Green Roof Integration and Property Values in New York City

Introduction

As the United States continues its efforts towards mitigating the effects of climate change (General Services Administration, 2011), interest in utilizing rooftop spaces within urban areas for vegetation and agriculture has seen an increase over the last several years (Dinardo, 2019; EPA, 2021; Stutz, 2010). These rooftop spaces, also known as green roofs, consist of vegetation planted in a growing media over a waterproof layer and a drainage layer installed on the rooftop of a building (Kim et al., 2018). Green roofs are typically categorized as either extensive, meaning constructed with shallow-rooted flowers and non-edible plants and lightweight soil mediums, or intensive, with deep-rooted plants and trees and heavier soil mediums (Sangkakool and Brudermann, 2017). Both categories of green roofs deliver various benefits such as mitigating the urban heat island effect, airborne pollution reduction, rooftop insulation, reduction of sewer overflow, and an increase in property values (EPA, 2021; General Services Administration, 2011; Stutz, 2010).

In 2019, New York City passed Local Law 92 and Local Law 94 requiring new building constructions and buildings with major rooftop renovations to be integrated with green roof systems or solar photovoltaic electricity generating systems (Urban Green Council, 2019). New York City organized Priority Districts based on the need for stormwater management and reduction of the urban heat-island effect (NYC Office of Long Term Planning and Sustainability, 2020) and provides a property tax abatement of $5.23 per square foot for property owners who install green roofs on their buildings in Queens, Staten Island, and most of Manhattan, and $15 per square foot in Priority Districts in the Bronx and Brooklyn. In addition, the New York City Department of Environmental Protection (DEP) offers the Green Infrastructure Grant Program

which provides up to $30 per square feet for property owners who retrofit at least 50% of their existing building with a green roof. However, there is limited empirical literature on how implementing green roofs may affect property values in an urban environment. My work aims to add to the existing literature by estimating the effects of green roof integration on property values in New York City using a robust sample of green roof buildings.

Literature Review

Several studies have been conducted analyzing the overarching environmental benefits of green roof technology such as increased energy efficiency (Sangkakool and Bruderman, 2017), thermal insulation (Manso et al., 2021), promoting biodiversity (Joshi and Teller, 2021), and stormwater management (Hui, 2011). In contrast, there is a limited amount of literature on estimating the effects of green roof integration on property values in an urban context despite its importance for understanding the underlying market value of these investments.

Green roof integration studies are also not often conducted within the United States (Kim et al., 2018; Mahdiyar et al, 2016; Sangkakool and Brudermann, 2017; Ziogou et al., 2018) which poses a significant limitation in the existing literature as it can be difficult to accurately conceptualize overseas neighborhoods and city structures as well as local laws and policies regarding adopting green roofs.

Bianchini and Hewage (2012) state that “natural landscapes benefit homeowners and investors by increasing the market value of properties.” As green roofs and green wall technologies are relatively novel, some studies utilize the provision of tree cover and natural greenery as a proxy for missing green roof and green wall data as tree cover offers similar qualities in terms of aesthetic and environmental benefits as green roofs and green walls. Peck

and Callaghan (1999) find that higher amounts of tree cover results in a 6-15% increase in home values.

Buildings integrated with green roofs are shown to have higher property values compared to buildings with standard roofing (Jim and Peng, 2012; Mahdiyar et al, 2016; Manso et al., 2021). Perini and Rosasco (2013) present a lower estimate of effects in property values for vertical green walls, and find that based on the location of the building integrated with a vertical green wall, the presence of green walls increases property values by 2-5%. Bianchini and Hewage (2012) find that buildings with extensive green roofs may have between 2-5% higher property values than buildings with standard roofing, and buildings with intensive green roofs have 10-20% higher property values compared to buildings with standard roofing. Noor et al. (2015) find that green spaces in Kuala Lumpur, Malaysia increase property value by up to 12%. In their review of existing literature on the costs and benefits of green roofs and green walls, Manso et al. (2021) state that buildings with green roofs have 2-20% higher property values compared to buildings with traditional flat roofs. Across the literature Manso et al. (2021) surveyed, buildings with green roofs have an average of 8.24% higher property values compared to buildings with traditional flat roofs.

