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Economic, Ecological and Social feasibilities of Green Roof Implementation in Urban Bangladesh

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ABSTRACT

Urban Rooftop gardening is becoming more important in our developing civilization as a result of its capacity to improve linked environmental and social services, boost resource utilization, and contribute to city food security. Urban microclimates have been found to benefit from less surface sealing and more vegetation. Therefore, green roofs offer an effective substitute for conventional roofs made of materials that completely seal the top layer. 'Green roofs,' often referred to as vegetated rooftops or 'living roofs,' are installed roofs that are covered in greenery, an environment for growth, and a water repellent membrane. Green roofs that are properly planned, built, and upheld offer several advantages for the natural world, society, economy, and appearance. The numerous advantages and characteristics of rooftop gardening in the setting of Bangladesh, particularly green roof techniques, will be covered in this article, combining past expertise with new ideas for the design of futuristic environmentally conscious cities.

Introduction

Throughout known human history, Settlements were modified, evolved into villages, towns, or cities, developed, or died away as human cultures progressed. With the onset of the Industrial Revolution, urban spaces broadened significantly, more rapidly and underwent far greater modifications than in prior evolutionary periods. The vast expanses that today's cities take up, as well as their construction, materials, and overall absence of flora had to influence the climatic features of metropolitan environments. According to one study, by 2050, the global urbanization rate would reach 69%, with 86% of people in rich countries and 66% in less developed countries living in cities (Hui).

Dhaka, the capital and the megacity of Bangladesh, is battling to guarantee the standard of its urban life and balanced urban expansion, including infrastructure, water supply, hygiene, and accommodation, despite a tremendous population increase. Dhaka's present-day population is nearly 21.7 million in 2021, up 3.5% from 2020 (Nawar et al). Furthermore, rising extreme temperatures and erratic rainfall patterns, as well as climate-induced natural disasters such as drought, flood, and cyclones, cause providing an adequate standard of living in Dhaka increasingly challenging. The city's variability in urban design also initiates intricacy in the essential planning efforts to address future issues (Byomkesh et al.), such as climate change. Rapid urbanization has influenced the untamed urbanization process, resulting in the dispersion and decrease of green spaces and, eventually, prompting adverse environmental effects (Zhow and Wang) . Dhaka, like other global megacities, suffers from the Urban Heat Island Effect (UHIE). UHIE is mostly produced when urban green space is replaced with thermal resources which hold solar radiation, causing the outside temperature to rise once it is reabsorbed (Huq et al).

Rooftop gardens and green roofs share a fine line. Whereas rooftop gardens are generally gardens made of plants that are planted in containers or pots, primarily for recreational purposes, green roofs are basically roofs planted with various types of vegetation/plants on top of a growth medium (substrate), primarily for ecological benefits. The idea was created to encourage plants on the roofs of buildings in order to reap many economic, social, and environmental advantages. The optimum decision for each component of the green roof is critical to achieving the greatest results from roofs with greenery. Green roof research reveals several social, environmental, and financial advantages including ecological and environmental benefits, economic benefits, food security advantages, Crisis time management, aesthetic benefits, recreational and community building benefits.

This paper reviews literature regarding green roof properties, environmental, social and economic benefits, challenges, opportunities and possible recommendations of green roofs. The study will aid policymakers in effective city planning and policy formulation in the event of urbanization. It will also help decision-makers, as well as scholars, determine the various ecological and economic benefits of urban agriculture, particularly green roof systems in structures, and raise awareness about the need to establish and upkeep more green spaces in Dhaka in the future to create a more balanced and healthier city.

