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Green Roof Technology- Effective Means of Sustainability and Environmental Protection

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ABSTRACT

Rapid urbanization has contributed to the problem of pollution, thermal heat island effect, decline in the species of organisms, and overexploitation of resources. World economies are setting sustainability goals for securing the future of upcoming generations. Green roof technology has revamped the concept of conventional roofs. Green roof technology helps in stormwater management, conservation of energy, pollution reduction, promoting urban agriculture, employment generation etc. This paper explains the structure of green roof technology and the essential characteristics of each component. It also highlights the role of green roofs and how they are effective for environmental wellbeing.This paper provides in depth knowledge of environmental and economic benefits of green roof technology to the readers.

Keywords: Urbanization, Thermal heat island, Sustainability, Green roof technology, Storm water management.

INTRODUCTION

Economic development has significantly contributed to urbanization, building construction, and waterproof surfaces. Urban hardscapes have replaced natural terrains which is the major reason for sewer overflows, reduction in vegetation cover, etc. [11] Building construction which covers contributed around a 3% increase in greenhouse gases, consuming around 40% of total global energy consumption.[38] The concept of sustainability has gone through various extensions which have broadened its scope to include environment, ecosystem, resources, and development. The word sustain is derived from the Latin word "sustenere," which means to hold up or keep elevated.[1] It is based on the fact that there is an upper limit to the physical exploitation of natural resources. Thus, it becomes essential to uphold their usage.

The green roof better known as a vegetated roof, eco-roof and living roof dates back thousands of years. The most classic example of green roof technology is the Hanging Gardens of Babylon constructed around 500BC which depicts the evolution history of this technology.[2] In hot climate regions like the Mediterranean, green roofs were prevalent to cope with extreme weather conditions.

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Dome-shaped dwellings often used dry grass to make storehouses and temporary shelters for migrants after the Spanish invasion back in the 1519s. [7] World Green Infrastructure network defines a Green roof as"a vegetated roofing system which is functionally integrated onto a roof area. Designs are site-specific depending on climatic conditions; slope; access; structural capacity and intended usage. Standard components are a tested waterproofing membrane; root barrier; drainage outlets; drainage layer; geofabric; grow media; vegetation; irrigation; maintenance regime."

Cold regions like Poland, France, and other areas of Central Europe made use of green roofs in prehistoric times for insulation and minimizing heat loss. A simple mechanism played an important role in survival. Green roof technology is as old as Vikings, and Scandinavia groups.[7]

Germany developed green roof technology for waterproofing flat roofs in the 1970s. [3] UN Earth Summit 1992 paved the way for the development of green roofs in Germany as it directed the implementation of Greenfields to mitigate threats to the environment.[4] In the context of Environmental protection, Green roof technology purifies the air, reduces air pollution and thermal effects, storm-water management, and reduces energy consumption.[3,5] A study conducted in Chicago found that 19.8 ha of green roofs reduced 1675 kg of air pollution between August 2006 and July 2007.[6] Another study in Italy aimed at finding the thermal effect of Green roofs concluded that this technology reduces the peak outdoor surface temperature from 56.3 °C to 28.6 °C. [6] Along with these environmental values, green roofs add to the aesthetics, recreation, and status symbol for the owners. Asian countries like Japan, Singapore, and Hong Kong have established green roof technology. Japanese Government passed the new Tokyo Plan in the year 2000 demanding any new building of more than 1000 square meters or more to have a minimum of 20% of green roofs.[9] Singapore National Park introduced the policy of covering 50% installation cost of green roofs. These initiatives came in as a response to tacklingthe urban heat effect and encouraging go-green habits.[10]

This paper extends the current literature by providing the purview of the past studies conducted and summarizing their results in one paper. Along with highlighting the environmental role of green roof technology, we place our focus on its structure, type and meaning. This paper is a one-stop destination to understand the concept of this technology from beginner to advanced level. This paper includes the findings of studies conducted across the world, thus this paper is an apt choice for international readers. Government can refer to this paper in the process of policy formation related to sustainability and environmental conservation.

