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# Vertical Farms and the New Green City

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## **ABSTRACT**

Urban agriculture, urban farming, or urban gardening is the practice of cultivating, processing and distributing food in or around urban areas. In densely populated regions, urban agriculture offers a new frontier for land use planners and landscape designers to become involved in the development and transformation of cities to support community farms, rooftop gardening, and vertical farms. Vertical farming is an agricultural method of cultivating vegetables that combines the design of building and farms all together in a high-rise building inside the cities. This form of farming can produce food in vertically stacked layers, vertically inclined surfaces and/or integrated in other structures, such as a skyscraper or warehouse. Technology now exists for indoor farming techniques, where all environmental factors can be controlled, and large cities are becoming pioneers of vertical farming. While urban agriculture has historically been an important source of food in many developing countries, recent concerns about economic and food security have resulted in a growing movement to produce food in cities of developed countries, including the United States and Europe. It is beginning to play an important role in the economic development of cities by repurposing vacant industrial buildings, supplying fresh and healthy food, and providing jobs in distressed areas. This industry, however, faces both challenges and opportunities. Using both case-based and survey research, this study provides a better understanding of vertical farming, and explores the potential to raise public awareness and garner community support for the continued growth of this industry in urban areas of developed economies.

## **Keywords**

Urban agriculture, vertical farms, technology, food production, sustainability

## **1 INTRODUCTION**

Urban agriculture offers an alternative land use for integrating multiple functions in densely populated areas. While urban agriculture has historically been an important element of cities in many developing countries, recent concerns about economic and food security have resulted in a growing movement to produce food in cities of developed countries. Urban agriculture offers a new frontier for land use planners and landscape designers to become involved in the development and transformation of cities to support community farms, rooftop gardening, and vertical farms. Vertical farming is a new agricultural method of cultivating vegetables that combines the design of building and farms all together in a high-rise building inside the cities. The challenge (and opportunity) is to design urban agriculture spaces to be multifunctional, while matching the needs and preferences of local residents, and protecting the environment. Large cities are becoming pioneers of vertical farming by repurposing vacant urban warehouses, and high-rises to grow food. When vacant space is available, the cost of property is often affordable to buy or rent. Urban agriculture and vertical farming are playing an important role in spurring economic development by repurposing vacant industrial buildings, supplying fresh and healthy food and providing jobs in distressed areas. This research explores the potential for, and experiences with, urban agricultural and vertical farming in the US.

## **2 BACKGROUND & LITERATURE REVIEW**

Although the concept has been newly introduced to urban areas, the idea of vertical farming has been around for some time. Examples of vertical farming can be found dating back to the ancient era in the Hanging Gardens of Babylon in on the Philon's Several Wonders of the Ancient World which dates back to 600 BC (Al-Kodmany, 2018). In the 1890's, community gardens were emerging in vacant lots in Detroit, New York, and Philadelphia so that locals could acquire their desired crops with ease (Lovell, 2010). The term "vertical farming" was coined in 1915 by Gilbert Ellis Bailey in which he wrote a book titled "Vertical Farming". In this book he discusses how farming hydroponically in a vertical structure would create economic and environmental benefits (Al-Kodmany, 2018). The great depression of the 1930's saw an increase in urban agriculture. While the reasons for urban agriculture were more so to money and survive than to help the environment and the economy, it was a concept that helped save lives when individuals were struggling to put food on the table for their families.

During World War II, food supplies were rationed and victory gardens were created. As a result, individuals in urban areas were gardening on their rooftops and allotted public spaces to help the cause (Lovell, 2010). Then in the 1980's Urban Agriculture began to shape into what we know it as today. Åke Olsson, who was a Swedish ecological farmer, proposed the concept of vertical farming in urban areas. He is known for having invented a spiral-shaped rail system for growing plants. A decade or so later, Dickson Despommier who was an American ecologist, revived Åke Olsson's concept of vertical farming by suggesting vertical farming take place in skyscrapers that could use "advanced greenhouse technology such as hydroponics and aeroponics to produce fish, poultry, fruit, and vegetables (Al-Kodmany, 2018).

There are multiple benefits of vertical farming, which include those that are environmental, social and economic. Environmental benefits include energy conservation, water recycling, and the reduced need for fossil fuels. Social and economic benefits include increased employment and creation of new jobs in cities, access to fresh foods with reduced transportation costs, and creating a more visually appealing environment.

## **2.1 Public Support**

Increasingly, advocates are recognizing the potential of urban gardening as a significant link in urban food security worldwide. Faced with enormous urban population growth and economic and political changes that increasingly undermine local food distribution systems, many cities around the world have begun to foster a range of experiments in urban agriculture. Vertical farming has numerous advantages over traditional farming, which includes more efficiency, adaptability, and environmental benefits, which is all made possible through carefully controlled systems. If its use becomes more widespread across, the fear of a dwindling food supply and detrimental climate change will slow down.