2. Literature Review

Because of the expanding population, urbanization is encroaching on more farms and green spaces, which damages the biosphere and increases the risk of natural catastrophes and other health risks (Mohapatra et al). Urbanization presents a challenge to the availability of food due to changing consumption habits and systems for food production and supply. People who live in areas that have historically been considered unsuitable for agriculture will need more access to food as a result of rapid urban growth and growing populations in megacities. Financial support is crucial for achieving food security in addition to physical food access. Residents of metropolitan and peri-urban areas are typically less advantaged than their counterparts in rural areas in this regard because they usually must buy their food, which makes them reliant on market prices and more susceptible to prospective higher prices (Szabo). According study, urban dwellers are inclined to purchase more than 90% of their food (Ruel & Garrett), and as a result, food costs are a significant factor in determining whether people can afford to buy food or not. Since food security is a multifaceted concept, it is challenging to determine its exact magnitude. However, macro-level urban growth significantly increases the risk of food insecurity in a nation. Further studies reveal that the most vulnerable nations to food insecurity are those that are rapidly urbanizing and have the lowest levels of human development (Szabo).

In Bangladesh, the percentage of urban residents increased in 2021 compared to the year before by 0.8 percentage points. As a result, Bangladesh's participation increased to a maximum of 38.95 percent in 2021. Notably, over the past few years, the proportion has steadily increased (Aaron). The supply of food, environmental issues, biodiversity, resource conservation, land control, social stability, and economic expansion are some of the primary socioeconomic concerns that urban and peri-urban areas must contend with (Dewan et al.).Using data from a recent field survey conducted in Bangladesh using the binary logistic model, it is discovered that rural households are probably more likely to have food security than urban ones (Mondal et al.). It is also discovered that rural and urban households' food security factors differ from one another. As a result, in order to determine which of the critical variables should be addressed in the creation of programs to increase food security in both rural and urban regions, policymakers and administrators must have a thorough understanding of the unique community-level situations.

Theoretically, there are a number of impacts that connect urbanization, economic growth, and the environment. The process of urbanization is typically accompanied in most nations by rapid economic growth, population shifts from rural to urban areas, the concentration of secondary and tertiary industries in urban areas, and an increase in the number of towns that are getting bigger every day (Li and Yong Ma). As a result of shifting production and altering human behavior after moving from rural to urban regions, the process of urbanization has an impact on the environment through modifying the amounts of harmful emissions. It is confirmed that, As urbanization quickens, comprehensive environmental quality will deteriorate. In a congested city like Dhaka, urban greenery is quickly disappearing, which is leading to a wide range of issues, particularly in urban ecology (Mowla).With rapid urbanization, Dhaka City, the capital of Bangladesh, is progressively falling short of sustaining outdoor life due to the Urban Heat Island (UHI) effect, which is one of the most documented phenomena of urban climate change (Tariq).The urban temperature in and around Dhaka is between 2.5°C and 7.5°C higher than the average farmland conditions surrounding area, and it is peak in the late afternoon and early evening(Tariq).This results in a rise in the need for urban energy resources for cooling and a decline in the standard of living for city dwellers. Research showed that Dhaka city's land surface area has grown by 25.33% and its inhabitants by 76.65% during 2001–2017 (Uddin et al.) and over the last 17 years, the city's annual average day and nighttime temperatures have risen at rates of 0.03 °C and 0.023 °C, respectively.

The National Park and Recreation Association (NRPA) released a book titled "Recreation, Park and Open Space Standards and Guidelines" in 1983 that was developed by Roger and Lancaster. Mr. Lancaster's primary argument in this book was that For every 1,000 people, a park system should have a core system of vegetation and 6.25 to 10.5 acres of developed green space (Lancaster).As the eighth-largest city in the world, Dhaka has experienced unplanned and haphazard industrialization, which has resulted in a significant amount of heat that has altered the energy balance of the region and is destroying the greenery and water bodies (Tasnim and Anwar).The results of a study that included five large metropolises show that the yearly Surface Urban Heat Island Intensity (SUHII) was higher in Dhaka and Chittagong than in the smaller cities (Dewan et al.)

