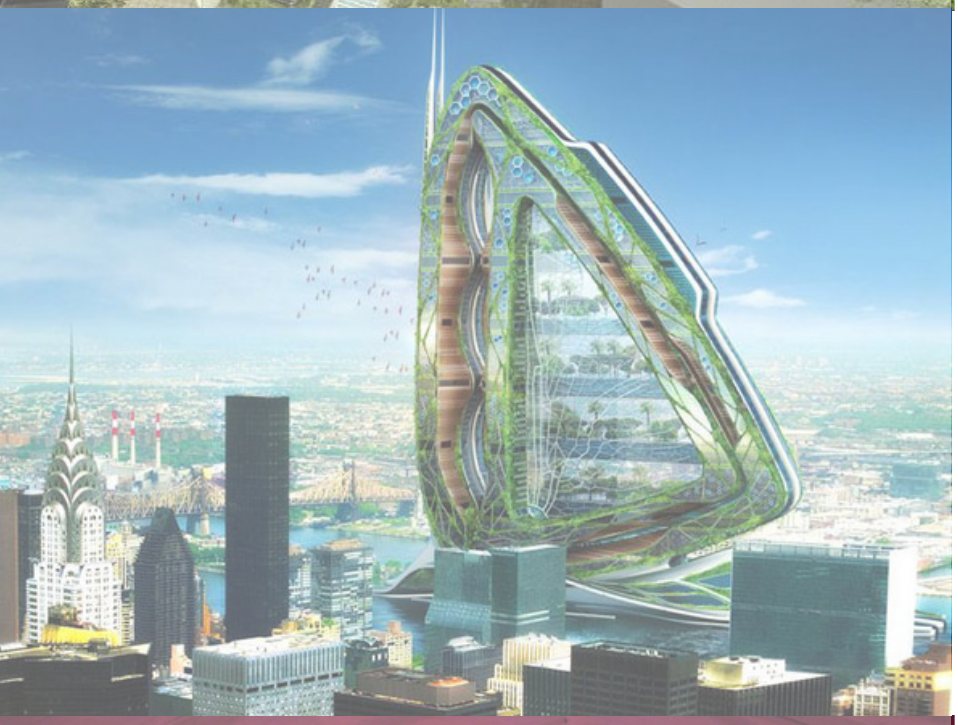

Non-Traditional Agriculture: Path to Future Food Production?

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make every drop count

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Abstract:

The world population is growing rapidly, and the amount of arable land is decreasing. This raises the issue of how to feed the 2050 projected population of nine billion people. Another issue is the presence of "food deserts." Food deserts are defined as urban neighborhoods and rural towns without ready access to fresh, healthy, and affordable food.

The purpose of this report is to examine possible alternatives for food production that are also located in close proximity to demand. Included in non-traditional production agriculture are several concepts currently in use, including greenhouses (covered agriculture), backyard gardens (called Victory Gardens during WW II), agriculture-designated land within urban areas, underground facilities (bomb shelters), urban agriculture in housing developments, and converted warehouses. Other production concepts are presented to demonstrate the breadth of discussion regarding meeting future food demand.

In the several cases of unique, non-traditional agriculture, each is a new industry with few players in the market, suggesting time will be the final decision-maker on viability (agronomic and economic). Greenhouses have been a part of production agriculture for centuries, with the technology well-defined. But retrofitting abandoned warehouses or constructing high rise facilities, as well as production in high rise housing units, will take time to perfect the systems involved, including a water and reuse system, fertilization, pest and disease control, harvesting, overall quality control, and logistics.

The necessary components of non-traditional food production facilities are resources, land, water, equipment and finances. Highly fertile land has for the most part been allocated to crop cultivation, and the quantity of high-quality water for irrigation is declining. Non-traditional systems typically have a much smaller land footprint and are highly efficient in water use. The implication is that non-traditional food production systems will provide society with more quantity, plus improved quality, of high-value food products per unit of land and per unit of water.

This is a broad, brief review of actual production facilities, as well as projections for the future. Included are greenhouses, retrofitted warehouses, below-surface facilities, high rise facilities, and production near cities. This piece is intended to provide insight into the broad range of non-traditional food production facilities emerging and envisioned at this time. The mention of any business is not to be interpreted as endorsement or suggestion that it is viable.

