

Analysis on the Microclimate Landscape Design of South China Gardens - Evidence from Qinghui Garden in Guangdong Province

Yuyi Zheng¹, Na Chang^{1*}

¹ School of Fine Arts, South China Normal University, Guangzhou, China

Email Address

309784066@qq.com (Na Chang)

*Correspondence: 309784066@qq.com

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Abstract:

This research aims to provide a positive reference for current landscape design. Based on the application of microclimate landscape design of South China Garden with Lingnan style of construction, the author analyzed the site environment characteristics, spatial layout, and users' perception of the space under microclimate conditions by taking Qinghui Garden, one of the four famous gardens in Guangdong Province, as the research object, and applying structured observation and qualitative research methods to explore the multiple environmental impacts of microclimates and then summarize the laws and effects of microclimate landscape design factors. Thus, the design suggestions were proposed as follow: first, corridors and plants could be used in the semi-open space to create a microclimate environment; the irregular shape of the water body is better than the geometric shape for cooling. Dispersed and irregularly shaped water bodies are the best for cooling. Third, Through landscape design, stone is used to create heat dissipation and air flow conditions in the space, changing the microclimate of the site. The study of these classical Lingnan garden micro-climate principle can play a positive role in the current landscape design.

Keywords:

Microclimate, Structured Observation, Qinghui Garden, Landscape Design

1. Introduction

Microclimate is the part of the ground boundary layer, whose temperature and humidity were affected by ground vegetation, soil and topography [1], in other words, it refers to the climate of a small local area, and the environmental characteristics of the microclimate can be improved [2]. As one of the design elements, it includes sun exposure, wind exposure and precipitation accumulation [3]. It is the small-scale climate form of different plots formed by the deviation of the climate in a specific area within a few kilometers [4]. The climate in a tiny space near the ground covers the environment ranging from tens of centimeters to tens of meters of vertical space,

not exceeding 150m. The microclimate is susceptible to factors such as surface heat in the landscape and water molecules , due to the close distance from the ground. [5] Although the description of the microclimate is different, it is commonly believed that it is to study the influence of various conditions on changing the climate in a small scale, and to create good temperature conditions for the space through landscape design. According to the amount of solar radiation, wind, precipitation or humidity and the resulting temperature, microclimate provides different levels of human comfort. [6] Microclimate comfort refers to the state of satisfaction that people feel in a small-scale climate environment. It can be evaluated according to human comfort, and related technologies, methods and measures can be taken to improve it. [7] The above research proves that the principle of microclimate helps to improve the landscape space environment.

2. Material and Method

2.1. Overview of the Case

The research case Qinghui Garden is located in Shunde District, Foshan, China, and its geographic coordinates are 113.255017N, 22.835519E. The region has a subtropical monsoon climate, especially hot and rainy in summer. The Lingnan garden building, which was built in the Ming Dynasty, is one of the four major gardens in Lingnan. It covers an area of 22,000 square meters. Qinghui Garden inherits the characteristics of Lingnan gardens with small scale and exquisite layout. The space of each area is relatively independent but interrelated. (Figure 1, Figure 2) There are tall trees and deep pools, good layout of water and piled-up stones, and routes full of flowers and trees in the park. It shows the super high art of gardening.

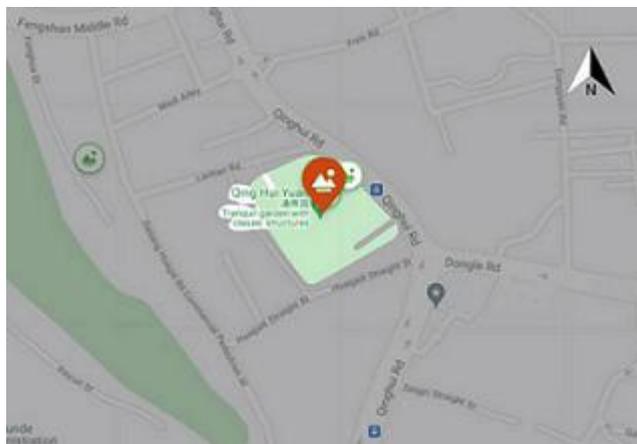


Figure 1. Satellite image of Qinghui Garden.



Figure 2. Floor plan of Qinghui Garden.

2.2. Selection of Characteristics of the Research Area

The specific space selected for the study is the main component of Qinghui Garden, such as the five observation points A, B, C, D, and E marked in (Figure 3). Through detailed research and analysis of these five garden landscape spaces with similar areas and representative spatial layouts (Figure 4), the factors affecting these microclimate changes include: sunshine, wind direction, water, stones, plants, etc. (Table 1).

