: Maria T. Padrón (Financial Advisor of Mayor)

1) As mayor, what have been your biggest goals/problems within Juncos?

    Unemployment
    Housing
    Crime
    Drug Addiction

2) What do you hope to achieve with the Rehab center? What activities and facilities will the center include? How long do individuals usually stay?

    This is a very personal issue to me – my son is a drug addict and has relapsed (is currently stable). Even as mayor, it is hard to find help for my son. Treatment in the hospital only lasts 21 days and then patients are sent back into the world susceptible to relapsing. I want to create a rehab and empowerment center to address the problems that Juncos has and allow individuals to regain power and control of their own life.

    Individuals would receive treatment for 21 days and then offered permanent or temporary housing in the Rehab Center. It would be the responsibility of the individual to decide how long they stayed in the facility and if chosen to negotiate work compensation thereafter.

    Activities will include: Restaurant, Bakery, horse stables, paddle boats, aquaponics, and wishes to have a pasta manufacturing company

3) Is this a public work, provided by government funds, or something you have decided to finance privately? (Who will manage the center? Are there grants that you are applying for?)

Municipal money bought the 28 acre land. Land will be given free to Agroponicos; it is the responsibility of Agroponicos to fund the construction of the system.
So far have invested $2.5 million into the project
$150,000 – grant for main office
3,000,000 – Loan for land, clinic and administration from the government

4) We heard that you were considering adding an aquaponic system to your center. What prompted you to do so?
(Who will be involved in the rehab center and how will the center be beneficial to them? What will they gain after leaving your center? Who will run the system?)

Answered from Question 2

5) Will other municipalities want to do what you are doing?

NO! No one wants to deal with the problems faced in Puerto Rico. No one will take the initiative or invest the money. (his answer is in the context of creating a center like his)

6) What role would Rehab members have in maintaining the aquaponic system?

Patients have the option in choosing where they would want to work within the Rehab Center. For aquaponic system, estimated that around 30 workers would contribute to the harvesting work. Workers would be compensated through the rehab center; half going to them the rest going to a private bank account. Rehab center would service an estimated 150 patients.

7) How will you provide training for employees? Who will supervise the system? Will this be a stable job for them?

Agroponicos would provide all necessary training. System would require several full time employees to supervise the system with the appropriate knowledge base. These individuals would not be members of the Rehab Center.

8) Would you plan to sell the crops? (Local markets, Rehab restaurant)

Yes, to places such as Elderly Center, Schools in Juncos (students would eat healthy food), prisons, supermarkets
Current Governor of Puerto Rico, Padilla, will create regulations to ensure anything grown from facility will be distributed and sold throughout Puerto Rico.

9) Understand legal process within Juncos. Tax breaks? Government Support?

Permits will not be a problem. He can provide tax exemptions because the facility is run through the municipality. This would create an incentive for small businesses to start up their company at the site. (Land would be provided)

Wants to create consortium with Caguas and San Juan to establish entitlement which makes it easier to qualify for federal funding.

Also he wishes to assume the property of abandoned buildings to transfer authority to him to do as he pleases

E. Interview with Mayor of Caguas

Right hand man and three staff members
Friday April 12th, 2013

City Hall
Caguas, Puerto Rico

Interviewers: Siena Mamayek, Bryan Manning
Scribe: Chelsea Bunyaviroch
Agroponicos Member: Jorge Jr. Casas

1) What have been the biggest goals/problems within Caguas?

Through his Strategic Planning Unit, he wants to restore self-sufficient agriculture as a main idea to promote economic development, job creation, healthy diet, ecological restoration and preservation.

2) What is your affiliation/relationship with the Botanical Gardens?

The Gardens were built through the director of the Strategic Planning Unit. Mayor had given this sector of his office money to purchase the land and build the Gardens.

3) Are you aware of the project proposals with Agroponicos at the Botanical Gardens? (If not explain) What is your attitude towards this project?

No, after explanation, were interested in the project. The mayor's staff stressed the importance of a business plan that he should submit through the mayor's office. See response to following question about attitude in conjunction with the Sustainable Food Initiative.

4) Do you see that aquaponics can be successful at the Gardens? Will you support this project? How?

Yes, would suggest Agroponicos to submit business proposal to the Caguas Sustainable Food Initiative. Agroponicos would then be able to produce herbs and spices at the Gardens which could directly supply the demands of the proposed dehydration facility. The Sustainable Food Initiative will promote locally grown produce as well as the dehydration center be a means for exportation and increase revenue to Caguas.

Mayor's office will also support Agroponicos directly. Caguas runs a lab that has machinery available to local entrepreneurs. The lab currently has a packaging machine that would allow Agroponicos to greatly reduce their harvesting time.

5) Is there any governmental support within the municipality to aid the progress of this project?

No money can be awarded through the municipality of Caguas; all money for construction of project must be done with grants. Potentially may use municipal bonds and borrow other municipal money based on potential income.

All incentives and benefits would be offered as part of the Sustainable Food Initiative.

*<u>*Note</u> – mayor's staff stated that Caguas is a very progressive municipality*
Major governs with the people not for the people
Wants to promote local production with the food initiative
He wants to create sustainable development while considering six main aspects: social, economic, environmental, cultural, production and transparency (no secrets with people).

F. Interview with Director of the Botanical Garden:

Thursday March 21st, 2013

Botanical Gardens
Caguas, Puerto Rico

Interviewers: Siena Mamayek, Bryan Manning
Interviewee: Omarf Ortega
Scribe: Xinxin Ding, Chelsea Bunyaviroch
Agroponicos Members: Pedro Jr. Casas, Jorge Casas

Note: The Director and the Casas family are *amigos*.

