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Green Roofs: More than Just a Pretty Face

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ABSTRACT

Green Roof is basically a traditional concept which is revived and executed to focus and improve adverse effects of our urban environment. Benefits and impacts of green roof are not fully understood and valued. This paper reviews and discusses the different benefits of green roofs as solutions in reducing the energy, maintaining indoor temperatures, enhancing sound insulation and fire resistance, increasing life span of the roof, providing green spaces in concrete jungles, reduction of UHI effects and improved air quality. In addition to all this green roof also increases the aesthetics of buildings and different research have shown that green roof also improves the energy performance of buildings in summers and winters.

Introduction

Any sort of roof that incorporates green technology is referred to as a "green roof." These are also referred to as eco-roofs. The goal of a green roof is to create a sustainable design that uses less energy in conditioning with use of its insulating properties. The function of green roofs in reducing the heat island effect is briefly discussed in this paper, along with the many kinds of green roofs, additional social and environmental advantages, and cost-benefit analysis.

There are several incentives to develop green roofs such as providing spaces that people often use e.g. architectural aspects, increasing the value of real estate, or achieving specific environmental advantages. Environmental advantages include improving air quality and internal thermal comfort as well as insulation of a building (to better regulate heat gain or loss). Root barriers and irrigation facilities may also be added to green roofs as extra layers. This in turn contributes to the preservation of our ecosystem by reducing the negative effects of urbanization and offering a novel design with an aesthetically pleasing architectural style (Latty, 2016). This adds to the perfect architectural fusion of economy and aesthete. Adding to these advantages, Little says roof gardens have many benefits for a structure, including: absorbing rainwater, insulating the structure, offering a home for animals, and decreasing temperature to lessen the urban heat island. Green roofs have been a traditional method of construction for dozens, though not thousands of years. They are still used often in Europe and are a rapidly expanding market in the United States and North.

One type of green roof is “Grey water treated” which is treated using rooftop lakes. Grey water

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is any liquid that has been around for washing inside the home, excluding toilet water.This includes water from sinks, baths, and washing. Although this water normally ends up in the trash, it can occasionally be used again, particularly for irrigation. So, it is possible to drain grey water on the green roof (Williams et al., 2021). Diversion pathways give extra rainwater a way to get to rainfall drainage systems. The filter keeps debris from building up between the backfill material and the organic material.

Extensive green roofs are yet another form of green roof. Intensive and vast rooftop gardens are the two different varieties. The greater thickness and plant diversity are supported by intensive green roofs. They weigh more and demand a lot of upkeep and are approachable because of the way they are constructed. Compared to intensive green roofs, these varieties of green roofs have less dense vegetation and require less upkeep. Although they were primarily created for aesthetic reasons, they also provide several environmental benefits (Banirazi Motlagh et al., 2021). The term "green roofs" could also refer to other components of a building that can incorporate eco-friendly technologies, such as a cool roof with solar panels (KOURA et al., 2017). Solar cell assemblies that are linked together form photovoltaic modules. The primary function of these panels is to turn solar energy into electrical energy. Most people agree that the best way to regulate pollutants in towns is to use rooftop gardens.In places where tree planting is difficult or impossible, green roofs offer most of the same advantages as actual trees (Shafique et al., 2018). If 80 percent of the rooftop area were green, Casey Trees and DC Greenworks research predicted that rooftop run-off in the commercial center of DC would be reduced by 56 percent. According to research, buildings with green roofs had midday roof temperatures in the range of 155°F, resulting in substantial energy efficiency, a healthier environment, and a longer roof lifespan (Cascone et al., 2018).

Methodology:

A thorough review of the literature on green roofs' development, varieties, plant components as well as the environmental, economic and social advantages was conducted. The study's primary sources include journals and books, the majority of which were published between 2013 and 2022.