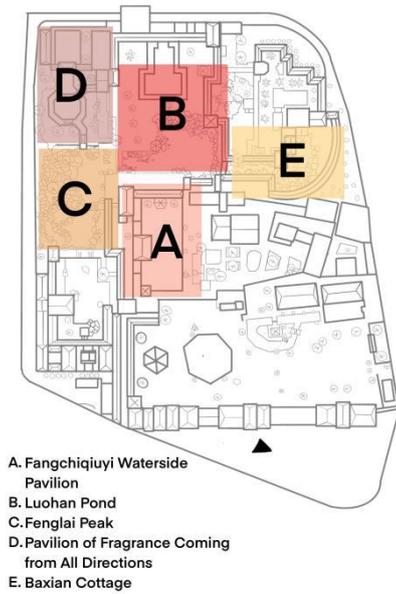


Figure 3. Floor plan of the locations of the test points.

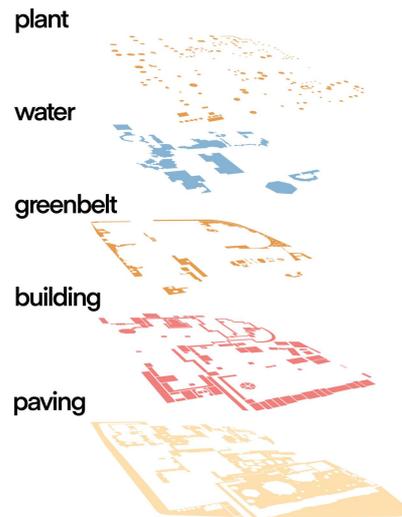


Figure 4. Layout of space elements space elements.

Table 1. The basic situation of the test points of Qinghui Garden.

Basic Information of the Observation points of Qinghui Garden							
Code of Observation Point	Location	Building Form and Material	Stones	Plants	Water and Drainage System	Paving Materials	Images from the Scene
A	Fangchiqiuyi Waterside Pavilion	corridor connecting the rectangular water pavilion, thatched hall and hexagonal pavilion in series	small stones from Yingde City of Guangdong Province around the tree pool and small arch	8 microphanerophytes; few bushes	geometric rectangle with large area of open water	pebbles; burnt granite; red sandstone floor tiles	
B	Luohan Pond	Hexagonal pavilion and corridor connecting the four-corner pavilion	granite stones vary in size and shape like ribbon in the pond	3 macrophanerophytes; 8 microphanerophytes; several bushes	natural form with fountain	square mud brick; gray granite; burnt granite	
C	Fenglai Peak	Corridor on the right and quadrangular pavilion	granite stones from Shandong Province are used	3 mesophanerophytes; several microphanerophytes and bushes	natural form with large flat and vertical area	red sandstone floor tiles; pebbles; burnt granite	

			to build an artificial hill				
D	Pavilion of Fragrance Coming from All Directions	octagonal water pavilion, lounge bridge and corridor	granite stones are piled up to make small hill view	3 macrophanerophytes; several mesophanerophytes and bushes	geometry with small areas surrounding the building	Square mud brick; Red sandstone floor tiles; Burnt granite	
E	Baxian Cottage	three single-family buildings with multiple corridors	stones from Yingde City of Guangdong Province are piled up as hill, and they are also used as a revetment beside the stream to create a small scene	several microphanerophytes; various of bushes	natural irregular shape with small areas of artificial atomization	square mud brick; red sandstone floor tiles; burnt granite	

2.3. Research Method

This research adopts the method of microclimate analysis and structured observation to obtain the landscape space design method and principle under the microclimate of Lingnan gardens. [8] In this study, some documents related to “Lingnan Garden”, “Qinghui Garden”, and “Microclimate” were searched through websites such as CNKI, Elsevier and Springer. This study analyzes the site combined with structured observation methods, studies the role of microclimate in Lingnan gardens, and summarizes and inherits the classic microclimate design methods in classical gardens.

2.3.1. Structured Observation Method

The structured observation method was proposed by Dr. Visas Mehta. [9] The structured observation method was used to conduct object sampling, time sampling, scene sampling, etc. for the constituent elements of the space and human behavior.

The best point of view is selected in the site, and the observation activities are limited to a certain range. In-depth field surveys are conducted, questionnaires are designed, and space examples are visited, investigated, photographed to collect actual data for statistics and analysis. [10]

3. Results and Discussion

3.1. Microclimate Analysis of Qinghui Garden

Qinghui Garden embodies the wisdom of dealing with the hot and humid climate in the area in its courtyard layout and ventilation design. At the same time, it also forms a courtyard construction technique with Lingnan characteristics. Natural ventilation is actively used in the courtyard layout to form a comfortable and pleasant microclimate. The basis and standard for the microclimate is human comfort. Human body comfort includes many aspects: thermal comfort, visual comfort, smell and hearing comfort with comprehensive reasons such as history, geography, culture, and ethnicity. Among them, thermal comfort has the greatest impact on the human body. [11]

From the perspective of spatial layout analysis, Mr. Liu Guanping believes that the design of Qinghui Garden is mostly landscaping and the overall layout of Qinghui Garden is adapted to the southern climate. The garden as a whole conforms to the prevailing wind direction in summer. The courtyard is built from sparsely to densely, with the building low in the front and high in the rear, forming a garden environment suitable for living and viewing. [12] Fang Xiaoshan and others [13] mentioned in his simulated research on the ventilation design elements of Shunde Qinghui Garden's layout that the layout of Qinghui Garden's ventilation design strategy is "The scale of the garden should be suitable, and the wind should be introduced into the garden." "There are wind outlets in the east and west, and wind corridors in the north and south." The appropriate scale of each ventilation element of Qinghui Garden and its key points of ventilation design provide a reference for the design of contemporary Lingnan Garden.