1) What is the mission statement of the Botanical Gardens? (Tourism, Community, Profit, Fun, Research, etc.?) (Mention funding)

   Mission Statement translated from Spanish:
   Become internationally recognized as a prime center in terms of investigation, education and interpretation of natural, cultural and sustainable resources.

   Vision Statement translated from Spanish:
   A world class Botanical Garden. Become the leader on tourist, cultural, natural and agro-tourism attraction in Puerto Rico and become the best alternative of sustainable tourism in the Caribbean.

   Garden has been open since 2007; he has been director for 1 year and 8 months. There have been internal issues with the Gardens maintaining the director position (6-7 directors have gone through the position during this time frame).

2) As Director of the Botanical Gardens, what are you trying to achieve with this park? (Are you trying to reach out to the community? If not, who are you trying to target? How involved is local government for funding/support?)

   Background: Site used to be a sugar cane plantation then dairy farms.Later, mayor bought site to avoid construction of home. Whole site is 60 acres but walking trails goes through 32-33 acres. He wants to expand the walking trails and also horseback riding and biking on those same trails.

   He wants to change venue from research to new activities to diversify profits. He would like to have a research center to educate people and integrate it with school field trips and alternative teaching methods (monitory).

   Liberty Health Care is given free membership to air commercials about the Garden. 3-4 Companies give $5,000 – 10,000

Most income comes from admission to maintain Garden but not sufficient for expansion (trouble determining price $12-7).
Gardens have had issues with bad marketing in the past
Do promotion to promote the Gardens (ex. Dogs Day)

Permits – is a public works because the land is owned by the municipality of Caguas however the Gardens have the right to manage how the land will be used.

3) Are you willing to start "hands-on" experience at the park?

   *Yes. Most interactive Program is "*Viva" *(yoga, photos, food, arts and Crafts, venue for weddings)*

4) We noticed that you have the space for hydroponics, and were wondering if you could tell us what happened with the original "Hydroponic Research Greenhouse?" (Probe deeper to identify the causes of failure)

   The hydroponics in the greenhouse has not been running for three years. Initially the beginning was very good and sold everything. Eventually system failed because not enough people to maintain system (educational issues) or funds to pay the workers, and also because there were as well as contractual issues and business issues.

   Currently he is negotiating with Mec Tech College to develop hydroponics again in the greenhouse for their agriculture school. This could be a ten year contract between the college and the Gardens. They would take over all of the greenhouses. Produce grown will be sold through the Gardens for their profits. Also would require rebuilding the hydroponic system as well as additional office space. The school would fund the building of the system and would pay rent for the land.

5) Despite the fate of the first hydroponic systems, we were wondering why this is still appealing to the Botanical Garden?

   He is very familiar with hydroponics therefore comfortable with these systems. Has agreement with college, noted above. He wants to use hydroponics as basis for research and education purpose.

6) What are your thoughts and concerns of aquaponics? How familiar with these systems are you? (Mention the Casa Family resources)

   His concerns with aquaponics are that it is relatively new to him. He says it would be nice to have but voiced his reservations. He is an agronomist.

7) Would you consider adding an aquaponic system here? Possible just dedicate one greenhouse to agroponicos?

He is currently reserving all greenhouses for the college research. After business meeting with the Casa's, he verbally agreed to allow our sponsor one greenhouse.

G. Interview with Farm Service Agency (FSA)

Friday, March 22nd, 2013

Farm Service Agency
Caguas, Puerto Rico

Interviewers: Bryan Manning, Chelsea Bunyaviroch, Siena Mamayek, Xinxin Ding
Scribe: Bryan Manning, Chelsea Bunyaviroch
Interviewee: Jacqueline Lazu (FSA Farm Loan Manager)
Agroponicos Member: Jorge Casas

1) Eligibility of aquaponic farm owners: What are the general requirements of eligibility for FSA's Farm Loan Programs? Are aquaponic farm owners or people who want to build or run an aquaponic farm eligible to obtain a FSA farm loan or loan guarantee?

    There are two major types of loans – the Ownership Loan and the Operating Loan. The main purpose of these two types of loans is to aid local farmers in their production. The Ownership Loan requires that applicants have at least a three-year experience on operating a farm. Applicants need to provide FSA with proof of their experience such as farm records or training certifications. The Operating Loan requires that applicants currently own a farm and are gaining profits from the business.

    Our sponsor provided their background and experiences on agriculture and aquaponics as well as photos of their farm operation and customers to the FSA officials. The FSA officials claimed that our sponsor was eligible for both the Ownership Loan and the Operating Loan.

2) When can you apply for a direct loan? A guaranteed loan? A land contract guarantee? Are there different requirements of eligibility?

    The FSA direct Ownership and Operating Loans have low interest rates (1%-5%) but an upper limit of $300,000. Therefore, if farm owners need funds more than $300,000, FSA direct loans are not suitable for them and they may need to apply for private loans. However, the shortcoming of private loans is that they usually have high interest rates (5%-10%). The land contract guarantee was a new program. The Caguas FSA office had not processed any one yet and therefore the FSA officials were not very familiar with this program.

    The eligibility requirements of direct loans are as described in the answer of Question 1. The eligibility requirements of guaranteed loan are based on the eligibility requirements of FSA direct loans and also include that that applicants need to have good economic standing and credits.

3) According to the *Your Guide to FSA Loans*, "For beginning farmer or rancher targeted funds only: I have operated a farm or ranch for 10 years or less." What are the beginning farmer/rancher targeted funds?