Due to its capacity to offer immediate advantages (food) and certain indirect ecosystem services at a large scale (protection of biodiversity), urban agriculture is becoming more and more relevant around the world (Gupta and Mehta). Urban agriculture has the potential to support community development, employment, economic expansion, and food security (Whittinghill and Rowe). Additionally, by taking into account urban vegetation, it is possible to availf societal benefits and advantages, including food production, a reduction in food miles, transportation, and supply chain length, a connection to nature, the promotion of healthy lifestyles, and support for biodiversity and the environment (Lucertin and Giustino). Its potential is however constrained by the battle for land with other urban development types, the absence of established land use rights, and health risks. This is where the use of green roof technology comes into play since it has the potential to solve a number of these issues without impairing the advantages that urban agriculture offers (Whittinghill and Rowe).

A vegetative layer cultivated on a rooftop is known as a "green roof" or "rooftop garden." Structure support, moisture barrier, heat insulation, root barrier, evaporation layer, filter membrane, growing medium, and vegetation are the elements that usually make up a green roof system. The effectiveness of green roofs has been the subject of extensive investigation. In urban areas or other constructed environments with little natural greenery, using green roofs might reduce the heat island effect. Vegetation on the outermost layer of the structure can be utilized to combat the heat island effect, depending on numerous aspects taken into consideration, according to a study (Alexandri and Jones)on the climatic features of nine cities. If used on a larger scale, they might reduce high urban temperatures, especially in hot climes, and bring them down to greater "human-friendly" levels while saving up to 100% of the energy used to cool structure (Alexandri and Jones). According to a Japanese research, green roofs may lower surface temperatures from 30 to 60 degrees Celsius (Yan). According to Santamouris, Green roof temperatures can be up to 30 to 40 degrees Fahrenheit lower than those of traditional roofs, and they can also cool the city's air by up to 5 degrees during the day. Furthermore, in contrast to traditional roofing materials, green roofs may minimize building energy use by 0.7%, which lowers high electricity demand and results in annual savings of $0.23 per square foot of the roof's exterior (Sailor et al.).

Green roof research has revealed several ecological, social, and fiscal advantages. A great deal of proof suggests that green roofs can provide numerous benefits, including storm water management, reduced urban heat island, increased urban plant, wildlife habitat, and roof life, improved air and water quality and quality of life, minimized building energy use expenses, reduced sound pollution, promoted leisure pursuits, and increased natural beauty and aesthetic value in urban environments (Berndtsson, Niu et al., Fioretti et al., Wu and Smith,Mahdiyar et al.). A research investigation conducted in Purbachal, Dhaka, using ENVI-met software simulation, indicates that intervention with urban trees and grass is most effective in lowering the Urban Heat Island effect because it reduces the average air temperature most efficiently during the day as well as night times when compared to roofs with greenery and exteriors that are green(Tariq).Green roofs are the finest urban stormwater control methods because the plant and underlying layers can store a huge quantity of water and the chances of flash flooding decrease in urban area. (Xiao-ping et al).

Greenroofs are particularly well-liked in both Europe and the USA. According to estimates, the North American green roof market grew by more than 10% in 2016 compared to 2015, maintaining a ten-year pattern of industry expansion. In that year, more than 900 green roof projects totaling more than four million square feet were reported by an array of industry participants in 40 U.S. states and six Canadian provinces.(Stand and Peck). In Germany, all flat roofs with a surface area larger than 100 m2 must have green roofs installed. In Esslingen, customers will receive compensation equal to 50% of the cost of the green roofs, and in Darmstadt, users might receive up to € 5000 for installing green roofs (Shafique et al.). Additionally, considering the environmental and societal benefits- in many big cities of USA, e.g. Chicago, Portland, Seattle, Washington, DC, New York ,Philadelphia, Baltimore, Minneapolis, Nashville, Austin- policies are promoting the installation of green roofs by providing various benefits and legislation in state level. It is also confirmed that Green roof technology may not only the best environmental practice for new buildings, and yet also a practical alternative for the remodeling of the existing buildings (Castleton et al.).