Wang Yuefen and others [14] believe that the inner courtyards of Lingnan classical gardens account for a relatively large proportion and tend to create open spaces with water as the core. Under the condition of external view borrowing, the internal space structure can be adjusted to strengthen the contrast between internal and external to achieve greater spatial transformation effects.

The water body also plays an important role in cooling down, especially in the hot and humid summer in the south. The coastal area often blows from the southeast wind, which provides a continuous flow of cool air to the middle and north of the courtyard. Whenever the hot monsoon blows from the south, the cool breeze is formed after cooling by the pool. A gust of wind blows from the front to the Miss Building and Xiyin Bookstore by the central pool; the other wind blows to the garden courtyard next to the Xiyin Bookstore, which has a good effect on regulating the temperature of the courtyard.[15] The above research proves that the spatial layout of Qinghui Garden produces a comfortable microclimate for the human body.

3.2. Results from Structured Observation

This case sets the best observation point and the behaviors of the masses, the recording time interval to formulate the form template before the recording is carried out, and chooses to conduct observations at the same time when the flow of people is high on Sunday. And the behavior of the crowd in the venue before the recording is carried out when the flow of people is high on Sunday, and to develop a form template for the recording time interval, and conduct observations at the same time. At the same time, the state of the crowd is different in various environmental characteristics. (Table 2, Table 3, Figure 5)

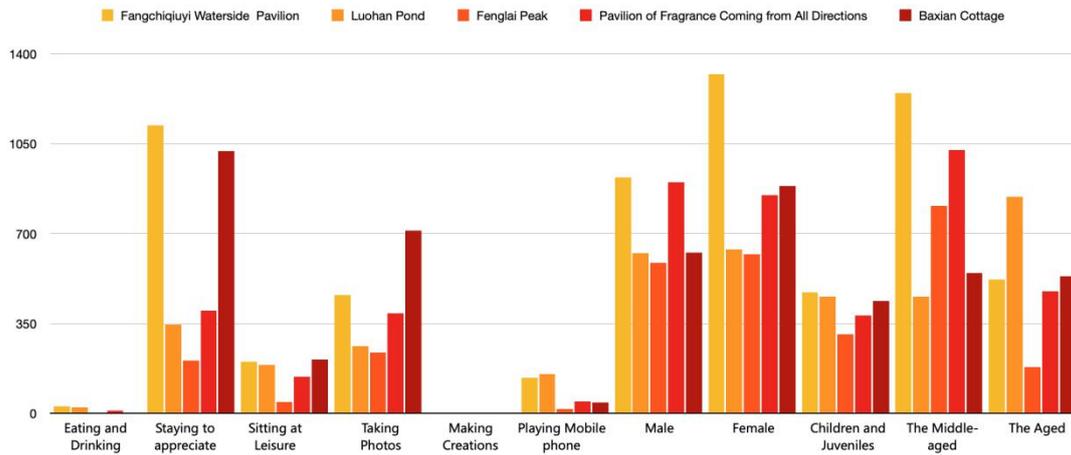


Figure 5. Histogram of structured observation behaviors data of observation points.

Table 2. Summary Table of Structured Observation Behaviors of Observation Points.

Summary Table of Structured Observation Behaviors of Observation Points							
Code of Observation	Location	Eating and Drinking	Staying to appreciate	Sitting at Leisure	Taking Photos	Making Creations	Playing Mobilepho
A	Fangchiquiyi Waterside Pavilion	√	√	√	√		√
B	Luohan Pond	√	√	√	√	√	√
C	Fenglai Peak		√	√	√	√	√
D	Pavilion of Fragrance Coming from All Directions	√	√	√	√		√
E	Baxian Cottage		√	√	√	√	√

Table 3. Summary Table of the Data of Structured Observation Behaviors of Observation Points.