   If a farm owner is a beginning farmer or a socially disadvantaged farmer, he/she may have priority when applying for loans because Federal Government designates special funds for beginning and socially disadvantaged farmers. The FSA definition of a beginning farmer is a person who operated a farm or ranch ten years or less. The FSA definition of a socially disadvantaged farmer is anyone of the following list: American Indian or Alaskan Native, Asian, Black or African American, Native Hawaiian or other Pacific Islander, Hispanic, a woman.

4) Is there any eligibility requirement for emergency loans other than a disaster designation and a minimum 30% production loss?

   Farm owners in a disaster designated areas are eligible to apply for the emergency loan if they suffered a minimum of 30% of production loss and if it has not been more than eight months since the designation is announced. The farmers could apply for the Emergency Loan to cover also the damage of their constructions or facilities. Moreover, in order for FSA to determine the production loss and other losses of the farm, it is critical for the farm to have a comprehensive record of their facilities, yearly production, and yearly profits for at least three years. If a farm is suffered from a significant loss but not eligible for the Emergency Loan, the owner can instead applied for an Operating Loan at a similar interest to the Emergency Loan at a lower interest rate.

5) We can see on the Farm Loan Information Chart the maximum loan amount, but is there a minimum loan amount requirement for each type of loan?

   No, there is no lower limit for FSA loans.

6) If the applicant is able to pay at least 5% of the purchase price, is the down payment ownership loan generally better than the direct ownership loan because of a lower interest rate?

   Yes, but according to the FSA officials, it was usually hard for applicants to obtain the 5% down payment before applying for the loan.

7) Does the business plan need to include an amortization schedule? (instruction provided?)

   Yes. FSA would determine the amortization schedule based on the expenses and income of the farm. In addition, FSA provided instruction for applicants to prepare for required documents and informed applicants of more USDA programs.

8) What are acceptable security properties?

For the Ownership Loan, the land purchased is usually used as security. For the Operating Loan, farm owners need to pay 0.5% of the prices of the asset they bought.

9) In general, how long does it take to review a guaranteed loan?

14 days.

H. Interview with Small Business Administration:

Wednesday March 27th, 2013

Plaza Scotia Bank Building
San Juan, Puerto Rico

Interviewers: Siena Mamayek, Xinxin Ding
Scribe: Bryan Manning, Chelsea Bunyaviroch
Interviewee: María de los Ángeles de Jesús

Note: The interview's overall recommendation was to consult with the PR-SBTDC (Puerto Rico Small Business and Technology Development Center)

1) What requirements must you have to register as a small business in Puerto Rico? What is the basic legal structure of a company? Advantages/disadvantages of different structures? Which would be most suitable for our sponsor?

   Question diverted quickly and was not helpful. Overall answer was that SBA does not have a lot of large businesses in agriculture. Our best advice would be to consult the PR –SBTDC for our sponsor and other beginning business to set up an appointment to discuss their business plan in much detail.

2) I see from the website that you offer services to help business's formulate a business model? How does one get involved with that? What are some pre-requisites?

   Requirements are listed in the booklet (given), and our sponsor call to set up an appointment to discuss their particular case and if needed refer to other resources.

3) The 7(a) Loan is SBA's most basic and common loan to help start-up and/or existing small business. What are the requirements? Is there a list of the requirements available? How can one apply?

   Of all the SBA loans, the 504 loan would be the most beneficial. However, since you have spoken with FSA about their loans regarding agriculture they would be the most beneficial. SBA loans have much higher interest rates than FSA loans. And SBA is strictly for the business industry, not necessarily as geared towards farmers.

***Additional Information Gathered:*
SBA is strictly a business industry with large amounts of loans with high interest rates, not necessarily "small"
SBA does not have a lot of large businesses in agriculture. There is one such cattle dairy farm that has not been successful in recent years.
The FSA would be the best option for farmers since the loans have low interest and geared towards limited resource clients.

I. Interview with Puerto Rico Department of Agriculture

Wednesday March 25th, 2013

Puerto Rico Department of Agriculture
San Juan, Puerto Rico

Interviewers: Bryan Manning, Xinxin Ding
Scribe: Chelsea Bunyaviroch, Siena Mamayek
Interviewees: Arnaldo Astacio Diaz

<u>Agriculture and Food Production in Puerto Rico:</u>

1) What contributes to the large quantity of food imports of Puerto Rico? What are the challenges and major concerns for agriculture in Puerto Rico?

    Historically, since 1950s the focus of the local economy has been on industry and therefore the government support and funding for local agriculture were very limited. Due to the low support and low profits of agriculture, many Puerto Rican farmers migrated to the US mainland in search for opportunities.

    One of the biggest challenges for Puerto Rico and local agriculture was water resources. As a small island, Puerto Rico largely relied on rain water and in the dry season (Nov-May) it had to get water from rivers and lakes. The problem with using river water was that if the river was over-drained, sea water may seep into the rivers. In addition, agricultural run-off may pollute underground water or rivers. Therefore, water resource conservation was one of the biggest concerns for Puerto Rico. For farms or companies who want to use river or underground water, they'll need to first obtain a permit from Department of Natural and Environmental Resources.

    Hurricanes are another problem that Puerto Rico faces. Hurricanes would cause great crop losses and damages to construction sites. Moreover, after a hurricane, the sea level would increase which prevents ships from transporting goods into Puerto Rico.

2) How prevalent is organic agriculture and other types of agriculture in Puerto Rico?

    There are no more than five farms certified by USDA as organic. Two of the local organic farms belong to local universities. Hydroponic farms were once built in Puerto Rico on a large scale, but the problems with high start-up expenses such as the PVC tubes, high operating costs of fertilizer, limited choices of crops and the lack of competitiveness of the produce made it difficult for the farms to sustain themselves.

