

The study on the performance of sponge city construction based on land use planning——cases of Canghai new area in Wuzhou

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Abstract:

There is still deteriorating trend of China's urban water environment, heavy rain and waterlogging disasters are still multiple. In addition to the concept of rainwater management is relatively backward, the overall planning of land use planning and road planning, green space system planning and other special planning is not organic combination, lack of the fast and efficient feedback mechanism. Meanwhile, the Ministry of Housing and Urban of China issued the "sponge city construction performance evaluation and assessment methods (Trial)" also emphasis on post-evaluation and assessment, can not be an early stage of the effective assessment of the planning stage.

The two aspects of urban storm water disaster prevention and surface runoff, which are closely related to the land use planning, are chosen in this paper as the main research object, the concept of sponge city construction performance is defined, the specific evaluation index is selected, and the calculation function is put forward, with the typical case study, the space Model simulation, statistical analysis and other research methods, through the GIS analysis, CAD, Civil 3D and PCSWMM modeling, practical case and ideal model comparative research and other technical means, the sponge city construction performance is studied qualitatively and quantitatively, and mainly on quantitative study.

There are two main results in this study: a method to quantify the performance of sponge city construction based on land use planning is explored in this paper through the application of the assessment model, and comparative evaluation of multiple plans in the early stage of planning. Based on the land use planning, some strategies to improve the performance of sponge city construction are put forward.

Key Word:

Sponge City, Quantitative assessment, Model, land use planning

Most cities in China today face a variety of water crises: water shortage, water pollution, urban rainstorms, increased surface runoff, falling groundwater levels, shrinking and even loss of aquatic habitats (Wang Hao, 2011). These problems which are systematic and comprehensive are not caused by a single water sector or a functional department. If we want to solve these "water problems," we need a more systematic and integrated solution. The "sponge city" theory is based on the basic characteristics of China's water conditions and the "water problems" it faces. In the construction of the sponge city, what can be done in the planning field and what kind of contribution can be made is still unclear. On July 10, 2015, the <Measures for the Evaluation and Assessment of Sponge City Construction Performance (Trial)> issued by the Ministry of Housing and Urban-Rural Development of China was also mainly to evaluate the performance of China's sponge city construction. Once the city is built, it will become a fact. After-the-fact evaluation can only evaluate the quality of the previous plan, but there is no way to change the existing facts. Therefore, it is particularly important to make an effective and reliable assessment of different planning schemes before the construction of the sponge city, and to select better schemes and further optimize them.

1. Sponge City Construction Performance Evaluation Method and Simulation

1.1. Definition of Sponge City Construction Performance Concept

The performance evaluation content of this paper is mainly in the urban planning land use planning, which belongs to the program evaluation before the implementation of the plan. The selected indicators are the urban storm flood control and surface runoff. The definition of the sponge city construction performance concept is based on the above considerations, and the concept can be defined as: land use planning to prevent floods in urban storms and to control the comprehensive ability of surface runoff.

1.2. Sponge City Construction Performance Evaluation Function

The performance evaluation of sponge city construction includes two major indicators: urban storm flood control and surface runoff, and urban storm flood control includes whether there is heavy rain or not, and the total accumulated water time and total water volume in the flood water in the flood season. According to the item index, this study uses AHP (Analytic hierarchy process) to conduct qualitative and quantitative evaluation and decision-making on the evaluation of the final sponge city construction performance. The sponge city construction performance hierarchy is shown in Figure 1.