Table1.Types of green roof technology[11], [12]

Basis of Comparison	Extensive	Intensive
Cost	Cheap to install and maintain	Expensive to install and maintain
Soil level and survival	Thin soil layer and can stand harsh weather	Thick soil layer and require irrigation during hot weather
Objective	Tackle environmental problems	Adding aesthetic value and creating landscape
Height	2-20cm	15-200cm

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LITERATURE REVIEW

Past research have targeted on the quite a number advantages of this technology. A research primarily based on the south coast of Sicily studied the electricity effectivity of significant extensive roof system established onan current residence holi day. The outcomes had been positive and located a reductiom in cooling and heating load through 80% and 34% respectively. An extensive roof minimizes the have an effect on of incoming warmness throughout the day presenting the alleviation and cooling effect. [2] Another learn about aimed at evaluating the effectiveness of green roofs in mitigating air pollution confirmed positive results. Air pollution eliminated through eco roofs have been quantified in Chicago and O3, NO2, PM10, and SO2 had been the four toxic gases that had been eliminated by means of the huge dry leaf deposition model. The whole air pollution elimination by using 19.8 ha of vegetated roofs used to be 1675 kg between August 2006 and July 2007.[5] Wooster (2022) carried out a comparative case study to recognize the success of Eco roofs in the promoting of city biodiversity. Green roofs noticed the boom of various flowers and fauna with birds, gastropod, and arthropod species. A research primarily based in New York was once of the view that if 50% of the roofs have been greened, the common floor roof temperature can be decreased by using 0.8°C. A greem roof is an efficient sustainability practice which is positive in lowering the city warmth island effect, promotion of biodiversity, and lowering air pollutants. [37] A previous literature based in Dublin centered on the overall performance of green roofs in lowering runoff through putting in a set of modular vegetated roofs at the CHQ building. The end result signaled the presence of a high degree of positive correlation between the quantity of rainfall and reduction in runoff. Although, the degree of temperature and run-off reduction had been now not extensively related. A correlation price of 0.069 was once determined between wind pace and reducting in runoff. It is specially due to the cause that greater wind velocity leads to greater evapo-transpiration.
[30]
Numerical simulation and experimental investigations have been undertaken to find out about the thermal conduct of widespread Greenroofs.

The giant vegetated roofs mirrored the preferred outcomes in a Mediterranean climate. The height out of doors floor temperature was once decreased from 56.3°C to 28.6°C and decreased the every day temperature fluctuations from 33.2°C to 5.6°C.[6] Green roof mechanism has a lengthy and wealthy records in developed international locations like Germany, Canada, Japan, and Hong Kong. DeutscherDachgartner-Verband higher recognised as the German Roof Gardening Association promotes inexperienced roof technological know-how on account that 1984. Government presents direct and oblique subsidies to lengthen the guide for the set up of inexperienced roofs.

Utility charges are kind of oblique subsidy havebeen constructions with traditional roofs have to pay one hundred percent of utility expenses whilst constructions with inexperienced roofs are solely entitled to 50%-80% of utility fees. Public and non-public organizations in Canada launched a lookup assignment titled “Greenbacks for Green roofs” in 1999. Singapore authorities covers 50% of Greenroof set up expenses and synergizes some

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new inexperienced initiatives. Urban Redevelopment Authority (URA), and LUSH (Landscaping for Urban Spaces and High Rises) are some of the extra initiatives of the Singapore government. Green roofs had been integrated into the Hong Kong authorities constructing initiatives with the aid of the Architectural Services Department in 2001. [10]
Along with catering to quite a number sustainability and environmental needs, there exist a number limitations to the adoption of inexperienced roofs. High startup capital investment, lack of monetary incentives, verbal exchange breakdown, and lack of professional and specialised jobs in green roof development are a few of the barriers.[38]

METHOD

This research study is based on secondary research. The researcher has thoroughly studied past studies based on green roof technology to effectively sum up its meaning, structure, and importance. Platforms like Scopus, Google Scholar, and Emerald have been utilized to ensure the presence of diverse data from various parts of the world. The researcher has listed the findings of various experiments and investigations conducted in past to offer overall results to the readers.