3) Do you think organic agriculture should be encouraged in Puerto Rico?

Department of Agriculture of Puerto Rico is trying to transform local farms into organic farms because organic agriculture can promote local food safety and protect local water resources.

Organic Certification:

1) How does obtaining an organic certification help local farms?

Organic farming and certification can help farmers earn more profits. Organic food is more expensive than non-organic food and organic food is popular in Puerto Rico if it is sold in supermarkets and some restaurants where people know about organic food and care about food safety more than prices. Organic food can be sold to local hospitals because local government policy requires that hospitals must use organic food.

2) Is there a certifying agency located in Puerto Rico? Does the Department of Agriculture work with any certifying agency?

Yes, the Department of Agriculture is working with Quality Certification Services (QCS) which has an office in Puerto Rico.

3) What are the components of organic certification? How much does it usually cost for the first application and the annual renewal?

There are two major fees that USDA certified farms need to pay:
First, the inspection fee ($125/acre for inspectors from Puerto Rico Department Agriculture) needs to be paid to the inspector who evaluates the farm and writes an inspection report to the USDA certifying agency for final evaluation and determination;
Second, a certain percentage of the gross profit of selling certified products needs to be paid to the QCS every year.

USDA offers an incentive program in Puerto Rico that reimburses certified farms 75% of the annual certification fee. The maximum amount of reimbursement is $750 per applicant per year.

4) For the application for organic certification, there is a requirement for a 3-year land transition period and a history of substances applied to the land. Does the written history need to be verified by any agency or expert?

   No soil testing would be needed for this requirement. Only a sworn testimony witnessed by a lawyer is needed.

5) Is there any program dealing with risk management? Does the "subsidy to insurance premium payments" help pay any kind of crop insurance?

   There was an insurance program involved in the benefits of bona fide where the Puerto Rican government paid for 90% of the insurance premium. This insurance program covers the crop losses due to natural hazards. The insurance is provided by a local insurance company Corporación de Seguros Agrícolas de Puerto Rico.

6) Is there any support or funding for organic agriculture?

   Yes, there are USDA incentive programs but not too much support from the local government except for organic training courses.

7) If a farm is not eligible for USDA organic certification but still wants to use non-USDA organic label, is it possible?

   No. Only farms that have obtained USDA organic certification can legally label their produce "organic". However, farms can put other labeling claims such as "GMO-free" on their produce if it is true to fact and the farms keep records on their produce.

Bona fide:

1) What is bona fide?

   Bona fide is a Puerto Rican incentive program that provides benefits to local farmers. It literally means "good faith" in Latin. Bona fide provides certified farmers many benefits such as an exemption of 90% off income taxes, exemption of 100% off property taxes, exemption from 100% of municipal taxes, etc.

2) Who are eligible to receive bona fide? How does one apply? What are the requirements?

   Bona fide is for farmers whose farms are larger than one acre and receives at least 50% of their income from agriculture. To obtain detailed information and to apply, local farmers need to go to regional offices in their respective municipality.

Legal Process:

1) Is aquaponics classified as agriculture?

   Yes, aquaponics is currently classified as agriculture in Puerto Rico

2) Is it possible to classify aquaponic system as both agriculture and aquaculture?

   Yes, it is possible for aquaponics to have two classifications depending on the major commercial products.

J. Financial Analysis

The full financial analysis was conducted using Excel. The data was provided by Agroponicos and most calculations were a function of weight or quantity. The full spreadsheet was provided to Agroponicos. A portion of the calculations are produced below:

System Parameters		
Beds		5
Rafts		12
Total Rafts		60
Holes/Raft		48
$/Bag		
Harvest Parameters		
Harvested Rafts/Week		20
Holes of Lettuce/Bed		48
Lettuce Produced by 4 rafts (Used, lbs./oz.)		
Lettuce Waste (Wasted, lbs./oz., 4 rafts)		
Oz./Bag		
Weekly Bags of Lettuce (Wasted, Used)		
Weekly Profit		
Profit (Estimated for 5 harvested beds)		
Profit (Estimated for 2 harvested beds)		
Profit (Estimated for 1 harvested beds)		
Total Expenses/Bag Lettuce (Per Week)		**Cost**
$/Bag		
$ Sticker/Bag		
$ Seed/Bag		
$ Soil/Bag		
Total $/Bag		
# of Bags of Lettuce		
Total for # bags		
Expenses: Seeds/Bag (Per Week)		
Seeds/Package		**Cost/Bag**
	50,000	
Seed/Hole [avg.] Note: Either 3 or 4		
Oz./Hole (100% useable, x% useable)		
Seed/Bag		
$ Seed/Bag		
Expenses: Soil/Bag (Per Week)		**Ideal**
Hole to bag Conversion (100% useable, x% useable)		
Soil Mix		**Mixture**
Weighted Cost/Week		
Cost/Hole (Replaced holes)		
Cost/Bag		

Figure 35: Agroponicos' financial analysis Excel spreadsheet.

K. General Information about USDA Grants

More programs and detailed information is available on NRCS official website http://www.pr.nrcs.usda.gov/programs/

Table 21: Four incentive programs from NRCS available in Puerto Rico.

