Urban Rooftops as Productive Resources
Rooftop Farming versus Conventional Green Roofs

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ABSTRACT:

Rooftops in our urban centers represent a vast potential of currently underused space. The transformation of these urban rooftops into an environmental, ecological resource through an increased implementation of green roof technology is becoming standard practice in many cities throughout the world. Due to the rapidly growing interest in urban agriculture, a new form of green roofs - rooftop farms - are emerging. This study compares the environmental, economic and social benefits of conventional and productive green roofs. The intent of this paper is to outline realizable benefits and establish methods for optimizing rooftop occupation in the urban environment.

The basis for this paper's argument is derived from data collected from a number of rooftop farming case studies located throughout North America, which highlight the differences between conventional green roofs and productive green roofs. Points of comparison fall into three groups: potential environmental, economical and social benefits.

In conclusion, this study argues that not only do productive green roofs meet the well-established environmental benefits of conventional green roofs, but they also provide extra social benefits that outweigh any additional structural requirements, operational necessities and associated costs. The implementation of productive green roofs should be considered and actively pursued wherever possible, due to their vital contribution to the advancement of urban agriculture, social and economic gains and potential job creation, which all strengthen our urban environments and communities.

CONFERENCE THEME: On Measurement
KEYWORDS: green roof, rooftop farming, urban agriculture, environmental and social benefits, building performance

INTRODUCTION

Roofs cover up to 32% of cities and built-up areas (Frazer 2005) and represent a vast potential of currently unused space in urban centers. An increased implementation of green roof technology to transform these urban rooftops into an environmental, ecological resource is becoming standard practice in many cities (Peck et al. 1999, Getter and Rowe 2006, Oberndorfer et al. 2007). Parallel to this investment in green infrastructure, urban dwellers also have developed a desire for more sustainable, health food. This rapidly growing the interest has fostered the development of urban agriculture projects cultivating organic, locally grown produce in many cities.

Through the synthesis of these two popular sustainable strategies, a new form of green roofs - the rooftop farm - is emerging. This approach is mainly applicable in dense urban areas and warehouse districts that lack open space for alternative water management infrastructure and ground based urban agriculture. It is no longer a question of whether or not green roofs should be implemented, but rather how their impact can be maximized beyond their recognized environmental values. This investigation juxtaposes scientifically measurable environmental and economic benefits as well as social benefits of conventional and productive agricultural green roofs. It outlines the significance of realizable benefits and provides an outline for optimizing rooftop design and occupation in the urban environment. It attempts to increase the recognition of productive green roofs, as a new typology of vegetated roofs that increases their applicability even further.

Figure 1: Eagle Street Farm, Greenpoint, Brooklyn, NY (http://www.cityfarmer.info)

With this assessment, the study contributes to the field of green roofs research, which focuses predominantly on environmental impacts, and broadens the knowledge on urban agriculture, which to date predominantly covers social, cultural and planning related aspects. In bringing these two fields of research together, this study engages in an interdisciplinary approach to analysis, which is necessary to gain a more holistic understanding of the built environment.

1. METHODOLOGY AND SOURCES

1.1. APPROACH

The basis for the argument of this study is derived from data collected from a number of North American rooftop farming case studies, which reveal the differences between conventional and productive green roofs. Data on the construction, operation and productivity of these emerging rooftop farms is set in relationship with the well-established research conducted and published on the performance and benefits of conventional green roofs. Points of comparison fall into three groups: environmental impact, life cycle costs analysis and social benefits. The findings and observation can be used as criteria for the design process of productive green roofs.

1.2. INTERDISCIPLINARY SOURCES

The analysis and understanding of green roofs and even more so of urban agriculture requires an interdisciplinary approach. Only when architectural, landscape architectural, ecological, economic, social and community aspects are collectively considered, a holistic approach to and evaluation of these emerging rooftop farm projects is possible, especially with the assessment of their potential impact to create more sustainable cities. Therefore sources from different areas of research were integrated in this study. The seminal articles on green roofs as urban ecosystems by Erica Oberndorfer et al (2007) and Kristin Getter and Bradley Rowe (2006) provide a detailed environmental analysis and performance evaluation of green roofs. Jeroen Mentens et al. (2005) offer comprehensive information on the impact of green roofs on urban water management. The research conducted by Nyuk Hien Wong et al. (2003) as well as Ulrich Porsche and Manfred Köhler (2003) present a basis for life cycle and cost analysis. The information on rooftop farms is derived from articles and data often published by the owners, farmers, and suppliers on the Internet, largely due to their very recent construction.

