i-ACES Vol. 3 No. 1 (2017)
Inquiry in ACES: An Undergraduate Research Journal
College of Agricultural, Consumer and Environmental Sciences
University of Illinois at Urbana-Champaign

i-ACES
{inquiry-ACES: Highlights of Undergraduate Research in ACES}

Potential for home-use hydroponic systems to increase food security in Cape Eleuthera, Bahamas

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ARTICLE INFO

Article history:
Accepted 21 April 2017

Keywords: Hydroponics, Food security, Bahamas, Sustainability, Agriculture

ABSTRACT

Historically, the development of food security in the Bahamas has been a challenge. Lack of fertile soil among the islands has hindered the growth of agricultural practices, leading to reliance on food imports for availability and consumption. As a potential solution for improving food security in the Bahamas, the economic viability of simplified hydroponics systems was investigated. Cape Eleuthera was used as a case study for implementing a home-use hydroponics initiative. Data from census, field studies, and examination of model hydroponic systems were obtained to determine preliminary implementation costs. Analysis of the occupied households residing in Eleuthera along with the projected cost of the model systems showed the initial investment cost for all households on Cape Eleuthera to have simplified hydroponic systems to be between $135,900 and $217,440. The relatively low start-up cost in combination with effective implementation and education strategies could make the application of home-use hydroponic systems on Cape Eleuthera a potential solution to increasing food security on the island.

INTRODUCTION

Food Security in the Bahamas

According to the World Food Summit in 1996, food security is defined as "when all people at all times have access to sufficient, safe, nutritious food to maintain a healthy and active life" (Inter-American Institute for Cooperation on Agriculture (IICA) accessed 2016). In the Bahamas, much of the country does not have this luxury. The Bahamas is over 80% dependent on imports, importing 98% of what they eat, which gives rise to several issues related to the security of their food system (Kendall & Petracco 2009; Wilkinson 2006). The term food security can refer to both the physical and the economic availability of food to meet the dietary needs of an individual (IICA accessed 2016). Through reliance on imports, the physical availability of food products is easily jeopardized if imports from suppliers are unable to be shipped to Bahamian islands, especially outlying islands, such as Cape Eleuthera, that are not as readily accessible as main islands like Nassau. Furthermore, the price of food is significantly higher than raw costs due to shipping and markups. For example, the price of one pound of red peppers in a central market located in Rock Sound on Cape Eleuthera is $6.43, whereas, in the U.S. the average rate from 2001 to 2014 was only $2.88 (USDA 2016). This type of price gap appears to be consistent regarding other types of produce such as lettuces and tomatoes (see Table 2). Poverty is often a significant link to food insecurity and is prevalent on Cape Eleuthera. With the unemployment rate currently at 7.6% in the Bahamas overall, and significantly higher in isolated outer islands, these prices are unaffordable to many local citizens, resulting in economic unavailability of food (Gardner 2009).

Agricultural Development in the Bahamas

Reliance on a foreign food supply is only a short term solution, lacking sustainability and security and prohibiting the Bahamas from advancing their agricultural and economic prosperity. As revenue from food imports usually goes to foreign suppliers, agriculture in the Bahamas currently makes up only 2.17% of the GDP (Ramkissoon 2002). Unfortunately, the development of conventional farming practices in the Bahamas poses several environmental and economic hurdles. The land has limited environmental resources suitable for farming, which gives little incentive for the Bahamian people to become farmers. Overall, the soil profile in the Bahamas is very poor; it is shallow and does not retain fertility or water well. Due to its alkaline nature, nutrients are unavailable to the crops grown in it, and thus, organic matter such as compost or fertilizer must be constantly added to the soil. This procedure must be done on a continual basis because once the organic matter breaks down, it has no lasting positive effect on the chemical make-up of the soil (Hedden 2011). Furthermore, the necessary fertilizer, pesticides, fungicides, and herbicides must be imported, so if any one of these components could not be shipped, the yield for that season would likely decrease significantly (Smith 2013).

In addition, even the land areas suitable for farming show little potential for profitable and worthwhile career prospects. For instance, the island of Andros is often cited as the 'breadbasket' of the Bahamas and has the greatest potential for farming (Smith 2011). However, a recent economic impact study on Andros showed that agriculture had the lowest revenue per person employed out of all activities on the island (Hargreaves-Allen 2010). Similarly, the Bahamian government has cleared 37,000 acres of land for low-cost agricultural leases, but only a quarter of this land has been leased to farmers. According to a 2009 government audit, most of those leases are not currently in production because most farmers cannot consistently produce enough crops to sustain direct sales to wholesalers and retailers (Smith 2011).