3. Methods

The study's aim is to investigate how using green roofs may be advantageous for the environment, the economy, and society in a city like Dhaka. The study used a lateral approach, looking at secondary data, resources, and earlier studies. Keywords and query strings were used to search across various databases. Additionally, Google Scholar was searched using the keywords and search terms to find articles from books and journals that discussed green roof technology and practices in Bangladesh and other countries. The study then looked into and used the articles from the publications. After an exclusion procedure, a total of more than 50 articles, including academic journals, professional publications, and physical and institutional reports, were chosen, containing the query key phrases and keyword strings. Thematic and material analysis comprises a detailed examination of each piece of text and the identification of central ideas from a study of several texts.

4. Findings and Discussion

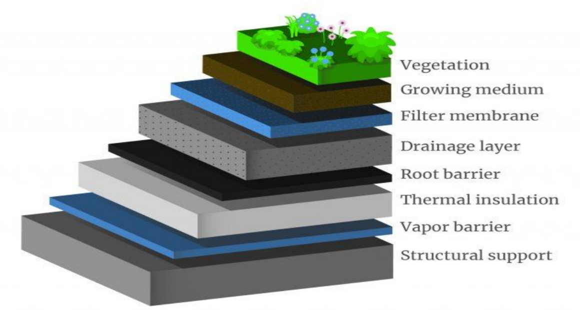

Fig. 1: Layers of Green roof (EPA)

Green roofs are built to minimize the negative effects of urbanization. The components of a green roof differ depending on the area and demands. The decision-making process of each layer based on location and climatic circumstances is critical for long-term conservation benefits.
Green roofs often, but not limited to, include the following sections:,

- A Waterproof Layering
- A root barrier membrane,
- A drainage section
- A filter layer/ insulation
- Growing medium
- Plants.
- Structural support

Green roofs commonly classified into four categories as follows-

intensive	> 12 inches	● high water holding capacity ● high capital and maintenance costs ● larger weight ● Resemble conventional gardens or parks
semi-intensive	Between 6 to 12 inches	● contain small plants, small shrubs and grass ● regular maintenance ● high capital costs
single-course extensive	3-4 inches	● Lighter ● Little capital
multi-course extensive	4-6 inches	● Light weight ● Less capital

According to the United States Environmental Protection Agency (EPA), Green roofs all have the same fundamental layering components, including an assortment of barriers that mitigate water or root damage to the building, an infiltration layer to help in water drainage, and a growth medium and vegetation layer.

4.1 Cost Effectiveness

An extensive roof is lighter than an intense roof. The components of the broad green roof are light in weight, and it also incorporates relatively substrate with typically little plants. As a result, calculating the usual capital cost breakdown of an extended green roof is simpler than for an intense green roof (Shafique et al.). Shafique and others identify that the expense of green roofs is the most significant barrier to the widespread use of green roofs. As a result, there is a necessity to design low-cost green roofs that can provide many advantages in metropolitan areas. The net present value (NPV) of this sort of green roof is now 10% to 14% higher than its conventional equivalent. A 20% reduction in green roof construction costs would make the social NPV of the practice smaller than the NPV of traditional roofs (Carter and Keeler).