Introduction

With the projected rapid increase in population and need to feed billions more mouths in the next few decades, the role of traditional large-scale agricultural production units will continue to play a major role. However, there are opportunities for non-traditional food production, including reasonably large production facilities in abandoned buildings, high-rise farms, urban gardens and other innovative and technological systems. Such systems are often discussed in the context of covered agriculture, but for the purpose here, the production unit does not have to be covered.

This paper is focused on non-traditional food production facilities, and the goal is to describe and highlight both the potential benefits and challenges for such facilities. The food from non-traditional production is becoming a greater portion of the total supply, and this trend is projected to continue, thus an overview is appropriate.

The world's population is expected to increase by two billion people over the next 30 years. This creates a major challenge in providing food and nutrition for a growing population with fewer resources, due to urban growth and associated loss of cropland, and a global decline in potable water. As cropland and irrigation water become scarcer, innovation will open the door to new methods and places to produce food.

Many of the non-traditional production units concentrate on vegetables and other high-value products. In most cases, such systems introduce new technology and new management systems, and may thus be riskier ventures than traditional food systems, but with greater financial rewards. Financial risk and uncertainty seem particularly high with underground bunkers, repurposed warehouses, and high rise facilities. Alternatively, these types of production units have highly efficient water use.

Regions with rapidly expanding populations or remote regions may be classified as particularly vulnerable to food unavailability. This includes intercity and rural areas where the population does not have easy access to healthy food. Projections show the largest population growth coming in Africa. Nigeria is projected to surpass the United States in 2050 with a population of 413 million (Friedman). The challenge for meeting demand for food across the earth is land availability. Most of the quality farmland is already used for agriculture, which means that further area expansion would occur on marginal land that is unlikely to sustain high yields and is vulnerable to degradation.

With both farmland and freshwater availability decreasing internationally, a non-traditional alternative for food production is potentially viable, along with plant breeding

and genetic engineering. Not only must society produce enough food for the population, it must get it to the people.

Recently, the U.S. Department of Agriculture has identified “food deserts,” which are defined as urban neighborhoods and rural towns without ready access to fresh, healthy, and affordable food. Instead of supermarkets and grocery stores, these communities may have no food access or are served only by fast food restaurants and convenience stores that offer few healthy, affordable food options. The lack of access contributes to a poor diet and can lead to higher levels of obesity and other diet-related diseases, such as diabetes and heart disease (Agriculture Marketing Service). In today’s market environment, there is an emphasis on locally grown food, which opens the door for small producers, whether in a covered facility or a garden near a population center. There are examples of community gardens near schools that achieve two goals at once, producing fruits and vegetables and increasing exercise as local residents walk to and attend to their part of the community garden.

No one system is best for all situations, as local comparative and absolute advantage vary widely. For example, in Cuba a shortage of food and inputs to traditional agriculture fostered the growth of small urban gardens around the city and peri-urban farming just outside the city. The government, as well as the citizens, was committed to feeding the population, leading to one of the most productive, semi-sustainable food production systems in the world. The city of Havana is filled with farms ranging from balcony planters to several hectare peri-urban fields that are contained in Havana’s greenbelt (Clouse).

In different parts the United States, housing developers are starting to build large, expensive homes around farms of varying size. For example, a Georgia development called Serenbe consists of a 1,000-acre track with 25 acres set aside for agriculture in the middle. Residents of these “Agrihoods” as they are being called, enjoy the benefits of not only nearby and healthy food, but the community affirmation they are a part of, and the personal growth associated with farming. One resident, Johnson Lemieux explains it as such, “To be clear, we're not roughing it," said Lemieux. "That farm is cared for by professional farmers. We buy the food. We were lucky to be so close to it, to be able to benefit. But we're not having to go out there and, you know, hoe the farm!” (CBS News) A very important distinction between this example and Havana is that the average price for a home in the Georgia development is between $500,000-750,000.

In the United States during World War II, it was common practice to find “Victory Gardens” in people’s yards (The National WWII Museum). During the war, the United States needed to ration available fruits and vegetables, so the government turned to the people to produce their own. With all the available distribution channels being used by the government, the majority of Victory Gardens would exclusively serve the immediate

community around them. By 1944, Victory Gardens were responsible for producing 40 percent of all the vegetables in the United States. More than one million tons of vegetables were grown in the gardens during the war.