RESULTANDDISCUSSION

Structure of Green Roof Technology

It includes:

1. Plants- It forms the upper part of green roofs and plays a significant role in cooling the room temperature through the process of evapo-transpiration. It removes the threat of surface runoff and improves air quality. [15] The rooftop has various limiting constraints restricting the growth of vegetation. Sedum Species is considered a good fit for green roofs as it can withstand drought conditions and showcase active photosynthetic metabolism for four months without rain. Stachys byzantine is known for its surface cooling during the dry season, Portulaca grandiflora suits tropical wet and dry climates, and Apteniacordifoliaas consumes less water. There are no specific vegetation species that suit green roofs. The suitability of vegetation largely depends upon the external weather conditions. The diversity of species in green roofs enhances the effectiveness in terms of survival, developing ecological community, and increased aesthetics.[14]
2. Growing medium- Density, Fertility, degree of drainage, and water retention capacity of growing medium determines the growth of plants. Organic components should be kept at a minimum level as it leads to the growth of weeds and increased risk of eutrophication. Past studies have recommended the use of pumice [17], zeolite [18], vermiculite, perlite, peat, scoria, and crushed brick for the growth medium.[19],[20],[21],[22] Density of the growth medium should be less as buildings have load restrictions and traditional architecture is not designed to hold green roofs.[14]
3. Filter Layer- A non-biodegradable fabric is placed to separate the growing medium and drainage layer. It prevents the flow of soil, fine particles, and plant waste to the drainage layer. It protects the drainage layer from clogging and washing away the growth medium.[15] Past studies have recommended the use of textile fabrics, non-woven geotextile filter fabric, and nonwoven polymer fabric for the filter layer.[14]
4. Drainage Layer- The drainage layer removes the excess water from plant roots and retains this excess water for utilization during the dry season.[16] Drainage modular panels are made up of plastic materials, drainage granular materials use crushed bricks, gravel, and stones to store excess water and retain moisture for dry seasons. 5-15mm of clay pebbles can be used for the granular

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layer. A granular layer can only be used on flat surfaces and used for small-scale establishments.[14]

5. Protection layer- Once the plants grow, there are chances that roots might penetrate the waterproof layers resulting in a leak. Therefore, it is important to have a protective layer. It even protects the waterproof layer from damage during construction or maintenance work. Protection Fabric weighs between 15 and 25 ounces per square yard, with a nominal thickness of ¼ inch.[16]
6. Waterproof/Root barrier- The primary need fora waterproof layer is to keep moisture away from the building and prevent any leakage. There is the various waterproof system available like thermoplastic membranes, single-ply membranes, modified bitumen sheets, fluid-applied asphalt membranes, etc. [16],[23]
7. Thermal insulation- This layer is constructed to protect the waterproof membranes from UV degradation or any damage. This layer is built below or above the waterproof membranes.
8. Structural Deck- It is a deck made up of concrete, metal, or woods upon which the structure of the green roof is placed.

Basic Components of Green Roof System[13]