Ichihara and Cohen (2011) provide literature on the effects of green roof integration on rental housing prices. The authors analyze the effects of green roofs on the prices of apartment rentals in Battery Park City, New York, New York using a hedonic regression model for the impact of green roofs on rental apartment unit prices while controlling for the distance to the nearest subway station, the number of bedrooms, the number of bathrooms, the distance to the nearest park, and household income. Their sample included 44 buildings in Battery Park City, 3

were buildings with green roofs. Ichihara and Cohen (2011) find that apartments in buildings with green roofs rent for 16.2% more than buildings without green roofs.

One of the most cited reasons for skepticism towards green roof integration is the short-term return of investment for property owners (van der Meulen, 2019). Van der Meulen (2017) notes that in the short-term, higher implementation and maintenance costs compared to traditional rooftops may deter potential green roof adopters away from the technology, though this is likely to be offset by the long-term energy savings green roofs provide (Sangkakool and Brudermann, 2017). Kim et al. (2018) constructed a life-cycle cost study for a green roof on a building at Seoul National University in South Korea, and found that the initial construction cost for extensive rooftop gardens is significantly more expensive than the cost of installing a traditional flat roof. However, over a 40-year lifespan, the lifecycle cost for an extensive rooftop garden is 38.9% lower than the traditional flat roof as the maintenance and replacement needs of the flat roof is more costly and frequent compared to the rooftop garden. Sangkakool and Brudermann (2017) also state that green roofs are subject to structural limitations and challenges especially in regards to the "high dead load" of the additional weight of soil, plants, rainwater, and other structural adaptations needed to support a green roof.

Conceptual Framework

Green roof technology has several economic, environmental, and social benefits that may contribute to buildings with green roofs having higher property values compared to buildings with traditional standard roofs (Jim and Peng, 2012; Mahdiyar et al, 2016; Manso et al, 2021). Figure 1 presents a few of the potential benefits of integrating buildings with green roofs in the categories of environmental, social, and economic gains. The hypothesis states that the culmination of these benefits has a positive effect on property value.

