ISSN 2959-6157

Research on the Updating and Selection of Greening in Sponge Cities

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Abstract:

With the frequent occurrence of urban waterlogging, the concept and construction of sponge city have been carried out in many inland cities. Urban greening is not only an integral and important part of sponge cities, but also has a considerable impact on climate and urban landscape. This paper analyzes the function and existing problems of sponge city greening. In the past planning, the selection of certain trees brought problems such as flying catkins and pollen to people's lives. Not only are they an allergen for many residents, but they also pose a fire hazard. At the same time, the construction of some green facilities lacks rationality. They are not only difficult to play the role of interception, but also easy to water in the flower bed in rainy weather, resulting in root rot. In addition, this paper also discusses the improvement of tree species and greening facilities. For some problem trees which are planted in a large area and difficult to renew in a short time, some mitigation measures are put forward. Finally, the vertical greening and rainwater gardens which have great potential in the green selection of sponge city are introduced. This paper is devoted to exploring more scientific and reasonable choices in the greening of sponge cities, while alleviating urban waterlogging and minimizing the impact on residents' lives.

Keywords: Sponge city, city greening, city updating.

1. Introduction

In recent years, numerous inland cities have initiated the construction of sponge cities to address the considerable surface runoff resulting from short-term intense rainfall. A sponge city refers to a city that can function like a sponge, demonstrating excellent resilience in adapting to environmental alterations and responding to natural disasters. It absorbs and retains water during rainfall and releases and utilizes the stored water as required. During the construction of sponge cities, the systematic nature of natural precipitation, surface water and groundwater should be coordinated, and their complexity and long-term nature should be taken into account. Among these, greening constitutes a vital component of sponge cities. Due to purposes like ornamental and shading, trees are extensively planted in cities. Simultaneously, plants can store and fix a certain quantity of water to achieve the goals of reducing the peak of runoff and delaying the occurrence time of the peak. Nevertheless, the construction of sponge cities does not entail completely dismantling and replacing the traditional drainage system; instead, it aims to alleviate the pressure on the traditional drainage system and complement it. Therefore, in addition to upgrading pipelines and constructing water storage tanks and other major facilities, the improvement of the original greening facilities is prone to being overlooked, and many places still employ the previous greening facilities. Moreover, there are numerous problems in these plans. Many street trees are distributed in paved roads with only a thin layer of soil, which is ineffective in reducing runoff. Some flower beds are unable to discharge excess water after reaching their absorption capacity limit, readily causing root rot in plants. Even the existence of many trees themselves can give rise to multiple issues. The flying catkins of poplar and willow, the dense small fruits of privet and banyan trees on the ground, and plants with peculiar odors such as Photinia have caused significant distress among urban residents. Consequently, this paper is committed to undertaking certain planning and renewal of the greening in sponge cities to fulfill the role of regulating precipitation runoff in sponge cities while exerting a lesser impact on the daily lives of residents.

2. The Functions and Existing Issues of Sponge City Greening

2.1 The Function of Greening

2.1.1 Mitigate urban waterlogging

During the process of urbanization, a multitude of urban ecological spaces have come into being. Notably, the area of artificially hardened regions has been constantly expanding, leading to over 70% of rainfall being transformed into runoff for discharge. The phenomenon of urban waterlogging has been exacerbated day by day, exerting a severe impact on the normal life of residents. In light of this, stormwater detention and storage have emerged as the core objective of sponge city construction. Urban greenery serves as a crucial carrier for the construction of sponge cities, capable of effectively mitigating and controlling urban stormwater runoff, achieving the outcome of in-situ detention and storage of precipitation, and facilitating the resource utilization of rainwater. When it rains, urban greening can absorb and stabilize a portion of surface runoff, and subsequently promote the return and circulation of water resources through transpiration. Urban green infrastructure encompasses a wide range of landscape types, such as parks, public green spaces, green corridors, street trees, urban forests, vertical greening, and so forth. Although its efficacy in intercepting rainwater is marginally inferior to measures like excavating and constructing reservoirs, greenery still plays a significant role thanks to its extensive coverage area. Currently, in accordance with the regulations of national garden cities and national ecological garden cities in China, the urban green space rate stands at 31% and 35% respectively, and some advanced cities have reached or even surpassed 40%. Moreover, with the development of urban rooftop greening and the integration of vertical greening in the future, green space is anticipated to cover more than 70% of the built-up area [1]. Simultaneously, urban greenery also possesses numerous functions such as providing shade, purifying the air, reducing noise, and alleviating the urban heat island effect. Hence, it is evident that urban greenery plays a pivotal role in the construction of sponge cities. It ought to be meticulously planned, and appropriate approaches should be adopted to transform urban green spaces, with the aim of enhancing their ecological and sponge benefits.