Literature Review:

Difference between Green Roof and Conventional Gardens:

It is important to first make the distinction between the extensive green roof and the usual roof garden. For a green roof the planting system is small and light and may be mounted on any kind of structure (such as wood or steel). The chosen plant species typically require little upkeep and establish a stable ecology. The extensive green roof is a structure that is typically unavailable to walkers; mobility is restricted to ensuring the survival of the plants and a waterproof roofing surface. You can install a rooftop garden on any massive amount of structure (concrete, tanbark, wood).The rooftop garden system is made up of layers 3 to 8. So in order to preserve the plant in the event of a protracted dry spell, tap water with a volume sufficient for the length of the area planted must always be supplied on the roof. A green roof normally includes the plant itself, a top-notch rootand water-repellent system, proper drainage, filtration cloth, as well as lightweight growth conditions. On top of a man-made building are designated places of vegetation, including plants, bushes, crops, or grass. It is important that the selection of the vegetation systems should be appropriate for the tower's roof's massive amount of capability. Green roofs can be seen on both personal and corporate constructions, including residences, apartment complexes, commercial properties and even government-owned institutions e.g. universities, hospitals, and outreach programs (Van der Meulen, 2019). A green roof also has a shorter lifespan than a conventional roof, which contributes to the cost of tags. A green roof can endure around 35 and 40 years whereas standard roofs typically last 17 to 20 years.

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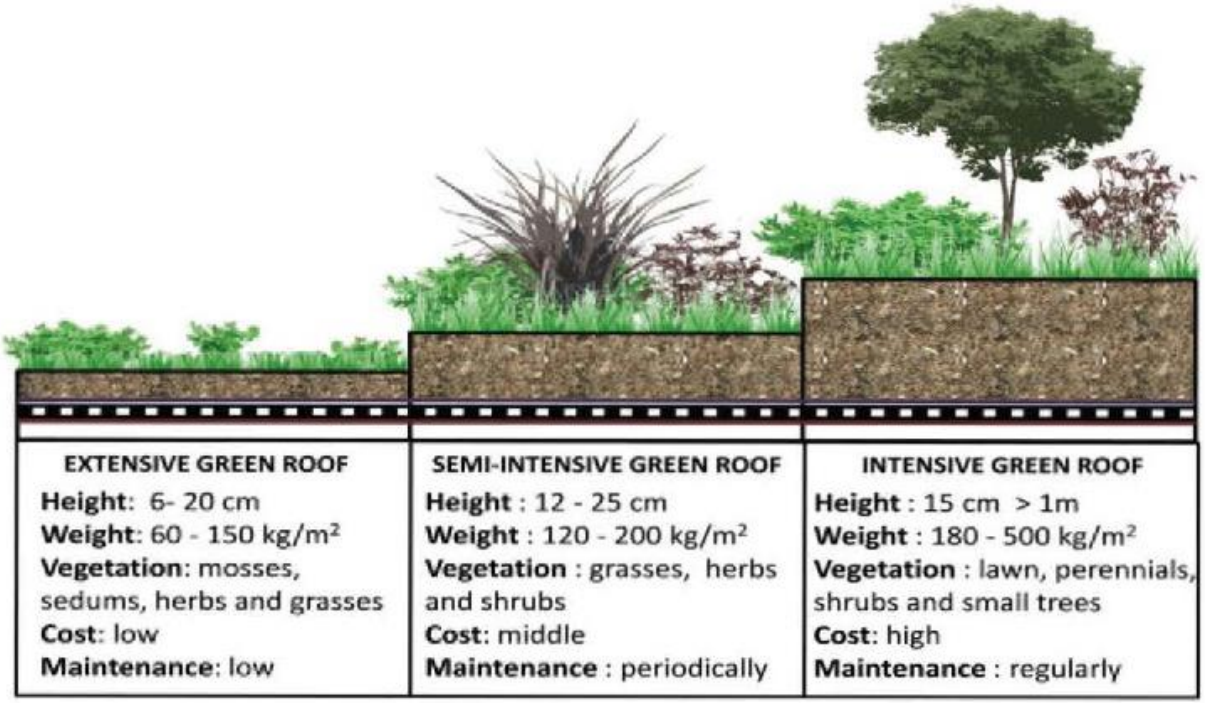

Figure 1: Types of green roof **Source** (Ezema et al., 2015)

Dive Into Further Types of Green Roof:

Three main forms of green roofs exist: • Extensive green roofs feature little plants, modest depths, and don't need irrigation. • Semi-Intensive green roofs are thicker, have more plants, and want some irrigation. • Intensive green roofs are the form of green roof that is the thickest, have the greatest watering capacity, and can support the biggest plants.