These examples show that under less than perfect conditions, agriculture can still thrive and produce at a level necessary to feed the population. This report makes a case for the potential of the people to adopt and innovate to help eliminate food deserts and meet the needs caused by exploding population growth worldwide.

Non-traditional agriculture calls for non-traditional technologies. One broadly used technology is what is commonly called hydroponics (Simple Hydro). Hydroponics is the process in which produce is grown without soil. The roots of the plant are immersed in a water solution that is full of nutrients. After the nutrients have been consumed by the plant, the water gets recycled and the process starts over again. A similar method is known as aeroponics, the difference being instead of totally immersed in water, the roots are sprayed with a nutrient-rich mist (Smarter Technology). Thirdly, there are innovations in large scale greenhouses, converting large barren areas into agricultural powerhouses. Following are just a few of the examples of how non-traditional production systems are evolving around the world, typically based on what is available.

Refurbished Buildings

Empty or unproductive warehouse or manufacturing facilities offer a unique opportunity to convert the buildings into food production facilities. Each facility brings with it a set of unique circumstances. Most of the buildings that are selected to become food production facilities are older and in disrepair and originally built for a different use.

Farmedhere, Chicago, Illinois

It is appropriate to start with one of the largest covered farming operations in the United States, Farmedhere in Chicago (Farmedhere). Farmedhere is built in a warehouse half the size of a normal Walmart Supercenter. Plans were made in 2013 to expand to 150,000 sq. ft. of vertical growing space. Currently, Farmedhere only produces small combination packs of Petite Salad Greens, Fresh Basil and Mint, Baby Arugula and Kale, and they produce their own Sweet Basil Vinaigrette. Farmedhere distributes to a wide range of food retailers, ranging from large retailers such as Whole Foods, to very small privately owned stores, such as Olivia's Market in Chicago. The goal of Farmedhere is to be "local," which they reinforce by avoiding transporting produce more than 25 miles from the growing facility.

Newark, New Jersey

In Newark, New Jersey, a vacant facility is being renovated that may become the largest vertical farm in the world. The farm is being constructed inside an old steel production facility of 69,000 sq. ft. (Walker). It is projected to grow an astounding two million pounds of kale, arugula, and romaine lettuce per year once completed. The facility will use aeroponic technology. The farm is being constructed by Aerofarms, which is attempting to be one of the first mainstream vertical farming companies in the United States. Aside from the Newark facility, there are immediate plans to build multiple farms in U.S. cities and on three other continents, according to Aerofarms (Aerofarm). The typical design for these vertical farms is trays stacked one on top of the other, with produce growing from each tray. This dramatically increases the potential production per square foot of a building.

There are other examples of buildings refurbished for food production around the world, but this introduces the concept. The opportunity is broad, given changes in the economy and availability of unoccupied, huge buildings, often near population centers.

Below-surface Facilities

Around the world, innovative producers are utilizing existing subterranean tunnels and shelters as locations to grow high-value produce. The former purpose of these subterranean environments includes retired military installations (WWII bomb shelters), retired storage facilities, and even natural caverns. The advantage of working underground is complete control of the climate. It is also very rare to see pesticide or herbicide usage underground. This complete control allows for very strict and precise watering and lighting. It allows for the production of consistent vegetables that can be transported farm-to-table quickly.

Growing Underground, London, England

In London, Growing Underground has redeveloped WWII-era bomb shelters into a sustainable urban farm. At the time of this report, this facility was in its first phase of production, which included the installation of very high tech ventilation, lighting, and water systems. The company's goal is to leave zero impact on the environment. Growing Underground was able to get started by an incredibly successful crowdfunding[1] venture that went on to be oversubscribed. The first round of produce to be grown is pea shoots, several varieties of radish, mustard, coriander, Red Amaranth, celery, parsley, and rocket.

[1]**Crowdfunding** is the process of raising money to fund what is typically a project or business venture through many donors using an online platform, such as Kickstarter, Indiegogo and Crowdfunder.

The end users of current production will be restaurants, with a consumer offering coming in the near future through what Growing Underground calls “Hyper-local delivery” (Poulter).

