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Ecological benefits of roof gardens and the difference of roof gardens in different regions

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Abstract. As a result of the rapid pace of urbanization today, environmental destruction is outpacing regeneration, and many "urban diseases" are occurring frequently. Therefore, there is a need for a facility that can protect the environment without destroying the original city - roof gardens. This paper focuses on the ecological benefits of rooftop gardens and their application in practical situations. It is found that rooftop gardens can improve air quality, store rainwater, mitigate the heat island effect and protect biodiversity. These effects have well alleviated the problems of urban air pollution, water resource stress, urban heat island effect and destruction of ecological environment. And research has found that there are already many excellent examples of the application of rooftop gardens at home and abroad, helping to confirm that rooftop gardens do indeed have the ecological benefits mentioned above, adding to the feasibility. Rooftop gardens are indispensable in the construction of future cities for the well-being of urban residents.

Keywords: Roof Garden, Ecological Benefits, Application.

1. Introduction

Due to the rapid development of science and technology, there has been a steady increase in both industrial and agricultural productivity. This progress has consequently led to the expansion of urban areas and a notable rise in the urban population. However, with the construction and development of cities, more and more "urban diseases" have appeared, such as urban air pollution, water shortage, and urban heat island effect. These urban diseases not only cause damage to the natural environment but also seriously endanger the physical and mental health of urban residents. To alleviate urban diseases and provide a better living environment for urban residents, urban roof gardens have been paid more and more attention.

The roof garden is a kind of landscape environment with ecological benefits. It is built on the roofs of all kinds of buildings by using some landscape plants on the ground. The vegetation of the roof garden itself is a part of the ecological environment, which provides a living environment for plants and improves the greening degree and biodiversity of the city. At the same time, the shape and size of the ecological environment can affect the ability of roof gardens to help improve biodiversity and ecosystem stability [1]. A variety of plants planted in the roof garden can absorb pollutants and toxic substances in the air and play a role in purifying the air. In addition to harmful air, plants can consume carbon dioxide and produce water vapor and oxygen, regulating atmospheric temperatures and mitigating the urban heat island effect. The cooling effect of roof greening is affected by many aspects, but as long as it is used well, it can make full use of space and add green at the same time and save energy to the greatest extent

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[2]. In addition, through the modern and mature roof greening technology transformation, the roof garden can play a role in storing rainwater, percolating to recharge groundwater, and slowly removing rainwater, alleviating the impact of urban flooding [3].

The roof garden enriches and facilitates People's Daily life, while also protecting the natural environment. Therefore, a systematic analysis of their ecological benefits is necessary. Firstly, this paper starts with the concept and classification of the roof garden and analyzes the essence and theoretical basis of the roof garden. Secondly, from the perspective of ecological benefits, this paper explores the role and impact of roof gardens and their contribution to human and environmental change. Finally, the feasibility of these functions of the roof garden was confirmed by case analysis.

2. Roof garden

2.1. The background of the roof garden

Between 604 and 562 BC, the Babylonian Kings built a fantastic tall building called the Hanging Garden. The hanging garden is full of exotic flowers and plants and has a complete water supply system. The ancient Greeks who visited Babylon called it a wonder of the world [4]. And this was the first roof garden. Therefore, Western countries have long begun to develop roof gardens and call them the fifth facade of buildings. The history of the European roof garden can be traced back to the Renaissance. In practical application, the West began the roof garden project after the middle of the 20th century.

The domestic research and exploration of the roof garden started late. The theoretical research on the roof garden began in the early 1960s in China. The first large rooftop garden in China was built in the 1970s at the Oriental Hotel in Guangzhou [5]. Nowadays, with the increasing density of the population, a large number of rural people flock to the city, the per capita green area is low, the urban buildings are dense, and the land resources are lack. A series of environmental problems occur frequently, and the emergence of roof gardens is an inevitable trend.