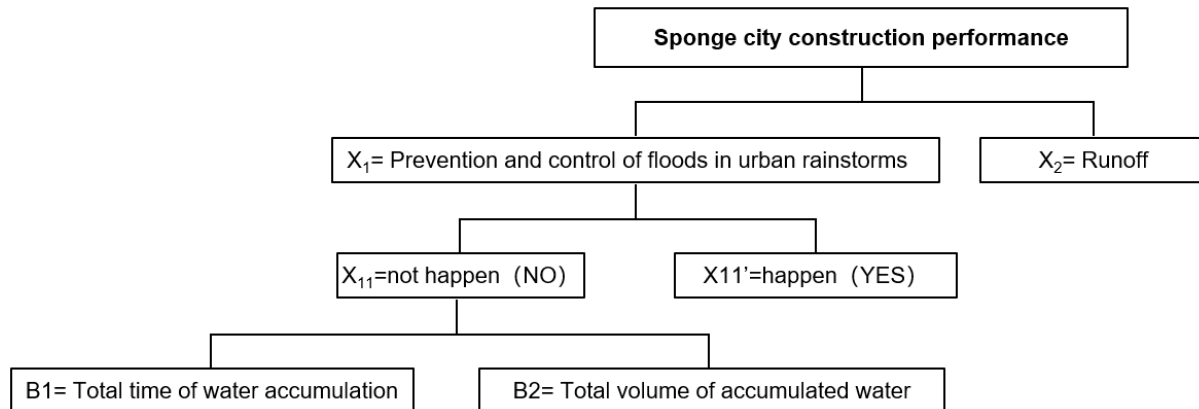


Figure 1. Sponge City Construction Performance Hierarchy

Source: author paint

1.3. Experimental Platform and Tools (PCSWMM software)

SWMM developed by EPA is a dynamic precipitation runoff simulation model, which is mainly used to simulate the time and long-term water and water quality simulation of a certain city. The evaluation software PCSWMM used in this paper is the commercialized software developed by the Canadian Institute of electronic water Resources based on the SWMM model.

1.4. Multi Scheme Model Simulation Method and Process of Sponge City Construction Performance

Through model simulation, a set of effective methods to observe and compare the multi scheme of land planning is set up in the early stage of planning, and the difference of the construction performance of the different land use scheme can be reflected as true as possible so as to select the better scheme and optimize it.

1.4.1. Establishing a multi-scheme model

The establishment of a multi-program model first requires the introduction of basic data, including geological data, climate data (including temperature, evaporation, wind speed, etc.), hydrological data (including rainfall, evaporation, etc.), terrain data and other data. The second is to introduce different land use planning schemes into the model.

1.4.2. Model simulation output data analysis

The total surface runoff of each land use plan, the total time of flood disasters and the total amount of floods were compared, and the performance index of sponge city construction was obtained. Then, the sponge city construction performance evaluation function was used to compare and score each plan, and better plan was selected and optimized.

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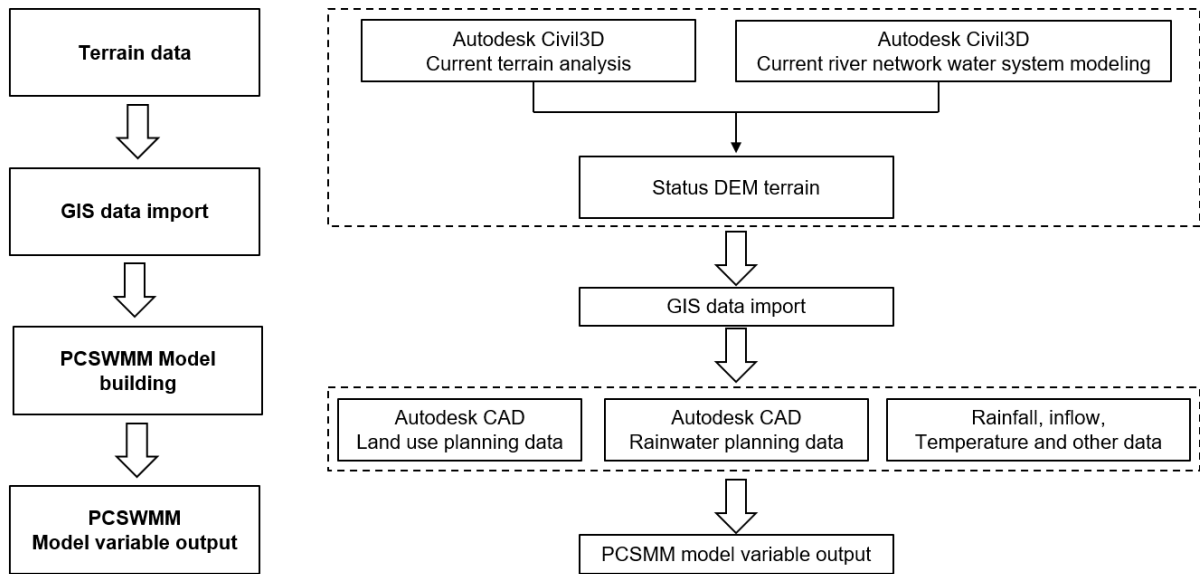