Tokyo Salad, Tokyo, Japan

The Tokyo Metro, the same organization that runs the city’s subway system, has started a new hydroponic growing operation underneath one of the main subway lines. They have named it “Tokyo Salad.” Tokyo Salad currently grows romaine, red mustard, riccola, Lollo Rosso, endive, and chicory; six kinds of lettuce and four kinds of baby leaf. The growing operation is housed in an extremely clean and regulated area in the tunnels. To gain entry into the farming area, one must don a white coat, mask, and hat. The goal of Tokyo Salad is more about food safety than it is about growing urban. “People’s consciousness about the safety of their food went up” (after the Fukushima nuclear disaster), said Masahiko Kakutani, an employee of Tokyo Metro. At Tokyo Metro, their principles are safety and peace of mind. So they took the concept to food. (Gingold). This is an example of innovative use of available space beneath a major population center, and close proximity of production to demand.

High Rise Facilities

A more elaborate concept being considered across the world is the incorporation of covered agriculture in high rise buildings (Malaysia). The idea is that several floors of a high rise structure would contain some form of covered agriculture, whether that is hydroponic, aeroponic, or normal greenhouse production. The plan is that these farms could provide for the tenants of the high rise and the area immediately surrounding the structure. Currently, there are none in existence, but the concept is being discussed. This idea involves some challenges that would need to be addressed. First, how is the water going to be distributed? With such close proximity to a large number of humans, there is risk for water contamination that could ruin the produce. There is also the risk of the tenants bringing in any number of perils such as disease and pests that could destroy the crop. Mixing thousands of people with any number of sicknesses in close proximity to compact agriculture can create major challenges for the environment and food safety. However, such systems have the potential for recycling plant nutrients from human waste, thereby reducing pressure on mined plant nutrients (Taylor, Lacewell, and Rodriguez-Kabana).

Greenhouses

Greenhouse technology has been commonplace for many years. In recent years, it has been taken to the extreme with huge greenhouse operations being built in areas with climate stress, water and/or non-arable land challenges. Over 900 acres of hydroponic tomatoes are grown in the U.S. Covered agriculture development is on a strong upward trend. More than half of Europe's fresh fruits and vegetables are grown under plastic or glass (Taylor, Lacewell, and Rodriguez-Kabana). It is estimated that greenhouse crop production is over 405,000 ha globally. The diversity of greenhouses is based on location and specific environment, so this is not a one size fits all solution (Foreign Agriculture Organization, 2013).

Almeria, Spain

About 20 miles outside the city of Almeria, Spain, an expansive, once barren stretch of land is now completely covered with plastic top greenhouses and produces more than half of Europe's fresh fruits and vegetables (Kaushik). Around 35 years ago, a mix of small and large companies began to build these greenhouses in varying sizes. Some are hydroponic systems while others use soil for production, together producing around 1.5 billion euros worth of produce a year. This production does come at a cost. The greenhouse conditions are very difficult to work in, the temperature inside these greenhouses is known to get above 45 degrees Celsius (Kaushik). These tough conditions lead to the majority of workers being a mixture of legal and illegal workers from Eastern Europe and Africa who often have to pay a "right to work" fee and are paid very little.

There is an extremely large environmental cost as well. Plastic waste is a huge issue in the area.. Pesticide and herbicide disposal is also common amongst the plastic litter. However, an apparent positive effect is the reduction of the region's temperature. Scientist say that with the amount of sunlight that is being reflected back into space that the regions temperature has lowered by 0.3 degrees Celsius every 10 years since 1985 (Kaushik).

Backyard Farms, Madison, Maine

The United States also has a very large greenhouse market, particularly when it comes to tomatoes. In Madison, Maine, Backyard Farms operates a 42-acre facility that produces one million tomatoes per week in the middle of winter (Backyard Farms). The facility is the largest building in Maine. Backyard Farms came into existence due to consumer sovereignty. If consumers wanted tomatoes in an off-season, they would have to settle for hard pink tomatoes shipped in from Florida or Mexico (Backyard Farms). In order to meet the year-round demand for tomatoes, a 24-acre facility was built; it was a wild success, leading to the expansion to the current 42 acres. In the tomato market, end-user

purchasing requires that the tomatoes' appearance be of utmost quality. That is a difficult task for field-grown tomatoes, which makes up the majority of tomato production. These field-growing operations do not produce uniform shape and color and are often used by the fast food, hospital, school, and prison systems, where appearance is not paramount. Everyday consumers expect the same large, bright red tomatoes every time they go to the grocery store and are willing to pay the higher price. This desire and willingness to pay the higher price allows for the expansion and profitability of greenhouse tomato production.