2.2. The concept of roof garden

A roof garden is created by using landscaping techniques on the roofs of various buildings. This entails selecting and arranging plants, trees, bushes, and turf with care. The objective is to create a lush, natural landscape on the rooftop. This is accomplished by strategically placing sitting places, pavilions, water features, and aesthetic components. These components help to divide the urban rooftop area into many useful sections. The idea is to combine natural beauty with areas for leisure and enjoyment.

Beyond just adhering to the rules of landscape design, various variables must be taken into account while designing and building rooftop gardens. Sustainable development and safety concerns are two of these. The load-bearing capability of the roof must be evaluated, efficient water supply and drainage systems must be designed, the overall structure must be managed, and future plant and garden feature upkeep must be planned. Rooftop gardens present different difficulties from ground-level landscapes, thus it is essential to address these issues for effective and long-lasting growth [6].

2.3. The classification of roof garden

According to the classification of landscape morphology and function, the roof garden can be divided into landscape ecological type, leisure and entertainment type, sports and fitness type, scientific research, and production type. According to the roof form of the landscape, it can be divided into a slope roof garden and a flat roof garden. According to the spatial organization, it can be divided into open roof garden, semi-open roof garden, and closed roof garden. (Tan Shuya) This paper will take the hotel apartment roof garden as the main body, and distinguish their differences by comparing two different types of roof gardens [7].

(1) The difference between a hotel apartment roof garden and a residential roof garden

A hotel apartment roof garden refers to the open outdoor space on the floor, balcony, terrace, and other structures above the hotel apartment building. This type of roof garden can be used by people to

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enter and conduct spontaneous activities, rest, and communication. The residential roof garden refers to the roof garden built on the roof of the residential area for the use of the community and residents.

Although the planting soil and roof load of the roof garden are all subject to the same restrictions, the functions of the roof garden of the hotel apartment are usually more abundant than those of the residential roof garden.

Therefore, the hotel apartment roof garden has the following characteristics compared with the residential roof garden:

a. Intensive layout of multiple functional Spaces. Compared with the single function space of residential roof gardens, the roof garden of serviced apartments has more abundant function space, and more space places can be built, such as roof squares, rooftop pools, rooftop restaurants and so on.

b. Comprehensive integration of multiple landscape elements and technical elements. As the roof garden of hotel-style apartments has the characteristics of an intensive layout of multiple functional Spaces, it is determined that the landscape elements and technical elements adopted by the roof garden should serve the functional space. Therefore, a variety of elements in the design are often used together to achieve a complete landscape effect.

c. Thematic landscape experience. Different from the residential roof garden, the hotel apartment roof garden emphasizes the characteristics of home activities. It emphasizes the theme of characteristic landscape. Therefore, the experience design of the space should have the theme of landscape experience, such as romantic love, parent-child happiness, sports health, landscape style, etc.

d. Diversity of users. Compared with the relatively fixed users of residential roof gardens, the users of hotel apartment roof gardens are diverse. The users of the hotel apartment roof garden mainly include the following two categories: business users and residential users.

e. The complexity of transportation organization. The users of residential roof gardens are relatively fixed, so the crowd activity law is relatively fixed, and the traffic organization is relatively simple. However, the roof garden space of serviced apartments often has a large number of users, and the demand for crowd activities is large and the activity forms are diverse, so the traffic organization is more complex.

(2) The difference between the rooftop garden of a serviced apartment and the rooftop garden of a hotel

The hotel roof garden is generally for the hotel to carry on the beautiful green, as well as for the hotel guests to relax and entertain. The difference between the two is not very big, the main difference lies in the travel experience above.