Figure 2. Schematic diagram of the modeling process
Source: author paint

2. Empirical Study on Performance Simulation and Evaluation of Sponge City Construction

2.1. Case Overview

Wuzhou is located in the eastern part of Guangxi China, located in the middle reaches of the Pearl River Basin, with an area of 12585 square kilometers and a population of 3.4 million. The research object of this paper is located in the south side of Cangwu County, Wuzhou City. The specific location is shown in Figure 3. It has been invaded by heavy rain and flood for many years.



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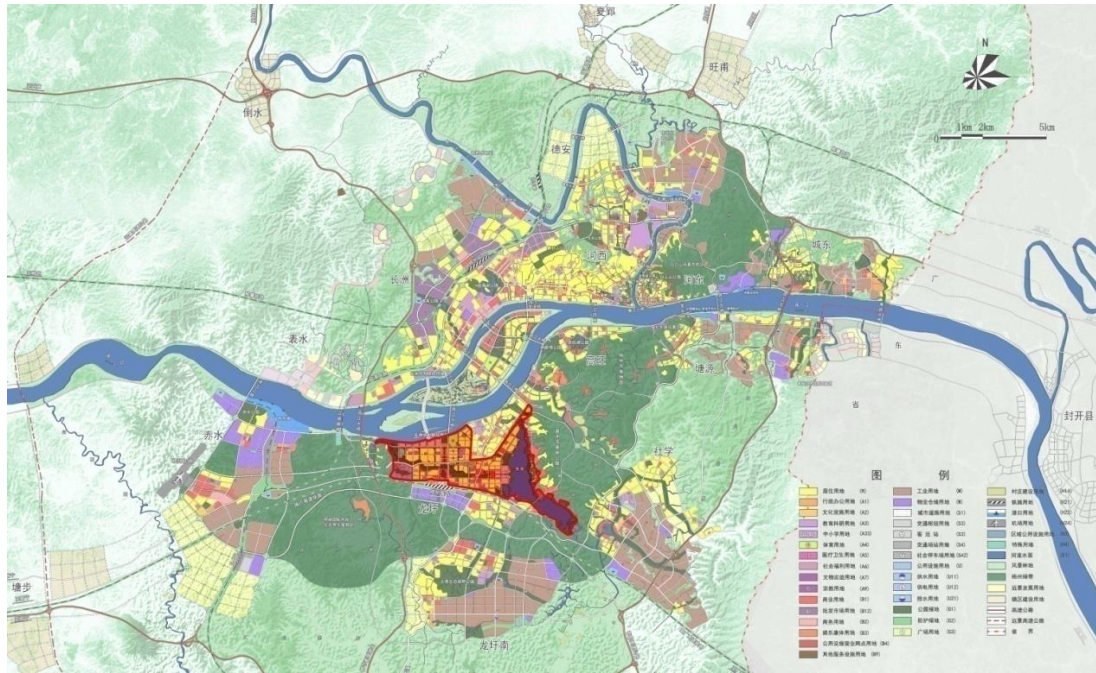
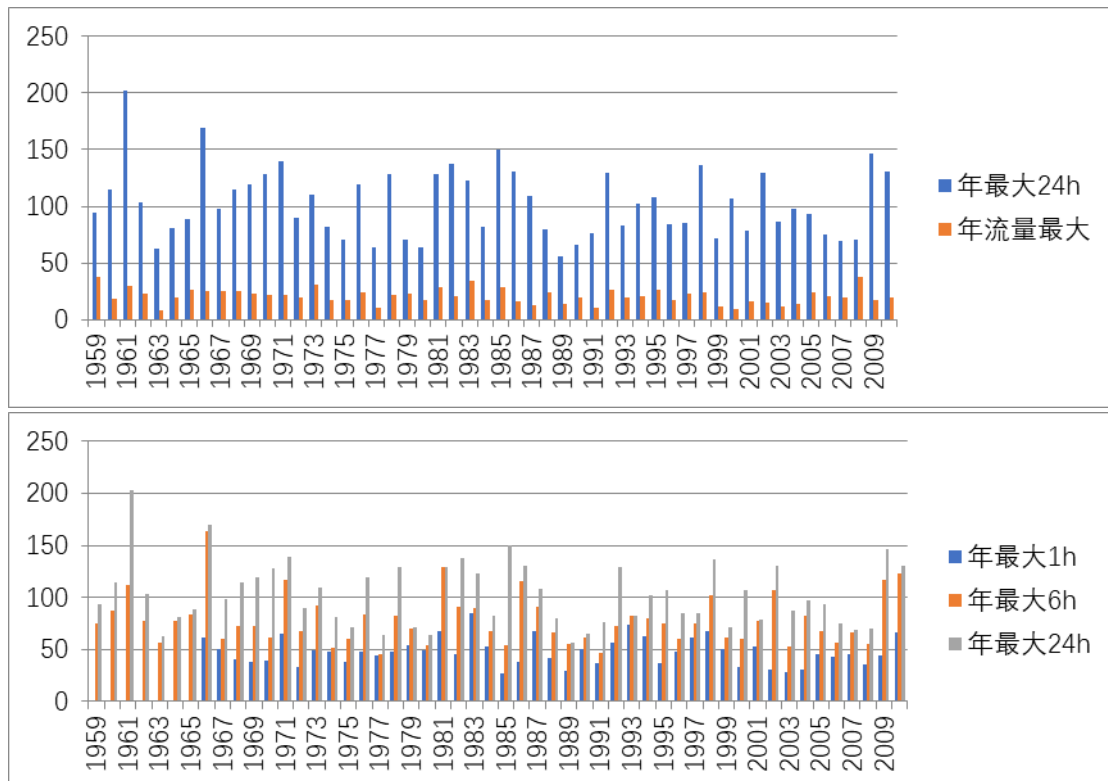