Figure 2: Brooklyn Grange, Long Island City, Queens, NY (http://brooklyngrange.files.wordpress.com/2010/08/bgfarm_notitle.jpg)

2. ROOFTOP FARMS

2.1. RECENT TRENDS

Over the past five years, numerous urban roof top farms started their operation in Toronto, New York, Vancouver, Chicago, Portland, Seattle and other North American cities (Chart 1). Their emergence over a short period of time reflects and responds to the growing interest of urban dwellers in locally produced organic food and more sustainable urban environments as well as the slow, but persistent acceptance of green roofs in North America.

2.2. EDUCATIONAL ROOFTOP FARMS

Already documented since 1999, the report on Urban Agriculture and Food Security Initiatives in Canada states that the use of rooftop gardens as farming spaces has considerable potential to produce substantial amounts of food and contribute to a sustainable urban environment (Fairholm 1999). Early community based pilot projects of food producing urban roof gardens can be found in Toronto and Vancouver. The Trent University Experimental Rooftop is one of the first rooftop farm of substantial size. Conceived and constructed as a research and organic vegetable garden more than 10 years ago, the farm is still run by a student group today and produces food for the local campus restaurant. Similar to this early case study, many recent rooftop farms have been established by educational institutions and youth centers. Their primary goals are to provide students with the educational experience of gardening and healthy food in dense neighborhoods where ground base gardens are not available.

2.3. COMMERCIAL ROOFTOP FARMS

Driven by the marketability of locally grown produce and fresh herbs on their menu as well as the convenience of having those directly available, many restaurants install kitchen garden on their roofs in dense urban neighbor-hoods. These rooftop gardens tend to be container gardens, which allows an easier installation on existing roofs and small, but deeper growing beds, which provide adequate space for the needs of one commercial user. The most recent developments are large commercial enterprises, such as Brooklyn Grange, which transform vacant, unused rooftops into large urban farms. Their operation began in 2008 with a small prototype, the Eagle Street Farm (Figure 1). After its first successful year, a nearly seven times larger, one-acre farm was installed on a rooftop in Long Island City and started operation in 2010 (Figure 2).

2.4. HYDROPONIC ROOFTOP FARMS

The rapidly increasing interest in and the growing market for locally grown, organic produce also fosters the development of hydroponic farms on urban rooftops. These farms grow vegetables with nutrient-rich, liquid growing medium in green houses. After testing the technology in small-scale applications, as for example the Science Barge on Hudson River, large scale projects are now either designed, such as Gotham Greens in Brooklyn, NY or under construction, like the Lufa Farm in Montreal, QC. This study looks at rooftop farms or productive green roofs, which fall technically in the category of intensive green roofs and follow their construction principles. Therefore these hydroponic rooftop farms will not be part of this study. The analysis and comparison between green roof and hydroponic farms offers a wide field for further research.

		year completed	retrofitted	new construction	container/ raised	surface beds	hydroponic	environmental	economic benefits	social benefits	size: total (cultivated) sq ft
EDUCATIONAL **schools**											
Trent University Experimental Rooftop Garden *www.cityfarmer.org/*	Toronto, ON	2000	•			•		•	•	•	30,000 (20,000)
Trillium Charter School *www.trilliumcharterschool.org*	Portland, OR	2010	•	•		•		•	•	•	
St. Simon Stock School *www.greenroofs.com/*	Bronx, NY	2005	•			•		•	•	•	3,500 (1000)
youth centers											
Gary Comer Youth Center *www.gcychome.org/*	Chicago, IL,	2006		•		•		•	•	•	8,400
YWCA Rooftop Community Food Garden *www.ywcavan.org*	Vancouver, BC	2006	•		•			•	•	•	2,100 (1,000)
COMMERCIAL **restaurant kitchen garden**											
Bastille *www.bastilleseattle.com/*	Seattle, WA	2009	•		•			•	•		4,500 (800)
Rocket Building *www.burnsiderocket.com/*	Portland, OR	2007		•	•			•	•		2,100 (800)
Organic Rooftop Farm Uncommon Ground Restaurant *www.uncommonground.com*	Chicago, IL	2008	•		•			•	•		2,500 (650)
Rooftop Kitchen Garden Fairmont Waterfront Hotel *www.cityfarmer.info*	Vancouver, BC	2006		•		•		•	•		2,100
commercial farms											
Eagle Street Rooftop Farm *www.RooftopFarms.org*	Brooklyn, NY	2008	•			•		•	•	•	6,000 (~5,500)
Brooklyn Grange *brooklyngrangefarm.com*	Queens, NY	2010	•			•		•	•	•	40,000 (37,000)
hydroponic farms											
Science Barge (prototype) BrightFarms/ NY Sun Works *brightfarmsystems.com*	New York, NY	2007		•			•	•	•	•	1,300
Gotham Greens (designed) *gothamgreens.com*	Brooklyn, NY	2011	•				•		•		16,000
Lufa Farm (under construction) *www.lufa.com/*	Montreal, QC	2011	•				•		•		31,000