Therefore, compared with the hotel roof garden, the hotel apartment roof garden has the following characteristics:

a. It has the characteristics of a family-style landscape atmosphere. Different from the hotel roof garden, which is often designed to focus on consumption and enjoyment, the landscape of the hotel apartment roof garden has a stronger family-style atmosphere, with a permanent parent-child park area, children's activity area, and even cute pet park and rooftop farm, to reflect the family-style activity landscape atmosphere of the hotel apartment roof garden.

b. It has the characteristics of a leisure and vacation landscape experience. For medium and long-term holiday tourists, the hotel apartment roof garden will often focus on creating a quiet, comfortable, green leisure holiday landscape experience, in the design of the roof garden, often uses the outward and inward vision to set a certain area of leisure platform or framework, so that the use of the crowd to stay, talk, walk, enjoy the scenery. To achieve relaxation, release pressure, and away from the hustle and bustle of the city leisure resort landscape environment.

3. Analysis of the ecological effect of roof garden

3.1. Impact of roof garden on air quality

The roof garden can improve air quality by absorbing dust in the air, reducing carbon dioxide in the atmosphere, and absorbing inhalable particles. The most prominent role is to fix carbon dioxide in the

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atmosphere and purify the air. Taking Kunming Spring City Roof Garden as an example, the garden is built on the top of the first floor of the shop, and all parts are connected by flyovers, which is a large roof garden. The garden features multiple landscape nodes, including ecological water features, regular plazas and lianas covered galleries. On the pavement, the pavement of a large area square will lead people's sight from near to far to the distance. In terms of plant configuration, the dense and orderly structure of the surrounding plants makes people walk among them without feeling depressed and bored, giving people a sense of rhythm and rhyme. The more levels of plant community, the more obvious the efficiency of carbon sequestration. It can be seen from Table 1, under the same area unit, the amount of CO2 fixed by the ecological multi-layer greening structure including big and small trees, shrubs and mixed plants is as high as 1100 kg/m3, and the lowest CO2 fixation efficiency is artificial lawn. Even artificial lawn mowing is not inefficient at fixing carbon dioxide [8]. Therefore, the roof garden can indeed play a role in improving air quality and purifying air.

Table 1. Plant species and CO_2 fixation.

Plant species		CO_2 fixation (kg/m^3)
Ecological compound afforestation densely planted trees	Large and small trees, shrubs, flowers and plants mixed area	1100
	Mixed area with dense planting of large and small trees	900
Sparsely planted trees	Large broad-leaved tree	805
	Small broad-leaved, coniferous or sparsely leaved trees	537
	Macro palmetto	410
Dense thicket		205～438
Perennial vines		103
Tall grass flower beds, tall aquatic plants or tall stem weeds		46
Low grass flower beds, low water plants or low stem weeds		14
Hand mowing lawn		0

3.2. Impact of roof garden on stormwater runoff

To some extent, the roof garden can reduce the pressure of heavy rain on the urban drainage system and can avoid the problem of urban land subsidence caused by the decline of the groundwater level. The problem is solved by building a reservoir on the roof laying drainage pipes and using vegetation layers to purify water. In the Singapore Admiralty community, for example, most of the rainwater is collected and filtered as it flows from the top of the building to the lower level, and then gravity flows to the middle level. The filtered water as well as the direct runoff from the top of the two towers was sufficient for three consecutive days of plant irrigation and refill of the two ecological pools. To maintain high water quality output and minimize the risk of algal blooms in tropical Singapore, the project introduced an ecological purification community to recycle and purify the ecological pool, and stormwater runoff from adjacent areas was also purified by vegetation filtration mechanisms and transported to the ecological pool. Singapore is a rainy city, so this design can maximize the use of water resources [9]. Therefore, the roof garden can indeed play a role in reducing surface rainwater runoff and storing rainwater.