Programs	Purposes	Eligibility	Incentives and funds	Offering cycle
Environmental Quality Incentive Program National On-Farm Energy Initiative[1]	Help producers to conserve energy.	Individuals, legal entities, Indian Tribes, or joint operations engaged in agricultural production and having resource concerns related to energy conservation.	Technical and financial assistance. Incentive payment up to $450,000 over a rolling six years..	Continuous basis.
Environmental Quality Incentive Program Organic Initiative[2]	Help organic producers to conserve natural resources.	Certified organic producers, producers transitioning to organic production, or producers selling less than $5000 organic products annually.	Technical and financial assistance. Up to $20,000 per fiscal year and up to $80,000 over a rolling six years.	Every fiscal year.
Conservation Stewardship Program[3]	Improve water and soil quality and enhance wild habitats.	Producers who own cropland, pastureland, rangeland, nonindustrial private forest land.	Payments for conservational performance.	Continuous sign-ups.
Conservation Innovation Grant Program[4]	Stimulate the development and adoption of innovative conservation methods.	Include applicant eligibility, project eligibility, and matching funds requirements.	Up to $30,000 for any project.	Every fiscal year.

[1] 2013 EQIP On-Farm Energy Initiative (U.S. Department of Agriculture Natural Resources Conservation Service, 2013a).
[2] 2013 EQIP Organic Initiative (U.S. Department of Agriculture Natural Resources Conservation Service, 2013b).
[3] Conservation Stewardship Program (CSP) in the Caribbean (U.S. Department of Agriculture Natural Resources Conservation Service, 2012).
[4] Caribbean Area Conservation Innovation Grant Program (CIG) - FY 2013 (U.S. Department of Agriculture, 2013).

L. General Application Process and the Cost of USDA Organic Certification

Background of the USDA Organic Certification

The National Organic Program (NOP) was initiated in 1990 by the USDA to set standards for organic products and operations, accredit organic certifiers, and enforce the regulations for organic production and operations (Coleman, 2012). The USDA organic certification is used by the NOP to regulate organic production, processing and handling so as to promote food safety and environmental quality.

Application Process and Labeling Regulation

To obtain an organic certification, producers needed to first be familiar with the organic regulations of NOP and then apply through an accredited certifying agent (Baier, 2012). The organic regulations and the list of accredited certifying agents are? available on the USDA NOP website. One can choose a certifying agent based on the distance from the agent to the farm, fee structure, accreditation standards, and additional services (Baier, 2012). The application process generally includes five steps (Baier, 2012):

1. Producers/handers adopt organic practices and submit application and fees;
2. The certifying agent reviews materials;
3. The inspector conducts an onsite inspection;
4. The certifying agent reviews the application and the inspection report;
5. The certifying agent issues organic certificate.

After obtaining the organic certification, the producer/handler needs to provide an annual update and fees to the certifying agent and repeat steps 3-5 every year.

USDA and the state department of agriculture have specific regulations for labeling claims (Baier, 2012). Only after obtaining the USDA Organic Certification can producers legally label their certified products with a USDA organic label and describe their products as organic. Other labeling claims, such as “GMO-free” and “pesticide-free”, are subject to state regulation. In Puerto Rico, non-organic labeling claims must be true to the fact and the producer should keep records of their products with labeling claims. For more information, producers should contact the Puerto Rico Department of Agriculture.

The Costs of USDA Organic Certification

To encourage organic agriculture and organic certification, USDA offered the National Organic Certification Cost-Share Program to reduce the cost of the organic certification. The National Organic Certification Cost-Share Program allows PRDA to reimburse eligible operations 75% of their certification costs, for up to $750 a year for one producer. However, if a farm is not eligible for USDA Organic Certification or cannot afford it even with the National

Organic Certification Cost-Share Program, other labeling claims may be used, if permitted by regulation.

To estimate the costs of organic certification in Puerto Rico, we first studied the fee structure of the Quality Certification Services. The Quality Certification Services is one certifying agent that offers the USDA certification in Puerto Rico. The fee structure of Quality Certification Services' USDA organic certification for crop producers is illustrated in Table 22. There is a $50 first-time application fee which is not included in Table 22. Option 1 was applicable to the farm that our sponsor currently owns. However, if our sponsor expanded and built other farms, Option 2 would then be a suitable choice.

Table 22: Fee structure of organic crop certification provided by QCS (Quality Certification Services, 2012a).

Option	Description	Annual Certification Fees	Assessments	Inspection
Grower Certification OPTION 1: Standard Grower Certification	Certification of an Individual Grower Operation	Based on Acreage: 0-20 ac.=$150 21-99 ac.= $200 100-500 ac.= $275 more than 500 ac.= $375 Verification for EU, Canada, Japan, Taiwan = $75/country	0.5% of gross sales Minimum Assessment : $150 per year Maximum Assessment: $6000 per year. **Gross Annual Organic Sales x .005 = Assessment Fee**	Varies (See Table 23). Additional expenses may include expenses from traveling, lodging and meals.
Grower Certification OPTION 2: Multi-Unit Umbrella Certification	Certification of a Primary Certified Location and Additional Associated Locations. (Each requires a separate Organic System Plan.)	$300.00 for Primary Certified Location and $500 for each additional associated location. Verification for EU, Canada, Japan, Taiwan = $75/country	0.5% of gross sales Primary Certified Location pays assessments for itself plus all of the associated locations. Maximum Assessment: $15,000.00 per year. **Gross Annual Organic Sales x .005 = Assessment Fee**	Same as above.

Inspection fees vary based on the size and complexity of the farm and operation, the traveling distance, and the individual inspector. Table 23 lists the rates of the inspection fee with respect to operation complexity. In addition, the inspection fee may also include additional expenses of mileage, driving time, lodging and meals of the inspector.

Table 23: QCS inspection fee rates based on the complexity of farm operation (Quality Certification Services, 2012b).