Figure 3. Location map of the study area
Source: author paint

The research in this paper is mainly aimed at the prevention and control of urban flood disasters and the surface runoff in different rainfall day study areas, especially the heavy rain days, and the evaluation of the performance of sponge city construction in different land use planning schemes. Therefore, the historical rainfall data within the study area is especially important for this study. According to the statistics of rainfall from 1959 to 2010 in the study area (the data is not classified because of the confidentiality of the data), the statistics are shown in Figure 4.



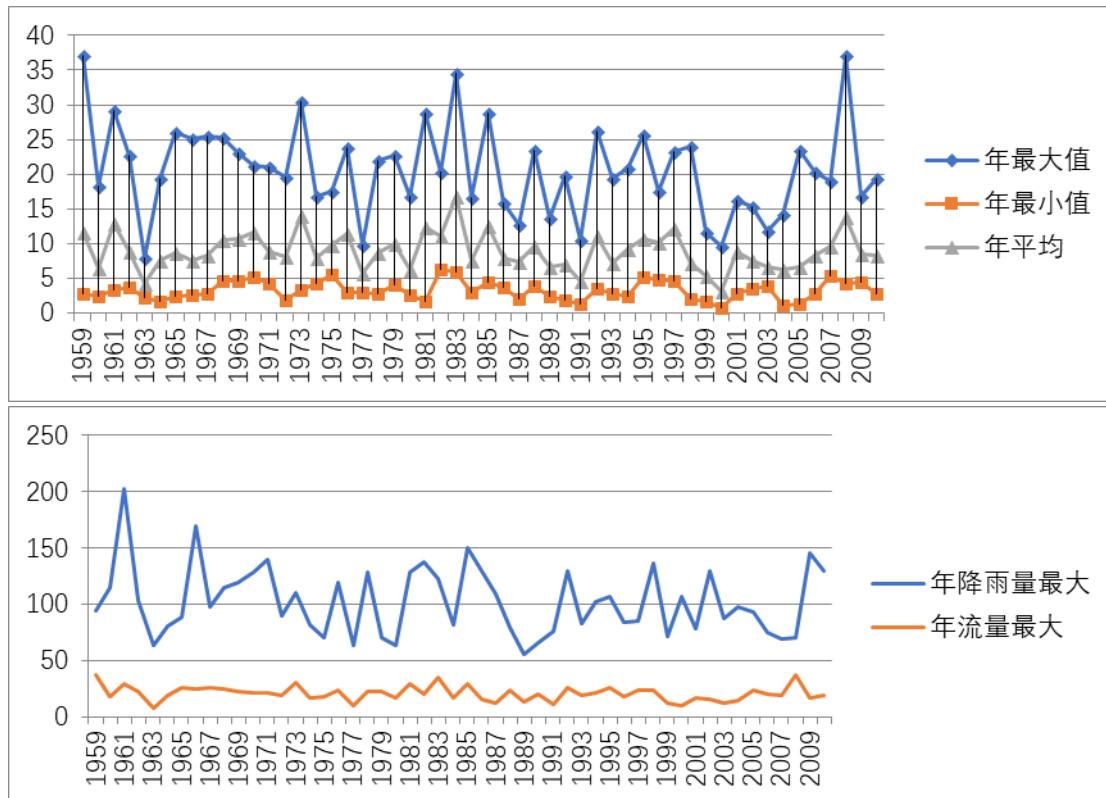
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Figure 4. 1959-2010 Annual Xiaohebu Hydrological Station Annual Rainfall & Flow Statistics
Source: Xiaxiaohebu Hydrological Station

2.2. Sponge City Construction Performance Model Simulation

In this paper, two sets of representative rainfall data of Wuzhou Rainy Day (Rainstorm Day and Light Rain Day) are selected, and the rainfall data of two rain days are recorded in the three-season land use planning model, and six different scenarios are obtained. .

Table 1. 24-hour rainfall on two rainy days

| Time | Rainfall on March 30, 2014 | Rainfall on April 22, 2014 |
|-------|----------------------------|----------------------------|
| 0:00 | 7.1 | 0 |
| 1:00 | 0 | 0 |
| 2:00 | 2.8 | 0 |
| 3:00 | 8.9 | 0 |
| 4:00 | 3 | 0 |
| 5:00 | 0 | 0 |
| 6:00 | 10.3 | 0 |
| 7:00 | 0 | 0.5 |
| 8:00 | 0 | 0.6 |
| 9:00 | 14 | 0.7 |
| 10:00 | 16.5 | 0.8 |
| 11:00 | 6.5 | 1.2 |
| 12:00 | 3 | 2.3 |
| 13:00 | 0 | 3.7 |
| 14:00 | 9 | 5.2 |
| 15:00 | 3 | 5.1 |
| 16:00 | 10.5 | 3.4 |
| 17:00 | 23.5 | 3.5 |
| 18:00 | 0 | 1.1 |

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| | | |
|-------|-------|------|
| 19:00 | 1.5 | 0.9 |
| 20:00 | 0 | 0.4 |
| 21:00 | 0 | 0.3 |
| 22:00 | 0 | 0 |
| 23:00 | 0 | 0 |
| 汇总 | 119.6 | 29.7 |

Source: Xi Xiaochebu Hydrological Station

Scene 1 is scenario 1 in the rainstorm day model simulation scenario on March 30, 2014, scenario 2 is scenario 1 on the April 22, 2014 rainy day model simulation scenario; scenario 3 is scenario 2 on March 30, 2014 rainstorm day Model simulation scenario, scenario 4 is scenario 2 simulation scenario on April 22, 2014, rainy day model; scenario 5 is scenario 3 on March 30, 2014 rainstorm day model simulation scenario, scenario 6 is scenario 3 in April 2014 The 22nd rainy day model simulates the scene.



