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Rooftop Farms: a Harmony of Sustainable Cities and Food

In the midst of busy city life, untapped resources go right over our heads (literally). Although I have lived in the city of Chicago since 1995, I began to view the city with a completely new perspective once I began working for Omni ecosystems, installing and maintaining green roof systems and rooftop farms. One day while viewing downtown from a few hundred feet above street level, I began to imagine a Chicago in its precolonial state, before the skyscrapers and pavement: a thriving fertile prairie land. Juxtaposing my admiration for the city with a yearning for a cohabitation between people and nature, I envisioned buildings rising from the ground in unison with the ecology perched on top of the manmade structures. My passion for green infrastructure began when I realized that human development does not need to come at the expense of green space or ecology; human development and ecology must exist symbiotically. Another pressing issue faced by Chicago is the the need for equitable food access. Luckily generating green space is a goal that can be solved alongside the need for equitable food access because food producing gardens create green space!

Faced by a city with excessive pavement and inequitable food access, the purpose of my thesis is to inspire people to reimagine urban landscapes. Traditional rooftops are unproductive and the space they occupy is an underutilized resource. Rooftop farms are an important part of the multifaceted solution which involves realizing sustainable urbanism by transforming toxic and unproductive surfaces into a patchwork of thriving ecosystems. Ultimately, rooftop farms

embody the triple bottom line of planet, profit, and people by providing ecosystem services, generating revenue, and creating community spaces that have the power to serve the people on top of, underneath, and all around the rooftop.

Chicago, like many cities all over the world, and even the cities that have yet to be built, is in need of a more functional built environment. Faced by growing populations and rapid urbanization, cities must be designed critically in order to accommodate everyone's needs. Space is in high demand within a city and it is a resource that cannot be wasted. Rooftops have historically been an overlooked space even though they can make up to approximately 20% or more of the surface area in an urban setting (Ulubeyli et al., 2017). The majority of rooftops in Chicago are black roofs. Black roofs absorb solar radiation, intensity energy demands for cooling a building, and provide no benefits compared to alternative roofs types.

The benefits of green roofs

Green roofs (vegetated roofs) provide a wide range of services. Green roofs lower utility bills in the summer and the winter. In the winter, the vegetation and growing media of a green roof provide an extra layer of insulation and maintain the temperature of a building. In the summer, green roofs reflect solar radiation and help decrease air conditioning loads by 25% (Omni Ecosystems). Furthermore, green roofs help cool down the entire city by mitigating the urban heat island effect (UHI). UHI is a dangerous consequence of unsustainable cities. Cities are warmer than the surrounding rural areas due to human actives and the lower albedo of urban land surfaces. According to the EPA, UHI is dangerous due to increased energy demands, lowered air and water quality, and heat related illness and mortality.

Traditional roof membranes require service or replacement 10-25 years after they are installed. Alternatively, green roofs can last longer than fifty years before they need to be replaced (Omni Ecosystems). Green roofs extend the life of a roof by providing an extra layer of protection from ultraviolet radiation, extreme weather, and freeze and thaw cycles. The longer life space of green roofs compared to traditional roofs, reduce both costs and waste in the long run.

In cities where natural landscapes are replaced with man made structures, green roofs reintroduce nature back into cities and onto buildings. Green roofs create a corridor of habitats across a city and serve as important destinations for migratory species such as birds and butterflies. Green roofs can also be specially designed for bee hives and equipped with beneficial plans for bees. Since bees are responsible for pollinating food crops, it is important that cities facilitate the survival of this endangered species.

Green roofs also have benefits such as storm water retention, improved air quality, decreased noise pollution, jobs, community space, and green space creation. Roof top farms are the pinnacle of green roofs because they offer the most significant benefits when compared to other green roof types. As long as the building can support the extra weight load, any green roof can be converted into a rooftop farm!

Z-Farming

Z-farming is a term that stands for ‘zero acreage farming’ (Specht et al., 2014). Z farming describes food production in or on urban structures and it is referred to as zero acreage because it is taking advantage of additional layers of vertical space rather than horizontal surface area.