3.3. Mitigation of heat island effect by roof garden

Roof gardens can absorb carbon dioxide from the atmosphere to a certain extent, increase air humidity, and thus alleviate the urban heat island effect. For example, Kunming Oriental Rose Garden roof Garden,

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the whole roof with aquatic plants as the main body, with rockery and other artificial landscapes, to create a refined leisure landscape, so that the whole roof is green, with clear zoning. Oriental Rose Garden uses a large number of garden plants commonly used in Kunming, such as rhododendrons palm and other subtropical evergreen deciduous plants, which are suitable for the natural conditions of Kunming, reduce the CO2 emissions of maintenance equipment, and reflect low carbon from the level of reducing maintenance management costs. Moreover, proper planting of vegetation can be very efficient in fixing carbon dioxide in the atmosphere. The "killer" of the heat island effect and global warming is that cars and industrialization in cities emit a large amount of carbon dioxide, which leads to the thickening of the atmosphere and the heat is not easy to dissipate, thus causing the temperature to rise and destroying the climate environment [8]. Therefore, roof gardens can indeed alleviate the urban heat island effect and treat the "urban disease".

3.4. Impacts of roof garden on biodiversity

Roof gardens can provide a living environment for flowers, birds, fish and insects, thus providing living space for some organisms deprived of their living environment due to the rapid development of cities, thereby protecting biodiversity. The Jacob Javits Convention Center Roof Garden is the second largest green roof on a single detached building in the United States. The roof garden features a wide variety of plants that are adapted to the region's climate to enhance biodiversity and sustainability. The Javits Center's rooftop garden has become a refuge for local wildlife, with birds, bats, and bees found and cultivated [9]. Therefore, roof gardens can have high biodiversity conservation benefits.

4. Architectural types of roof gardens in different regions

4.1. Hotel apartment roof garden

The roof garden located in the International Financial Center of Zhujiang New Town in Guangzhou belongs to the roof garden of a hotel apartment. It is the rooftop garden of the Superior Garden Club, which connects the dining room and indoor pool and is also equipped with a golf driving range (Figure 1). The landscape design of the roof garden of a hotel apartment determines the applicable population and the way of use. To fully consider the needs of the surrounding population to carry out landscape design. Due to the loading requirements on the roof of the roof garden, the landscape design is restrictive. The limited space of the roof garden, the roof garden is divided into four landscape areas according to their functions: the restaurant landscape area, the landscape golf practice area, the children's activity area, and the multi-functional activity area. The landscape golf practice area is the main area, and other functional areas are supplemented. Each functional area is connected by the winding walk and steps, and the overall space planning layout shows an intensive layout. In addition, the key problem of the roof garden of the hotel apartment is the problem of waterproofing and drainage. The roof garden is combined with drainage board and non-woven fabric so that it has the function of drainage and water storage [7].

Through this case, it can be found that the landscape design of the roof garden is mainly reflected in planning and design, experience design and plant design. In terms of planning and design, the landscape design and roof load distribution corresponding design, to achieve the perfect unity of landscape effect and structure; The space layout adopts the intensive design form to create four functional Spaces of "one main and three auxiliary"; The transition space between different functional Spaces can realize the effective conversion of space and form the space effect of "small in the big". In terms of experience design, through the combination of landscape visual experience and holiday cultural experience, the landscape effect of the roof garden is maximized. In terms of plant design, combined with the load, the configuration technique of "based on small trees, shrubs and ground cover plants, supplemented by trees" is used, and the characteristics of plants such as flowers, leaves and stems are combined with the configuration technique of bionic plants combined with real plants is used to form the detailed greening landscape effect.

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Figure 1. General plan of the roof garden landscape [7].

4.2. Apartment roof garden

Sichuan Agricultural University is located in Ya 'an City, known as the "Rainy City". Here the environment is beautiful, belongs to the subtropical monsoon humid climate area, and rainfall is sufficient throughout the year. Humidity is high, wind is low, and sunshine is low. The per capita green area of the school is less, the student apartment has no air conditioning, and the students on the top floor live a cold life in winter and a hot life in summer. The roof is nearly rectangular. The load of the roof is more than 350 kg/m, and people can step on the roof, so it is suitable for building roof gardens. The roof is divided into three functional areas, namely the activity area, the rest area and the water scenic area. The three functional areas provide residents with different use needs (Figure 2) [10].