Table 1: Urban rooftop farms in North America. Source: (Author 2011)

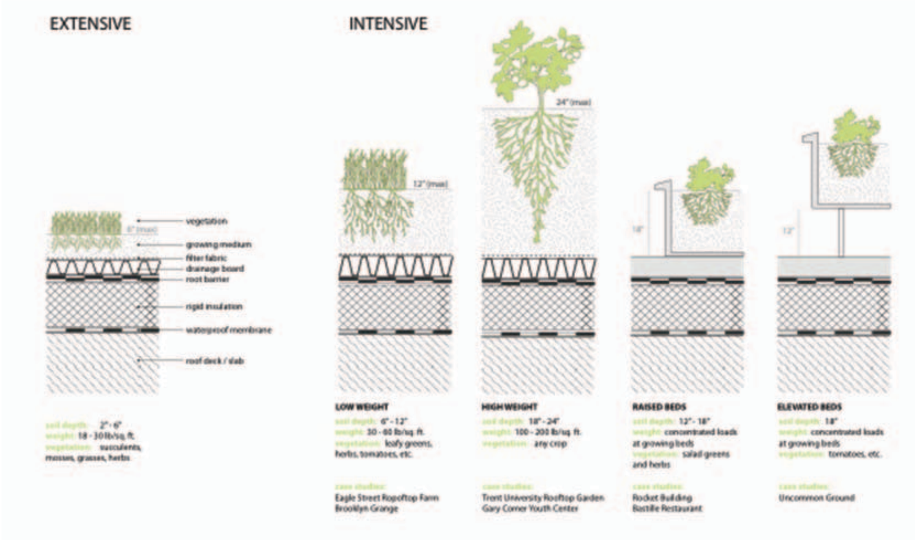

Figure 3: Green roof and rooftop farm construction types. Source: (Author 2011)

3. CONSTRUCTION AND DESIGN

3.1. GREEN ROOF TYPES

Green roofs basically consist of a vegetation layer, a substrate (or growing medium) layer, in which water is retained and the vegetation is anchored, and a drainage layer (or reservoir board) to evacuate or store excess water (Mentens et al. 2005). A waterproofing membrane and root barrier separates these water-carrying layers from the actual roof structure, which consists of an insulation layer and the roof slab or structural support. The depth of the substrate determines the roof's environmental properties, the plant selection that can be grown and the weight and therefore the structural requirements of the roof. Two main types of green roofs are distinguished based on the depth of their substrate layer: extensive with substrate layers with a depth less than 6" (15 cm) and intensive with substrate layers thicker than 6" (15 cm) (Mentens et al. 2005). In order to compare conventional and productive green roofs, the construction type of rooftop farms must be carefully examined. Most rooftop farms investigated in this study have continues substrate layer and surface growing beds. They fall into the group of intensive green roofs and their building performance and benefits can be compared (Figure 3). Whereas, rooftop farms with raised beds cover only a certain percentage of the roof area with growing area. Elevated beds are even lifted of the roof surface. Both construction systems realize only a small percentage of environmental benefits and do not improve the building performance and can therefore not be directly compared with conventional green roofs.

3.2. SUBSTRATE COMPOSITION

The most critical component for the success of a green roof or rooftop farm is its substrate, which is characterized by its composition, depth and weight. For long-term sustainability, substrate is commonly composed out of 80% (or more) mineral, often light-weight aggregate and 20% (or less) organic material (Luckett 2009). The porous mineral components provide weight reduction, store water and break down very slowly to maintain the volume of the growing medium. The organic components break down quickly and become available as nutrients for the plants. Especially with the intensive use of the growing medium through the rooftop farms, the organic material has to be replaced and recharge with fertilizing compost or organic matter. Therefore organic rooftop farms include often a compost cycle into their operation.