However, When juxtaposed to a black or reflective roof, a green roof may require a higher starting investment; nevertheless, the life cycle accumulative values of benefits from a green roof have been calculated to be 27 years, positive net present value, and 100% return on investment (Wu and Smith). As a result of this finding, the green roof option is more financially viable than the other two roof options. The two most essential purposes of a green roof in urban environments are the exterior temperature decrease and thermal efficiency (Wong et a)l. Green roofs increase thermal insulation in the building, allowing it to cool in the summer and save energy expenses. Green roof plants and substrates absorb less sunlight than other forms of roofing systems, reducing expenses on cooling costs (Yan). Alexandri and Jones depict the decline in surface temperature at several locations. The hot and arid region displays the greatest drop in surface temperature from green roofs. Methods for bridging the cost gap between green roofs and conventional roofs were measured by including air quality advantages. A research (Niu et al) utilizing Washington, DC as a test environment discovered that the NPV of green roofs is roughly 30-40% less than that of conventional roofs during their lifetime (40 years) (without counting green roof upkeep expenses).The net present value (NPV) analysis revealed that storm water infrastructure benefits totaled $1.04 million (M), while fee-based storm water benefits were $0.220.32 M/y, based on air conditioner usage, harmful gas reductions, natural gas consumption, and energy savings using US Environmental Protection Agency models. Energy savings were predicted to be $0.87 million per year, while air conditioner resizing advantages were estimated to be $0.02 to $0.04 million per year, and avoided emissions benefits (based on current emission trading prices) were $0.09 million to $0.41 million per year.

4.2 Food Security

By 2050, the population of the globe is expected to surpass 9 billion people, according to UN estimates. By this time, 80% of the world's population, according to the UN, will live in cities. Additionally, it forecasts that by 2050, we will require an additional seventy percent to meet the needs of an additional population of 3 billion people globally. An evaluation (Lucertini and Giustino) made in order to develop the urban agriculture in the city of Venice's mainland and to analyze vegetable self-sufficiency potential for the population through urban agriculture discovers that the potential vegetable output is quite high, despite only a yield of 31%. But when done on a big scale, it is feasible to meet the city's horticulture vegetable needs. Rooftop agriculture has the potential to play a significant role in urban food security if expanded on a wider scale.

4.3 Storm water Runoff Mitigation

A number of researchers studied the hydrological behavior of green roofs in different parts around the world and concluded that the water retention from green roofs varies between 55% to 88% (Xiao-ping et al., Zhang, et al., Speak et al.).Green roof vegetation is vital for water retention since each plant has its unique water holding and transpiration capability (Razzaghmanesh and Beecham).According to research done on an extensive green roof in Manchester and 69 rainfall events, the green roofs absorbed 65.7% of the runoff. Nevertheless, grasses were the best at retaining the most water. Water retention from green roofs is also affected by a drainage layer and a green roof slope (Villarrea and Bengtsson). Green roofs have also been discovered to be quite useful in preventing urban flash flood I (Liu et al). In Venice, a total water retention of 360,139.4 m3 year was calculated based on 774,493.4 m2 of green roofs and 831 mm of rainfall in 2020 (Lucertini and Giustino).Furthermore, studies have revealed that green roofs are the best practices for not only rainwater runoff control but also improving water quality (Liu et al., Nagase and Dunnett). Green roof material and plant layers play an essential part in runoff mitigation and pollution absorption from precipitation.

There are two types of drainage frameworks that are often used: drainage modular panels constructed of (polyethylene or polystyrene) with holes to store more water throughout the draining process. And drainage granular materials have large pore spaces that allow for more water storage. It has been demonstrated that the thermal behavior of rubber (Kazemi and Courad) is superior to that of other layering materials, and a form of layer known as Nophadrain (5 + 1) can store up to 4.3 L/m2 of water (Wong and Jim). Furthermore, drainage layers can improve a building's energy efficiency. The most difficult difficulties for the drainage layer are its expense and removal. As a result, more study is required to determine the most cost-effective and environmentally friendly drainage layer.

4.4 Crisis management benefits

Lucertini and Giustino state that Green roof management might be an important component in promoting urban green corridors, as well as recreating habitats such as green borders and beehives for beneficial insects. It may also improve human well-being, particularly in terms of mental and psychological health and stress recovery. Furthermore, urban agriculture can be viewed as a catalyst for a resilient community in which people contribute to the construction of resilient urban neighborhoods capable of adapting and recovering when faced with a crisis like COVID lockdown.