2.1.2 Beautification of urban landscapes

In the landscape design of modern urban road greening, the sponge city theory is adopted, adapting to local circumstances to forge a living environment featuring an integrated sense and a distinct landscape image, thereby elevating the well-being of urban residents. The application of the sponge city theory enables comprehensive planning during the design process, optimizes water resources, selects appropriate aquatic plants, and emphasizes the creation of a green space ambiance with rich spatial hierarchies and an exquisite artistic conception. The original water system is integrated with the sponge city concept, and through the convergence of the core and nodes, it forms an entirety. The overall road greening is ecologically natural with an amiable and appropriate scale. It also enhancing the adaptability of the city, facilitating urbanization construction and escalating the happiness index of residents.

2.1.3 Optimization of the urban ecological environment in sponge cities

During the high-temperature summer season, large-leafed and crown-shaped trees not only effectively shield against solar radiation but also absorb heat through their evapotranspiration process, thereby effectively modulating the temperature. Concurrently, air quality and noise within cities have consistently been among the factors influencing the normal lives of urban residents. The street trees flanking the roads can absorb the carbon dioxide emitted by vehicles through photosynthesis, thereby enhancing air quality. They can also utilize their leaves to intercept the dust in the air, effectively precluding the occurrence of dusty scenes. The noise issue resulting from vehicles can also be effectively mitigated by the planting of street trees, alleviating the noise-related distress endured by urban residents. Street trees also exert a significant role in enhancing the aesthetic appeal of the city. It effectively counterbalance the rigidity imparted by reinforced concrete structures and elevating the comfort level of residents' lives. Also, it adding a splash of color to the urban landscape.

2.1.4 Enhancing people‘s health level

The research team of the University of Alabama carried out a study in 2023, primarily verifying the "20-minute park effect" from the perspectives of physiology and biochemistry. Beyond questionnaires, the researchers selected urban parks as the research venues. Simultaneously, saliva samples of the participants were collected to determine the concentrations of cortisol and dehydroepiandrosterone, hormones representing stress indicators within their bodies. The outcomes revealed that 76.7% of the tourists involved in the study expressed that they felt relaxed and experienced an enhancement in their sense of well-being after visiting the park. Significantly, 78.3% of the tourists exhibited a notable decline in cortisol levels after visiting the park, signifying effective stress alleviation. Concurrently, the decrease in dehydroepiandrosterone concentration was greater than that under the natural state, with an average reduction reaching 27%. These studies explicitly point out that greenery confers benefits to people's physical and mental well-being. When strolling in the park for over 21.8 minutes, a reduction in the cortisol level within the human body can be detected [2]. Hence, both psychological sensations and physiological and biochemical indicators substantiate the positive influence of visiting parks on people's physical and mental health. Disregarding the intricate scientific principles, a simplistic comprehension is that a brief respite in the green landscape can conspicuously lower the levels of cortisol and dehydroepiandrosterone in the human body. The reduction in these hormone levels mitigates stress.

2.2 Existing Problem

2.2.1 The growth and survival issues of street trees

In urban greening, a considerable number of trees are planted in paved areas, where the exposed soil portion is relatively limited. The root systems of these trees are unable to extend effectively, and normal growth requirements cannot be fulfilled merely through daily precipitation. Simultaneously, it proves challenging to retain a substantial amount of runoff during rainfall. During periods of intense heat, if adequate water retention measures for trees are not executed and specific actions, such as spraying water to moisturize and cool the tree crowns, are not adopted, the survival rate and normal growth of the trees will be profoundly impacted. For certain flood-intolerant tree species planted in cities, meticulous attention must be paid to drainage during the planting process. In numerous regions, when planting trees, adding flower beds or fences that stand higher than the curb around the soil periphery can readily give rise to water accumulation (as shown in Fig. 1). In seasons characterized by abundant precipitation, the underdeveloped root systems and shallow soil, upon reaching their absorption ceilings, accumulate in the flower beds and prove difficult to drain away. This can result in root rot and the inability of the trees to survive.