Structured Observation Behavior Data at Observation Points												
Code of Observation Point	Location	Eating and Drinking	Staying to appreciate	Sitting at Leisure	Taking Photos	Making Creations	Playing Mobilephone	Male	Female	Children and Juveniles	The Middle-aged	The Aged
A	Chengyi Pavilion	27	1122	201	461	0	139	919	1321	471	1247	522
B	Luohan Pond	24	346	190	262	1	153	624	639	454	454	844
C	Fenglai Peak	0	206	44	237	0	18	587	620	308	808	181
D	Pavilion of Fragrance Coming from All Directions	12	401	143	389	0	46	899	849	382	1026	476

E	Baxian Cottage	0	1022	209	712	0	42	625	885	438	547	533
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3.2.1. Observation Site A

The solar radiant heat is blocked by the buildings in the space. The building surrounds the water area with a linear space of corridors, water pavilions, thatched cottages, and hexagonal pavilions. Because a large area of water can absorb most of the heat, the trees can provide shade, and people will feel comfortable on the edge of the pool. Because the large area of the water can absorb most of the heat and the trees can provide shade, people by the pool will feel comfortable.

The first water area in the park is the largest water system in this park, so there is a large flow of people. It has a rigid revetment of the regular geometric shape. There are no excessive plants and only 8 trees in this water area, which play a role in shading. In the east and west of the square pool, the corridor connects the waterside pavilions, the thatched cottages and the pavilions to form a space suitable for shading and enjoying the coolness.

The east and west sides of the square pool are connected by corridors to connect the pavilion, thatched pavilion and pavilion to form a space suitable for shading and enjoying the coolness. There are corridor buildings, plants, and water systems around which are clearly partitioned. There are obvious partitions around the square pool, including corridor buildings, plants, and water systems. As there is no shelter from a large number of plants, the exposed area on the right is hot, which is inversely proportional to the corridor on the left (Figure 6).

According to the Figure 7, we can see that the crowd stay for the longest time in the corridor and water pavilion area, and the most frequent behavior is to watch the beautiful scenery.

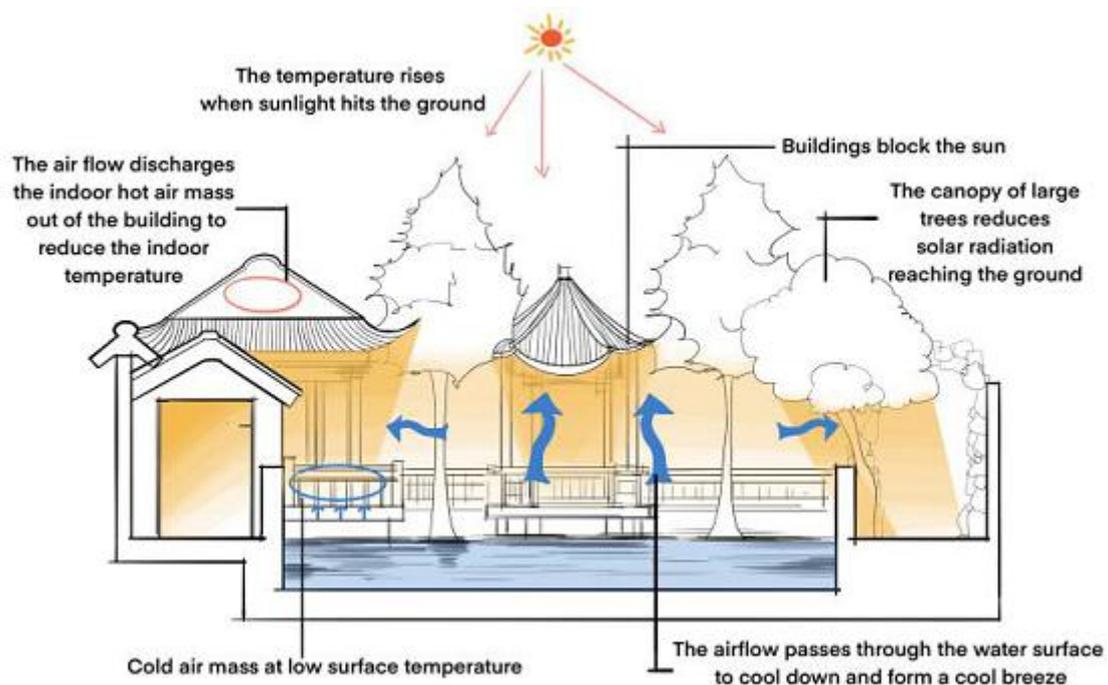


Figure 6. Schematic diagram of microclimate at observation site A.

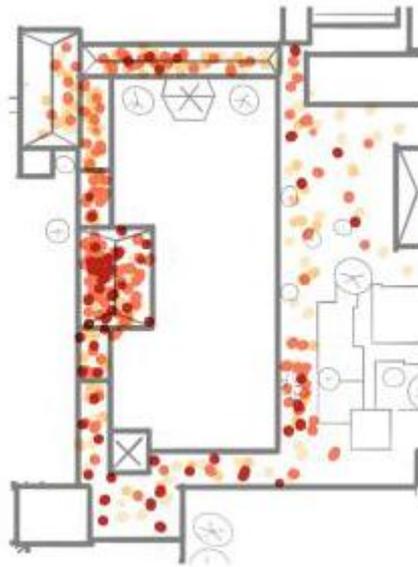


Figure 7. Schematic diagram of population distribution at observation site A.