To add to the environmental and economic hurdles facing agriculture in the Bahamas, social factors also play a role in the lack of agricultural development. Although there is interest in fresh local produce in the Bahamas, farming as a profession is generally observed as demeaning and subservient work. Since the majority rule, Bahamians have been encouraged to move away from agriculture and start working in tourism and financial services (Hedden 2011). According to *Agriculture in the Bahamas* by Godfrey Eneas, the percentage of farm workers decreased from 4.4% in 1970 to 4% in 2011. This decline is likely the result of lack of interest and has led to reliance on immigrant labor to make up the workforce employed in agriculture (Smith 2013).

Emerging Solutions to Improve Food Security

As numerous challenges face agricultural development, large-scale farming may be a difficult obstacle for the Bahamas to achieve in order to attain significant economic returns. However, from the standpoint of improving food security in the Bahamas, sustainable initiatives such as backyard gardening, hydroponics, and small-scale local farms may be the answer. For these initiatives to be a success, national support for local products and Bahamian agribusiness must be achieved (IICA accessed 2016). Furthermore, increasing the knowledge and awareness of native plants (such as hot peppers, sweet potatoes, pineapple and coconut palm) that have the potential for successful growth by sustainable farming practices would be beneficial to Bahamians wanting to grow local produce. With several unpredictable environmental factors for conventional farming and gardening in the Bahamas, it is hypothesized that simplified hydroponics technology is a solution to overcoming these obstacles with respect to home gardens and small-scale farms.

Hydroponic gardening would provide access to local, fresh, and nutritious fruits and vegetables that are otherwise unaffordable for most households. Importing food contributes to increased price of perishable goods and an abundance of unhealthy processed snack foods. In general, incomes have increased in developing countries over the last 50 years, and many food prices have fallen (Keats & Wiggins 2014). However, this does not mean that foods contributing to an adequate diet are affordable. The percentage of adults who are overweight or obese more than tripled in developing countries from 1980 to 2008 (Keats & Wiggins 2014). This increase is likely due to a combination of increasing incomes and unhealthier processed foods being cheaper. Access to nutritious home-grown produce could lead to increased knowledge of proper nutrition, thus improving local diets and alleviating growing obesity rates.

Hydroponics can be water culture or aquaculture (aquaponics) based. In water culture hydroponics, plant roots are completely immersed in a nutrient solution, whereas in aquaponics, fish are introduced and their waste is used as the nutrient base for the plant solutions. Water culture hydroponics is easier to set up on a small scale, thus making it an ideal method for local people to use as a home garden or small-scale farm (Schmidt et al. 1983). A 2015 study published in the International Journal of Environmental Research and Public Health found that hydroponic gardening of lettuce uses land and water more efficiently than conventional farming (Barbosa et al. 2015). Because freshwater and land for farming is limited in the Bahamas, and even more so on outlying islands such as Cape Eleuthera, hydroponics appears to be a better use of the limited resources available in the Bahamas when compared to conventional farming.

Specifically, simplified hydroponic technology was designed to utilize fewer resources such as space, water and energy, while requiring minimal labor inputs and no expensive equipment (Saparamadu & Liyanarachchi 2013). This technology has already been implemented in twelve Latin American and African countries. These applications have indicated that, once growing beds are prepared and the transplanting is over, a 40 m^2 space can provide a family of four over a pound of fresh vegetables per person each day (Saparamadu & Liyanarachchi 2013). Therefore, investigating the potential application of this technology among households in the Bahamas could lead to necessary understanding to create systems for providing food security.

The objective of this research was to investigate and analyze the economic viability and overall feasibility of using home hydroponic systems as a resource for improving food security in the Bahamas, using the island of Cape Eleuthera as a case study.

MATERIALS AND METHODS

The following materials and methods were used to analyze the potential for implementing home hydroponic systems as a resource to improve food security on Cape Eleuthera.

Two model hydroponic systems were used to estimate and examine the start-up costs for a home- use hydroponic system. The first type is a homemade version using raw materials for personal construction. Homemade systems can be made from simple materials of which only three factors are required. The system must support the plant above the solution, the solution must be aerated, and light must be prevented from reaching the solution to prevent algae growth (Schmidt et al. 1983). Through research of several online blogs depicting various ways to construct a home-use hydroponic system, different systems were investigated while considering cost, materials, and construction. The second type of home-use hydroponic system used as a model was a ready-made kit. After investigating kits for sale online, one was selected that was similar to the homemade version in both structure and price.