Figure 1: Green Roof Benefits

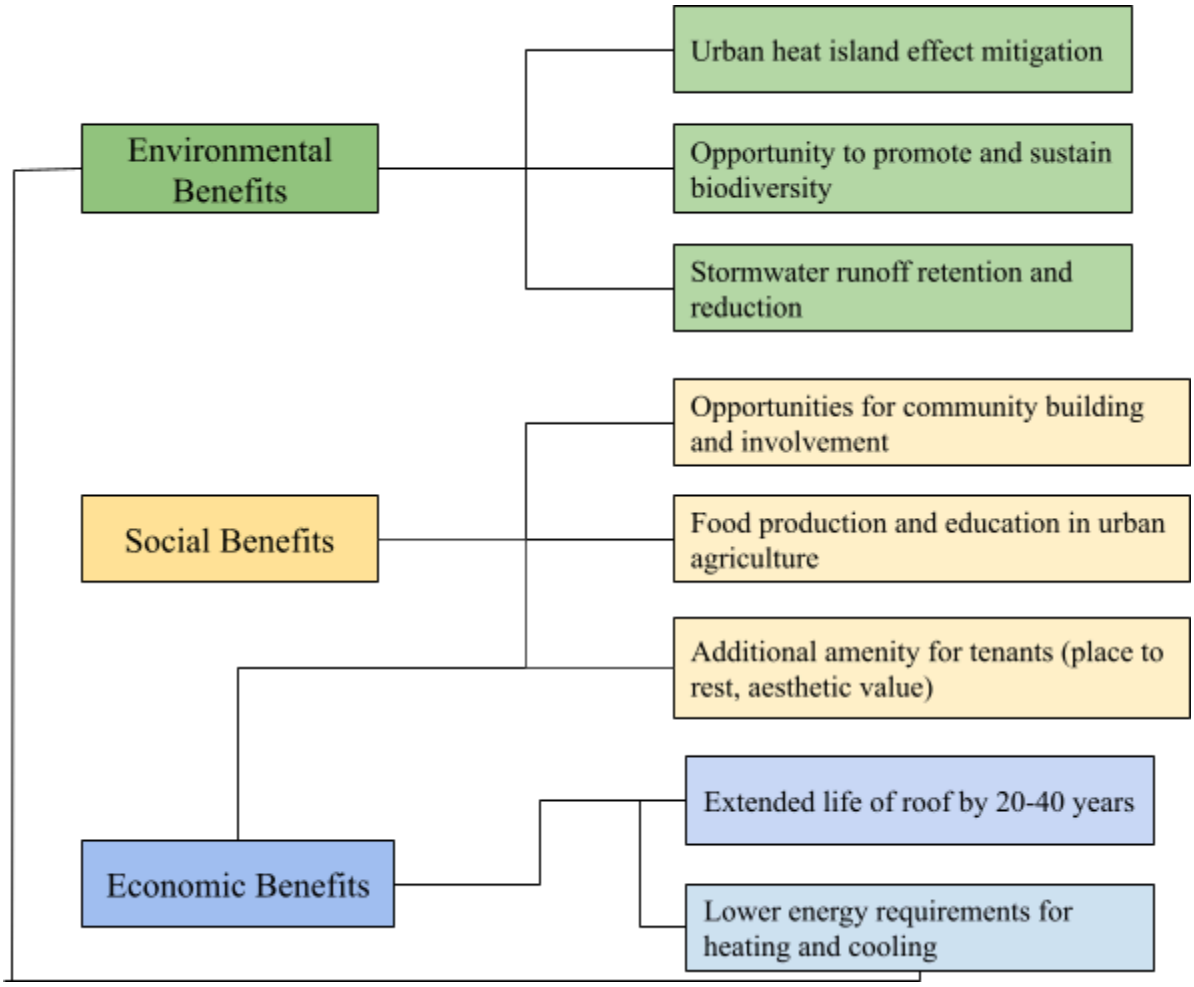


Fig. 1: Environmental, social, and economic benefits of green roof integration for urban areas.

Green roofs provide several environmental benefits for both the building itself as well as areas in close proximity. One of the most cited environmental benefits for green roofs is mitigating the urban heat-island effect, where buildings and other urban infrastructure absorb heat more so than natural landscapes, making temperatures in urban areas higher (EPA, 2022). Manso et al. (2021) state that "Plants have the ability to absorb solar radiation to develop their biological functions (photosynthesis, transpiration, evaporation and respiration) and create a milder microclimate as evapotranspiration cools both the plant foliage and the ambient air

around them." They find that in the studies they surveyed, green roofs and green walls provide an average of 1°C to 3°C reduction in surrounding temperatures.

Green roofs are also able to support various types of flora, as well as provide habitats for birds and insects (Joshi and Teller, 2021). This is beneficial for promoting biodiversity and conserving indiginous species of wild flowers and plants "which serve as a part of the food chain for essential pollinators such as wild bees along with enhancing aesthetic appearance" (Joshi and Teller, 2021). Managing stormwater runoff is also a significant environmental benefit of green roof integration, as green roofs have the potential to reduce the quantity of stormwater runoff in the case of rainfall (Joshi and Teller, 2021; Kim et al., 2018) through their ability to retain water and to thus not overload sewage systems in urban areas (Jim and Peng, 2012).

There are several social benefits to green roofs as well. Rooftop farms and rooftop gardens can provide aesthetic value for residents (Kim et al., 2018) and this may contribute to higher property value. Rooftop gardens and rooftop farms are valued by neighborhood residents as places for urban agriculture, community building, and educational opportunities for children, though rooftop farms may have greater social benefits compared to rooftop gardens. Rooftop gardens, however, were the more preferred option for residents in the Kim et al. (2018) work as the residents value an area to rest, reduction in the UHI effect, and improvements to the urban landscape. Kim et al. (2018) state "the potential social benefits of roof farms in urban areas include the growth of community cohesion, improvement of community food security (especially for low-income neighbors), and provision of educational opportunities through urban farming. In general, people had positive attitudes towards green roofs on buildings in urban areas."

Lastly, the economic benefits of green roof integration may be positive for both residents and property owners. The composition of a green roof includes a waterproof layer, and while

similar to the waterproof membrane on traditional roofs, green roofs may be able to provide over 50 years of in-service life compared to the 10-20 years of a traditional roof's in-service life. The insulation green roofs provide is both an environmental and economic benefit for residents and property owners, as the thermal insulation allows for lower energy requirements for heating and cooling (Jim and Peng, 2021; Kim et al., 2018; Manso et al, 2021).

Empirical Approach and Data

The objective of this study is to estimate the effects of implementing green roof technology on the property values of residential buildings in New York City. The culmination of the several environmental, social, and economic benefits of integrating buildings with green roofs has a positive effect on property value in urban areas. This study aims to quantify changes in property value due to green roof technology integration using the New York City green roof data aggregated in 2016 by the Green Roof Researchers Alliance and the Nature Conservancy in tandem with the property value information from the 2016/17 New York City Property Valuation and Assessment Data provided by the NYC Department of Finance as well as the 2021 New York City Property Valuation and Assessment Data.