During the month-long COVID-19 lockdown, a cross-sectional survey (Das et al.) was conducted to assess the extent and identify the determinants of food insecurity and coping strategies in urban and rural households in Bangladesh. It was discovered that approximately 90% of the households were suffering from various grades of food insecurity. Severe food insecurity was more prevalent in urban families (42%) than in rural ones (15%)(Das et al.).Policies should address multiple components of living standards in urban and rural regions to increase the resilience of local food systems. To improve local food production and establish more resilient systems of food production in urban areas after COVID-19, the potential of home gardening and urban agriculture should be adopted (Kang et al.).

4.5 Energy conservation benefits

A research (Guo) using sedum green roofs to evaluate energy conservation in Guangzhou, China, found a 3.83% decrease in yearly cooling energy. Zhao and Xue investigated the power consumption of lightweight green roofs in Shanghai, China, and discovered that utilizing green roofs saved roughly 20.9% of energy during the day and 15.3% at night. According to Alexandri and Jones, Green roofs and green walls can provide a modest amount of temperature relief from the urban heat island effect. In addition to adding an additional insulating layer to the structure's material, roof vegetation can dramatically reduce cooling load needs inside the building. Energy savings can also be substantial, ranging from 90% to 35%. Mumbai achieves a 72% drop, cutting its cooling energy consumption from 11 h to 6, whereas Athens and Beijing achieve 66% and 64% reductions, reducing their energy demand by 4 and 3 h, respectively. The greatest decrease can be seen in Brasilia (68%), with a 6-hour drop in demand for coolers. It is followed by a 66% and 2 h decline for Hong Kong, a 52% and 2 h reduction for Montreal, a 43% and 2 h drop for Athens, a 37% and 2 h fall for Beijing, a 37% and 3 h drop for Riyadh, and a 35% and 3 h decline for Mumbai (Alexandri and Jones).

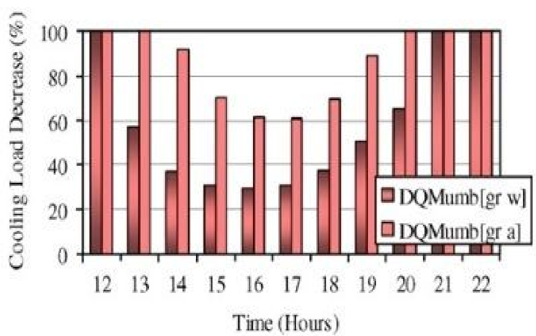

Fig 2:Cooling load decrease in Mumbai (Alexandri and Jones)

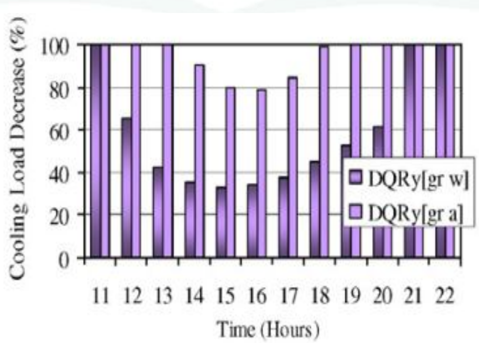

Fig. 3: Cooling load decrease in Riadh

4.6 Biodiversity Conservation

According to the findings (Wooster et al.), green roofs can have ecological value by luring and maintaining urban wildlife that may provide significant functional capabilities. In urban Sydney, Australia, it was discovered that the green roof supported four times the bird, almost seven times the arthropod, and twice the gastropod variety of the conventional roof. This was done by monitoring local biodiversity using motion sensing camera traps and frequent bug surveys. Locally uncommon species were only drawn to the green roof. There is evidence to support the claim that green roofs have a higher species variety than conventional roofs and may support both common and unusual species. It is not yet known, according to Williams et al., if they can maintain biodiversity in a manner similar to that of ground-level habitats, mimic ground-level biological communities, or make it easier for creatures to travel through urban environments.