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Figure 5. Scene 1, 2 initial state
Source: author paint



Figure 6. Scene 3, 4 initial state
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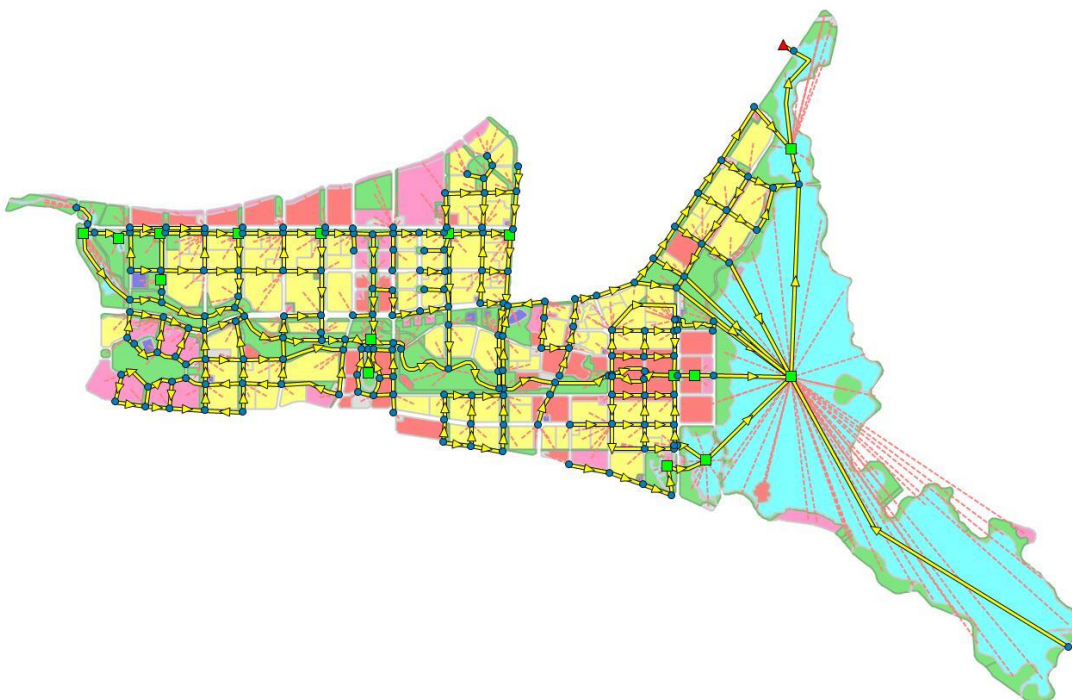


Figure 7. Scene 5, 6 initial state
Source: author paint

According to the performance evaluation indicators of the sponge city construction and research needs, the total green area, green space rate, total water area, water area percentage, total rainfall, total surface runoff, average water storage volume, maximum water storage volume, the number of rainstorm disaster points, the time of the most torrential rain disaster, the average torrential rain disaster time, the total time of the torrential rain disaster,

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the total flood amount of the torrential rain disaster, and the average flood amount of the torrential rain disaster point are comparative parameters.