Extensive green roof:

Characteristics of extensive green roofs consist of deeper soils and higher maximum weight. This particular type of green roof has a lightweight, thin covering of growth material (green foundation), and a variety of plants that are tailored to the circumstances on the roof. They require very little maintenance and are so inexpensive to construct that they're the least expensive, lightest green roof available. They are perfect for incorporating into new construction or enhancing less approachable properties because of their simple installation, continuous upkeep and environmental sensitivity. You can use sedum mats in place of planting and unplugging germinating seeds rather than putting soil and plants individually (Abass et al., 2020). Due to the obvious adaptable, weather-resistant material and plants utilized, they offer a lightweight, virtually immediate green effect that requires almost no care. Its instructional potential is expanded by guided reality (Mahdiyar et al., 2018). Therefore, they continue to be popular.

The following people would benefit from extensive roofs: DIY enthusiasts, fans of simple construction and maintenance, people with less structurally sound characteristics, people who prefer to prune without using chemicals, people who want to save money, and environmental groups who are more particularly worried about biodiversity and animals. The Schoonover Center's green roof is open for academic and communications activities, but this can accommodate meetings or recreational activities. Teachers, pupils, and workers can enjoy beautiful sights from the Center for Media Arts and Sciences' office and entrance.

Semi-extensive green roof:

A semi-intensive green roof requires more upkeep and at times needs irrigation systems, although it has a thicker layer of starter culture to increase the variety of plants. These have both extensive and intensive living features. Typically utilized to achieve the significant environmental benefits of an extended roof with only an intensive roof's more varied, strength, and stable plant and soil mixture. They use a thicker, richer foundation and draining solution that is tailored to the needs

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of the apartment's inhabitants, and feature a broader, more complicated variety of plant combinations over extensive roofs. Harder sedum plants can be used where necessary to enhance installation and minimize care whereas small bushes, blooming plants, and taller grasslands can be added to enhance the usable 7 garden effect (Testa & Krarti, 2017). For those wishing to explore the environment and boost biodiversity, those with approachable rooftops, buildings with moderate structural soundness, and semi-intensive roofing are ideal.

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Intensive green roof:

This roof has a photovoltaic panel next to it, which enhances its beneficial effects on the environment and society. The much more expensive, heavier living roofs are also the finest at managing drains, regulating temperatures, and replicating the appearance of a natural environment (Yang & Wang, 2014). They could then be used for farming. An entirely planted rooftop garden is much more suited to publicly accessible roofs because of the number and quality of material used (for the aesthetic benefits too). You must take into account both the initial building and maintenance. How simple is it to reach and maintain? You must ensure that your roof is structurally sound before adopting an intense roof, or you would need to make considerable modifications. With the foundation’s maximum depth of 400mm, intensive roofs can change and potential to 500 kg per square meter.The ideal candidates for intensive roofs are those who: love a wide variety of plants and animals, want an attractive rooftop garden, want commercial space, individuals with a larger budget,want to communicate with others and enjoy their surroundings, live in cities with agrarian or interest in growing vegetables,value the atmosphere but aren't concerned regarding routine maintenance (presumably by a practitioner), as well as people who don't mind fertilizer.

Additional social opportunities are given by intensive green roofs because of their larger support system. For example, Elaborate green roofing at the Holzer Clinic in Columbus, Ohio (right) is reachable from the 2nd reception room. It offers a visually appealing environment to improve the emotional and psychological welfare of customers and caregivers because it is planted with bushes, palms, and flowering plants.