Traditional rural farming operations are extremely land intensive and compete for valuable ecosystems. Ground level urban farming operations also compete for urban land and are at risk for eviction and competition with urban development and real estate projects.

As cities become more dense, various entities compete for finite space and limiting resources. In order to maximize services to urban inhabitants, landscapes must be designed for multiple cooperating functions, not competing. While competition results in losses, cooperation results in win-win situations. Buildings and agriculture can cooperate in the form of building integrated agriculture (BIA). BIA can exist in a variety of forms including rooftop gardens, rooftop greenhouses, edible green walls, indoor farms, closed forms and open forms. BIA has the ability to utilize synergies between built environment and agriculture through the recycling of resources. For example, food waste from the building can be converted into compost for a rooftop farm, closing, the loop of food production and waste. In some forms of rooftop farms heat and water can also be exchanged through the farm and the building.

BIA is a revolutionary concept because it minimizes the impacts of agriculture while providing increased services compared to a stand alone building or agriculture operation. Unlike traditional farms, rooftop farms are not solely production oriented. Rooftop farms have the ability to meet economic, social, and environmental needs depending on how they are designed and managed. For example, rooftop farms have the ability to be managed in a way that allows for community interaction and learning. If a building or school lacks a yard or field, rooftop farms provide a valuable space in a previously unusable one.

Rooftop agriculture vs ground based approaches

Rooftop agriculture has a unique set of challenges and benefits compared to ground based approaches. Since green roofs are design to protect the roof it is important that roof top farmers are carful and aware of the unique characteristics of the roof they are working on. While some rooftop farms have deeper growing media, the majority of rooftop farms have shallow growing media in order to reduce the weight load on the building. When working on shallow growing media farmers must not use tools that can puncture to roof membrane. Puncturing the roof membrane can result in leaks, damage to the roof, and repair costs. For this reason tilling with large tools is not as common on roof tops.

One of the most important considerations for an open air rooftop farm is windspeed. Wind speed must be taken into consideration in order to ensure that the plants are secured within the growing media. Higher altitudes are associated with higher wind speeds and certain altitudes or windy regions may be unsuitable for open air rooftop farms, especially because uprooted plants may pose a safety hazard to pedestrians below the farm. Under higher wind speeds an enclosure or green house is more suitable than an open air farm.

Although some people have doubts regarding the productivity of rooftop agriculture, from my experience on both rooftop and ground levels farms, rooftop agriculture is capable of substantial yields. According to a study conducted at Michigan State University, evaluating the survival and productivity of vegetable and herb production, roof top agriculture has the potential to perform similarly to in ground approaches when sophisticated irrigation, fertilization, and management are utilized (Whittinghill et all., 2013). The study also suggested that *Allium*

species, tomato, bean, cucumber, Budapest hot banana pepper, basil, and chive perform well on extensive green roof systems.

Farms located on accent lots are one of the most common form of urban agriculture. Vacant lot urban farms do have merit because they are the least expensive way to acquire land in Chicago due to the vacant lot program. With this said, vacant lot farms are problematic in many ways that rooftop farms are not. For example, vacant lots are often unequipped with a water source, and installing a water main is very expensive. On rooftop farms, irrigation is the norm because the farm has access to the water from building it is onto of. Vacant lots are also at risk of eviction. While rooftop farms may compete for other roof services, it is easy for a rooftop farm to cohabit with other roof amenities and even solar power panels.

The most important difference between rooftop and ground based urban agriculture is the reduced exposure to pollutants on rooftop farms. One of the greatest hazards of urban agriculture is growing food in contaminated soil. Vacant lots are often dumping grounds for years before they are put to use and people can be exposed to harmful toxins such as lead when they consume food that has taken it up through the soil. Since traditional soil is too heavy for rooftop farms, the soil must be carefully engineered. Due to the high level of control regarding the source of rooftop growing media, the food is safe to eat.