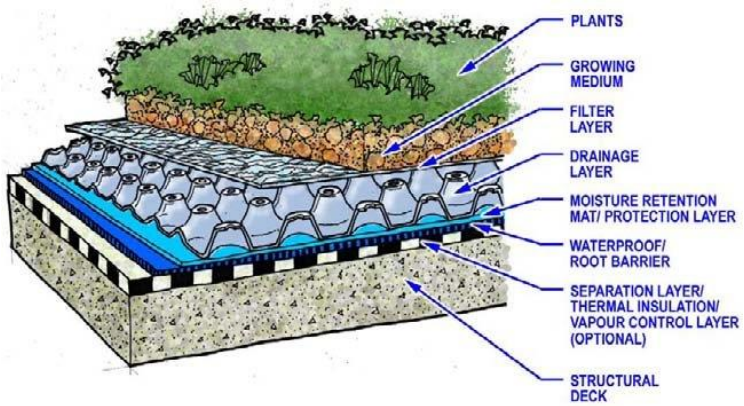

Figure1.Basic Components of Green Roof System

Role Of Green Roof Technology in Sustainability and Environmental Protection

1. Storm Water Management- Urbanizations, population growth, climate change, and global warming has compelled mankind to focus on the concept of sustainability. Surface runoff remains an issue in urban areas as stormwater finds it difficult to infiltrate due to impermeable areas. Low-impact development technologies like green roofs help in increasing water retention, and evapo-transpiration, thus reducing runoff..Stormwater takes away the soil and air pollutants that enter the water bodies creating havoc for aquatic life. In India, there have been numerous cases of fluoride above permissible limits which has led to diseases like viral infections, diarrhea, cancer, methemoglobinemia,etc.Past studies have proved that as the organic content in soil substrate is increased doubling the pore spaces enhances the water retention capacity.[25] In the context of vegetation type, grasses have been found more effective in runoff reduction. Authors are of the view that plants with greater height, diameter, and root biomass are more effective in runoff

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control. Once the water is absorbed by vegetation and growth medium, the remaining water will move from the filter layer to drainage. The water will be stored in modular panels and utilized in the dry season by evaporation.[15]

Another study showed that slope influences the water retention capacity of green roofs. The lowertheroof,thehigher the retention.[26]

Table2.Relationship between the slope and water retention when rainfall intensity is 0.4mm/min[27]

Slope	Water retention
2°	54%
8°	30%
14°	21%

Table3.Relationship between the slope and water retention when rainfall intensity is 0.8mm/min[27]

Slope	Water retention
2°	62%
8°	42%
14°	39%

Table4.Conclusion of past studies on runoff retention by green roofs

Location	Retention percent	Literature
Germany	50%	[31]
Sweden	46%	[32]
Georgia	78%	[33]
Auckland	66%	[33]
Michigan	60%	[33]

2. SAVING ENERGY- Green roofs act as an energy-saving technology by the means of cooling impact and reduction in urban heat islands. Surfaces of Buildings and standard roofs of urban areas lack the ability of natural cooling due to their inorganic surface. It is known as an Urban heat island.

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This in turn increases the energy costs due to the increased use of air conditioners and cooling technologies for maintaining the microclimate.[24] Past research has revealed that every 0.6-degree Celsius increase in air temperature boosts the cooling demand by 1.5-2%. Green roofs mitigate the effect of urban heat islands with the process of evapotranspiration. In this, moisture present in the vegetation or soil surface is evaporated, and water retained in plant tissues is transpired and ultimately released into the atmosphere. This process utilizes a part of solar radiation and prevents it from heating the roof. Green roofs are effective even in the winter season through insulation which minimizes heat loss.[31] The cooling impact of green roofs depends upon the thickness of the substrate, type of vegetation, structure, and location of the building. Vegetation provides shade; the depth of growth medium restricts the heat flux. Sedum spuria and Sedum kamtschaticum are considered effective in improving thermal performance. The cooling effect of green roofs can be studied with the help of software like EnergyPlus, TRNSYS, remote sensing, etc. The concept of green roofs is found economically viable by researchers. A study in Madrid, Spain revealed that 1% reduction in energy use, 6% savings in summers, and 0.5% savings in winters.[11] Another study was of the view that green roofs can reduce the surface temperature by 15–45◦C and air temperature by 5◦C. [24]

3. BIODIVERSITY- Green roofs help in attracting the diversity of plants and animals provided it offers a congenial environment for the same. Past studies are of the view that native plants are more successful in the long run to boost the colonization of local insects. Water requirements and lack of a favorable environment on the roof limit the growth of native plants. Green roofs have been found successful for the habitation of beetles, wasps, honeybees, and spiders. A deeper growth medium has a higher capacity to hold water, and nutrients and promote the growth of plants with deeper roots. Variation in the depth of growth medium in the safe roof can create multiple microclimates to promote the growth of various plants.[11] It was found that green roof is effective in the habitation of more than 30 species of organisms including IsotomaViridis, Parisotoma notabilis, and Ceratophyselladenticulata. [32,33] A study in Sydney found species like AmegillaCingulata, Scutiphora pedicellate, Dianella caerulea, Apis mellifera, and M. cordifolium.[34]