4.7 Air quality

Air pollution may be reduced by green roofs in two different ways. The plants first use their stomata to catch the tiny air contaminants. Second, the lower surface temperature caused by the green roofs facilitates the combustion of fossil fuels to fulfill energy demands. According to research by Zhang et al., a 1000 m2 green roof can collect around 160–220 kg of dust annually, which helps to improve the local ecology.

4.8 Sound pollution reduction

Connelly and Hodgson investigated green roofs and non-vegetated roofs in the field to check the noise level reduction. From the results, it is proved that vegetated roofs reduced noise frequency by 10 and 20 dB. Green roofs have ability to absorb the sound waves and to reduce the sound level as compared to non-vegetated roof.

4.9 Social Benefits

By adding green space into metropolitan areas, green roofs give reprieve from artificial development. Multiple investigations have found that green roofs offer an appealing advantage to city dwellers by reducing air and noise pollution. Green open areas catch the interest and have attempted to bring communities together for roof gardening. Green roofs also increase the appraised value of a home (Liu et al.). Social contacts provide benefits, particularly for vulnerable groups of individuals who utilize gardening as a restorative greening activity (Lucertini and Giustino).

5. Limitations and further research

The researchers' work on green roofs has proven tough, but it has provided a wealth of potential for future study. A study to determine why green roofs have not been widely implemented in Bangladesh (particularly in Dhaka), despite the fact that the country's environmental variables conceptually endorse this technology, concludes that a lack of expertise and misunderstandings are major impediments to the execution of green roofs in urban Bangladesh (Hossain et al.). The limitations and some backdrops of Green roof implementation in Bangladesh are-

- elevated initial development costs
- Insufficient local research has been conducted, therefore building participants and owners are unaware of the advantages of a green roof.
- a substantial expenditure for upkeep
- Roof leakage issues – If the green roof is not installed properly on the roof, there is considerable potential for roof leakage and structural building collapse.
- Reduced usage of polymer materials and their disposal- More study is required to identify a suitable replacement that will improve the performance of green roofs over an extended length of time.
- Lack of interaction and collaboration amongst several disciplines (including citizens, agricultural professionals, civil and environmental engineers, and biodiversity specialists)

6. Recommendation and Conclusion

A possible strategy for sustainable urban planning is rooftop farming and green roof implementation, which may also improve air quality, minimize heat intrusion, reduce pathways for native plants and animals, and have a variety of positive social and environmental effects. Generally speaking, green roofs and walls cool the microclimate around them, which can result in substantial energy savings for cooling, depending on the kind of climate, the quantity, and the placement of vegetation on the structure. It is strongly advised that incentives promoting the implementation of this method in heavily urbanized watersheds given the favorable social advantages and relatively innovative nature of the practice.

The following considerations should guide the selection of green roof components.

- To enhance aesthetic and ecological performance
- Prevent flash flooding, lower surface temperatures (which will lower energy costs)
- Increase food output
- collect and utilize rainwater,
- Improve air quality
- Recreational activities.

Before green roof technology can be applied to urban agriculture on a larger scale, installation costs must be brought down, roof weight restrictions must be determined, and suitable management techniques must be developed to guarantee that urban communities continue to receive the advantages of green roofs, such as energy savings and storm water management.The benefits of a green roof must be explained to and supported by the building's owners and other interested parties.The amount of energy that may be saved by green roofs depends on a variety of factors, including the depth and makeup of the substrate, the climate, the kind of plant, the watering method, the style of green roof, and the insulation in the design. It is very important that all these factors are kept in mind while policizing and implementing green roof in a large scale to properly secure all the benefits from the green roofs. Nevertheless, more in depth real experimental work on each component of the green roof is required, and multidisciplinary research collaboration in dealing the challenges is imminent.

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