	Bastille Restaurant's Rooftop Garden	Eagle Street Rooftop Farm	Brooklyn Grange	Gary Comer Youth Center	Trent University Environmental and Resource Sciences Vegetable Garden
location	Ballard Seattle, WA	Green Point Brooklyn, NY	Long Island City, Queens, NY	Grand Crossing Chicago, IL	Toronto, ON Canada
year completed	2009	2008	2010	2006	2000
roof area/ cultivated area	2,500 sq. ft./ 800 sq. ft.	6,000 sq. ft./ 5,400 sq. ft.	40,000 sq. ft./ 37,000 sq. ft.	8,160 sq. ft./ 5,800 sq.ft.	30,000 sq. ft. 20,000 sq. ft.
percentage growing area	32%	90%	93%	71%	66%
containment	containers and raised beds	surface beds	surface beds	surface beds	surface beds
substrate depth	containers: 18" raised beds: 12"	6"-7"	7.5"	24"	18"
substrate weight	NA	ca. 60 lb/ cubic ft. 33 lb/ sq. ft.	"rooflite intensive" 44-53 lb/ cubic ft. 30 lb/ sq. ft.	NA	saturated soil 100lb/ cubic ft. 150 lb/ sq. ft.
retrofit or new construction	retrofit	retrofit	retrofit	included in new construction	included in original construction
construction system building	1-story warehouse, needed structural retrofit	3-story prewar warehouse	7-story warehouse, supports 130 lb/ sq. ft.	steel structure, built 2006	NA, built 2000
construction cost	NA	$10/ sq. ft. material cost	$ 5/ sq. ft. material cost	NA, $ 30 Million project in total	NA
annual precipitation	37.2"	47.3"	47.3"	35.8"	31.2"
irrigation system	drip irrigation	drip irrigation	drip irrigation	irrigation system	irrigation system
hardiness zone	7-8	6-8	6-8	5-6	5-6
growing season	Mar 10 - Nov 17, 251 days all year round, sun shading + heated growing beds	April 1 - Nov. 15, 227 days	April 1 - Nov. 15, 227 days 9 months with cover crops during the winter months	April 20 - Oct. 24, 187 days sunken courtyard extends season	May 9 - Oct. 6, 149 days
yield	NA	NA	16,000 lb, 0.4 lb/ sq. ft. 5.5 tons/ acre	1,000 lb 0.12 lb/ sq. ft.	NA
crop distribution	downstairs restaurant	CSA, local farmers market, local restaurants	CSA, local farmers market, local restaurants	students, center's cafeteria, local restaurants	local cafeteria, restaurant on campus
number of employees	1 part-time + kitchen staff	1 employee + many volunteers	5 partners (part time) + many volunteers	1 full-time, 2 part-time employees (students)	run by students, 1 full time gardener over the summer
social and educational programs	rooftop farm tours	apprenticeship, education programs	apprenticeship, education programs	multilayered educational programs	
web site	*http://www.digginfood.com/2009/09/bastille-restaurants-rooftop-garden/*	http://rooftopfarms.org/	http://brooklyngrangefarm.com/	http://www.gcychome.org/	http://www.cityfarmer.org/

Table 2: Rooftop farming case studies. Source: (Author 2011)

CONSTRUCTABILITY AND SUBSTRATE WEIGHT

The constructability of vegetated roofs depends largely on their increased weight, which is predominantly defined by the weight and depth of the substrate. Some of the educational rooftop farms investigated here were integrated during the design phase of the buildings and had generous budgets. This allowed the realization of an optimal depth of growing medium and structural support. The Trent University rooftop garden accommodates for example the weight of saturated soil, which equals approximately 100 lb per cubic foot. Therefore the roof caries a dead load of 180lb per square foot. The constraining factor for retrofitting existing rooftops is the load-bearing capacity of the roof, therefore lighter

substrate mixes have to be developed for these applications. The retrofitted rooftop farms in New York City have been successfully constructed on prewar warehouse type buildings. Their roofs usually support as much load as their individual ceilings. The roof that carries the Brooklyn Grange for example supports roughly 130 lb per square foot. All of the farm's materials combined weigh only between 30 - 40 lb per square foot, even when the soil is fully saturated with water - much less than the structural limit of the roof (Table 2).

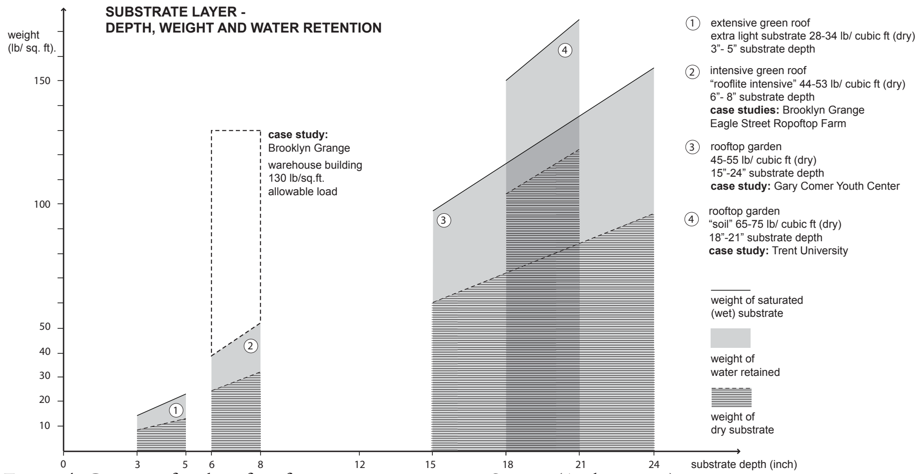

Figure 4: Green roof and rooftop farm construction types. Source: (Author 2011)