Additionally, background research and analysis of sources were used to obtain research data and information to assist in the generation of ideas for practicality and avenues for implementation. Field studies were also utilized to generate data and critically analyze the prospective application of this research. These efforts include first-hand observations of abandoned homes and impoverished local conditions, working on the aquaponic farm at Cape Eleuthera Institute (CEI), and the collection of local produce prices in Rock Sound grocery store in Cape Eleuthera. Furthermore, calculations using primary research were used to generate research data for analysis. These include the calculation of projected start-up costs using estimated households on Eleuthera in combination with the individual costs of home-use hydroponic system models. Also, the amount of produce grown to equal the initial investment costs of each home-use hydroponic system model was calculated using data collection of local food prices (see Table 3 and Table 4).

DATA AND RESULTS

Population data, model costs for home-use systems, and local produce prices were obtained and analyzed to determine the economic viability of household hydroponic systems in Cape Eleuthera.

Population data for the number of people living on Cape Eleuthera was most recently reported in 2010. The population was recorded to be 8,202. Of that population, there were 4,267 households, but only 2,718 were reported as occupied dwellings (Dorsett 2012).

The system chosen to act as home hydroponic system ‘Model 1’ (Hydroponics-at Home 2007) was chosen for low-cost, accessible materials, and ease of construction. The materials, the cost of materials, and the finished product of ‘Model 1’ can be seen in Table 1 and Figure 1.

Table 1. Estimated cost of materials for home-use hydroponic system ‘Model 1’ (Hydroponics-at Home 2007).

Materials	Estimated Cost
18 gallon storage bin	$8.97
6 heavy duty mesh pots	$9.90
3 gallons Rockwool Growcube (chopped rockwool)	$5.95
Growing solution (recommended: Dyna-Grow brand 7-9-5)	$12.95
Aquarium air pump	$6.99
Air stone(s) and air hose	$3.00
60 mL syringe (for precise measurements of growing solution)	$2.60
Utility Knife	$2.76
Total materials:	**$53.12**

Figure 1. Completed construction of home-use hydroponic system 'Model 1' (Hydroponics-at Home 2007).

The system selected to act as home hydroponic system 'Model 2' was the H2OtoGro® Hydroponic Bubbler system #4. The retail price is $79.00, which features 100% food grade materials including a 4-gallon growth bin, a garden hose adapter drain, a water level indicator, a nutrient fill hole, a starter kits of nutrients, growth medium, and net cups (H2OtoGro® 2015). This system can be seen in Figure 2.

From the 2010 census data of occupied households residing in Cape Eleuthera and the projected cost of the model systems, the initial investment cost for all households to have home hydroponic systems would be between $135,900 and $217,440. In addition, Table 3 and Table 4 depict the estimated amount of grown produce to equal the initial investment of each model system.

Figure 2. The H2OtoGro® Hydroponic Bubbler, home-use hydroponic system 'Model 2' (H2OtoGro® 2015).

Table 2. Price inflation due to importing produce: a comparison of produce prices in Cape Eleuthera versus the United States (U.S.) (USDA 2016).

Produce type	Unit	U.S. cost per unit	Cape Eleuthera cost per unit
Red Peppers	1 pound	$2.88	$6.43
Cherry Tomatoes	1 pint	$2.20	$4.80
Lettuce, Romaine	3 hearts	$3.04	$6.41
Greens, Arugula	5 ounces	$2.49*	$7.48
*obtained from Aldi online price listing (SimplyNature accessed 2016)			

DISCUSSION

From the data, it appears that home-use hydroponic systems on Cape Eleuthera could be a solution to increasing food security with relatively low investment costs. Initially, implementation would only be carried out on a subset of the population; therefore, if put into effect, the preliminary costs would likely be lower than this estimate. Furthermore, the total savings from produce growth seen in Table 3 and Table 4 could potentially pay off the initial investment in a matter of months after growth is established. That being said, further research must be done to investigate local and national interest in this initiative as well as an established growth rate. Some problems and obstacles to overcome regarding this project would be a possible lack of interest among the local population regarding growing foods themselves and upkeep. Further, the community as a whole is poor and may not be able to afford the water, electricity, and growing materials needed to maintain the system for future years. Finally, local knowledge regarding the maintenance and upkeep of hydroponic systems is currently limited.

Table 3. Estimated growth of produce to equal the initial investment cost of 'Model 1' home-use hydroponic system.

Produce type	Growth unit	Estimated Growth Amount	Market cost in Cape Eleuthera per growth unit
Red Peppers	2.5 pounds	7-8 large peppers	$16.07
Cherry Tomatoes	2 pints	50 cherry tomatoes	$9.60
Lettuce, Romaine	6 hearts	24 cups, chopped	$12.82
Greens, Arugula	10 ounces	8 cups	$14.96
Total:			**$53.45**

Table 4. Estimated growth of produce to equal the initial investment cost of 'Model 2' home-use hydroponic system.

