



Green roof benefits, opportunities and challenges – A review

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ABSTRACT

Research on the green roof has been raised expeditiously over the past decade. Green roof have been proposed as the sustainable practice to mitigate the adverse effects of urbanization. This review paper includes the history of the green roof, green roof components and multiple benefits (environmental, social and economical) associated with the green roof technology. This paper also emphasizes how the green roof works in different areas, their performance in reducing the stormwater and energy costs, improving air and ecological performance. The benefits of green roof show that it plays an important role in making cities safe, sustainable and resilient to climate change. Therefore, many countries are giving incentives to the house owners for the application of green roof. However, initial high construction costs, high maintenance costs and roof leakage problems are the main challenges associated with the application of green roofs. These challenges can be overcome with the of new cost effective green roof design that can work more effectively and efficiently in any area. Advanced modification and trends of green roof application are also included in this paper. The paper also highlights the research challenges and research gap of the green roof. At the end, for the better performance of the green roofs, some of the recommendations are also provided.

1. Introduction

Climate change and urbanization are the topics of current interest. In the developed countries, urbanization forecasted to attain approximately 83% in 2030 [1]. Due to the rapid economic growth, urbanization is increasing in many countries which degrade the natural landscape as well as the nearby environment [2,3]. These problems can be solved by applying the green stormwater infrastructure strategies. The introduction of new urban development strategies such as rain gardens, green roofs, green walls and bioretention systems can mitigate the adverse effects of urbanization and improve the environment of an area [4,5]. Green roofs also referred as vegetated roofs [5], cool roofs [6], eco roofs (due to ecological benefits), roof garden or living roofs [7–12]. Green roofs are the basically roofs planted with different kind of vegetation/plants on the top of growth medium (substrate). This concept was designed to encourage the vegetations on the top of building to get multiple social, economical and environmental benefits. A green roof typically consists of several components, including vegetation, substrate, filter layer, drainage material, insulation, root barrier and water proofing membranes [13]. The optimal selection of each component of the green roof is very important to get the best outcomes

from the green roofs. Each component is equally important and plays very important role for the better performance of green roof in an area [14]. Due to multiple benefits, green roofs are being implemented in many countries. More research is going on the implementation and performance of green roofs in different regions around the world. Fig. 1 shows the 2016 green roof for excellence awards in buildings.

In recent decades, green roofs proved as the sustainable practices and have gained much popularity around the globe [16]. Research on the green roofs shows numerous social, environmental and economical benefits. Significant evidence shows that green roofs can give multiple benefits, such as stormwater management, reduced urban heat island, increased urban plant, wildlife habitat and roof life, enhance the air and water quality and quality of life, decreased the energy consumptions costs of the building, decreased the noise pollution, procreates the recreational activities and increased the green areas and aesthetic value in urban environments [16–20]. As the result of water quality enhancement, green roofs decrease the burden of the water treatment facilities in an area [10,21–25]. Due to the above benefits many countries started to implement the green roofs in buildings. As the result of this more and more green roofs are established day by day around the globe.

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Fig. 1. Green Roof selected for 2016 Excellence Awards in buildings: green roofs on residential buildings (1,2); institutional buildings (3,4); commercial buildings (5,6), pictures taken from [15].

Green roofs commonly classified into four categories. These are intensive, semi-intensive, single-course extensive and multi-course extensive [26]. Intensive green roofs are categorized on the basis of substrate thickness (> 12 in.), a wide variety of plants/vegetations similar ground-level landscapes, high water holding capacity, high capital and maintenance costs and larger weight. Due to the large soil depth, it has more water holding capacity and the plant selection can be more diverse as small trees and shrubs. This also requires more consideration about the building structure capability to bear large weight. Therefore, this type of roofs requires high maintenance in the form of irrigating, weeding and fertile. Green roofs with 6–12 in. substrate thickness, referred as semi-intensive green roofs. Semi-intensive green roofs contain the moderately substrate thickness and usually contain small plants, small shrubs and grass. These roofs require regular maintenance and high capital costs for the better performance. On the other hand, Single-course extensive roofs are the roofs with substrate thickness 3–4 in. In Single-course extensive roofs, mostly sedum uses as the vegetation layer and typically not required irrigation. It required little capital and maintenance costs as compared to all other roofs. These roofs usually very light weight and very useful where the building weight restrictions. While multi-course extensive roofs consist of 4–6 in. substrate thickness. This roof type is usually light weight and mostly use in the USA. Of the four types, single and multi-course extensive roofs are most common around the world due to less weight, not require irrigation and less capital and maintenance costs.

1.1. Methodology

This paper reviewed the global literature from different source, i.e peer reviews, research articles, books, case studies, conferences, technical reports, design guidelines, project summaries and group discussions. A search of a number of different keyword for the green roof that includes green roof technology, green roof history, green roof components, green roof benefits, green roof policies, a new combination of green roof for multiple benefits using Open access, Google scholar, different journal and conferences were used to find the useful information. This review is giving an insightful overview of the green roof to the common user to understand the green roof technology. This review also explains the each component of the green roof and their benefits in details. Many studies were reported to show the green roof benefits for stormwater management and improving the environmental performance in the different areas.

This paper gives an overview of green roof technology and shows how they have significantly contributed to the provide multiple benefits (social, environmental and economical) in urban areas. This review paper differs from the previous review works on the green roofs in terms of various aspects. First of all, on the contrary to the previous literature focusing on one specific topic only, the concept of green roof is explored in a holistic way in this review paper. The review initiates with a historical overview of the green roof technology following by theoretical basics and concise explanations. Then, the green roof each component is comprehensively described with their benefits. Green roof each benefit with the life cycle assessment is described in details.

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