I merged the green roof data from the Green Roof Researchers Alliance and the Nature Conservancy with the property value information from the 2016/17 New York City Property Valuation and Assessment Data as well as the 2021 New York City Property Valuation and Assessment Data in order to obtain information on property values and specific aspects of the buildings with green roofs such as number of stories within a building, number of units within a building, the year of construction, and the gross square feet measurement of the property.

The Green Roof Researchers Alliance and the Nature Conservancy aggregated the green roof data using manually digitized footprints of green roof surfaces based on publicly available

imagery collected in 2016 from NYC Department of Parks and Recreation and the NYC Department of Environmental Protection, greenroofs.com, and greenhomenyc.org (Tregalia et al., 2018). The New York City Property Valuation and Assessment Data is collected each year by the New York City Department of Finance in order to calculate property taxes, grant eligibility, and exemptions or abatements. It includes exact figures for property values for specific buildings and includes detailed geographic location such as borough, block, lot, address, and zip code as well as building characteristics such as the year of construction, the gross square footage of the property, the number of stories within the building, and the number of units within the building.

This study will use a modified hedonic fixed effects regression model similar to the Ichihara and Cohen (2011) model. The regression equation can be written as:

$$Log(propertyvalue)_{i.c.} = \beta1(stories)_{i.c.} + \beta2(units)_{i.c.} + \beta3\,(age_of_building)_{i.c.} + \beta4(frontlot)_{i.c.} + \beta5(depthlot)_{i.c.} + \delta1(has_green_roof)_{i.c.} + \varepsilon_{i.c.}$$

(1)

The dependent variable is log-transformed so that the percentage change in property value is presented as the outcome. The independent variables are the number of stories within the apartment building, the number of units within the apartment building, the building's year of construction, the property's lot dimensions (front and depth) in gross square feet, and lastly an indicator variable for whether the building has a green roof or not.

Ideally, the model would include several other potential determinants of property value including property characteristics such as unit layouts (bedrooms/bathrooms), central air-conditioning, contextual factors such as the quality of local schools, and location and distance variables such as whether the building is near a waterfront, distance to nearest public transportation, and distance to the nearest park (Touissant-Comeau and Lee, 2018). These

qualities were not available in the datasets used as access to this information in New York City on a large scale is limited to licensed real estate agents. However, the New York City Department of Finance uses the size, location, number of units, and the age of the building to determine residential property value. The physical aspects of the building such as gross square footage and number of units are also the largest determinants of property value (Touissant-Comeau and Lee, 2018).

The covariates used are to control for variation in building aspects which influence property value. Subscript (i) refers to the individual residential buildings where $i = 1, 2, \ldots 1331$ since the sample includes a building with a green roof and the comparable buildings that closely match the green roof building but do not have a green roof. Subscript (c) refers to the zip code fixed effects used to account for variation in property value between specific neighborhoods.

The sample includes residential buildings with green roofs and residential buildings without green roofs. Each building with a green roof is compared to similar buildings in the same borough, block, and zip code. The sample excludes residential buildings that were constructed before 2000 and after 2016 as well as buildings in Tax Class 3 intended for utilities and buildings in Tax Class 4 intended for commercial and industrial purposes. Due to data constraints, the data assumes that green roof integration occurred in the same year of construction. In my sample, there are 66 residential buildings with green roofs and 1,265 standard residential buildings.

Table 1: Descriptive statistics for full sample

Summary Statistics: Green Roof Building Sample Means					
	Count	Mean	S.D.	Min.	Max.
Total Market Value	66	$53,600,000	$61,200,000	$1,232,000	$203,000,000
Year Built	66	2007.758	3.725425	2000	2013
# of Units	66	220.8333	201.0519	11	839
Front of lot, sqft.	66	169.8797	103.4294	25	575
Depth of lot, sqft.	66	147.7471	66.04353	70	328
Total lot sqft.	66	21380.22	19179.9	2680	113275
# of Stories	66	14.80303	11.36827	4	51
Observations	66				
Summary Statistics: Non-Green Roof Building Sample Means					
	Count	Mean	S.D.	Min.	Max.
Total Market Value	1265	$15,400,000	$31,000,000	$169,312	$403,000,000
Year Built	1265	2009.421	4.922053	2000	2016
# of Units	1265	79.07352	109.7951	6	1615
Front of lot, sqft.	1265	114.9979	76.85088	11.58	740
Depth of lot, sqft.	1265	129.6243	64.87672	17.32	749.86
Total lot sqft.	1265	10520.21	10924.85	80	88000
# of Stories	1265	9.728656	8.863981	0	71
Observations	1265				

Table 1: Descriptive statistics for the sample of 66 green roof buildings and the sample of 1265 buildings without green roofs. Each green roof building has multiple comparable non-green roof buildings matched by the borough, block, and zip code.