4. ENVIRONMENTAL BENEFITS

4.1. STORM-WATER MANAGEMENT

In the United States, 60-95% of the built-up area is covered by impervious surfaces (Frazer 2005). These hard, nonporous surfaces cannot absorb precipitation and therefore contribute to heavy runoff, which constitutes about 75% of the rainfall in cities. Dense urban areas often lack space to build low-impact storm-water management facilities; therefore green roofs are ideal storm-water management tools. They utilize an unused spatial resource and keep the water at its source. The same is true for urban roof farms (with surface growing beds). They offer the same water management benefits and additionally the opportunity to cultivate produce in places where no open space or vacant lots for ground based growing are available. Green roofs and rooftop farms retain water during rainfall events, delay its runoff, and increase the volume of water returned to the atmosphere directly through evapotranspiration. The depth of substrate has the greatest effect on the runoff rate (Mentens et al. 2005). In general, the deeper the substrate layer, the lower the run-off rate.

4.2. WATER REQUIREMENTS

One of the main differences between conventional, extensive green roofs, which are intended to mitigate runoff and intensive, productive green roofs is their water need. Extensive roofs are adapted to the local climate and water naturally available through precipitation, also during dry periods in the summer. Rooftop farms, however, must have access to enough water during the growing season for their crops to thrive. Roof top farms with thick substrate layers (6"-24") can retain up to 85% of rainwater (Mentens et al. 2005). Eggshell or dimpled reservoir mats integrated in the drainage layer can provide additional water retention and storage (Luckett 2009). Nevertheless, depending on the local climate and annual precipitation pattern, additional irrigation might be necessary. The water needs for local agriculture are a guide, but since rooftops receive more sun exposure and wind, which dry out the soil, the water needs on a productive roof will be higher than for ground based farming in the same location. Therefore the dimensioning and integration of an effective irrigation system is important. Localized drip irrigation, which brings the water directly to the roots, is most effective since the water cannot be blown off the roof by the wind. Rain water availability, water retention potential of the substrate, farming methods as well as the water needs of the crop species grown need to be balanced. In regions with seasonal fluctuation of precipitation, especially in climates with winter rains and summer droughts, the potential of rainwater harvesting and storage should be taken into consideration. The use of harvested rainwater reduces the demand for potable, communal water for irrigation and the environmental strain on fresh water resources during the summer months.

4.3. SUMMER COOLING

Besides the ability to retain rainwater, green roofs add insulation and thermal mass, which increases with the depth and composition of the substrate, to the roof. The improved insulation value and mass reduce the heat transfer through the roof. Simultaneously, the vegetation of the green roof promotes physical shading and an increased evapotranspiration rate. (Oberndorfer et al. 2007) This improved performance is reflected in the breakdown of the total solar radiation absorbed by the planted roof: 27% is reflected, 60% is absorbed by the plants and the soil and only 13% is transmitted into the soil (Eumorfopoulou 1998). The solar energy gain on a green roof can be reduced by up to 87% compared with non-shaded buildings surface (Wong et al. 2003). The reduced heat transfer into the building results in improved building performance and energy savings. This is especially evident during warm summer month and lowers the energy demands for the building cooling system (Oberndorfer et al. 2007).

Rooftop farms with continuous surface beds and deep

substrate layers offer additional insulation and thermal mass to improve the building performance and buffer temperature swings. Container rooftop gardens, with a low percentage of growing area coverage and unequal distribution of substrate across the roof area or rooftop gardens with elevated beds, do not provide these improvements of building performance.

4.4. URBAN HEAT ISLAND EFFECT

On an urban scale, the summer cooling of green roofs and rooftop farms contributes also to the mitigation of the urban heat island effect. Metropolitan areas, through their lack vegetation and agglomeration of dark impervious surfaces, are significantly warmer than their surrounding rural areas, especially at night. The air temperature above vegetated roofs can be up to 30°C lower compared to conventional roofs, resulting in up to 15% of annual energy consumption savings (Getter and Rowe 2006).

4.5. EVAPOTRANSPIRATION

Experiments on green roofs suggest that most of the summer cooling benefits from green roofs are attributed to evapotranspiration, which is the sum of evaporation from the soil and plant transpiration to the atmosphere (Oberndorfer et al. 2007). When water is readily available, the evapotranspiration rates are much greater on vegetated roofs than on roofs with growing medium alone, especially during the summer months (Obern-dorfer et al. 2007). Transpiration from living plants is responsible for a substantial portion of the cooling benefits of green roofs. Through the selection of plant species with high leaf conductivity or surface area, this proportion could be even further increased (Oberndorfer et al. 2007). Many crops cultivated on rooftop farms have large leaves and high water conductivity. Therefore the summer cooling effect offered by productive green roofs with ample vegetation is very large. In this respect, the need for additional irrigation water is offset by the cooling effect through the increased plant transpiration. Rooftop farms can outperform the cooling benefit of conventional green roofs that strive to adapt planting to water availability.