3.2.2. Observation Site B

Three large trees are planted here, which are higher than the building. The huge tree canopies provide shade for almost the entire Luohan Pool. The solar radiation is first weakened by the tree canopies and the building further reduces the temperature. The irregular stones on the ground scatter heat from a small amount of solar radiation. And the heat is also weakened by the small bushes between the stones. The water body absorbs the remaining heat, and the artificial fountain creates a large amount of water molecules for the space. That is how the comfortable microclimate forms. (Figure 8).

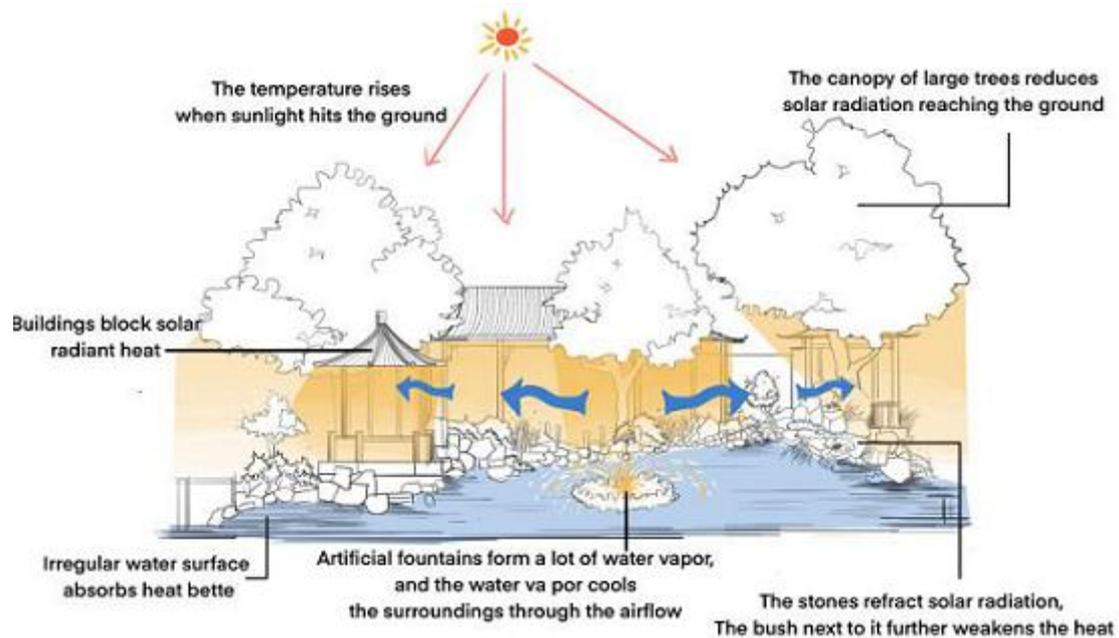


Figure 8. Schematic diagram of microclimate at observation site B.

According to the observation of the crowd behavior in this space as Figure 9, the observation objects on the right side spend more time and have more behaviors, due to there are fewer plants and buildings on the left side than on the right side. In the same comfortable space, the crowd tends to the open corridor space.

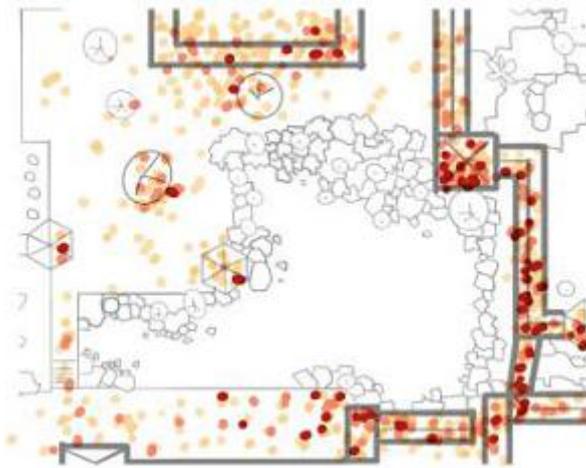


Figure 9. Schematic diagram of population distribution at observation site B.

Both observation site A and observation site B have large areas of water. It is obvious that the irregular water surface is more popular than the geometric rectangular water surface comparing the observation site A with the observation site B, so people will stay longer. The irregular soft revetment water body at observation site B makes people more comfortable than the geometric rigid revetment water body at observation site A. In terms of vegetation structure, the arbor-grass vegetation structure is preferred, which increases canopy density. It is beneficial to cooling, humidifying and ventilation. The larger the shade area of the arbor, the better the temperature and humidity can be adjusted. The waterfront and wood-shaped space is the kind of microclimate thermal comfort space in summer. [16]

3.2.3. Observation Site C

Compared with the other 4 observation sites, observation site C is characterized by a large number of stones. And the rest is almost all water area. There are a few plants among stones. The space is not large. The only building is the pavilion on the top of the mountain and a small corridor. The water is arranged vertically and the stacked rocks make mountains. There are caves in the mountains.