Deeper look at the Advantages of Green Roof:

Aesthetic benefits:

There’s no denying that a green roof is eye-catching and, in the case of an existing structure, certain to draw attention. The days of vast expanses on decorations of metal, glass as well as grey cement are long since gone. People like attractive architecture, and rooftop gardens frequently play a major 8 role in the overall design. Green roofs make an area that is appealing to renters and residents of nearby buildings (Tang & Zheng, 2019). They can offer a haven and a spot to unwind which will lessen stress and boost creativity. Additionally, green roofs might provide more secure leisure areas. By giving residents of flat buildings a secure outside area to have lunch and relax,flat structure roofs can be transformed into leisure green spaces. It has been demonstrated that exposure to plants and other natural environments can help lower blood pressure, lessen anxiety, and boost user happiness.

Being a common component of green roofs, seats or stools are generally given to provide an amenity zone for building inhabitants. A difference can be made by adding windscreens to such spaces. For building occupants, green roofs or roof gardens can serve as an oasis in the bustling metropolis. The rooftop view of greenery has a positive effect on people who work and live in green buildings as opposed to structures that are less environmentally friendly in terms of output per worker. Viewing green plants offers several health benefits, including alleviating tension in the muscles, reducing blood pressure, stress reduction, and boosting mood. These benefits can be translated into increased worker productivity and higher-caliber health.

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Furthermore, green roofs are more attractive than other commonly used structural infrastructure, such as retention ponds and drainage pipelines (Dixon & Wilkinson, 2016). Such green roofs can also make a desirable area for residents of nearby buildings.People of neighboring buildings can also see and interact with the outdoors thanks to a green construction with a green roof while, additionally, they offer individuals who live below them a better view.The usefulness of a rooftop garden as an outdoor or leisure area will depend on the elevation of ramparts and the type of other structural elements.

When compared to individuals who did not have beautiful scenery, those who could see trees and flowers reported less anxiety, more work satisfaction, and fewer illnesses (Aboelata, 2021). To create a rather more comfortable cityscape, green roofs add aesthetic value and personal interaction to urban planning. This increases the visual appeal of the urban scene and the energy of city life. Houses and neighborhoods both have more visually appealing characteristics thanks to green roofs. Hence, urban greenery has long been marketed as a simple and successful method for improving building design and expanding investment opportunities.

Economic benefits:

Urban centers have a greater temperature due to the urban heat island effect (UHIE) implying that cooling your home will cost more throughout the summer. Green roofs serve as a barrier to insulate buildings by preventing the entry of either warm or cold air. Buildings can benefit from the enhanced value of the property, longer roof life,local reward and reward schemes as a result of using less energy to heat and cool them. The majority of home and company owners who install green roofs do so on a variety of grounds. The city reaps the benefits of needing less stormwater runoff infrastructure. According to Zhang & He (2021), the installation of substantial green roofs on a city-wide scale might reduce the expense of stormwater drainage equipment by up to 70%.

