Running Head: VERTICAL FARMING

Expanding Farming to a New Dimension

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Abstract

Currently, the human population is growing exponentially, and eco-friendly solutions to meeting food needs are being examined. Whereas conventional farms are horizontally oriented, vertical farming is a new approach that grows food on a vertical axis. These modern high-rises will increase food production, provide locally grown food in cities, and reduce agriculture's negative effects on the environment. However, cost and energy efficiency are factors in implementing vertical farms. Our research is focused on demonstrating that vertical farming is a viable solution to emerging environmental and societal problems. Through examining several types of lights and growing a variety of plants under controlled environmental conditions, we found that plants grow best under fluorescent lights. This bodes well for the concept because it shows that the most efficient light source is not costly, which is helpful in offsetting the initial costs associated with implementing a vertical farm. Thus, the growing problem of limited food supply can be solved through new, innovative cultivation techniques. Moreover, this helps to reduce carbon emissions, cultural eutrophication, and other problems associated with modern farming.

Literature Review

At present, the human population is experiencing exponential growth. Applying the most conservative estimates, it is predicted that the human population will increase by three billion people by the year 2050. With the assumption that farming practices continue as they are today, it is estimated that 2.5 billion acres of new land, or land 20 percent larger than the size of the country of Brazil (Despommier, 2009), will be needed to grow crops to feed these new mouths. According to the Food and Agriculture Organization and NASA (2009), over 80 percent of the land suitable for growing crops is currently in use, and about 15 percent of that land has been rendered useless due to poor management. However, Dickson Despommier, a professor of environmental health sciences and microbiology at Columbia University in New York, has a potential solution: vertical farming.

Vertical farming is a system of sustainably growing crops in an urban environment, using methods of growing without soil implemented through hydroponics and aeroponics, artificial sunlight, recycled resources, and other available technologies. Scientists agree that "vertical farming is an idea that can work in a big way" (Walsh, 2008). The crops would be grown within a building, ideally a skyscraper, and each floor would house a different crop. Different studies and calculations have demonstrated the benefits of vertical farming: to the environment, ecosystems damaged by traditional farming, and society. But the underlying question is whether or not vertical farming will be proven feasible or economical in the long term, and ultimately, whether or not it would be feasible or economical to implement vertical farms in large cities.

Historical Overview

The idea of vertical farming emerged through Professor Dickson Despommier's medical ecology class at Columbia University in 1999. Despommier and his students studied rooftop

gardening and soon discovered that the approach was much too small-scale. In challenging his students to feed Manhattan's population through rooftop gardening established over 13 acres, calculations demonstrated that only about two percent of the population could be fed (Walsh, 2008). A far more ambitious idea was introduced: a sustainable, 30-story "vertical farm." Despommier imagines high-rise vertical farms, or "farmscrapers," with glass walls that allow natural sunlight, use recycled waste water to grow crops, and that produce energy by composting non-edible parts of plants. Vertical farming would help the environment by reducing waste, amount of water used to supplement crops, carbon dioxide emissions during transportation, and pesticides used. Along with environmental benefits, farming indoors would completely eliminate many problems of traditional farming, including weather-related crop destruction, detrimental pests, and much more. Despommier's Vertical Farm Project (2009) claims that a vertical farm on one acre of land can grow as much food as can be grown on four to six acres through traditional farming. In time, the increased production of crops will be necessary to feed the growing human population. In addition, the significantly increased crop yield could allow cities to become local, self-sustainable growing environments.

One of the most incontrovertible benefits of vertical farming is the ability to grow more crops year-round. Technologies can allow scientists to easily monitor and manipulate air temperature, humidity, light intensity, amount of nutrients, dissolved oxygen, and even the carbon dioxide content in the air. Through hydroponics, crops can be grown without soil in water and mineral solutions, as well as suspended in misty conditions through aeroponics. Benjamin Linsley, a spokesman for the sustainable energy firm New York Sun Works, agrees that growing crops without soil has great benefits: "We need to find new ways to grow food. If you can stick farming anywhere you like - and say 'we don't need soil' - then a huge door opens" (Ehrenburg,

2008). Furthermore, other benefits of growing crops hydroponically and aeroponically in protected chambers include healthier and more nutritious crops, as various scientific studies have shown (Bawaba, 2010). These methods also allow for quicker and easier crop production when compared to traditional growing methods. “The environment can be more easily and inexpensively controlled, and you will get fresher, more nutritious, and safe food,” says Dr. Edward Harwood, founder of Aerofarms, a company that works with aeroponic growing technologies (Bawaba, 2010).

Through aeroponics and hydroponics, medicinal herbs can also be grown year round, with the added health benefits of eliminating the use of laboratory chemicals. Dr. Mike Nichols, a horticulture science lecturer at Massey University in New Zealand, says, “Medicinal herbs are very important because there’s a big move away from laboratory-produced chemicals to more natural alternatives. These plants are capable of making a valuable contribution to human health” (Scientists grow, 1999). Herbs and plants grown hydroponically and aeroponically allow quicker and easier crop production than plants grown with traditional methods, and yield a significantly lesser amount of waste. A system of plants grown aeroponically can be kept alive with about 50 liters of nutrient-rich water, and only about 15 essential nutrients and trace elements are needed to grow the plants. The growing plants’ roots are sprayed with a fine mist of nutrient-rich water every few minutes. Technology allows scientists to manipulate the water’s temperature in such a way that allows an increase or decrease in growth rate of the plants. No waste is produced through these growing methods, as the nutrient solution is re-circulated through the growing chamber.