What can be done to encourage support for vertical farming and entrepreneurial urban agriculture? Its future may depend on the level of understanding and acceptance it can garner from key institutions—local governments, local foundations, community development corporations, neighborhood organizations, and key state and federal government agencies. Community-based organizations claim to be sensitive to the wishes of its constituents. A survey of New York's 5 boroughs, discovered as many as 120 deserted buildings which could be potentially revolutionized. These buildings could be turned into vertical farms to serve the needy inhabitants of those parts of the city. There are infinite number of such sites in other cities worldwide (Despommier, 2010).

The literature underscores the importance of having community residents buy into the idea of urban agriculture in their neighborhoods. Its many benefits do not necessarily result in an automatic attachment to city farming as an activity worth doing, especially if it is felt that a neighborhood's needs for jobs or more and better housing are more important. Many potentially supportive organizations are generally unaware of the benefits of such projects or are skeptical about their durability and lasting significance. It may be critical therefore for advocates to convince others of the positive community benefits. A positive correlation was found by Yusoff, Hussain & Tukiman (2017), indicating that the practices of urban farming activity are linked with the commitment and the awareness of urban communities towards preserving and protecting the natural resources for future growth through establishing environmentally-friendly educational community programs held in the neighborhood green spaces.

## **3 RESEARCH OBJECTIVES**

The purpose of this research is to explore the experiences of founders of vertical farms to better understand the opportunities and challenges. From the consumer perspective, we will obtain levels of awareness for urban agriculture and vertical farming and dietary preferences. This study will also evaluate the key benefits of the industry on an economic, environmental and social level. In this we can measure key communication points that are effective in raising awareness and garnering support for vertical farming among communities and important stakeholder groups.

## **4 RESEARCH METHODOLOGY**

The purpose of this project is to apply case-based research to understand the opportunities, barriers and sources of support for the growth of vertical farming and urban agriculture to help meet the needs of communities in cities. A systematic review of the existing literature and available statistical data was conducted. To gain perspective of companies involved in urban and vertical farming, personal interviews were conducted among founders in each country. It was determined that survey research would be used to collect data from consumers in each of the three countries to measure levels of awareness, and attitudes towards benefits of vertical farming, and dietary preferences and behavior.

## **5 DATA COLLECTION**

### **5.1 Interview**

Farm One was founded three years ago by Rob Laing and is located in downtown Manhattan. At Farm One they grow rare herbs specially ordered by chefs of top tier restaurants in New York City. This vertical farm utilizes a hydronic system to grow plants. This means that water and LED lights are used to simulate the ideal growing environment for each individual plant. New York

City tap water is used to irrigate the plants throughout the farm and is filtered by a process known as reverse osmosis to ensure purity. As many as 80 different seed varieties can be grown at once.

Different systems are used to grow the plants based on the plants preferences. The most commonly used system is “deep water culture”. Holes are poked in a floating raft where the plants roots are completely under water, and the leaves and flowers are exposed to the air and lights. Once the water is properly filtered, nutrients are introduced to the water. The farm uses a nutrient solution consisting of ground up fish and other plants. There is one main water reservoir where the solution is poured into. This cycles the water throughout the entire farm. The second system used is called “flood and drain”. Plants are flooded with water then after a certain amount of time, the water is drained from the plant and goes to the one below. It will take an hour for the water to drain from each plant and this process is repeated every three hours. It is critical that the roots are constantly given oxygen while the water is being drained. The plant will survive as long as it is getting proper levels of oxygen.

Along with different growing environments, Farm One uses an alternative plant medium to soil specific plants. It is made of ground up coconut husk and peat moss. Remarkably, it feels just like regular dirt. To monitor plant growth, CEO Rob Laing built software that calculates how much nutrient solution needs to be added based on the plant's electric connectivity and temperature reading. Workers will take these readings daily and enter the data into the software to track progression. An electric connectivity reading of 2.5 or less means that more nutrient solution needs to be added. An ideal temperature reading is 70 degrees Fahrenheit (21.2 degrees Celsius). Farm One is able to simulate the ideal growing environment for a plant using LED lights. These lights are on for 17 hours each day. The seven hours that they are off replicate what it would be like at night. Plants get a circadian rhythm (natural 24-hour cycle). Plants in the farm usually close up around 10 p.m., and re-open at 9 a.m.

Waste production is reduced in several ways using Farm One’s method. First, the water is cycled through the entire farm. The amount of water being used is equivalent to what an average person would use in one day. Second, vertical farming cuts out the long transportation process. They deliver all goods to chefs by bus or train for guaranteed freshness. Chefs will specify their order ahead of time. There is no need to rent out trucks or use special packaging to preserve the product. This eliminates Styrofoam packaging waste as well as offer a cheaper more efficient system.