Fig. 1 Street Trees [3]

2.2.2 The negative impacts brought by some tree species

Beyond taking into account the water absorption capacity and landscape value of trees, it is essential to comprehensively assess the potential implications they may entail. For example, in regions like Shaanxi and Anhui, poplar and willow trees are extensively cultivated. During the late spring and early summer period, a copious amount of poplar and willow catkins flutter throughout the cities, posing substantial inconveniences to the lives of residents. Individuals with allergic predispositions, upon contact or inhalation of substances such as willow and poplar catkins and pollen, are susceptible to symptoms like runny nose, sneezing, and shortness of breath. Skin contact can readily induce skin itching, swelling, or even desquamation, and when entering the eyes, it may trigger conjunctivitis and other symptoms. Concurrently, poplar catkins contain a significant quantity of plant fibers, which are combustible substances and possess a dry characteristic. They have a low ignition point and a rapid combustion rate. Once encountering a fire source, combustion incidents can transpire, augmenting their hazardous nature. Poplar catkins have a fluffy structure and are prone to accumulation within a short time span. When aggregated, they tend to form a clustered configuration. This renders poplar catkins likely to intensify the fire upon encountering an open flame. If not addressed promptly, they might also be carried by the wind and spread the fire to other objects.

2.2.3 The blind pursuit of high-efficiency facilities

The greening concept of sponge cities lies in enhancing the soil through appropriate means without impeding the normal growth of greenbelt trees and the satisfactory performance of their ecological functions, thereby augmenting the sponge benefits of rainwater interception and infiltration. If, merely for the pursuit of greater benefits, rather than adopting measures in line with local conditions, facilities like bioretention facilities, grassed swales, and sunken greenbelts are indiscriminately promoted and utilized. The greenbelts are excavated to a considerable depth with storage and infiltration facilities subsequently installed beneath. Ultimately, this results in the decline of large trees, leaving only low-growing vegetation to be employed in conjunction with various facilities, and even causes the greenery of the city to lose its vitality.

3. The Updating and Selection of Greening in Sponge Cities

3.1 Roadway Greening

In the context of road greening, all aspects of street trees must be comprehensively contemplated, including factors such as rainwater interception, shading provision, growth duration, defoliation, odor emission, and allergenicity. Concerning the rainwater interception capacity of tree canopies, that of coniferous arbor trees approximates 3.1

to 16.7 mm, broadleaf arbor trees range from 3.3 to 5.5 mm, and broadleaf shrubs fall within 3.2 to 5.7 mm. The factors influencing the canopy's interception capacity are highly complex, and the data obtained by different scholars through diverse methods exhibit variations. Nevertheless, in general, it can be deduced that the rainwater interception capacity of single-layer plants lags behind that of the multi-layer structure combining arbors and shrubs, and the rainwater interception rate of coniferous tree canopies exceeds that of broadleaf trees. Hence, when planning the greening layout, greater consideration could be given to the vertical planting configuration integrating coniferous arbor trees and shrubs [3].

Secondly, measures ought to be implemented for certain trees that might have an impact on the daily lives of residents. For instance, poplar and willow trees, which are extensively cultivated in the north, release catkins during the period from April to June each year. During the planning stage, the utilization of female poplar trees should be curtailed, and more improved male poplar trees should be employed. Simultaneously, efforts should be expedited to adjust the tree species structure and vigorously promote the cultivation of high-quality tree species to alleviate the environmental pollution induced by poplar catkins. For poplar trees that have been extensively planted or possess a long history, catkin suppressants such as Yihua No.1, Zhiyuan, and gibberellin, or soluble collagen can also be employed to address the catkin problem. However, the annual expenditure for this is substantial. Concurrently, plants with allergenic pollen should be meticulously considered during planning. Many regions have already initiated large-scale renewal of allergenic tree species. For example, in Beijing in 2021, pollen allergen tree species such as Juniperus and Sabina were replaced on a considerable scale with Exochorda [4].

Finally, rational planting is indispensable, and the planting density and soil content of road greening should be meticulously planned. The spacing between street trees can also exert an influence on the canopy coverage area. On one hand, the central reservation greenbelt typically consists of small arbor trees or shrubs, and a tree spacing of 3-5 meters enables more efficient utilization of the greening space and generates a greater canopy coverage. On the other hand, the sidewalk greenbelt and roadside greenbelt often lack a reasonable estimation of the canopy size of greening trees, and the issue of narrow tree spacing prevails. This leads to canopy intersection, which not only impedes the normal growth of trees but also hinders the enhancement of canopy coverage. Similarly, in locations with narrow sidewalks, compact spatial conditions, and close proximities between trees and buildings, a deficiency in reasonable anticipation of future canopy scale can impede canopy growth, prevent the normal development of some large-canopy tree species, and even escalate unnecessary maintenance and management costs. For instance, large-canopy trees planted in the green spaces between residential buildings not only compromise normal lighting and ventilation requirements but also necessitate regular tree pruning. This inflates the cost of tree management. It is also feasible to appropriately augment the land area. As depicted in Fig. 2, the land of several adjacent trees can be consolidated to facilitate tree growth and prevent the surrounding pavement from being compromised by tree roots.