According to the modern architectural style and the actual situation of the roof, the roof is divided into two parts by using water grinding hard pavement and soft lawn area, and then the water edge platform and herbaceous flower bed make the two areas into one and soften the hard pavement. The main purpose of building roof gardens is to improve the urban green coverage rate and improve the living environment of residents. Therefore, it is necessary to consider the ecology of the roof garden, combine it with the climate, and reflect the ecological environment effect of landscaping based on plant landscaping. The roof area is limited, must make good use of the limited space, and the construction of fine and beautiful roof garden. According to the architectural style and the concept of ecological conservation, renewable wooden boxes were used as planting beds, which both relieved the load on the roof and beautified the view. Plant planting is the theme of the roof garden, but due to the poor ecological conditions of the roof, its sunshine, temperature, wind, and other conditions are different from the ground conditions. Therefore, according to the local climate characteristics and roof conditions, the design of an ecological good roof plant landscape. Small trees, shrubs, herbs and lianas are scattered, well - organized and fresh. Evergreen lianas were applied to the fence walls to form vertical greening. According to the height of green plants, regular cultivation can beautify and purify the roof space, so that it is full of vitality and vitality.

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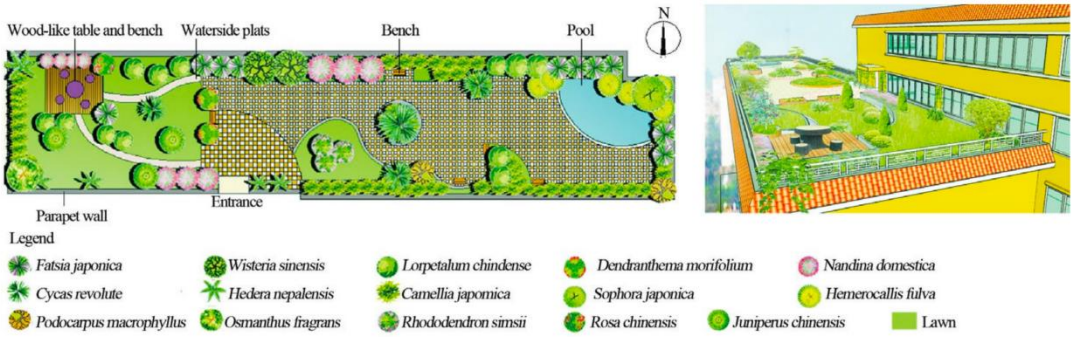

Figure 2. General layout [10].

4.3. Roof garden for public recreation

Saitama Square Roof Garden is located in Saitama Square, Japan, which was built on the ruins of the downtown railway. As a typical public recreational roof garden, the Saitama Square roof garden connects Tokyo's largest gymnasium, as well as many residential, office and commercial buildings, connecting the new town and the old Town, becoming a busy transit point [11].

As a busy transit place, the roof garden of Saitamb Square should not only ensure that commuters can quickly pass through to different destinations, but also provide leisure and entertainment places for surrounding residents. Therefore, "flexible and multi-functional" has become the design highlight of the roof green square. To achieve flexibility and multi-function, the designer adopts the design strategy of "point, line, surface" to formulate the landscape design scheme, which has good practicability. "Point" is the beech tree array, square seat, beech tree array for the user's walking route is not limited, people can according to personal preferences to quickly pass or stay rest. The "line" is the corridor of wind and rain, which is arranged according to the shortest distance between the entrances and exit, ensuring that the crowd can quickly pass through the square without being wet by rain and snow. The "face" is a lawn, a multi-purpose sunk side square and a glass tower, providing a variety of activity Spaces and possibilities for the site.