Operation Type	Operation Complexity			
	Simple	Moderate	Complex	Very Complex
Grower Only	$150-200	225-275	300-375	400-500
Grower and Handler	$200-250	275-325	350-400	425-525
Grower and Livestock	$200-250	275-325	350-400	425-525
Grower, Handler and Livestock	$275-325	350-400	425-525	525-600
Handler/Processor	$150-275	300-375	400-600	600-700
Livestock Only	$150-200	225-300	325-400	400-500
Grower Group	$300-400	400-500	500-650	650-800
Retail Establishments & Restaurants	$400-500	500-650	650-800	800-1000

M. Risk Management Programs

Table 24: Illustrations and comparisons of FCI, NAP, SURE, Emergency Loans, and DSA.

Programs	Program Nature	Eligible Producers	Eligible losses	Coverage	Costs
Federal Crop Insurance (FCI)[5]	insurance	Puerto Rican farmers who grow insurable crops	Crop losses caused by natural hazards.	Different percentage coverage depending on types of crops and amount of losses.	Depends on the coverage rate, the type of crop and, the amount of crop insured and amount of losses.
Noninsured Crop Disaster Assistance Program (NAP)[6]	Equality of FCI	Producers who share in the risk of producing eligible crops and whose nonfarm adjusted gross yearly income does not exceed $500,000.	Crops grown for food which are not covered by FCI, etc.	NAP covers the amount of loss greater than 50% of the expected production based on the approved yield and reported acreage up to $100,000.	A service fee which is the less than $250 per crop or $750 per producer.
Supplemental Revenue Assistance Payments Program (SURE)[7]	A supplemental program to Federal Crop Insurance and NAP.	Same as NAP.	Crops covered by either Federal Crop Insurance or NAP.	The SURE guarantee covers a loss of at least 10% production loss but cannot exceed 90% of the total expected revenue. Combining payments of NAP and SURE cannot exceed $100,000.	No fee listed for registration.
Emergency loans[8]	Loan	The farm is located in a county that has a disaster designation no more than 8 months ago and suffered at least 30% production loss or a physical loss.	Crops or physical properties caused by natural hazards.	The lesser of 100% actual or physical losses, and $500,000.	Loan interests.
Disaster Set-Aside (DSA)[8]	Loan servicing option	The farm is located in a county that has a disaster designation whose owner cannot pay FSA loans on schedule.	n\a	n\a	No fee listed.

[5] Insurance Program for the year 2009-2010 (Corporación de Seguros Agrícolas de Puerto Rico, 2009)
[6] Fact Sheet of Noninsured Crop Disaster Assistance Program (NAP) for 2011 and Subsequent Years (U.S. Department of Agriculture Farm Service Agency, 2011a)
[7] Fact Sheet of Supplemental Revenue Assistance Payments (SURE) Program (U.S. Department of Agriculture Farm Service Agency, 2011b).
[8] FSA loan programs (Bitterman, 2012).

N. References and Places for More Information

The information about the support programs was obtained by online search and interviews. The sources of information and places for more information are listed in Table 25.

Table 25: Sources of information of the support programs and suggested places for more information.

Programs	Sources of Information	Places for More Information
Farm Service Agency (FSA) Loans	*Your Guide to FSA Farm Loans* (Bitterman, 2012) and the interview with an FSA loan manager.	A local FSA office.
Small Business Administration (SBA) Loans	SBA website (http://www.sba.gov/home) and the interview with a deputy district director of SBA	A local SBA office.
Puerto Rico Small Business and Technology Development Center (PR-SBTDC) Programs	PR-SBTDC website (http://www.prsbtdc.org/) and the interview with a deputy district director of SBA.	A local PR-SBTDC office.
USDA Natural Resources Conservation Services (NRCS) Incentives and Grants	USDA NRCS website (Appendix K).	A local USDA NRCS office.
USDA Rural Development (RD) Grants	USDA RD website (http://www.rurdev.usda.gov/RD_Grants.html)	A local USDA RD office.
Bona Fide	The interview with an official of Puerto Rico Department of Agriculture (PRDA).	PRDA.
USDA Organic Certification	The interview with an official of PRDA.	PRDA.
Risk Management Programs	The Corporación de Seguros Agrícolas de Puerto Rico (CSA) website (www.csa.gobierno.pr/) and the FSA website (Appendix M).	CSA or a local FSA office.

O. Puerto Rico Green Energy Fund

Agroponicos has stated that energy consumption is one of their main sources of operating expenses (41% of total expenses). These expenses are attributed to running water pumps, air pumps, and the air conditioning in their office trailer. The pumps are constantly running, while the air conditioning is running only during harvesting. The estimated power requirement provided by Agroponicos is 20 kW. To help mitigate energy costs, the company is looking specifically towards solar panels.

The Puerto Rico Green Energy Incentives Act (2010) established a Green Energy Fund (GEF) to co-invest in the development of renewable energy projects on the island. In 2011, $20 million was allocated to the GEF and by 2017, $40 million will be invested. Funds are divided out on a first come, first serve basis (Government of Puerto Rico; Puerto Rico Green Energy Fund, n.d.). The fund will provide aid to Tier 1 projects, between 0 to 100 kW, and Tier 2 projects, 100 kW to 1 MW.