Additionally, depending on the location, ground based agriculture can be exposed to heightened levels of air pollution because it is often closer to street level and automobile exhaust. A case study in New York compared the air quality above one of the largest urban rooftop vegetable farms, Brooklyn Grange (Tong et al., 2016). According to the study, street level samples had the most variable PM2.5 concentration. At roof level (26 m above ground), there

was a 1-33 % reduction in PM2.5 concentration. Larger particles (1.6 μm) was also more prevalent at street level. Although the study cannot speak for every meteorological condition or location, the study concluded that PM2.5 exposure has an inverse relationship with altitude, vegetables grown on a roof will have lower pollution loads than crops grown on ground level near a road, and that ground level plants are more likely to remove air pollution. Due to the overall lower air quality of urban setting, it is my recommendation that food grown in urban settings undergo periodic testing for heavy metal and pollution contamination.

Financial Barriers and Incentives

The most significant barriers in realizing the widespread implementation of green roofs and rooftop farms are financial barriers and structural barriers. One of the first steps in installing a green roof is consulting an engineer in order to determine the structural capacity of the rooftop. Many buildings have not been designed with consideration for significant weight loads on the roof. Since retrofitting rooftops can be expensive it is important to design future buildings with roof use in consideration early on in the planning stages.

Green roof installation can be two to six times more expensive than conventional roof systems. This steep initial investment deters many building owners from installing a green roof because our society has been ingrained to favor short-term gains over long-term payoffs. Despite the installation cost, green roofs generate a return on investment because of reduced utility costs, extension of the life of the roof, and the sale of produce. In order to make green roofs a financially feasible option for more people, governments must continue to provide incentive programs.

The Green Roof Improvement Fund[1] is a program in Chicago IL from 2006. The program included a 50% grant match for the cost of installing a green roof on an existing building located in the Central Loop TIF District with a $100,000 maximum grant per project. The Green Roof grant program also awards $5,000 grants for green roofs that take place on residential and smaller scale projects. These monetary incentives will aid in meeting the Chicago Energy Conservation Code which states that all new flat roofs must meet the U.S. EPA Energy Star cool roof standards. Cities all around the world must continue building upon programs that force change in sustainability though new sets of standards and incentives.

The Chicago Zoning Ordinance 17-4-1015[2] is a green roof incentive program from 2015. Buildings in the downtown mixed use districts are eligible for a floor areas ratio bonus if they have a green roof that covers more than 50% of the roof area or at least 2,000 square feet of roof area.

The New York City green Infrastructure Grant Program[3] is led by the Department of Environmental Protection and is available to private property owners in the combined sewer areas of New York City. In order to qualify, the roof must manage the first inch of rainfall. Grants are up to $5 million. The program is designed to have a long term impact because grantees must agree to have the the property maintained for 20 years. Since 2011, the grant program has awarded $13 million to 33 private property owners. This program is reducing runoff pollution into waterbodies and the sewer system through the water retention power of green infrastructure.

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[1] https://www.energycodes.gov/resource-center/policy/green-roof-improvement-fund-chicago-il-2006

[2] https://chicagocode.org/17-4-1000/

[3] http://www.adaptationclearinghouse.org/resources/new-york-city-green-infrastructure-grant-program.html

New York City also offers a Green Roof Property Tax Abatement Program[4] for one year after the construction of a green roof on residential and commercial buildings, available through March 15, 2018. The original legislations passed in 2008 provided tax relief of $4.50 per square foot with a cap of $100,000. In 2013 the abatement was increased to $5.23 per square foot with a cap of $200,000. The green roof must cover half of the usable rooftop space (space not already consumed by other roof amenities) and the vegetation must cover at least 80% of the useable space. Applicants must agree to a maintenance plan for three years after the abatement.

Philadelphia offers the Stormwater Management Incentives Program and the Greened Acre Retrofit Program[5] in order to reduce the price of stormwater best management practices. Non-residential properties located in the Philadelphia Water Department and Philadelphia Industrial Development Corporation offer grants in order to incentivize construction and retrofits for green infrastructure. Projects must manage at least the first inch of runoff. In addition to the grant money, recipients receive Philadelphia Stormwater Management Service credits. Property owners must also agree to maintain the property for a minimum of forty-five years.