Opportunities

Some forms of non-traditional agriculture are proving to be economically viable in theory and have potential for further expansion and development in the future. At different times in history, Cuba, the United States and other countries have proven that a society can adapt to produce the food necessary to feed itself. If world powers do not prepare for coming population growth, specifically in "food deserts," the consequences could be disastrous.

Non-traditional agriculture has the potential to substantially contribute to producing enough food to feed 9 billion people and to making that food accessible. In the traditional agricultural systems, food is often produced far away from end users. Getting produce from the farm to the end user can be very expensive and time consuming, and can negatively impact the quality. Quantity is critical in meeting global food demand, but nutritional quality is just as important.

Higher production costs of urban developments such as Farmedhere in Chicago are offset in part or total by reduced transportation costs. The strategic location also allows for the great reduction in local food deserts, and more so, the ability for individuals to obtain healthier alternatives.

An issue very prominent in the United States isn't access to food, but access to healthy food. Fast food chains and inexpensive, low-quality food sources litter the landscape. Healthier alternatives are predominantly sold at high-end grocery stores that do not exist in food deserts. Strategically placing non-traditional agricultural production facilities would allow for individuals of any socioeconomic class to have access to healthy food. The right to eat healthy and have access to fresh produce should not be exclusively for the wealthy or those with access to adequate transportation.

Lastly, with the expanding population of earth, the pressure on land and water will be critical. These alternative systems provide for food production with less land and less water per unit of food. This is a major opportunity near urban populations and countries with serious tillable land and/or freshwater availability.

Challenges and Summary

Non-traditional agriculture does not come without challenges. First, it is currently expensive to power the LED lights that a majority of the farms use, excluding greenhouses. Opponents to covered agriculture argue that the amount of electricity needed to grow offsets any environmental benefits that covered agriculture provides. Another limitation in covered agriculture, excluding greenhouses, is what produce is actually grown. Currently, it is very common for only leafy greens to be grown. Most vertical farms "grow a salad"; kale, arugula, lettuce, etc. It is not considered financially feasible to grow large vegetables with current technology. Trying to feed nine billion people with a garden salad will not do the trick; this is an issue because all grains and large vegetables, including fruit, are expected to be grown outside of non-traditional agriculture. Greenhouses show some potential in being a remedy, but currently resources are not being focused on greenhouses.

Unfortunately, very few vertical farm operations are active; hence, it is difficult to evaluate profitability. Of the examples list above, only Farmedhere in Chicago said that they had turned a profit. However, internationally there are operations functioning and providing vegetables and other high-value food products to urban populations. Others insist they are still in a development phase and are waiting for improvements in LED and management technology to turn a profit.

A common theme is proving the concept of vertical agriculture, not necessarily proving its profitability. This suggests there are dramatic needs for technological advances and addressing the talent that will be required to effectively operate non-traditional food production operations. Needs will include engineers for the equipment that provides light, water, and ventilation, as well as advanced agronomic sciences addressing nutrients, disease, and pest protection and harvesting.

Summary comments for non-traditional agriculture include the following.

- Non-traditional agriculture includes technologies to help cope with climate change and limited land and water availability plus perhaps provide a cooling effect by reflecting sunlight.
- There is potential for fresh water conservation, recapture and rainwater capture.
- Concentrated production requires a higher level of management and science than open field production as generally practiced.
- In many cases non-traditional agriculture generates more plastic waste, particularly for high value crops grown under a plastic wrap and for covering greenhouses.
- Capital cost or investment is typically higher that field production.
- Pesticide use is likely higher to assure no outbreak of pests or disease.

- Greater potential for catastrophic risk, such as plant diseases, insect pest, water contamination, and hail, and storm damage to greenhouses exists.
- Some systems are more dependent on fossil fuels than traditional crop systems (grow lights and maintaining preferred environment).
- It offers potential for better recapture and recycling of plant nutrients as well as the water used in production.
- Bottom line, costs of non-traditional agriculture versus traditional field based production is greater due to intensification, energy, labor, etc.
- The major issues for non-traditional agriculture are: energy, labor, water, product quality, marketing, food safety, and making a profit (Giacomelli).