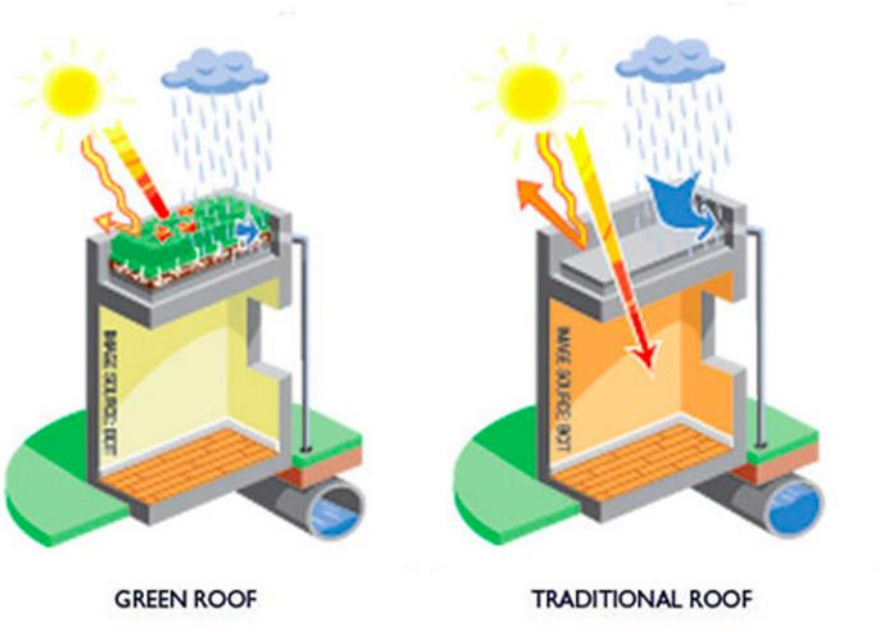

Figure 2: Green roof vs. conventional roof
Source (Kulmatycki, 2020)

With such a green roof, daylight isn't absorbed by the vegetation but rather by the actual pitched roof, as this graph demonstrates. This indicates that the structure is collecting less heat. Additionally, it demonstrates how vegetation reduces the UHIE by reflecting less sunshine into the atmosphere. So because the heat island effect is a result of climate change, rising global

temperatures, and urbanization, the environment benefits from its reduction (Kotzen, 2018).

Green roofs can reduce energy use by reducing the need for electricity and natural gas. As a result of the decreased need for non-renewable sources like oil and gas, there are also ecological advantages. According to research by the United States National Parks Service, a green roof might just save households up to $1 million (USD) over 40 years. The bulk of these savings come from poor energy costs associated with air conditioning systems for the residents. However, due to differences in building size and other factors, this figure may vary. According to Rosenzweig, green roofs reduced daytime temperature trends by 19°C and nighttime temperatures by 8°C in July. The study also discovered that internal temperatures were reduced by 2°C. As a result, the house requires less cooling during the summertime.

Governments in North America have started to develop rules and subsidies for rooftop gardens on both residential and commercial buildings. This was created to encourage the use of rooftop gardens via financial incentives such as construction grants, stormwater runoff levies and land tax exemptions. These subsidies actively encourage people to install green roofs to lower UHIE, improve stormwater runoff infrastructure and encourage environmentally friendly construction techniques. Cost-saving advantages are increased by these initiatives and strategies (Akther et al., 2018). People are trying to reduce the potential dangers and repercussions as a result of the developing climate change challenges. Another way to achieve this is through green roofs. Although they're more expensive initially, it is apparent that they will pay for themselves in the long run because of the energy efficiency. Though installing a green roof often costs more up front than installing a conventional roof, numerous economic advantages might offset this. Improved R-value (a dimension of a material's resistance to heat transfer) of the roof installation, composed of inferior roof temperatures, decreases sounds, which protects energy and water. Chiefly in municipal areas with minimal green space, a green roof may increase house values and commercial viability. An evaluation study was conducted by the University of Michigan contrasting a conventional roof with a green roof covering an area of 350 square meters. The study examined several advantages of green roofs, including energy savings, improvement in health benefits from reduced pollutants, and watershed management ("Green roof delivers economic and environmental benefits," 2013). A green roof would save around $200,000 over its anticipated 40-year lifespan, nearly two-thirds of those would derive from lower energy expenditures. Any particular green roof's economic advantages will, nevertheless, vary depending on its layout, surroundings, environment, and the structure itself.

Environmental Benefits:

In the modern world, a growing population is occurring quite quickly. With the erection of structures near one another, several cities around the world are quickly becoming extremely urbanized. Increasing construction work and deforestation has resulted in a loss of greenery and a host of ecological concerns, including the urban heat island effect. The result has been a significant rise in air temperature in urban areas. In turn the urban heat island has increased energy demand. The ability of vegetation and plants to capture airborne dirt and dust particles is crucial. In the course of photosynthesis, vegetation also uses carbon dioxides to produce oxygen and glucose throughout the day. This aids in both lowering the quantity of carbon dioxide in the atmosphere and raising its oxygen content (Scharf & Zluwa, 2017). Urban development involves a significant amount of tree cutting. As a result, the quality of air reduces as air temperature rises and oxygen levels fall. According to Dowdey, in areas without rooftop gardens, rainfall from buildings' rooftops enters sewers very quickly, and flooding results when the sewer system is unable to handle the quantity of water entering it.