The following criteria must be met by **Incentive Reservation Holder** (Customer or Property Owner):

1) Residential, commercial, industrial, agricultural, and non-for-profit (education or otherwise)
2) Government entities are only eligible for Tier II projects, but tenants are eligible for all programs
3) Unsuccessful Incentive Reservation Holder may apply in the future. If a previous applicant has defaulted causing the **PREAA** (Puerto Rico Energy Affairs Administration) to request a devolution or a recapture of a disbursed incentive, they will not be eligible to apply in the future

The following criteria must be met by the **Application**:

1) The application must be completed by either visiting:
   a. www.prgef.com
   b. www.prdoesitbetter.com
   c. PREAA Office
2) Pay a non-refundable fee

The following criteria must be met by the **Eligible Projects**:

1) The Green Energy Project (GEP) must *not* have begun construction or installation before submittal of the application and before receiving notice of approval of the incentive.
2) Only permitting is allowed

The following criteria must be met by the **Eligible Total Project Costs**:

1) The Applicant (in many cases, the **Incentive Reservation Holder** or representative) must submit a single project quote signed by the **Incentive Reservation Holder** and the sales representative to show evidence of the cost. The quote shall include the equipment to be used, including brand, model number and quantity. The following may be included as part of **the Total Project Costs** of a **GEP** for eligibility and incentive calculation purposes.
    a. Equipment costs:
        i. Photovoltaic (PV) modules
        ii. Wind Turbines
        iii. Inverters
        iv. Metering Devices
        v. Other balance of system equipment necessary for the system measurement
            1. On-site system measurement, monitoring and data acquisition equipment
        vi. PREAA certified accessory equipment, such as batteries and charge controllers
            1. For stand-alone systems that cannot connect to the utility grid
            2. Under other circumstances indicated in the Reference Guides, will be considered as eligible Total Project Costs.
    b. Engineering, design and permitting
        i. Construction, installation and mounting cost directly associated with the GEP. This includes mounting and anchoring structures like car ports or a structure that is needed for the **GET** (Green Energy Technology) equipment.
    c. PREAA may request copies of construction documents and evidence of costs incurred (ex. paid invoices, cancelled checks, others) before determining final incentive amount to be reserved or paid.

The following criteria must be met by the **Installers, Installation, Metering, Certifications and Equipment**:

1) Installation must be performed by a PREAA **Certified Renewable Energy Systems Installer** or else the **Applicant** will be disqualified. If engineering or architectural work is being conducted by the **Certified Renewable Energy Systems Installer**, he or she must be a licensed or authorized professional. All equipment must be new.
    a. **Certified Equipment:**
    http://www.prgef.com/Pdfs/PhotovoltaicModules.pdf
    http://www.prgef.com/Pdfs/Inverters.pdf
    b. **Certified Renewable Energy Systems Installer**
    http://www.prgef.com/Pdfs/PhotovoltaicInstallers.pdf

2) Insurance must be provided to the **PREAA** and be sufficient to cover the risks until completion

3) All installations must be connected at the Point of Interconnection with the Electric Utility, and comply with the National Electrical Code, PREPA standards and local net metering laws and regulations. In addition, all installations must have monitoring capability that is readily available to the **Incentive Reservation Holder** and **PREAA**.
    a. All Systems Performance and Revenue Meters must provide feedback to the **Incentive Reservation Holder** and **PREAA**. There should be remote communication so data can be collected, accessed remotely and downloaded for processing by PREAA.
    b. **GEP Incentive Reservation Holders** are required to report annual energy production to PREAA via electronic data exchange.

4) All **GEPs** must be installed with System Performance and Revenue Grade Meters which allow the **Incentive Reservation Holder** and **PREAA** to determine the amount of green energy production.
    a. Accuracy must be certified by a Nationally Recognized Technical Laboratory (NTRL) such as UL and TUV
    b. PREAA staff must be able to access the facilities
    c. The **Incentive Reservation Holder** may be invoiced an amount of no more than $500, if more than two inspections are required due to any non-performance of the metering system

5) All **Incentive Reservation Holders** must submit an interconnection application to PREPA.
    a. It is advisable that the local electric power utility determines if the **GEP** can be interconnected to the grid and can be metered. If selected, this agreement will be necessary before receiving the incentive unless PREAA creates an exception.

6) All structures should be permanent for at least 5 years or else the **Incentive Reservation Holder** will have to pay back the incentive.

7) For systems that receive $16,000 or more from this program, additional certifications will be needed:
    a. Certificate issued by the Puerto Rico Treasury Department evidencing that **Applicant** does not have any income tax debts outstanding, or if a debt is outstanding, he or she has a validly agreed upon a current payment plan.
    b. Certificate of filing income tax returns with the Puerto Rico Treasury Department for the first 5 years. **Applicants** that have been organized or doing business in

Puerto Rico for less than 5 years will submit the applicable Treasury Department for detailing the circumstances for the non-submittal of income tax returns for the period of five (5) years.

c. Certificate of no debt for real and personal property taxes payable to CRIM (Centro de Recaudación de Impuestos Municipales)
d. Certificate of no debt with the Puerto Rico Department of Labor
e. Certificate of no debt for Worker's Compensation Insurance
f. Certificate of no debt for child support under Puerto Rico law issues by ASUME or under the law of any other applicable state of the United States
g. Sworn Statement in compliance with Act No. 428 of September 22, 2004[9].

[9] To amend Sections 1, 3 and 7 of Act No. 458 of December 29, 2000, as amended, to provide that any natural or juridical person who wishes to participate in the award of bids or the granting of a contract with any government agency or instrumentality, public corporation or municipality shall submit a sworn statement indicating if he/she has been convicted or plead guilty to any crime listed under Section 3 of the aforementioned Act in Puerto Rico, the United States or in any other country.

P. Terminology on Agroponicos' System

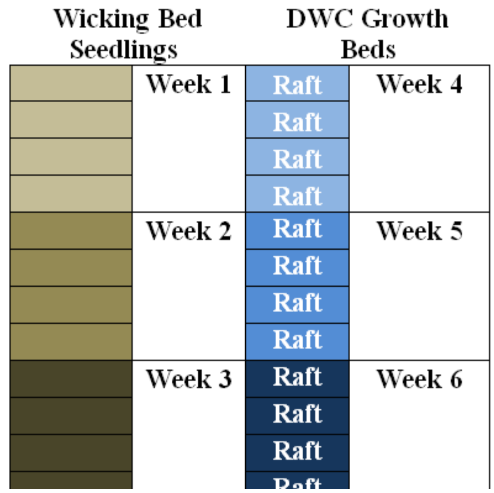

Figure 36: Lettuce bed diagram.

