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The Environmental Benefits of Implementing Green Roofs on City Skyscrapers

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THE ENVIRONMENTAL BENEFITS OF IMPLEMENTING GREEN ROOFS ON CITY SKYSCRAPERS

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Table of Contents

List of Figures

1 INTRODUCTION

Climate change is the most severe threat to humankind this century, threatening to devastate cities through excessive pollutants, increased temperatures, sea-level rise, natural disasters, and flooding. With this forecast of climate change in the coming decades, innovative, sustainable solutions must combat it. These solutions are crucial, given that two out of every three people on the planet are projected to live in cities by 2050, as reported by the United Nations (UN) (2018, para. 1). One possible solution to this problem is installing green roofs on the top of city skyscrapers. According to the Environmental Protection Agency (EPA), a green roof is a "vegetative layer grown on a rooftop" (2019, para. 2).

Figure 1: Pictorial Representation of EPA Region 8 Headquarters Green Roof (EPA, 2019).

Figure 1 above exhibits the green roof on the top of the EPA Region 8 Headquarters in Denver, Colorado. Studies have shown that green roofs make buildings more sustainable and environmentally friendly, which could provide the foundation for a brighter future in cities. Several environmental benefits come with implementing green roofs on city skyscrapers, such as improved stormwater management, carbon sequestration, and energy conservation.

2 STORMWATER MANAGEMENT

One environmental benefit associated with implementing green roofs on city skyscrapers is improved stormwater management. Green roofs reduce the amount of runoff from rooftops through water infiltrating the vegetation layer. They provide a longer average lag time between rainfall and runoff peaks due to a certain amount of rainfall volume stored in the soil layer

(Cristiano et al., 2021, pp. 1-2). This rainfall volume then gets absorbed by the vegetation roots before eventually reentering the atmosphere through evapotranspiration. It is important to note that specific parameters contribute to the retained rainfall volume. Those factors include the roof dimensions, soil type and thickness, and vegetation species. Depending on the amount of retained rainfall volume, it can be reused for purposes like irrigation and other non-drinking uses (Cristiano et al., 2021, p. 2). The most critical aspect of green roofs is that they provide more sustainable drainage systems. As stated by Dr. Anna M. Baryła, Professor in the Department of Environmental Management at the Warsaw University of Life Sciences, green roofs "form absorbent surfaces for rainwater, which they retain with the aid of profile and plants" (2019, p. 12).

Baryla carried out a study investigating the effectiveness of different green roof drainage layers in reducing stormwater runoff. In this study, two aggregates, Leca® and quartzite grit, were utilized as the drainage layers and simulated under field conditions (Baryla, 2019, p. 12). The figure below indicates the experimental setup.

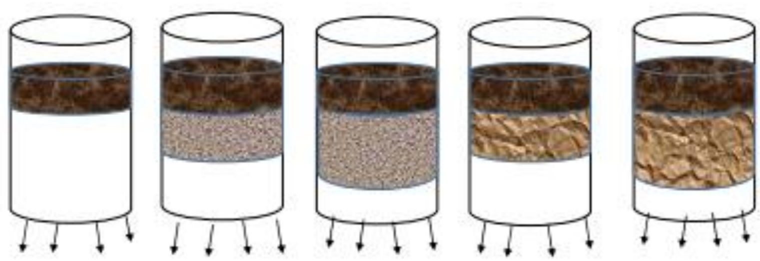

Figure 2: Schematic of Field Experiment (Baryla, 2019, p. 13).