4. SOLAR ENERGY- This benefit is an aftereffect of the cooling impact of green roofs. High temperature in the concrete roofs due to the urban heat island effect reduces the power generation capacity of solar photovoltaics. Thus, solar panels produce more electrical output in cooler roofs than conventional ones. Heat flux in concrete roofs increases the operating temperature of solar cells and this heat raises the temperature of the surroundings. Conversion of photovoltaics energy depends upon the temperature; therefore, it becomes necessary to cool down the temperature.[34] The results of the previous studies differ due to surroundings, climate, study period, and scale of observation. Green roofs are effective in reducing the impact of urban heat islands, lowering the operating temperature of PV panels, and thereby increasing the energy generation capacity of solar panels.

Table5.Contribution of Green Roofs to increasing the power generation of solar panels [35]

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Study Location	Increase in power output [%]
Berlin	6%
New York	2.6%
Spain	1-3%
Singapore	1-2%

5. POLLUTION REDUCTION-Green roofs reduce the threats of radioactive contamination by blocking electromagnetic radiation by up to 94%. These radiations are believed to increase the chances of diseases like cancer, and cardiovascular problems.[31] Extensive green roofs are found more effective in noise reduction from traffic, airplanes, and outdoor disturbances. Studies have found that a green roof with a thickness of 2 to 6 inches can reduce the noise by 8 decibels. Noise reduction depends upon thickness, growing medium, drainage layer, the weight of the roof, and its coverage.[11]

Vegetation in green roofs can absorb gaseous pollutants like Co2, No2, poly-aromatic hydrocarbons, and suspended particulate matter. Specific types of vegetation are found effective in carbon sequestration allowing green roofs to act as a carbon sink. Another study in Chicago found that green roof vegetation removed harmful components of air like NO2, PM10, and SO2 by 27%, 14%, and 7% respectively. [11],[12], [36]

Table6.Relevance of green roofs in reducing pollution according to past research

Key highlights	References
Total air pollutant removed=1675kg; Area of green roof = 19.8ha Pollutants removed: O3=52%, NO2= 27%, SO2= 7%, PM 10=14%	[36]
Particulate matter removed=4000kg, Area of vegetation= 2000meter square	[37]

Green roofs help in runoff reduction which has helped in minimizing the impact of nitrogen, and pollutants in runoff.[12]

Table 7: Benefits of Green Roof Technology at a glance

Benefits	**Findings**

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Economic	**Employment Generation-** Generates job opportunities in the form of construction, installation, maintenance of the green roof, suppliers of the growth medium, drainage layer, filter layer, etc. A 2009 study based in Washington DC found that under conservative scenario Green roof practices created 1179 average job opportunities every year and brought in $599.8 million in investment.[11] **Roof Longevity-** Average life expectancy of a green roof is 40 years while a conventional roof lasts only 17 years. It is due to the protection provided by the vegetative layer.[11] **Cooling effect-** The vegetation layer captures the heat and allows transpiration during day time. It brings down the temperature and helps in cutting the cost of AC, fans in concrete buildings. Research in the US indicated that Eco rooftops reduced the peak temperature from 0.5 K to 3.5 K.[12]
Environmental	**Stormwater management-** It slows down and retains the stormwater. It reduces the runoff rate by 65%. [11] **Biodiversity-** A study based in Barangaroo, Central Sydney found that green roof vegetation covers like Dianella caerulea, and Viola hederacea attract various species of pollinators, insects,etc.[33] **Urban Agriculture-** Green roofs have encouraged agriculture in metropolitan cities.[11] **Acoustics-** A 2-6 inches thick green roof can reduce the noise levels of roofs by 8 decibels. The top floors of the buildings have maximum acoustics benefits.[11] **Improving air quality-** Atwo-year study in Michigan on a 2.5-inch-thick extensive sedum roof showed net carbon sequestration of 378 grams of carbon per square meter in the plant material, root biomass, and growth medium.[11]