For lettuce:

Lettuce Bed
1 bed = 12 rafts
1 raft = 48 net pots
1 harvest = 4 rafts/bed
1 bag = 10 Oz. = .625 lb.

Each seedling of lettuce is grown for three weeks in the wicking bed and then three weeks in DWC growth beds before being harvested. Each raft contains 48 net pots, which are containers that hold the seeds and the plant food. The plant food consists of Coco-Tek and vermiculite mixture. Each harvest consists of five beds of lettuce, or 20 rafts.

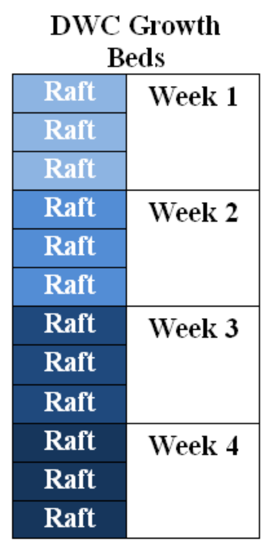

Figure 37: Chives bed diagram.

For chives:

Chive Conversion
1 bed = 12 rafts
1 raft = 240 net pots
1 harvest = 4 rafts/bed
1 bag = 16 Oz = 1 lb.

Each raft of chives is grown in the DWC growth beds for four weeks before being harvested. Each raft contains 240 net pots, which are containers that hold the seeds and the plant food. The plant food consists of Coco-Tek and vermiculite mixture but is not replaced frequently. Each harvest consists of one bed of chives, or three rafts.

Q. Analysis of Business Structures

Agroponicos is currently a corporation. Our sponsor is currently the only stockholders in their business and make up the board of directors in their company. If they wish to expand to other municipalities, it's important to assess what business structures are available and will best suit the needs of the business for the future.

To determine which business structures will best suit Agroponicos, we considered the ease of acquiring start-up capital and/or resources, who would be liable for any incurred costs or debt and who makes the decisions in the company. As indicated by the case study, the payout rate of the upfront costs is relatively slow. Therefore, it is important to choose a business structure that will have access to a large amount of start-up capital and/or resources to cover the upfront costs of the system. In general with medium to large or expanding businesses, limiting owner liability is also an important aspect to consider. This aspect is also important in case a business fails, so the owner will not have to incur a large amount of debt. Finally when deciding which business structure will work best, it's important to understand how each business structure makes decisions so if a company wishes to change who makes the decisions in the future they can plan accordingly.

In a corporation, they can generate capital through selling stocks however they do not have access to many grants. When paying back any debts, the business is responsible for liabilities instead of the owner which will be ideal for expanding the business. However, if they sell large amounts of stock, they run the risk of changing who makes the decisions in the company that's more reflective of the people who own the most shares.

One option that our sponsor can take is electing their business to become an S. Corporation. Agroponicos will have the same benefits of generating capital through stocks and having the business responsible for liabilities. However they will not be double taxed so only the shareholders will be taxed and not both the shareholders and the business.

If they wish to explore other possible business structures, they can look into forming a Cooperative system which has the benefits of pooling other members' resources and access to more grant programs which in turn reduces start-up costs. Liabilities will also be shared among the members so costs and debts will not be a hindrance on one person. In addition, because of the democratic system of appointing their board of directors, the weight of one member's vote will not be influenced by the amount of stocks they own. The biggest challenge of this system is finding devoted members that will keep the business running and will be able to fund the business.

Another option to consider is whether or not to split the business into two separate businesses with one business being for profit and the other business being not-for-profit. This organization can be beneficial if Agroponicos wishes to sell produce commercially but also provide education to other people who wish to learn more about or build systems for aquaponics. As a non-profit business, the educational products will have access to more grants and loans, especially if they are geared towards education. From there they can easily expand their abilities to provide services for education and consulting for aquaponic systems in Puerto Rico and in turn can advertise for their produce or any other produce that is grown via aquaponic systems.

Other business structures that have been considered but are not recommended are the Limited Liability Company, and the Partnership. The best way to find funding for the system is through loans so there will not be a significant amount of start-up capital. However in terms of liability, a Limited Liability Company can pay off their debts as a company whereas a Partnership must pay off their debts amongst the partners. In addition, a Limited Liability Company votes on a board of directors to make business decisions and the partners of a Partnership make business decisions.

Another business structure that will not be recommended in terms of the qualifications specified above is the Sole Proprietorship. Finding start-up capital will be difficult and the owner is responsible for all liabilities. However one main component of the sole proprietorship is that the owner can choose how he/she wishes to run the company.

Another option to consider is whether or not to split the business into two separate businesses with one business being for profit and the other business being not-for-profit. To qualify as a non-profit, the owner or a business cannot take any profit from what they sell, the organization cannot influence legislation as a substantial part of its activities and it may not participate in any campaign activities for or against any candidates (Internal Revenue Service, 2013). As a non-profit business, the business will be exempted from federal taxes, and they will have access to more grants and loans, especially if they are geared towards education. This organization can be beneficial if Agroponicos wishes to sell produce commercially but also provide education to other people who wish to learn more about or build systems for aquaponics. From there they can easily expand their abilities to provide services for education and consulting for aquaponic systems in Puerto Rico and in turn can advertise for their produce or any other produce that is grown via aquaponic systems.