As represented in Figure 2 above, four columns with a diameter of 320 mm were filled with the drainage layers at thicknesses of 5 cm and 10 cm, and one column with a diameter of 320 mm was filled with an intensive substrate layer at a thickness of 5 cm (Baryla, 2019, pp. 13-14). The study was conducted over 92 days, in which the columns were supplied 307.80 mm of atmospheric and simulated precipitation through 21 rainfall events (Baryla, 2019, p. 14). The results were as follows: "The average retention of the substrate was 48%; for a 5 cm drainage layer of Leca®[, the average] retention was 57%, for a 10 cm layer of Leca[, the] average retention was 61%. For a 5 cm layer of quartzite grit[, the] average retention was 50%, for [a] 10 cm layer of quartzite grit[, the average retention was] 53%" (Baryla, 2019, p. 12). These findings indicate that drainage layers are highly effective in decreasing runoff, demonstrating that they are an essential component in implementing green roofs to improve the environment of cities.

The environmental regulation that ties into stormwater management practices for green roofs is the Clean Water Act (CWA) of 1977. The CWA bans the discharge of a pollutant from a point source into navigable waters of the United States unless a permit is acquired from the National Pollution Discharge Elimination System (NPDES) Program (Rich, 2021, p. 1). This legislation can be traced back to the enactment of the Federal Water Pollution Control Act (FWPCA) of 1948 and several amendments that slowly expanded federal intervention in the years before the approval of the CWA (Rich, 2021, p. 1). The CWA is pivotal for preventing the discharge of excessive pollutants into waterways, therefore benefiting public health and aquatic life. One type of discharge regulated by permits distributed to industrial and municipal facilities by the NPDES Program is Stormwater, which directly relates to green roofs (Rich, 2021, p. 1). With this legislation emphasizing stormwater management, proper measures must be taken to incorporate stormwater management practices into green roofs for combating runoff. The issuance of discharge requirements through the CWA will go a long way to ensure that green roofs are a success, further assisting in reducing stormwater runoff from rooftops of city skyscrapers.

3 CARBON SEQUESTRATION

A second environmental benefit associated with implementing green roofs on city skyscrapers is improved carbon sequestration. According to the United States Geological Survey (USGS), carbon sequestration is "the process of capturing and storing atmospheric carbon dioxide [CO_2]" (n.d., para. 1). This practice is critical because of the strong correlation between CO_2 emissions and global warming. Studies have shown that conventional pollution-control strategies concentrate on simply controlling the source of new air pollutants without reducing the existing pollutants (Shafique et al., 2020, p. 1). However, green roofs are different with carbon sequestration, as illustrated in the figure below.