4.6. CARBON SEQUESTRATION AND NOISE REDUCTION

Studies show that extensive green roofs with a low biomass have only a very small potential to offset carbon emissions in cities. Intensive green roofs and intensively planted rooftop farms, however, could make a significant contribution to the air quality in cities as urban carbon sinks (Oberndorfer et al. 2007). Green roofs also reduce also sound pollution. Substrate and vegetation absorb sound waves outside buildings and prevent their inward transmission (Dunnett and Kingsbury 2004).

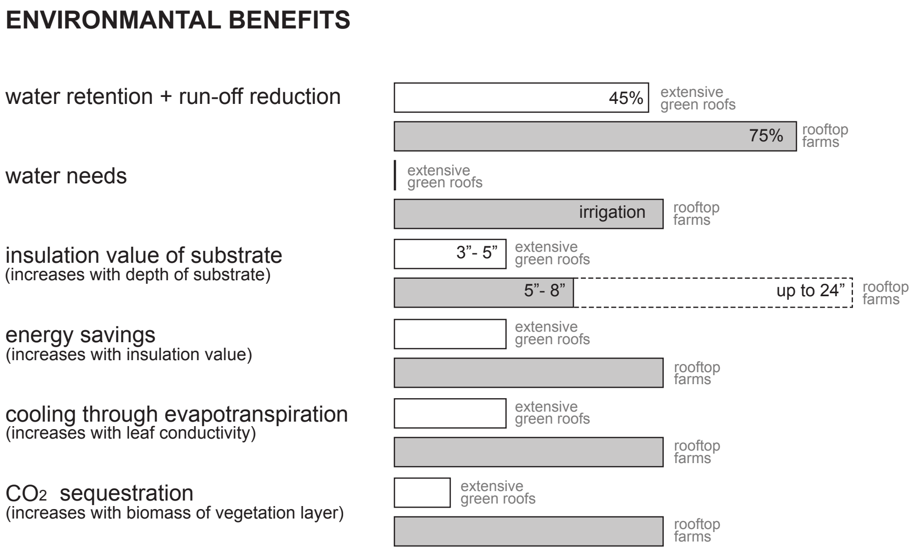

Figure 5: Environmental benefits of extensive green roofs and rooftop farms. Source: (Author 2011)

5. ECONOMIC BENEFITS

5.1. LIFE CYCLE COST ANALYSIS

So far developer and building owners have often shied away from green roofs based on their higher initial costs and the slower return of investment. The life cycle cost analysis of green roofs could be improved by evaluate their various areas of value more holistically and by considering benefits that are difficult to quantify. These assessments have to include the importance of human well-being and the longer-term goals of environmental sustainability. Productive green roofs offer in addition the value of their yields, jobs and educational programs.

5.2. EXTENDED LONGEVITY

On conventional urban roof surfaces high temperatures are often reached through sun exposure, which create high levels of stress on the roofing systems and materials. Dark waterproofing membranes deteriorate rapidly in ultraviolet light (Oberndorfer et al. 2007). The vegetation cover and substrate layer of green roofs moderate the temperature extremes and physically protect the waterproofing membrane from ultraviolet (UV) radiation and mechanical forces (Wong et al. 2003). A correctly installed vegetated roof has an increased lifespan of 3-4 times that of a conventional roof (Wong et al. 2003, Luckett 2009). Some green roofs in Berlin even demonstrate a lifespan of more than 90 years without needing major repairs (Porsche and Köhler 2003).

5.3. INITIAL COSTS

The price of the installation of green roofs depends on the location, availability of green roof construction systems, the substrate depth, its composition and the type of vegetation. In comparison to low-priced, conventional roofs (with a lifespan of only 15 years), green roofs can cost up to three times more (Porsche and Köhler 2003). Recently documented prices in the United States range from $7.50 per sq. ft. for conventional roofs to $25 per sq. ft. for the installation for green roofs. Over the 60-year lifespan of the green roof, the conventional roof will need three major repairs or replacements. After a total roof investment of $ 51 per sq. ft. (including the inflation rate) the conventional roof will be twice as expensive than the green roof. (Luckett 2009). A short-lived, low-first-cost product is often not the cost-effective alternative. (Wong et al. 2003) A higher first cost for green roofs will be justified many times over for a durable product with minimal maintenance and environmental benefits, especially since this calculation does not take the larger use resource and environmental strains in account for renewing a roof three times. The construction and installation cost of rooftop farms vary widely depending on the structural capacity of the building, substrate depth and farming method. Some of the institutional, educational projects are very well funded, whereas the commercial projects are start-ups with low budgets. The cost for the retrofit for the Eagle Street Farm with a substrate depth of 6" was only $10 per sq. ft., which were funded by donations and installed with the help of volunteer work (Figure 6).