Results and Discussion

Table 2 displays the regression results of the hedonic regression model in Equation 1 for the effects of green roofs on property value. The coefficient for the green roof indicator variable is 0.200, meaning that buildings with green roofs are estimated to have 20% higher property values compared to buildings with traditional roofing. The coefficient for the age of the building is 0.027, meaning that buildings that are newer relative to 2000 are estimated to have 2.7% higher property values than older buildings. The coefficient for the quantity of units within a building is 0.003, meaning that each additional unit within a building is estimated to increase

property value by 0.3%. The coefficient for the quantity of stories is 0.020, indicating that there is an estimated 2% increase in property value with each story. An additional square foot in the front of the lot of the property and the depth of the lot of the property is estimated to increase the property value by 0.3% and 0.2% respectively. All coefficients are statistically significant at the 1% level apart from the green roof indicator variable which is statistically significant at the 10% level.

Table 2: Regression results for green roof effects on property value

Regression Results: GR Effects on Property Value	
	Log(Total Market Value)
Green Roof Indicator	0.200* (0.117)
Age of Building	0.027*** (0.005)
# of Units	0.003*** (0.001)
Front of lot, sqft.	0.003*** (0.000)
Depth of lot, sqft.	0.002*** (0.000)
# of Stories	0.020*** (0.006)
Zip Code Fixed Effects	Yes
Constant	14.529*** (0.114)
Observations	1331
R2	0.56
Standard errors in parentheses	
*$p < 0.10$, **$p < 0.05$, ***$p < 0.01$	

Table 2: fixed-effects regression results for estimating green roof effects on property value. The sample includes 66 residential buildings with green roofs and 1265 comparable buildings with the same borough, block, and zip code. This model includes zip code fixed effects using the market value as the dependent variable.

The positive sign of the green roof indicator coefficient aligns with the existing literature that suggests buildings with green roofs have higher property values than buildings with standard roofing. While the green roof indicator coefficient is consistent with the higher estimates in the literature (Bianchini and Hewage, 2012), it falls well above the 8.24% average Manso et al. (2021) provides in their review of previous green roof studies. Overstatement of the green roof indicator coefficient is very likely a result of being unable to account for other potential determinants of property value such as unit layouts, neighborhood characteristics and perceptions, and updated luxury unit amenities. The inability to obtain data for these several potential determinants of property value is a significant limitation to the study and these characteristics may be absorbed by the green roof indicator variable. Consequently, the model is unable to fully account for features of properties that may affect the total property value. Causality cannot be fully attributed using this approach.

It is important to note that green roof integration should be evaluated on a case-by-case basis as not all urban areas will have the same needs (van der Meulen, 2019). The median age of buildings in New York City is about 90 years old (Kolomatsky, 2017) and older buildings may require substantial renovations in order to support a green roof. This may limit green roof integration in the City especially if the economic benefits are what appeal to property owners most.

Aggregating residential apartment information with greater specificity and merging it with a sample of both standard roof buildings and green roof buildings and curating a model with additional controls would be grounds for future research in addition to other opportunities for future studies such as quantifying the potential effects of green roofs intended for agriculture on urban food insecurity, estimating the impact of other sustainable technology on housing costs,

and quantifying the potential social value from green infrastructure for urban areas in terms of community involvement.

Conclusion

While it comes with its caveats, green roofs may provide substantial benefits for the concrete jungle. Although retrofitting green roofs onto New York City's old buildings may not be entirely feasible, integrating buildings with green roof technology in urban areas has several environmental, social, and economic benefits to consider for both residents and property owners. With an estimated 20% higher property values for buildings with green roofs, adoption of green roof technology in city policy may be an economically beneficial opportunity for property owners in addition to a positive motion for residents as well as the environment. Property owners may be incentivized to adopt more sustainable technology if made aware of the significant economic prospects. As more major cities continue to adopt sustainable technology, their benefits in terms of property value are important to take into account in policy and practice.

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