Table 2. Statistics of different scenes

| Data | Rainy day on March 30, 2014 | | | Rainy day on April 22, 2014 | | |
|--|-----------------------------|---------|---------|-----------------------------|---------|---------|
| | scene 1 | scene 3 | scene 5 | scene 2 | scene 4 | scene 6 |
| Total area of green space (hectare) | 561.50 | 370.44 | 326.80 | 561.50 | 370.44 | 326.80 |
| Greenland rate (%) | 32.33 | 21.33 | 18.82 | 32.33 | 21.33 | 18.82 |
| Total water area (hectare) | 121.18 | 335.96 | 490.06 | 121.18 | 335.96 | 490.06 |
| Percentage of water area (%) | 6.98 | 19.35 | 28.22 | 6.98 | 19.35 | 28.22 |
| Total rainfall (million cubic meters) | 207.70 | 207.70 | 207.70 | 51.58 | 51.58 | 51.58 |
| Total surface runoff (million cubic meters) | 149.58 | 127.88 | 110.01 | 27.52 | 25.16 | 21.91 |
| Average water storage volume (million cubic meters) | 25.43 | 31.40 | 88.85 | 4.00 | 3.49 | 8.17 |
| Maximum water storage volume (million cubic meters) | 69.15 | 101.58 | 276.94 | 7.35 | 6.21 | 22.49 |
| Number of rainstorm waterlogging disaster points | 26.00 | 34.00 | 8.00 | 0.00 | 0.00 | 0.00 |
| The longest rainstorm waterlogging time (H) | 11.69 | 11.85 | 4.18 | 0.00 | 0.00 | 0.00 |
| Average time of rainstorm waterlogging disaster (H) | 5.97 | 4.41 | 3.74 | 0.00 | 0.00 | 0.00 |
| Total time of rainstorm waterlogging disaster (H) | 155.20 | 149.80 | 29.91 | 0.00 | 0.00 | 0.00 |
| Total flood water of rainstorm waterlogging | 65.68 | 22.61 | 18.35 | 0.00 | 0.00 | 0.00 |
| Average flood volume at the point of rainstorm waterlogging (million cubic meters) | 2.53 | 0.66 | 2.29 | 0.00 | 0.00 | 0.00 |

Source: author paint

2.3 Analysis of model simulation results

- (1) There are differences in the performance of sponge cities in different land use schemes.
- (2) High green land ratio does not necessarily represent low surface runoff.
- (3) The area of green land does not play a significant role in terms of prevention and control of rainstorm waterlogging.
- (4) The size of the water area does not necessarily play a decisive role in the prevention and control of rainstorm waterlogging disasters.
- (5) Water density plays an important role in the prevention and control of rainstorm waterlogging.

3. Urban Land Use Optimization Strategy

3.1. Set Up an Ideal Model

The research area of this paper is very large, there are many types of land use, and the geological conditions are also very complicated. Therefore, the surface runoff obtained, the time of flood disaster, the total amount of flood and other data of the model simulation are a result of many factors. It is difficult to determine which specific factor plays a decisive role in a certain result.

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A series of ideal models are established, that is, without considering the changes of topography, soil characteristics, groundwater conditions and erosion, only certain presets and changes are made for the variables to be studied, and the model output data is collated according to the research purpose, trying to figure out the relationship. According to the research needs, three sets of ideal models were established to study the pre-development and post-development changes of the site, the role of the green space system and the difference between the urban functional land.