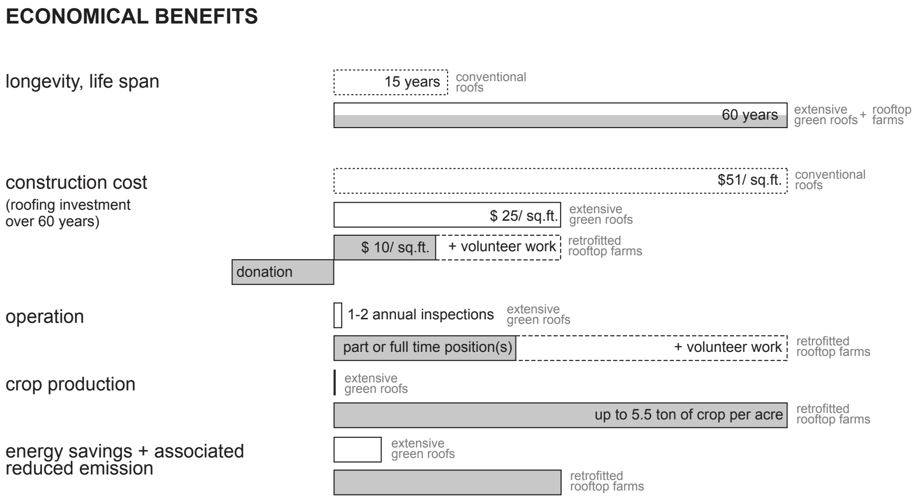

Figure 6: Economical benefits of extensive green oofs and rooftop farms. Source: (Author 2011)

5.4. OPERATIONAL REQUIREMENTS AND PRODUCTION

The vegetation of any green roof requires maintenance. Extensive roofs need low maintenance; only 1-2 annual inspections to remove weeds and tree seedlings and check the roof waterproofing and drainages systems. Intensive green roofs require more maintenance depending on the selection of plants. The maintenance of rooftop farms is part of the operation. Depending on the type of farm, this can be either part of the curriculum of the educational institution or part of the business plan of a commercial enterprise, which results in job creation. Most rooftop farms investigated have one full- or part-time employee, but rely mostly on volunteers supporting the farms throughout the growing season.

5.5. ECONOMIC VALUE OF ENVIRONMENTAL BENEFITS

The environmental benefits of green roofs also translate in economic benefits. Although difficult to include in a per-project cost analysis, the reduction of storm-water runoff though green roofs has an enormous value for cities and communities. It releases city finances from new investments and maintenance cost of their urban storm-water treatment facilities. If 6% of the roof area in Toronto would be covered with green roofs, the impact on storm-water retention would equal the construction of a $ 60million (CDN) retention tunnel (Peck et al. 1999).

Many communities across the US have adopted storm-water treatment fees to fund the treatment of storm- water runoff. Most of these fees are assessed across the entire population based on the treatment cost and not based on the "polluter pays principle". Currently, storm-water fees are unrealistically low. The adjustment of these to reflect the actual cost of storm-water infrastructure and treatment and the introduction of credit for green roofs construction would help to create an additional financial incentive for green roof implementation.

5.6. ENERGY SAVINGS

Green roofs improve building performance, especially during the summer (see 4.3.). Research studies have shown that green roofs can reduce the indoor temperatures by at least 3°C to 4°C when outdoor temperatures are between 25°C - 30°C (Peck et al. 1999). The decrease of the indoor temperature by 0.5°C may reduce electricity demand for air conditioning by up to 8% (Dunnett and Kingsbury 2004). For individual building it has been shown, that the electricity use for cooling on a summer day can be reduced by 64%.

Buildings consume 36% of all energy used and contribute to 65% of all electricity consumption; therefore the implementation of green roofs on a large scale could generate significant energy savings (Kula 2005). After the installation of a green roof on the Chicago city hall, the energy savings could be $4000 annually for heating and cooling combined. If all buildings in Chicago had green roofs, the savings could be $ 100 Million annually (Laberge 2003). In addition to the immediate energy savings, the reduced emission through decreased energy consumption is also considered as an environmental benefit.