In Portland, Environmental Services offered an incentive of $5 per square foot of green roof[6]. A total of $2 million helped fund over 130 projects that totaled in over 8 acres of eco roofs. These eco roofs manage about 4.4 million gallons of storm water every year.

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[4] http://www.adaptationclearinghouse.org/resources/new-york-city-green-roof-property-tax-abatement-program.html

[5] http://www.adaptationclearinghouse.org/resources/city-of-philadelphia-stormwater-incentives-grants.html

[6] https://www.portlandoregon.gov/bes/article/547491

Toronto offers an Eco-Roof Incentive Program[7] for commercial, industrial and institutional buildings. The program began in march 2009 as part of various city programs including the City's Climate Change Action Plan, the Green Bylaw, and the Green Standard. Recipients will be granted $50 per aware meter with a cap of $1000,000. Priority is given to roofs in areas most impacted by storm water runoff and the urban head island effect.

The above are examples of government programs that incentivize the creation of green roofs and decrease the financial barriers for rooftop farms. While Chicago is known for its progressive policies regarding green roofs, there are examples of policy that can also increase the financial barriers for green roofs. This year in Illinois, the amendments to Senate Bill9 (SB9) propose an increased excise and service tax on landscaping services to 6.25%. Under the umbrella of landscaping, green roof installation and maintenance will become more expensive and this will discourage people from considering a green roof who would otherwise be able to afford one.

The illegal cash-based landscaping black market poses a threat to legitimate green roof businesses. Landscaping businesses already operate on a low margin so the increased tax will force companies to raise their prices in order to remain profitable. Unregulated landscape services do not file payroll taxes, workers' comp insurance and business insurance. Additionally, the landscaping blackmarket will bypass the tax increase under SB9, gaining even more competitive advantage over legitimate businesses. Unregulated landscaping services are notorious for cutting corners and paying less attention of quality. The cheater price of an

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[7] http://www.adaptationclearinghouse.org/resources/toronto-s-eco-roof-incentive-program.html

unregulated green roof service is, therefore, not worth the social and environmental cots thought the green roof lifecycle.

SN9 includes other tax increases on products such as sugary drinks and soda. Landscaping services seem out of place in this bill because taxing sugary drinks encourages healthy activities, while taxing green space on the other hand, deters healthy activity. The SB9 taxes on landscaping services are inexcusable because they exacerbate the financial barrier for green roofs, and it is in the governments best interest to pass bills that facilitate more sustainable cities. I recommend that cities offer programs that are specially designed to incentivize rooftop farms because they are generally more expensive than other forms of green roofs.

Omni Ecosystems

Omni Ecosystems was founded by Molly Meyer and Micheal Repkin in 2009. Since their beginning, Omni has developed major innovations in the field of green infrastructure and rooftop farming. The Comprehensive green roof system, developed by Omni, combines the benefits of intensive (IGR) and extensive green roofs (EGR). EGR are the most lightweight (10-35 saturated psf), require minimal maintenance, and exhibit low ecological diversity. EGRs are composed mostly of sedum plants and are not intended as usable food production, social, or community outdoor spaces. EGR are often the least expensive vegetated roof option, but also provide less services. IGR are the heaviest (over 50 saturated psf). Many buildings are not equipped with the structural load capacity necessary to support an IGR. An IGR is also much more expensive and requires more maintenance. Although IGRs require more input, they offer more services compared to an EGR, such as greater ecological diversity, greater stormwater retention and

usable outdoor areas that can resemble parks and farms. Semi-intensive green roofs have a weight (35-50 saturated psf), ecological diversity, and maintenance requirement in-between EGRs and IGRs. Although at first glance, a semi-intensive roof appears to be a compromise between EGRs and IGRs, they often provide mediocre aspects of each roof. CGR merge the convenience of an EGR with the productivity of an IGR. The first CGR was implemented by Micheal Repkin in 2006, when a client desired a food producing roof on top of a building with limited structural capacity. With CGR, Omni Ecosystems offer greater opportunities to clients by providing lightweight roof systems that also offer agricultural capabilities.