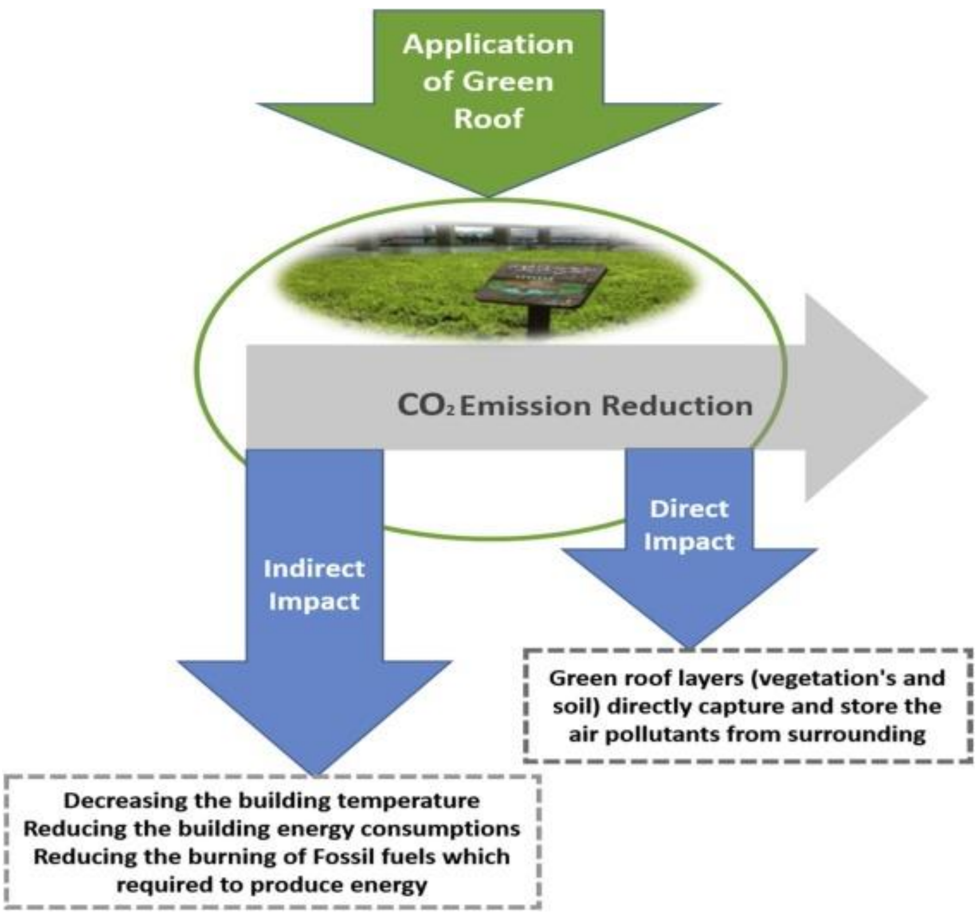

Figure 3: Schematic of Green Roof Working Mechanism (Shafique et al., 2020, p. 3).

As portrayed in Figure 3 on page 5, carbon sequestration helps alleviate rooftop air pollution through vegetation and soil media, which seize and store pollutants (Shafique et al., 2020, p. 1). It also decreases carbon emissions in the air through photosynthesis, which traps the CO_2 in plants and roots (Shafique et al., 2020, p. 1). Another notable practice that contributes to reduced CO_2 emissions is trees. Studies have found that placing trees on green roofs could "significantly reduce CO_2 emissions in urban areas" through photosynthesis (Shafique et al., 2020, p. 3).

In a modeling study that examined the influence of trees on removing air pollution in the United States, it was discovered that trees could trap an annual amount of 711,000 metric tons of CO_2 in the U.S. (Shafique et al., 2020, p. 3). Another modeling study found that installing non-woody plants on green roofs could decrease 7.87 metric tons of air pollutants each year (Shafique et al., 2020, p. 4). An additional study was conducted, which examined current literature on the benefits of green roofs regarding reduced carbon emissions. This study consisted of gathering articles published in databases, such as Scopus and Web of Science (WOS) (Shafique et al., 2020, p. 2). Those articles were screened to include only those that featured environmental benefits from green roofs (Shafique et al., 2020, p. 2). Given that the study was concentrated on recent developments of green-roof carbon sequestration, the period was narrowed from 2000 to March 2019 (Shafique et al., 2020, pp. 2-3). The study results indicate that planting trees is the most effective way to reduce CO_2 emissions, especially given that the rooftop area of buildings comprises 50% of the total impervious area of urban regions (Shafique et al., 2020, p. 3).

The environmental regulation that links with carbon sequestration practices for green roofs is the Clean Air Act (CAA) of 1970. This legislation regulates the amount of pollution produced by "area sources" and "major sources" (Cromwick, 2021, pp. 1-2). "Area sources" are defined by the CAA as "any stationary source that is not a major source," which includes idling cars (Cromwick, 2021, p. 1). With "major sources," on the other hand, those are defined as "stationary sources that emit or have the potential to emit 10 tons per year or more of a hazardous air pollutant or 25 tons per year or more of a combination of hazardous air pollutants" (Cromwick, 2021, p. 2). These sources include industrial buildings and power plants, which have a more significant impact on the environment than idling cars (Cromwick, 2021, p. 2). Both "area sources" and "major sources" directly impact cities by releasing large amounts of CO_2 emissions. Thus, the CAA, combined with green roofs, is vital to reducing CO_2 emissions for fighting climate change and bettering the environment of cities.