The major factor contributing to the island's heat effect in urban areas is the absorbing and storage of solar heat in cement buildings and infrastructure, which causes the air temperature in those places to rise above that of surrounding rural areas (He et al., 2015). The air - conditioning system load for these buildings will need to grow as the temperature rises. As a result, the air conditioners will require more energy, which also causes them to vent more heated exhaust air outside, worsening the urban heat island effect.

It has been demonstrated that roof gardens significantly reduce both the surface and air temperatures. According to Little, the primary reason green roofs reduce these temperatures would be that they cover the roof top's high-temperature surfaces and block the cooling effects of the plants' evaporation and transpiration.

Summary of environmental benefits:

- **Stormwater runoff management**: Soft planting reduces the risk of flooding by retaining a significant amount of annual rainfall and reducing runoff. This is highly beneficial for Sustainable Urban Drainage (SUDs) planning. The amount of water absorbed depends on the level of substrate used in the landscaping and seeing how vertical greenery assists with flowing water control in the clip below lower down.
- **Environment trying to disguise**: A roof garden makes a building blend in with its surroundings and replaces some of the tops of the permeable earth that were lost during the building process.
- **Better air quality:** Based on Little, a green roof's vegetation greatly improves air quality by removing certain particles from the air and polluting gasses from the surrounding area. The main reason why green roofs lower these temperatures is that they conceal the building's heat-absorbing surface. The rate of evaporation from the plant growth naturally reduces the air's warmth and increases its humidity. Photosynthetic refers to a plant's active electrochemical reduction of co2 to oxygen. Research suggests that under ideal circumstances, a matured elongated planted building's green leaf surface will absorb (0.3024 x 48) 14.51g of atmospheric co2 and release (0.3024 x 32) 9.68g of carbon dioxide (Tam et al., 2016).
- **The urban heat island effect**, or the dip in temperature between metropolitan areas and the nation, is declining. In large cities, this can change by up to 5 degrees. Big building components will both collect and release solar energy in an urban landscape; yet, this energy would not instantly disappear. The bottom of anything like a green roof will take part of this heat, and so as water evaporates from growing plants, the atmosphere will chill and become even more humid (Jeffers et al., 2022)

Social Benefits:

Communities gain from green roofs via economic savings, environmental betterment, and employment creation. Some of these are made to encourage group activities, exercise, education, or even other civic endeavors.

- Green roofs minimize rainwater management costs, reduce the chance of flooding, enhance air quality, decrease noise pollution, and combat the urban heat island effect. Reduced urban neighborhoods have fewer green areas and are more negatively impacted by growing energy costs and diseases brought on 13 by the heat. By easing the strain on these traditionally underprivileged populations, the installation of rooftop gardens on public structures in these neighborhoods would support environmental equality projects.
- Access to services and urban agriculture can be achieved through the use of intensive green roofs.
- Despite the environmental importance of green roofs, parkland and community projects are valued more highly in some places. Whenever the scenery on the ground surface is restricted, the problems of building a social and recreational place on a rooftop become more appealing.
- Improving social cohesion, which promotes health and wellbeing, may be accomplished through expanding access to adequate green spaces in metropolitan settings. It also aids in the promotion of mental health, physical and emotional healing, room for recreation, crime reduction, promotion of physical exercise and social contact, and improved livability. Increased organizational sense of pride in place, degree of confidence, civic engagement, decreased violence, aggressiveness, graffiti, and littering, improved quality of health as a result of exposure to nature.