Fig. 2 New Type of Street Tree Facilities [1]

3.2 Vertical Greening

In the current urban greening construction landscape, vertical greening undoubtedly holds vast potential. It not only exploits numerous spaces for rainfall absorption but also exhibits functions such as dust reduction, noise mitigation, air purification, and microclimate regulation, enabling residents to tangibly experience its benefits. The development of vertical greening undoubtedly holds positive significance in surmounting the bottlenecks of urban greening. The principal types of vertical greening encompass wall greening, corridor frame greening, slope greening, bridge greening, column greening, roof greening, balcony and window sill greening, among others. In terms of the adopted technical modalities, they are predominantly natural and artificial. Natural vertical greening refers to the form where plants are directly planted on the ground, slopes, walls, etc., and grow to cover the vertical surface based on their inherent growth characteristics or with the assistance of support structures. Artificial vertical greening, on the other hand, is a method of vertical greening that relies on planting beds such as planting troughs and planting blankets. This article primarily focuses on wall and roof greening, which are more universally applicable and offer greater greening benefits. In roof greening, the load-bearing capacity of the roof needs to be taken into account initially, namely whether it can withstand the weight of plants and water-absorbed soil. Some structures with expansive roof areas but simplistic load-bearing configurations, such as old stadiums that primarily rely on the walls for load-bearing, might be incapable of supporting roof greening. Roof greening can be classified into four types: garden-style, pergola-style, carpet-style, and potted flower arrangement style. Owing to the constraints of the roof greening area, plants selected for roof greening are typically those with strong resilience, low stature, shallow root systems, and ease of transplantation, such as Bermuda grass, Sedum lineare, Commelina communis, Lantana camara, Hibiscus syriacus. For wall greening, it is advisable to opt for the use of ropes, grids, to assist in shaping landscapes, as shown in Fig. 3, and to regularly clear away dead leaves to maintain aesthetic appeal. When developers regard wall greening as a selling point and consumers also consider greening as part of their house-purchasing considerations, the incentives and positive feedback it generates undoubtedly constitute an important driving force for the advancement of vertical greening.

Fig. 3. Vertical Greening Plant Wall at the Shanghai [5]

3.3 Rain Garden

A rain garden is a shallow concave green space that is either artificially excavated or naturally occurring. Its operational process primarily comprises “rainwater retention - infiltration - purification - water storage - recycling”. It is capable of absorbing natural rainfall or surface water and, via the influence of plants and the sandy soil beneath them, attains the objective of absorbing and purifying water quality. These surface waters, subsequent to purification in the rain garden, infiltrate underground to replenish groundwater, thereby actualizing the recycling of rainwater.

In urban areas, construction can be initiated around certain existing puddles or wetlands. Through the combined planting of aquatic and terrestrial species, with Acorus calamus serving as the principal water-purifying plant and complemented by other ornamental plants such as Schefflera octophylla, Nephrolepis auriculata, Euryops pectinatus, Tulbaghia violacea, Coreopsis basalis, a captivating landscape is created [6]. This facility not only precludes the emergence of black and odorous water bodies within the city, mitigates urban waterlogging to a certain degree, but also attracts residents and tourists for appreciation and recreation, offering coolness and shade to citizens during the torrid summer.

4. Conclusion

This paper summarizes the benefits and functions of greening in sponge cities, encompassing alleviating urban waterlogging, regulating the urban microclimate, enhancing the landscape, and modulating the hormone levels within the human body. These functions are intimately related to people's lives and hold considerable significance. Nevertheless, concurrently, there exist several problems in the selection, planning, and planting facilities of greening, including phenomena such as catkins, pollen, and odors emanating from tree species themselves that adversely affect people's daily lives, along with the utilization of inappropriate planting facilities.

This paper examines the selection of street trees and facilities. Some trees with strong interception capabilities are given preference, and the impact on residents' lives is mitigated. Certain trees that have been extensively applied but have negative implications can have their hazards reduced through specific treatments. Simultaneously, some facilities with substantial development potential, like vertical greening and rain gardens, are anticipated to play a crucial role in intercepting and purifying rainwater in the future.

In the current greening of sponge cities, there are certain challenges in addressing these improvement issues. Firstly, a significant number of original plans can only be iteratively updated gradually. Simultaneously, in new urban construction, economic factors must be considered, and some fast-growing trees are inevitably employed. Moreover, most vertical greening requires advance design and planning of its feasibility prior to building construction, which undoubtedly decelerates the pace of large-scale implementation. Nevertheless, every optimization and improvement of urban greening facilities will contribute to the alleviation of urban waterlogging and the enhancement of the residents' experience.

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