When the heat radiated by the sun reaches the space, there is almost no place to shade. Stacked stones can scatter solar radiation to reduce heat, and bushes can absorb heat. The waterfall plays a real role in cooling down. The water flow falls from a high place and hits the rocks to produce a large number of water molecules in the air. The temperature difference between the inside and outside of the cave forms an airflow, which brings water molecules to the entire space. The water molecules greatly reduces the temperature of the space to form a good microclimate (Figure 10).

Compared with the observation sites A, B, D and E, the observation site C is shallow water. Stones are piled in the water to form a path, So crowds can touch the water, which fully satisfies people's psychology of water loving. The behavior of the crowd in this space varies widely through observation and recording (Figure 11). There are many routes and activities for the crowd. They can go to the mountain to see the scenery and play in the water. The space and people have frequent interactions. Therefore, there are few or no behaviors of staying in this space for a long time, such as eating, playing on the phone, and sitting. The crowd is moving. The microclimate generated by this space is suitable for tourists. If this space want a long stay of the crowd, some buildings can be appropriately added.

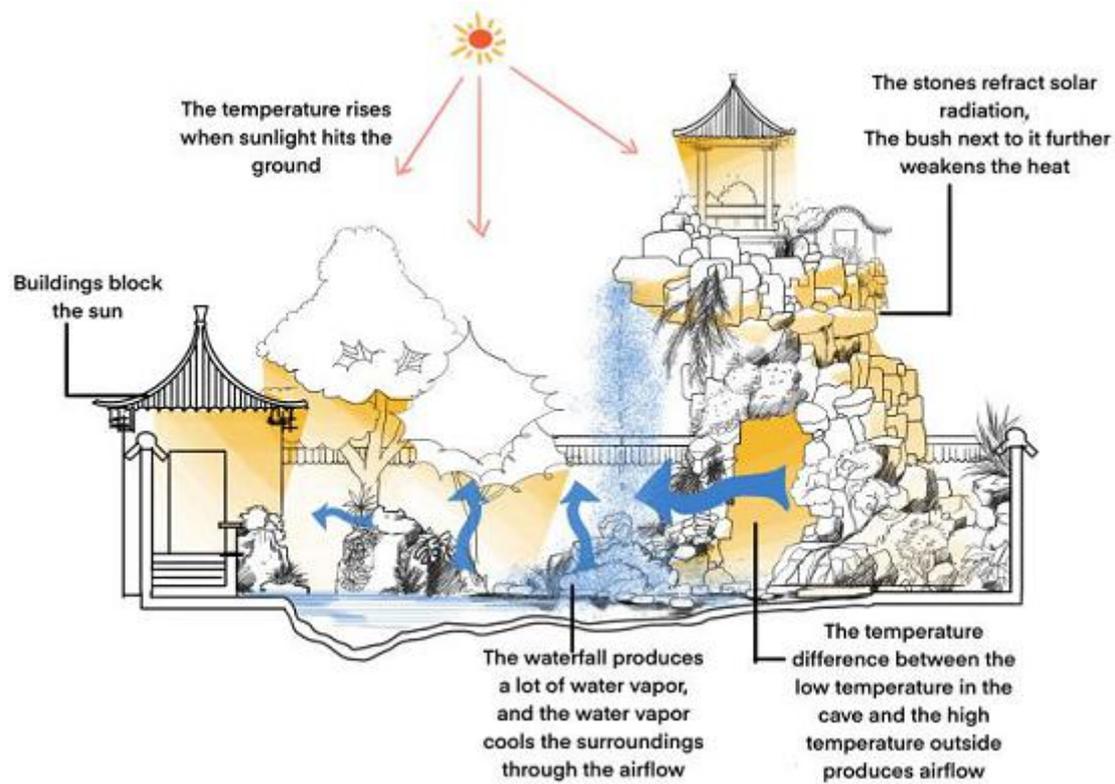


Figure 10. Schematic diagram of microclimate at observation site C



Figure 11. Schematic diagram of population distribution at observation site C.

3.2.4. Observation Site D

Buildings, plants, rocks, and waters are balanced together. Large arbors are planted around the octagonal pavilion on the left, and the huge tree canopies covers the surrounding area for shade. Corresponding small trees and bushes are planted to prevent the heat from reaching the underlying surface under the big arbors. What makes the space cool is the flowing water on the underlying surface. The water is in a small geometric shape and flows throughout the space. The entire waterside pavilion is surrounded by two branches of the flowing water. The building is in the center and its windows with cased glass can be opened willingly. As shown in the figure (Figure

13) the plants and shelter on the left are less than those on the right. There is a temperature difference between the two sides, so the air will be convective. In addition to the artificial fountain, the water molecules in the space are enlarged, and flow in the space to form a comfortable microclimate. The flow of water molecules in each space reduces the temperature in the house. Coupled with a circle of running water outside the building, the temperature of the octagonal pavilion is cool. That is how a comfortable microclimate forms.