The overall design of the project follows five design principles: practicality and safety, exquisite, humanistic care, ecological and stability principles. Practicality is the fundamental purpose of building a public recreational roof garden, which should not only combine the characteristics of the site but also meet the needs of users. Creating green space through plants is the basic function of roof gardens. Only by ensuring a certain number of green plants can the ecological benefits, social benefits and economic benefits of greening be played. Safety is the basic requirement of public recreational roof gardens, mainly including the safety of the building itself and the safety of the users. Since the roof garden has a certain height from the ground, the design of the strength and height of the protective railings should meet the relevant standards to prevent accidental falls. Plant designs should avoid the use of pollen species that are toxic and likely to cause user allergy. Public recreational roof gardens are used by a wide range of people and a large number of people, so humanistic care is particularly important. In the design, it is mainly manifested as humanized design, that is, the design can better meet the user's deeper material needs and spiritual needs of the landscape environment. Create the environment and human dialogue, enhance the user's sense of identity, and produce the agglomeration effect.

The thinking of roof garden landscape design should not be limited to the human-centered concept but should consider how to carry out greening design under the premise of sustainable development so that human society and nature develop in harmony.

5. Promotion and application

In order to better serve the public, the existing research should innovate and improve the technology. By summarizing the excellent case experience at home and abroad, this paper promotes and applies it from three aspects: government policy support, advanced technical support, and extensive public support [12].

DOI: 10.54254/2755-2721/85/20240740

5.1. Government policy support

In the areas with the rapid development of roof gardens, local governments have well combined with their own geographical environment and natural conditions, formulated reasonable and appropriate relevant laws and regulations, and given certain economic support to the builders of the roof garden, and clarified the responsible person and the beneficiary subject of the roof garden, so that the construction, landscape design and roof planning get a harmonious development. Roof gardens have also been effectively promoted.

5.2. Advanced technical support

The pursuit of natural and landscape environment is based on the improvement of social infrastructure services, and the roof garden in many areas with relatively backward economic development is still only a kind of landscape luxury accessory existence, so the government in the economically developed areas is relatively more able to research the experience and practice of the roof garden technology is an essential and important way of technological progress. Only by encouraging and supporting researchers to carry out innovative designs and combining with the introduction of advanced technology from various countries can we promote the progress of roof garden construction technology in the whole region.

5.3. Extensive public participation

The support of the public is essential, whether it is the participants in the construction or the users after the completion. The builders are not just working hard and time-consuming but creating an urban landscape rich in economic and social value to promote the widespread use of roof gardens. The users should protect and cherish the roof garden and provide their own support for the later maintenance of the roof garden.

6. Conclusion

From the perspective of urban harm, this paper discusses the ways to solve urban problems based on the ecological benefits of roof gardens and highlights the direct differences between different types of roof gardens through a comparative analysis of examples of roof gardens.

This study found that roof gardens have four ecological benefits: air purification, stormwater runoff reduction, heat island mitigation, and biodiversity conservation. On the one hand, through the rational allocation of plants, plants can be used to absorb dust and reduce carbon dioxide, to achieve the effect of improving air quality and mitigating tropical benefits of roof gardens. On the other hand, by building a reservoir or drainage pipe on the roof, the pressure of rainstorms on the urban drainage system can be reduced to some extent. At the same time, the roof garden can provide a living environment for flowers, birds, fish, and insects, which is conducive to the protection of biodiversity. In addition, this paper proves the wide applicability of the roof garden by introducing the roof garden of the hotel apartment, apartment roof garden, and other examples. Case studies also show that it is possible to alleviate urban diseases by building roof gardens in rainy or urbanized areas. To better make the roof garden serve the public, it is necessary to promote and apply the roof garden from three aspects: government policy support, advanced technical support and extensive public support. At present, the research of roof gardens has been very in-depth, and it has a very wide range of applications at home and abroad. But if rooftop gardens were applied to entire cities, the ills of urbanization could be eradicated. It is expected that the further development of science and technology can make the roof garden fully popular.

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