An important element that sets Omni Ecosystems' CGR from other forms of green roofs is the growing media. Traditional green roof growing media typically replicates the physical and chemical properties of soil while ignoring the biological properties. Alternatively, the soil found on a CGR considers the physical, chemical, and biological elements of soil by inoculating the rowing media with microbial ecosystems and nitrogen fixating bacteria. The growing media used on Omni Ecosystems CGR, developed by Repkin, is called infinity growing medium. While conventional soil is too heavy for rooftop use, infinity growing medium is lighter in weight because it utilizes porous volcanic rock. In comparison to other green roof growing media, the infinity growth medium is also more effective at collecting storm water. For example, a 3 inch Omni CGR is just as effective as a typical 5-inch green roof, and a 5-inch Omni CGR is comparable to an 8-inch typical green roof (Meyer 2012). Due to their light weight and productivity, CGR create opportunities for retrofitting buildings with green roofs.

Omni Ecosystems has partnered with the Roof Crop LLC since 2013. When Omni installs a rooftop farm, the roof owner has the option to lease the farm to the Roof Crop at no

additional cost. The Roof Crop maintains, harvests, and sells the produce which generates revenue and can offset installation cost in as little as five years. The partnership between Omni Ecosystems and the Roof Crop create more opportunities by reducing the cost and maintenance for the rooftop farms owner. Traditionally, agricultural operations must be large enough to make a significant harvest and many rooftops are not large enough to generate the volume needed for a commercial farming operation. The Roof Crop is an innovative concept because a single company is capitalizing on a patchwork of multiple farmers in order to generate a composite volume of produce that is much larger than the individual farms are capable of on their own.

Examples

Although rooftop farming is a relatively new field in popular media, a variety of examples of highly functioning rooftop farms around the world already exists. Rooftop farms can take many different forms and can be managed according to the purpose and function of the farm, whether it is for profit, therapy, or community. There is a trend for restaurants to house a rooftop farm directly above operations in order to source the most hyper-local produce (it doesn't get much more local than directly above one's ceiling). In Vancouver, the Fairmount Hotel is equipped with a rooftop farm that saves the kitchen about $30,000 a year in produce costs (Whittinghill, 2012)

In addition to restaurants, catering companies and convention centers can also benefit from rooftop farms. The largest farm to fork rooftop garden in Chicago is located on top of McCormick Place West and is run by the Botanic Garden's Windy City Harvest program[8]. The

[8] https://www.chicagobotanic.org/pr/release/chicago_botanic_garden_plants_largest_farm_to_fork_rooftop_garden_chicago_and_midwest

20,000 square foot vegetable and herb garden is projected to yield 4,000 pounds of fresh produce (or 5700 servings) in its first year, and yields are expected to increase to 8,000- 12,000 pounds of produce a year. The crops grown on the roof include kale, collards, carrots, radishes, green and red romaine lettuces, peppers, yellow, red and green bush beans, golden beets, cherry tomatoes, bulb fennel, garlic chives, dill, cilantro, and parsley. SAVOR, the convention center's catering company, uses these crops in order to provide sustainable, hyper-local food for various events throughout the growing season.

Rooftop farms are also great fits for hospitals. The Schwab Rehabilitation Hospital in Chicago is equipped with a 10,000 square foot rooftop garden. Although hospital catering companies can certainly benefit from rooftop farms, this garden is not production oriented. Instead, the Schwab rooftop garden is designed as a therapeutic tool. Hospitals have the tendency to feel bleak and depressing. A rooftop garden provides patients with a space to connect with nature without leaving the premises of the hospital. The garden is wheelchair accessible and also contains a 50-foot coy stream.