From the perspective of structured observation behavior, the number of behavior activities in this space is relatively average compared to several other observation sites. Compared with the observation site C, the underlying surface is also surrounded by water and it also has spatial elements. But too much or too little elements will form a different microclimate, and people's behavior in the space will be affected by the microclimate. According to Table 3, observation site C has a microclimate suitable for tourists to sightseeing, and observation site D has a microclimate suitable for tourists to rest.

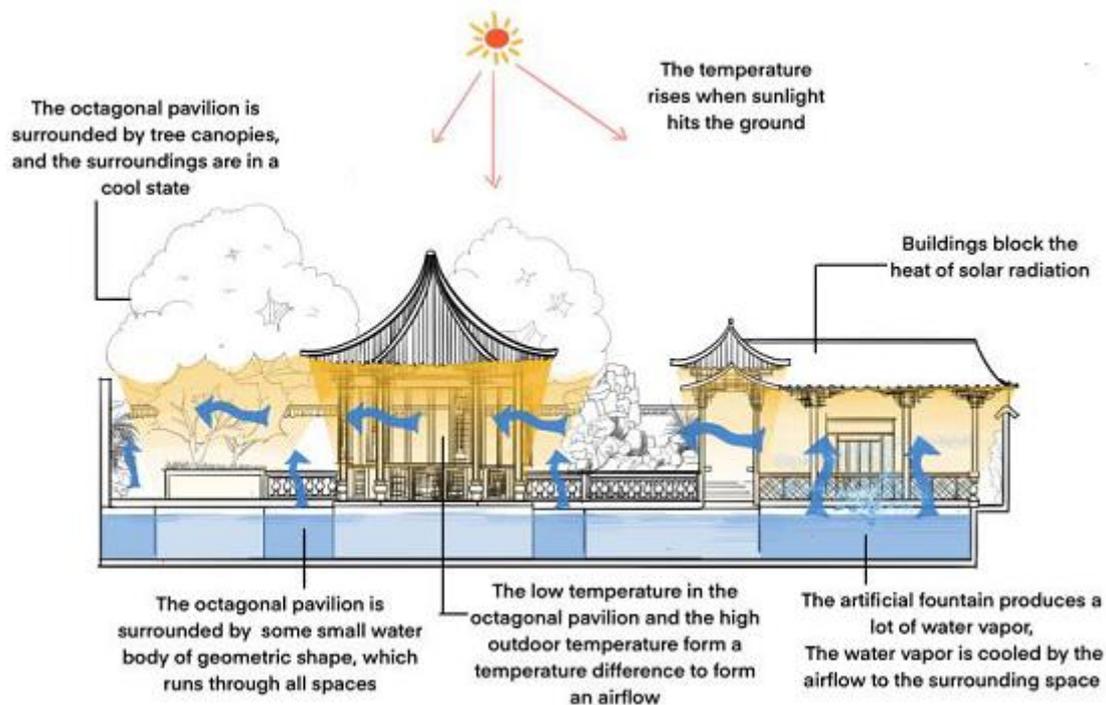


Figure 12. Schematic diagram of microclimate at observation site.

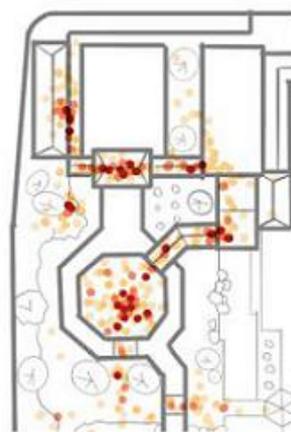


Figure 13. Schematic diagram of population distribution at observation site D.

3.2.5. Observation Site E

This space has many buildings. Detached buildings and multiple corridors form a geometric shape, and a small area of water fills up the excess space. When the heat radiated by the sun reaches the space, and the heat is mainly blocked by the building. The shadow area formed between the space and the building can effectively avoid direct sunlight, and the excess space is the water area, which plays a role in cooling down. The boundary between the building and the water is treated with stones. The stones are piled up to form revetments and hills. The trend of the mountain is consistent with the corridor, and shrubs are planted among the rocks. The rough stone can disperse heat, the mountain is accompanied by layers of flowing water, and the space has an atomization system. That is how the comfortable microclimate forms. Bagneid quantified the microclimate effects of every element in the courtyard: fountains, vegetation, ponds, and surface wetting. [17] Airflow brings the comfortable temperature generated by these elements to each space. (Figure 14, Figure 15).