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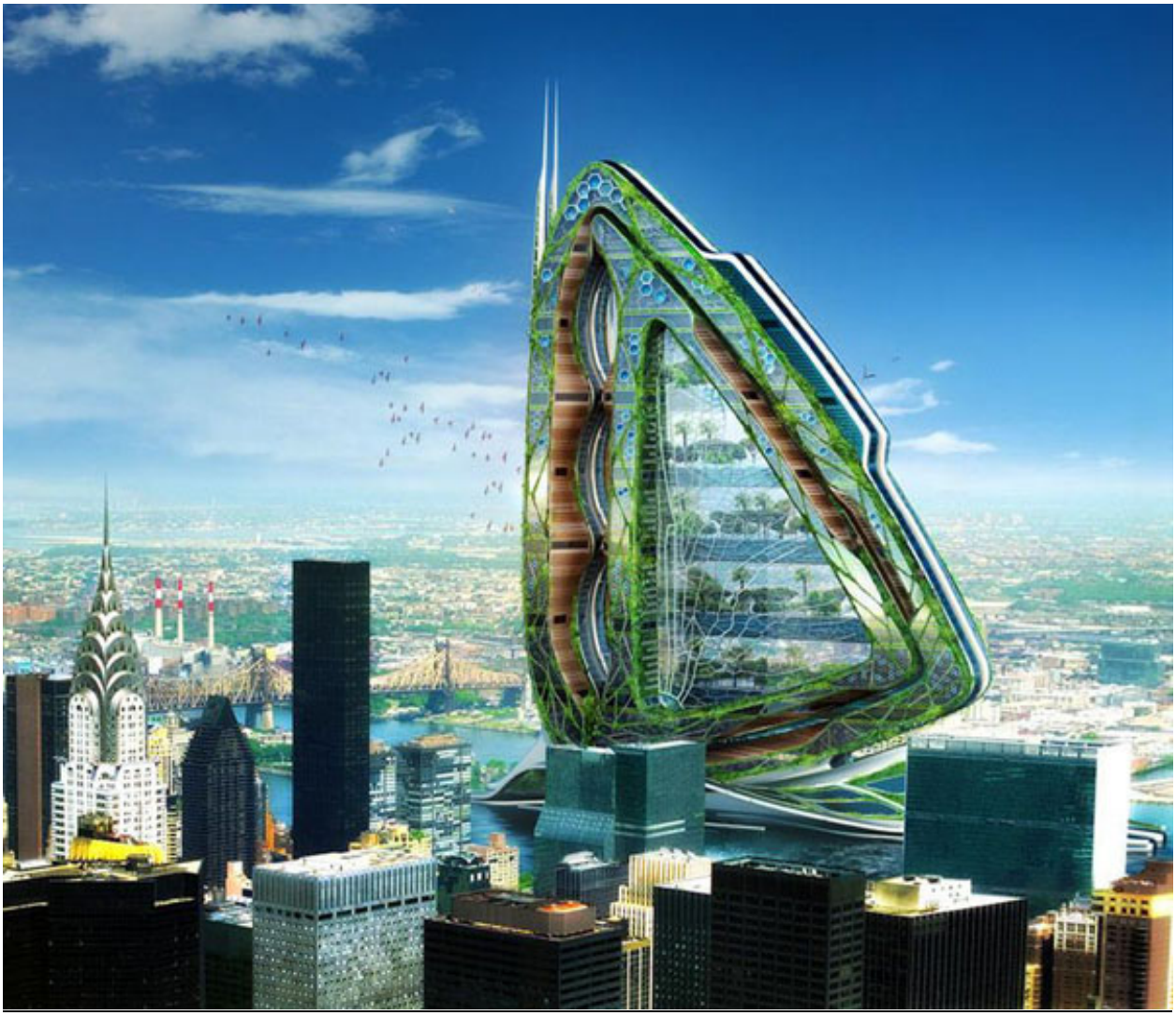
Appendix
Photo examples

Backyard Farms, Maine
https://www.backyardfarms.com/how-we-grow/our-greenhouse

Tokyo Metro, Tokyo, Japan
Courtesy of: *Naomi Gingold/PRI*

London Underground, London England
http://www.dezeen.com/2014/02/18/underground-farm-built-in-tunnels-12-storeys-beneath-london/

Farmedhere, Chicago, Illinois
http://chicagotonight.wttw.com/2014/06/23/vertical-farming-s-rise-chicago



High-rise Concept, Dragonfly
http://inhabitat.com/dragonfly-urban-agriculture-concept-for-ny/

Courtesy of NASA, International Space Station

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