4 ENERGY CONSERVATION

In addition to better stormwater management and carbon sequestration, improved energy conservation is an environmental benefit associated with implementing green roofs on city skyscrapers. Urban areas are prone to the heat island effect, which the EPA details as follows: "Structures such as buildings, roads, and other infrastructure absorb and re-emit the sun's heat more than natural landscapes such as forests and water bodies. Urban areas, where these structures are highly concentrated, and greenery is limited, become "islands" of higher temperatures relative to outlying areas" (2020, para. 1). Research has shown that urban areas in the U.S. experience higher temperatures than suburban areas in the U.S. due to the heat island effect. It has been found that daytime temperatures are one to seven degrees Fahrenheit higher, and nighttime temperatures are two to five degrees Fahrenheit higher (EPA, 2020, para. 2). These temperatures are expected to grow further in the coming decades with more buildings, spatial extent, and population density (EPA, 2020, para. 2). Also, implementing green roofs can drastically reduce the energy usage of skyscrapers through vegetation. Vegetation supplies a shading effect from the heat and improves evapotranspiration rates around buildings (Shafique et al., 2020, p. 6). As a result, green roofs can decrease the amount of heat absorbed by structures, leading to reductions in cooling demands and energy consumption (Shafique et al., 2020, p. 1).

In the Pacific Northwest, a study was performed to assess whether artificial reflective shading could provide thermoregulation and moisture retention on skyscraper rooftops (Bollman et al., 2021, p. 2). The study consisted of utilizing modular shading structures and a tub and tray system on a building rooftop at the U.S. EPA Pacific Ecological Systems Division research laboratory in Corvallis, Oregon, for one month (Bollman et al., 2021, pp. 2-3).

Figure 4: Schematic of Tub and Tray System (Bollman et al., 2021, p. 2).

Figure 4 above renders the tub and tray system. As shown, six 61 cm x 122 cm polycarbonate tubs, each containing three 53 cm × 38 cm high-density polyethylene (HDPE) nursery trays filled to a depth of roughly 9 cm with growing media, were situated on the roof (Bollman et al., 2021, p. 3). The first three tubs and trays were exposed to heat, while the other three were placed under aluminum-frame shading structures fitted with 61 cm x 122 cm white reflective acrylic panel shades (Bollman et al., 2021, p. 3). The findings of this study display that shading structures are effective in lessening green roof media temperatures and lowering light intensity by approximately 40% (Bollman et al., 2021, p. 7). The results show that green roofs could help buildings conserve energy by reducing heat absorption and cooling demands.

The environmental regulation that connects to energy conservation practices for green roofs is the Energy Policy Act of 2005. This legislation established tax credits and other financial incentives for investing in renewable energy sources (Fortin, 2021, p. 1). A drastic increase in energy prices and an overdependence on fossil fuels made the Energy Policy Act of 2005 necessary. Between 2003 and 2006, oil prices rose by 100%, and between 2004 and 2006, natural gas prices tripled (Fortin, 2021, p. 1). As a result of this legislation, however, between 2005 and 2019, wind energy production grew by a factor of 15, and total renewable energy generation rose by 11% (Fortin, 2021, p. 2). These values are strong evidence that financial incentives for renewable energy through the Energy Policy Act of 2005 could greatly help advance green roofs.

5 CONCLUSION

Implementing green roofs on city skyscrapers leads to many environmental benefits, including improved stormwater management, carbon sequestration, and energy conservation. Green roofs are an essential method to fight climate change, the number-one threat to humanity this century. They will help reduce the impact of excessive pollutants, increased temperatures, sea-level rise, natural disasters, and flooding on cities. Green roofs are an innovative and sustainable solution that will provide more environmentally friendly and aesthetically pleasing buildings, accommodating the forecasted rise in the city population by 2050. They will supply the groundwork for a stronger future in cities, making the world a better place.

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