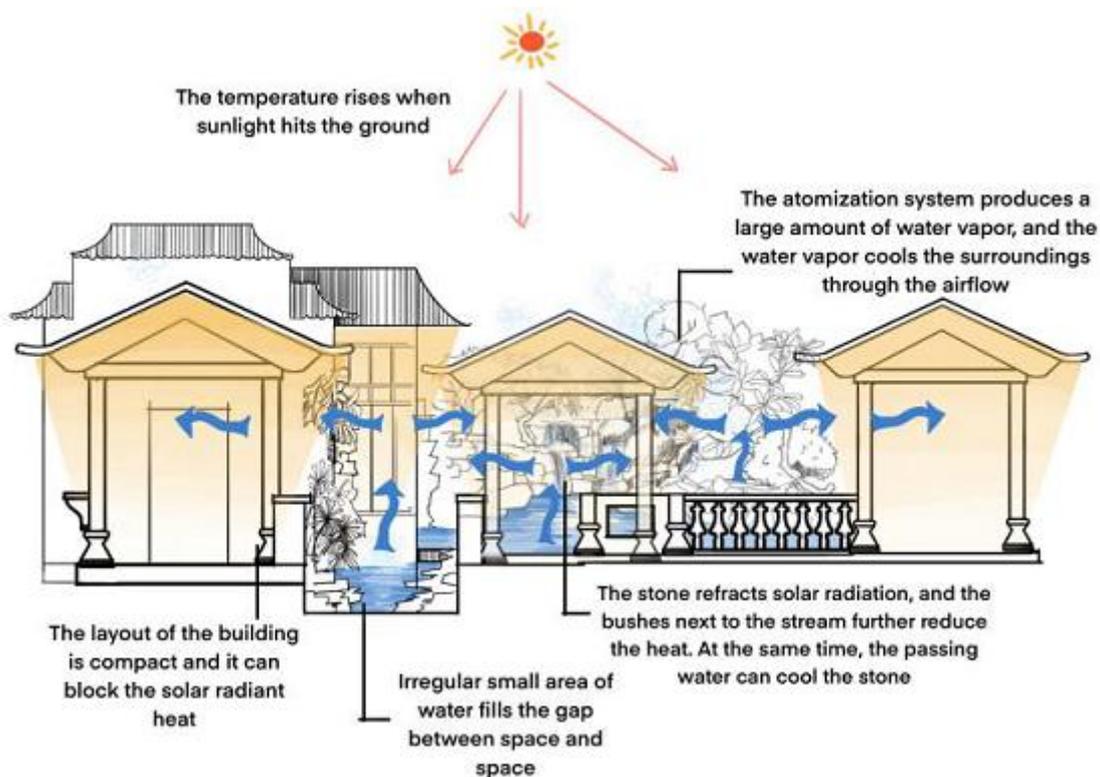


Figure 14. Schematic diagram of microclimate at observation site E.



Figure 15. Schematic diagram of population distribution at observation site E.

4. Conclusions

The following three conclusions are drawn through the landscape design of the 5 observation sites of Qinghui Garden:

First, in terms of spatial layout, the boundary between a fully enclosed architectural space and an open courtyard space (or water space), can use corridors or tall arders to form a semi-open space, which can create a comfortable microclimate environment .

Second, in terms of water area design, the vertical design generates more water molecules than the graphic design to cool down; as for the water graphic design, relevant scholars also believe that the water surface should not be too large in the study of the microclimate effectiveness of the water body, and the cooling effect of the decentralized water body is better than the centralized one. [18] On this basis, the irregular shape of the water body is better than the geometric shape for cooling. Dispersed and irregularly shaped water bodies are the best for cooling.

Third, the higher the reflectivity of the floor material, the greater the specific heat capacity, and the lower the ground temperature in hot and high-temperature areas. For example, the site "Fenglai Peak" is a landscaped space made of piles of rocks, which are laid out according to the sunshine and the wind. When visitors walk into the space, they feel that the temperature is lower than the outside in summer, and will feel warmer in winter, which obviously enhances human comfort. This space not only prioritizes the microclimate design, but also takes into account the aesthetic design, which forms a undulating and interesting natural texture space. The design creates a microclimate environment suitable for short stays, which can be used as a design for passage or transition space in landscape design.

As a preliminary study of "Research on the Inheritance of Garden Art in the Urban Agglomeration of Guangdong-Hong Kong-Macao Greater Bay Area from a Modern Perspective" of Guangdong Philosophy and Social Sciences (co-construction project) , this study only conducted an on-site observation of Qinghui Garden among the many gardens in Lingnan. The difficulties and coping methods in the observation have accumulated experience for the next step of the study, and the obtained preliminary landscape design rules provide a reference for the microclimate adaptability design method. At the same time, there are many shortcomings this, for example, only observation is made in a certain period of time, which is limited to the research. In the follow-up research, various types of spaces should be discussed, and various garden landscape designs in the Lingnan area should be included.

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this article.

Author Contributions

Z.Y.Y proposes a formal analysis after conceptualization. After the implementation of the research method and coordinated project plan, the data was collected through investigation and research. After passing the software data chart and verification, the first draft is reviewed and edited. N.C. provided guidance on the research methods, review and editing of this study, as well as tools and funds.

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