6. SOCIAL BENEFITS

6.1 RECOGNITION OF SOCIAL BENEFITS

Green roof research focuses primarily on environmental performance; though social and community benefits as well as improvements of the urban human habitat are acknowledged as by-products. Living roofs provide aesthetic and psychological benefits for people in urban areas. Even green roofs that are only accessible as visual relief provide relaxation, improve human health and reduce patients' recovery times in healthcare environments through the simple visual contact with vegetation (Copper-Marcus and Barnes 1999). Likewise, the visual and physical access of employees to green roofs at their workplace increases employee satisfaction, productivity and reduces stress (Luckett 2009).

In this respect, the benefits of urban rooftop farms start where conventional green roofs end. One of their primary goals is to provide social benefits. For educational rooftop farms this agenda is obvious, but also commercially run rooftop farms investigated in this study build also on strong community ties, educational programs, and volunteer projects.

6.2 EDUCATION AND ACCESS TO FRESH FOOD

Educational rooftop farms, such as the Gary Comer Youth Center in Chicago, have multilayered educational programs. Children learn about the seed-to-harvest cycle, environmental concerns,

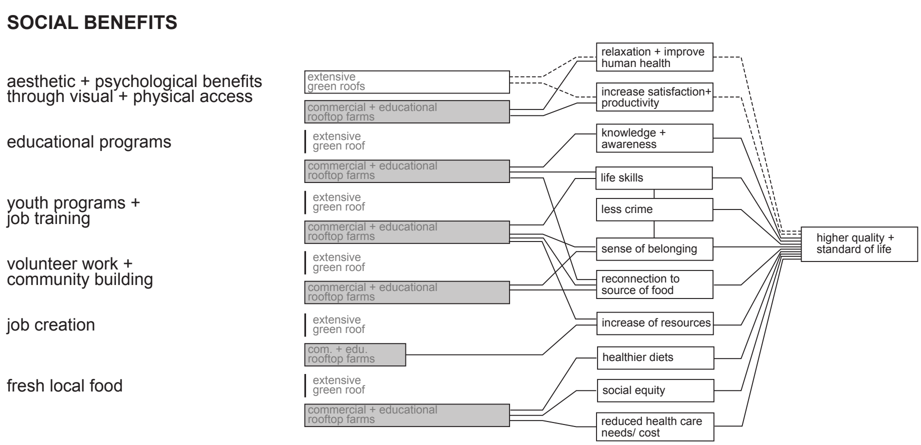

Figure 7: Social benefits of extensive green roofs and rooftop farms. Source: (Author 2011)


Figure 8: Gary Comer Youth Center (http://www.thelocalbeet.com/wp-content/uploads/2009/07/Kessler_GaryComer-1.jpg)

botany, and the processes of nurturing growth in a garden. They also learn about nutrition and healthier diets, which could eventually have a tremendous impact on the public health of their community. This education on healthier diets is immediately put in action with the increased access to fresh food. The vegetables grown on the rooftop are used by cooking classes, local cafeterias or distribute to the students and their families. Similar educational programs for children and teenagers are also offered by some of the commercially run rooftop farms. Furthermore, their greatest contribution to the community is providing access to locally grown fresh produce, especially in urban areas that are challenged with otherwise low availability of healthy food. The produce is either sold directly at the farm, on farmers markets or through community supported agriculture (CSA) organizations.

6.3 COMMUNITY BUILDING

The community around rooftop farms flourishes not only with new access to fresh food, but more importantly with the development of new networks and community ties. Most rooftop farms rely on volunteer work and therefore offer community members the chance to get in direct contact with the source of their food. People describe the experience of being involved in the process of producing there own food as very fulfilling. This sense of accomplishment has especially a positive impact on youth growing up under challenging circumstances. Therefore many rooftop farms offer youth programs and job training. Commercially run rooftop farms also contribute to the larger community by creating an economic stimulus, particularly in neighborhoods that otherwise suffer from low business activity. New farm enterprises might directly or indirectly create new employment opportunities and attract other businesses to the location.

CONCLUSION

The comparison shows that not only do productive green roofs meet the well-established environmental benefits of conventional green roofs, such as the contribution to water management, summer cooling and an improved building performance (as described by Getter and Rowe 2006 and Oberndorfer et al. 2007), but they also provide additional social and economical benefits. These benefits include educational programs, community building and health benefits as well as resource conservation, production of local produce and job creation. The challenge for the allied design and planning professions is to learn from the emerging successful case studies. The retrofit of existing buildings covering a greater area of dense urban centers would have a strong, positive impact on the urban environment.

In conclusion, this investigation shows that productive green roofs should be implemented wherever possible, due to their vital contribution to the advancement of urban agriculture and the associated environmental, social and economic gains, all of which strengthen the environment and urban communities.

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