Addressing existing and potential injustice of agriculture

The agricultural system is notorious for social and environmental injustices on a global scale. Even though urban agriculture is independent of the main culprits of agricultural injustice (namely industrial farming techniques, multinational corporations, international trade agreements, etc.), urban agriculture can still be responsible for injustice. A few years ago in New York, a newspaper article was published, praising the development of urban farming. All the farmers mentioned came from well to do backgrounds and none of them were people of color.

This article received criticism because it misrepresented the reality of urban agriculture as a practice led by affluent white people. The article completely ignored the role of urban agriculture in alleviating hunger in systematically disadvantaged communities of color (Reynolds 2015).

Urban agriculture has the ability to support or dismantle social and political oppression. Affluent white people often receive the most recognition and funding while disadvantaged groups of color are left to struggle for resources. Many people assume an inherent goodness of urban agriculture before critically analyzing it, and structural inequalities are at risk of becoming hidden or legitimated by progressive narratives (focusing on positive impacts such as food access, education, job creation, and public and environmental health) while ignoring disparities (Reynolds 2015).

Due to the high cost of rooftop farms, they have the potential to exclude disadvantaged communities. Although government incentive programs can make rooftop farms more available, green roof companies themselves must also make an effort to dismantle systematic injustice. Omni Ecosystems has partnered with After School Matters in order to create a program in which inner city youth are payed to receive hands on experience at Omni Ecosystems, learning valuable skills and gaining work experience.

Rooftop agriculture and the local economy

Globalization is a double edged sward with various benefits and pitfalls. In the case of food, globalization has resulted in a dependance on a flawed system that is notorious for human rights violations and environmental degradation. Cities that are dependent on imported food can

utilize urban agriculture practices such as rooftop farming in order to ween off of the globalized and industrial food systems that has undermined local economic resilience and the autonomy of local communities.

The concept of local self reliance is defined as the ability of a locality (town, city, state) to produce basic necessities (such as food, water, and energy) from within the limits of the localities own physical footprint (Grewal, 2012). Americans have one of the largest resource footprints in the world. Local self reliance can help American cities reduce their footprint by encouraging communities to use resources more efficiently and sustainably.

Grewal conducted a study by compelling information based off of current polices, laws, available area, crop statistics, and human needs in order to evaluate the potential for local self reliance of food in the City of Cleveland. Grewal created three different scenarios based off of various urban agriculture tactics.

Currently, Cleveland is 1.7% self reliant in fresh produce and .1% in total food and beverage (Grewal, 2012). The first scenario determined that Cleveland can generate between 22% and 48% of fresh produce demand if 80% of every vacant lot is utilized. The second scenario determined that between 31% and 68% of fresh produce demand can be meet if 80% of every vacant lot and 9% of every residential lot is utilized. The third scenario, which used the data from scenario two in addition to 62% of every industrial and commercial rooftop, generated between 46% and 100% of Cleveland's fresh produce demand.

Currently, Cleveland retains $1.5 million of produce from the 50 acres of existing community gardens. Based off of these scenarios, Cleveland has the potential to retain $28.9 million and $114.7 million. Local food initiatives such as rooftop farms have the ability to facilitate local self reliance, improve the local economy, reduce transportation emissions, strengthen sense of community, and improve standards of heath and food access. Although this study was based off of Cleveland, similarities can also be inferred to Chicago because both are midwestern cities that have been faced with vacant land, lack of food access, obesity, and hunger.

Based off of the expected population growth, the world will need an additional 1 billion hectares of arable farm land by 2050 in order to meet food demands (Vogel, 2008). This additional agricultural land is at risk of displacing valuable rainforests and countless other natural habitats. While population rates and resource demands are rising, the finite space and carrying capacity on earth is remaining the same. We are in need of a solution that will feed the growing population while also protecting the earths resources and land. While there have been serious inquiries of colonizing other planets in order to sustain the population, there is an overlooked and more practical frontier much closer to home: rooftops. Rooftop farms have the ability to provide food access, but they will need the support of city planners, government incentives, and a shift in the way we think about land use and food.

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