CONCLUSION

This research has listed the importance of green roof technology in achieving sustainability goals. The essentials of the structure of a green roof are explained to enhance the productivity of green roofs in environmental protection. This paper has a conceptual framework around the role of this technology and why it is being adopted by various countries. It includes the findings of past observations and studies conducted in various parts of the world to understand the success of green roof technology. This paper offers the knowledge of studies conducted across the world making it an apt choice for not only local but also international readers. This study is primarily based in secondary data. There is a further scope to support the findings of this paper through primary research and experimentation.

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REFERENCES

1. Dixon, J. A., & Fallon, L. A. (1989). The concept of sustainability: origins, extensions, and usefulness for policy. *Society & Natural Resources*, *2*(1), 73-84.
2. Gagliano, A., Detommaso, M., Nocera, F., Patania, F., &Aneli, S. (2014). The retrofit of existing buildings through the exploitation of the green roofs–a simulation study. *Energy Procedia*, *62*, 52-61.
3. Abass, F., Ismail, L. H., Wahab, I. A., &Elgadi, A. A. (2020). A review of green roof: definition, history, evolution and functions. In *IOP Conference Series: Materials Science and Engineering* (Vol. 713, No. 1, p. 012048). IOP Publishing.
4. Jim, C. Y. (2017). An archaeological and historical exploration of the origins of green roofs. *Urban Forestry & Urban Greening*, *27*, 32-42.
5. Yang, J., Yu, Q., & Gong, P. (2008). Quantifying air pollution removal by green roofs in Chicago. *Atmospheric environment*, *42*(31), 7266-7273.
6. Gagliano, A., Nocera, F., Detommaso, M., &Evola, G. (2016). Thermal behavior of an extensive green roof: Numerical simulations and experimental investigations. *International Journal of Heat and Technology*, *34*(2), 226-234.
7. Osmundson, T. (1999). *Roof gardens: history, design, and construction*. WW Norton & Company.
8. Donnelly, M. C. (1992). *Architecture in the Scandinavian countries*. Mit Press.
9. Peck, S. (2001). Tokyo begins to tackle urban heat with green roofs. *Green Roofs Infrastructure Monitor*, *32*(4).
10. Ismail, Z., Abd Aziz, H., Nasir, N. M., &Taib, M. Z. M. (2012, September). Comparative study on green roof mechanism in developed countries. In *2012 IEEE Symposium on Business, Engineering and Industrial Applications* (pp. 678-683). IEEE.
11. GSA, U. (2011). The benefits and challenges of green roofs on public and commercial buildings. *A Report of the United States General Service Administration*.
12. Yeung, K. K. A., & Li, W. C. (2014). A comprehensive study of green roof performance.
13. Townshend, D., &Duggie, A. (2007). Study on green roof application in Hong Kong. *Architectural services department*.
14. Vijayaraghavan, K. (2016). Green roofs: A critical review on the role of components, benefits, limitations and trends. *Renewable and sustainable energy reviews*, *57*, 740-752.
15. Srivastava, R. (2011). *Green roof design and practices: a case of Delhi* (Doctoral dissertation, Kent State University).
16. Mikaël Gartner, P. E., & Engineers, D. Structural Implications of Green Roofs, Terraces, and Walls.
17. Kotsiris, G., Nektarios, P. A., Ntoulas, N., &Kargas, G. (2013). An adaptive approach to intensive green roofs in the Mediterranean climatic region. *Urban forestry & urban greening*, *12*(3), 380-392.
18. Palla, A., Gnecco, I., & Lanza, L. G. (2009). Unsaturated 2D modelling of subsurface water flow in the coarse-grained porous matrix of a green roof. *Journal of Hydrology*, *379*(1-2), 193-204.
19. Cao, C. T., Farrell, C., Kristiansen, P. E., & Rayner, J. P. (2014). Biochar makes green roof substrates lighter and improves water supply to plants. *Ecological Engineering*, *71*, 368-374.