Current Trends and Practices

Although vertical farms have not yet been implemented in cities today, hydroponics and aeroponics have been utilized in growing crops on a smaller scale for decades. Hydroponic and aeroponic growing methods have been used to grow fruits and vegetables commercially in countries such as Singapore for many years. Furthermore, Valcent Products, the United Kingdom's research division of a Canadian company, has recently developed a smaller-scale version of a vertical farm for application in warehouses or large greenhouses. Their technology, called VertiCrop, has been installed in Paignton Zoo's Environmental Park in Devon, England. VertiCrop allows eight times the number of crops to be grown when compared to a conventional greenhouse, while using only 60 percent of the energy and five percent of the water (Vertical farming, 2010) that would be used to grow crops traditionally using an automated watering system. Although crops grown in this system are currently only feeding zoo animals, efficiently growing crops while dramatically reducing the amount of water, land, and energy needed to grow the crops is an essential constituent to a successful vertical farm. Although building a vertical farm is currently more costly than sticking with traditional farming methods, a significant amount of energy and water is saved through the implementation of hydroponics and aeroponics, which would be put in use in vertical farm buildings. When taking into account the amount of fuel saved during transportation as well, the environmental benefits and the amount of energy saved are phenomenal. Currently, Valcent Products is working to develop even smaller-scale vertical farm systems for domestic greenhouses. "Vertical agriculture will really come into its own in towns and cities," says Kevin Frediani, a representative of Valcent Products who organized VertiCrop. "Schools, hospitals and housing estates could have their own vertifarms, tended by a new generation of vertical farmers" (Bouquet, 2010).

On another note, students and staff of Tortolita Middle School in Tuscon, Arizona, have farmed aeroponically for a different purpose: charity. Using aeroponic technology in three indoor AeroGardens, students grew and harvested tomatoes, jalapenos, cilantro, and other ingredients to make salsa. Crops that were planted in August were able to be harvested in November. The salsa was sold to members of the community, and profits were given to charity. The "Salsa Project" was started by teacher Kathleen Neighbors and her students. It would be prudent to conclude that technology that is friendly enough to be implemented in a school could easily implemented on a larger scale, and therefore in an urban vertical farm.

Issues and Controversies

On the other hand, the research of some scientists, architects, and futurologists (Vertical farming, 2010) has indicated that at present, building a vertical farm is not cost effective or practical. Gary Lawrence, the former planning director for the city of Seattle, Washington, informs, "There's a huge amount of research going on, but we need to get the costs down." (Ehrenberg, 2008) This poses the ultimate question concerning vertical farming: whether or not the costs of building and implementing a vertical farm will outweigh the benefits. Lawrence asserts that "the choice to act is a policy and financial issue" (Ehrenberg, 2008). Furthermore, "net-zero" is a term used to describe a building that uses no more energy than it generates itself. However, achieving net-zero is especially costly, and cost is one of the biggest obstacles to generating greater interest in ideas like vertical farming.

Critics of vertical farming also wonder about the effects of banishing soil and natural sunlight from agriculture, and how these changes will affect taste and nutrition of the crops. Despommier agues that the right taste and nutrition are simply a matter of "getting the science right" (Steel, 2009), since the crops are grown using hydroponics and aeroponics. In addition,

scientists at NASA and other organizations are working to perfect LED lights to emit light in the best wavelengths for plants. They have found that mostly red and blue, and some green light, is most ideal for healthy plant growth (Ehrenberg, 2008).

Another controversy surrounding the idea of vertical farming is the costs and energy requirements in producing crops year-round. The primary input for crop growth, sunlight, is free and abundant in traditional farming, whereas artificial resources would have to compensate in vertical farming. Bruce Bugbee, a Utah State University crop physiologist, says that the power demands of growing crops through vertical farming would require about 100 times the amount of light as used by people working in office buildings (EarthTalk: Living building, vertical farming, 2009) which would make the practice too costly compared to traditional farming. However, scientists who support vertical farming argue that vertical farms could produce their own power by utilizing local renewable energy sources, such as solar, wind, tidal, and geothermal energy, as well as through burning biomass from crop waste. Furthermore, current research is being done to try to find the most efficient artificial light source for plant growth, as in our group's current research.

A problem that has yet to be researched on a deep level is whether or not traditional farmers would approve of working in an indoor vertical farm, and the changes that vertical farming would bring to the lives of farmers. People currently making a living through traditional farming could face difficulties if farms were to go vertical in the future. As their land is left to heal, farmers may be left to suffer economically. On the other hand, behavioral studies of vertical farming and current society's view of it have yet to be researched on a deep level. As the idea has emerged quite recently, most people are not educated about vertical farming and concepts surrounding its works. If the public were more educated about vertical farming and its benefits to

the environment and to society, however, they might be more willing to spend time and money to develop a vertical farm in a local urban environment. Moreover, further research and analysis about vertical farming and how it would affect the economy should be conducted, because this may help further convince the public to adopt and localize vertical farming.

The ultimate question that scientists, economists, and city planners face is whether or not the environmental and societal benefits of vertical farming outweigh the building costs and controversies that the shift from traditional to indoor vertical farming would bring. Despite its flaws, the idea of vertical farming has pronounced benefits that could greatly benefit society and the environment if vertical farms were to be implemented in urban environment

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