The most exciting prospect from this visit is the need of a reliable self-sustaining energy supply. The farm manager shared that he believes vertical farming will take off when solar energy is better applied and understood. Farm One would produce even less waste using solar panels and not require as much electricity to power the farm. Processes would become better refined and plants would be grown and delivered in a more efficient manner.

## 5.2 Survey Data

The customer survey handed out to faculty members and students of Molloy College will be analyzed in this section. One hundred people completed this survey and it yielded some interesting results.

In the United States we were able to get 100 people to take the survey. Our audience demographic was 55% male, 75% 18-24 years old, 87% followed no specific diet, and 78% lived in the suburbs. More people were aware of vertical farming (37%) than urban agriculture (34%). When asked to rank the benefits of vertical farming, our sample population agreed that *creating jobs in cities* and *reducing the use of pesticides* were the most important. This shows that our sample cares about reducing harmful chemicals in the food we eat, and helping the local economy. We noticed that many respondents in our community are concerned about using too much energy, and its effect on the environment, as well as where our food will come from in the future.

An important finding was the change in the importance ratings after participants were exposed to the benefits of vertical farming. First, we asked this question and 33.0% were neutral, 41.2% thought it was “somewhat important,” and 13.4% rated it as very important. After we introduced the benefits of vertical farming as mentioned above, we asked the same question again. The change in responses was impressive. We saw a 5% increase in votes for “somewhat important” and a 22% increase for “very important.” There was also a 24% decrease in “neither important nor unimportant.” This data shows the importance of public perception in regards to vertical farming. Locally grown food can have enormous benefits not only to the environment but to the customer as well. Waste production and energy consumption decrease while the freshness and quality of the product increases.

## 6 KEY FINDINGS

Key findings in this study include the pre-post reaction of survey respondents to the importance of vertical farming. We asked “how important do you feel that vertical farming would be in the area that you live, or the nearest city?” in the beginning of the survey. After reading the list benefits of vertical farming, and ranking the list on the basis of importance, we re-asked the question. In all three countries, respondents thought vertical farming was more important after being made aware of the benefits. As the chart below shows, there was a significant jump in “very important” answers. When made aware of vertical farming’s advantages these respondents are much more favorable. This applies to all three countries, and across the varied demographic profiles.

## 7 CONCLUSIONS

The major findings from this research indicate that the awareness levels for vertical farming are low, the public is not educated as to the potential benefits of urban agriculture and vertical farming. There is also a realization of the need to encourage urban support of such projects as they can benefit the environment, society, and the economy. The surveys were structured in such a way that not only would we be able to gather data, but we would also be able to educate the survey respondents simultaneously. This helped close the gap between those who were educated on the subject and those who were newcomers to the concept of urban agriculture/vertical farming.

It's important to note that while urban agriculture/vertical farmers have many opportunities (environmentally, social, and economically), they also face significant challenges. As discussed, funding and generating capital is the biggest issue at hand but other challenges involving proper management, public and government support, and technology are other issues involved. As a result, there are few vertical farms located globally. This is a problem that needs to be addressed. With climate change becoming an issue, food supply becoming a future issue, the importance of non-GMO/organic food, and the economic benefit of stimulating growth while creating jobs, creates a concern that this issue hasn't had more light shined upon it. Al Gore discusses the concept of vertical farming in his film titled "An Inconvenient Truth" and even this isn't enough to generate public support, he has gone as far as bringing celebrities alongside his global campaigns to bring more attention to the issue.

Historically, urban agriculture was a means to survive in developing countries and economies. As such, families used rooftop farming to help put food on the table for their children while using the saved money to help pay for rent. While presently there are still cases of urban agriculture as a means to survive in developing countries/economies, in many developed countries technology has evolved that make vertical farming more viable and successful, such as hydroponics and aeroponics. There are also complex irrigation systems, LED lighting, and complicated design systems to make vertical farming possible. As technology continues to develop, and expenses associated with vertical farming are lowered, these farms could see further global expansion. There is potential for a green society.

## 8 RECOMMENDATIONS FOR FUTURE RESEARCH

Future research should address the limitations of this study, namely any distortions in the data due to the demographic skew or language barriers. Research should be ongoing and expand to cover other regions or countries to understand the different challenges and opportunities that vertical farmers, and populations, face regarding local food sources. Ideally, future research will use a random sample rather than convenience sample, with a larger sample size and distribution across demographic variables. Importantly objectives of future research should focus on the optimizing key message points that would result in the developing of types of communication that builds awareness and public support. Ultimately the goal is to encourage policy-making that helps the vertical farming industry, and community participation, continue to grow.

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