Webology, Volume 18, Number 2, 2021
ISSN: 1735-188X
DOI: 10.29121/WEB/V18I2/13

20. Vijayaraghavan, K., & Joshi, U. M. (2014). Can green roof act as a sink for contaminants? A methodological study to evaluate runoff quality from green roofs. *Environmental Pollution*, *194*, 121-129.
21. Zhao, M., Tabares-Velasco, P. C., Srebric, J., Komarneni, S., &Berghage, R. (2014). Effects of plant and substrate selection on thermal performance of green roofs during the summer. *Building and Environment*, *78*, 199-211.
22. Vijayaraghavan, K., & Raja, F. D. (2014). Experimental characterisation and evaluation of perlite as a sorbent for heavy metal ions in single and quaternary solutions. *Journal of Water Process Engineering*, *4*, 179-184.
23. Townshend, D. (2007). Study on green roof application in Hong Kong–Urbis Limited. *Hong Kong*.
24. Liu, H., Kong, F., Yin, H., Middel, A., Zheng, X., Huang, J.& Wen, Z. (2021). Impacts of green roofs on water, temperature, and air quality: A bibliometric review. *Building and Environment*, *196*, 107794.
25. Getter, K. L., Rowe, D. B., & Andresen, J. A. (2007). Quantifying the effect of slope on extensive green roof stormwater retention. *Ecological engineering*, *31*(4), 225-231.
26. Villarreal, E. L., & Bengtsson, L. (2005). Response of a Sedum green-roof to individual rain events. *Ecological Engineering*, *25*(1), 1-7.
27. Villarreal, E. L. (2007). Runoff detention effect of a sedum green-roof. *Hydrology Research*, *38*(1), 99-105.
28. Mentens, J., Raes, D., &Hermy, M. (2006). Green roofs as a tool for solving the rainwater runoff problem in the urbanized 21st century?. *Landscape and urban planning*, *77*(3), 217-226.
29. Bengtsson, L., Grahn, L., & Olsson, J. (2005). Hydrological function of a thin extensive green roof in southern Sweden. *Hydrology Research*, *36*(3), 259-268.
30. Tolderlund, L. (2010). *Design guidelines and maintenance manual for green roofs in the semi-arid and arid west*. Denver: Green Roofs for Healthy Cities.
31. Fountain, M. T., & Hopkin, S. P. (2004). Biodiversity of Collembola in urban soils and the use of Folsomia candida to assess soil 'quality'. *Ecotoxicology*, *13*(6), 555-572.
32. Dunger, W. (1989). The return of soil fauna to coal mined areas in the German Democratic Republic. *Animals in Primary Succession. The Role of Fauna in Reclaimed Land*, 307-337.
33. Azis, S. S. A., Sipan, I., Sapri, M., Yusoff, N. S. M., & Hashim, H. A. (2019). Comparison on energy saving: green roof and green wall. *Planning Malaysia*, *17*.
34. Yang, J., Yu, Q., & Gong, P. (2008). Quantifying air pollution removal by green roofs in Chicago. *Atmospheric environment*, *42*(31), 7266-7273.
35. Johnson, J., & Newton, J. (1996). Building green, a guide for using plants on roofs and pavement. *The London Ecology Unit, London*.
36. Council, W. E. (2013). World energy scenarios. *World Energy Council*.
37. Tillinger, D., Ostroff, G., Beattie, D., Berghage, R., Mankiewicz, P., & Montalto, F. (2006). Hydrologic functions of green roofs in New York City. *Green Roofs in the New York metropolitan region: Research Report. Columbia University Center for Climate System Research and NASA Goddard Institute for Space Study*, 27-36.
38. Kasai, N., &Jabbour, C. J. C. (2014). Barriers to green buildings at two Brazilian Engineering Schools. *International Journal of Sustainable Built Environment*, *3*(1), 87-95.