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Psychological Benefits:

While advantages for the mind and society will vary according to the size and style of the green roof, green roofs can provide aesthetically pleasing green areas, chances for social interaction, and several environmental advantages. These advantages that different people receive from their experience are also impacted by variation in their situations and aspirations. It is sometimes used to extrapolate from studies on green areas to illustrate the potential mental benefits of covered rooftops. Studies are being conducted to determine what characteristics of green roofs can enhance these advantages (Joimel et al., 2022). Depending on the setting and design, visible and practical access to natural roofs can promote human flourishing by:

- Stress reduction, greater creativity, and psychological relief have all been linked with green roofs that offer areas for exercising or occasions for meditation.
- Exposure to vegetated rooftops, even if only for 40 seconds, increases productivity, reaction rates, and retention of knowledge. Thus the advantages of interacting with natural green places may be extended via green roofs.
- When contrasted to synthetic natural environments, actual natural surroundings make people feel good more.
- More biodiversity in green areas is positively and significantly associated with emotionally restorative effects, which might also influence green roof design choices.
- Contact with natural spaces lowers stress hormone levels and strengthens the health of the amygdala, the brain region responsible for feelings. This lowers the likelihood of acquiring teenage and adult psychiatric problems by 15 to 55 percent, in childhood and adolescence.

Conclusion

This essay aims to provide a thorough analysis of the many kinds, elements, and environmental advantages of green roofs for sustainable urban development (Korol & Shushunova, 2016). The expansion of urban infrastructure and buildings is expected to increase the impervious area in the river system due to the nation's rapid rise in improved living standards. In the past few decades, sustainable urban development initiatives have caused an increase in extensive use of rooftop gardens. A green roof is a practical way to increase the quantity of vegetation in urban areas where there is little open space below; however, a lot of unutilized roof space is still impermeable and contributes to storms and water runoff.

This article also examined the creation and use of green roofs in various nations. In ensuring the sustainability of urban development, additional green roof installations in urban areas should be encouraged. Whenever native species of plants are planted, the advantages of green roofs are enhanced. Utilizing native plants is crucial since they are familiar to animals and have evolved to withstand local climates. Rainwater is absorbed mostly by the plant and the organic material after being caught by the vegetation. The extra water is treated through to multiple elements and either evaporates into the atmosphere or leaves the roof using drains (Shafique et al., 2018). The roof does this by collecting just about all the rainfall before it exits the roof, thereby reducing floods and hazardous waste. Therefore, green roofs are tremendously advantageous to people from both an economic and environmental standpoint.

A green roof that is easily accessible increases the number of green spaces in cities and enhances the comfort and satisfaction of the building's residents by offering an aesthetically beautiful setting for gatherings or relaxation (Stovin et al., 2015). Some green roofs feature urban agriculture and have plants that can be picked by the property's residents or the neighborhood, such as herbs and vegetables. Insects and birds that have been displaced from their native habitats by urban development and the lack of green space may find refuge on a green roof (Shafique & Luo, 2019).Not only this but they also aid in reducing erosion and retaining stormwater. There is less green space and more impermeable areas as a result of the increased urbanization of towns and cities. Rainfall typically pours through gutters on the building's roof before entering a storm drain. Either one enters the municipal pumping station through the storm drain or is immediately dumped into the environment through lakes, rivers, and streams.

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In a broad sense, green roofs offer several benefits, such as lowering energy consumption by lowering the energy consumption of a building, raising building standards, adding artistic appeal along with facilities and amenities, improving urban air quality, boosting stormwater management mitigation, lowering air temperatures, improving the environment in urban environments, aiding in the expulsion of urban stormwater pollutants as well as mitigating the effects of urban heat islands ("Using Monte Carlo simulation: Assessing the net benefits of early detection of Alzheimer's disease," 2018).

Compared to their drawbacks, they have a lot of positives. The roles that green gardens play in the development have a huge impact. Several of these garden's environmental advantages include modifying the climate by reducing the island's heat, controlling stormwater runoff, lowering pollution to the environment, and establishing a habitat for wildlife. Green roofs also have been demonstrated to prolong the life of the roof and cut down on energy usage. In addition to roof pools being extensively embraced, the cost element may be regarded as the least important consideration given the advantages of the roof gardens.

After taking into consideration all said above, it can be concluded that the importance and advantages of green roofs is not to be underestimated.

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