Produce type	Growth unit	Estimated Growth Amount	Market cost in Cape Eleuthera per growth unit
Red Peppers	4 pounds	12 large peppers	$25.72
Cherry Tomatoes	3 pints	75 cherry tomatoes	$14.40
Lettuce, Romaine	8 hearts	32 cups, chopped	$17.09
Greens, Arugula	15 ounces	12 cups	$22.44
Total:			**$79.65**

One avenue to overcome a lack of interest would be initial implementation of simplified hydroponics in school systems. Case studies suggest that hydroponics can be effectively taught in the classroom (Ortiz et al. 2009). The techniques are easy to understand and require no prior scientific knowledge of hydroponic plant growth (Caldeyro-Stajano 2004). Furthermore, plant growth is achieved quickly and maintenance of plant beds after start-up only takes an average of 15-20 minutes per day (Caldeyro-Stajano 2004; Saparamadu & Liyanarachchi 2013). These aspects make simplified hydroponic technology a perfect application for an academic setting. Through a school unit, students would be given the raw materials in class to construct their own hydroponic system. Throughout the year, they would learn to grow and harvest produce hydroponically, maintain their systems, and even participate in cooking classes where they learn how to make recipes using their grown produce. Not only would this stimulate interest in hydroponic farming among youth, but it would also teach the students how to maintain their crops independently and use the produce they grow. With this knowledge in place, at the end of the school year students could take their hydroponic system home and continue growing their produce, while teaching their families methods for upkeep and maintenance.

Other possibilities for education and implementation of simplified hydroponics should also be explored. During field studies and traveling on Cape Eleuthera, it was observed that there were a large number of churches (usually more than one) among the small communities. Therefore, classes could be taught through local churches to introduce adult populations to hydroponic gardening and maintenance. Moreover, institutions such as the Island School and Cape Eleuthera Institute could put outreach and extension programs into effect that include classes and additional workshops to continue education in this area. Then, local communities could continue to grow their farms and become more efficient in their yields. With the knowledge and experience to develop more efficient growth practices, families would be able to grow more produce, saving them more money, and thus helping alleviate the maintenance costs of each system. Finally, education and awareness from these efforts could lead to more interest and the development of community hydroponic farms at a larger-scale. Studies suggest that every $1 invested in a community garden yields $6 worth of produce (Bellows et al. 2003); therefore, larger-scale community gardens could be a future progression from home-use hydroponic systems in order to increase food security in communities as a whole.

In order to overcome challenges related to lack of resources, additional factors should be taken into consideration. For instance, if electricity to run the aeration pump is inaccessible, other methods of simplified hydroponics can be utilized. Plants can be grown in low-cost natural substrates such as sand or pumice. With this method no aeration or commercial energy is required, and plants only need to be watered once a day with nutrient solution for sufficient maintenance (Saparamadu & Liyanarachchi 2013).

Funding for this project could potentially come from a variety of sources. Part of the Bahamian Department of Agriculture's $7 million budget goes toward backyard gardening initiatives, and this project (including every household on Eleuthera) would require around 2-3% of the total budget. Furthermore, organizations such as the Food and Agriculture Organization have carried out various ventures related to agriculture and food security in the Bahamas since 2008 (Government of the Bahamas & Food and Agriculture Organization 2012). Project budgets have ranged from $10,000-$500,000 dollars; therefore, it is possible they could fund this initiative. Finally, since individual system start-up costs are relatively cheap, it is possible that a select number of individual households or school districts could financially support the start-up costs for home-use or class programs to instigate hydroponic gardening.

CONCLUSION

Home-use hydroponic systems could be a solution to help increase food security in the Bahamas. Simplified hydroponic systems have relatively low investment costs, are a sustainable way of growing produce, and offer an easy to learn, convenient growing method for an area with limited resources (fresh water, electricity, and fertile soil) such as the Bahamas. Potential implementation of home-use hydroponic systems in school systems, churches and extension programs would provide educational benefit as well as increased food security and access to fresh, nutritious foods; however, further research must be done to investigate produce growth rates in the model systems as well as potential interest and funding of this initiative.

ACKNOWLEDGEMENTS

Financial contribution for travel to Cape Eleuthera, Bahamas was provided by the James Scholar Enrichment Fund within the College of ACES. Special thanks to Dr. Brian Allen, Dr. David Allen, and Dr. Soo-Yeun Lee for their advisement and technical expertise. Further thanks to the researchers and staff at Cape Eleuthera Institute in the Bahamas.

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