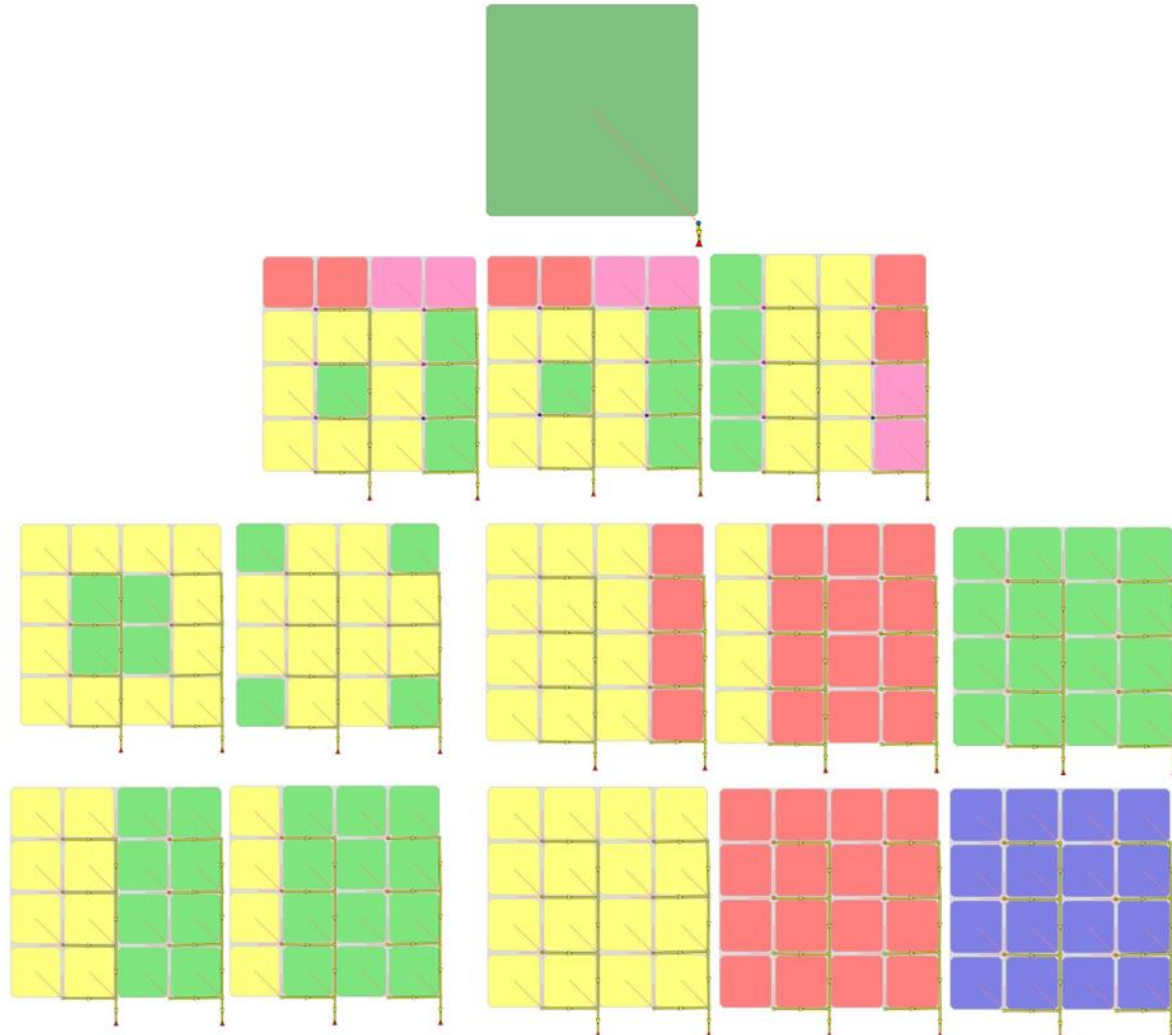


Figure 8. ideal model diagram

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3.2. introduction of LID (low impact development) control technology

Three LID technical measures of ecological detention unit, green roof and rainwater garden were introduced, and program 3 were introduced to establish model simulation to compare the effect of LID control measures on the construction performance of sponge city.

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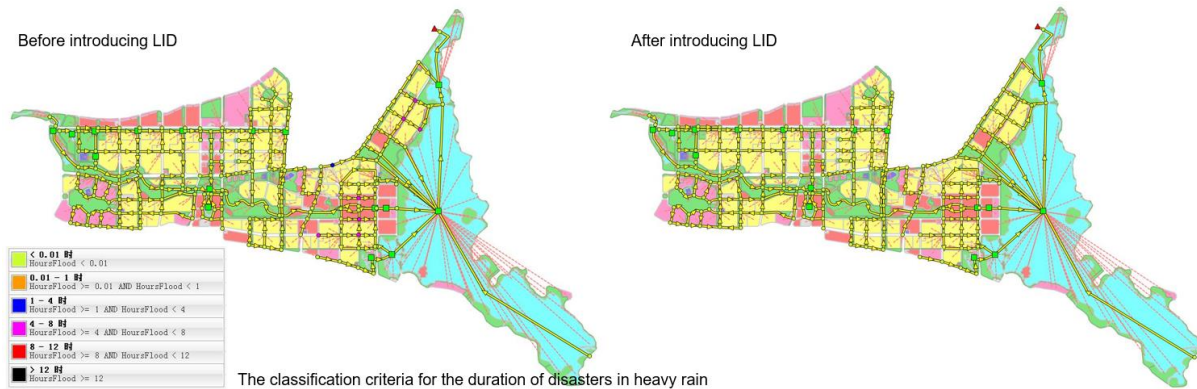


Figure 9. contrast map before and after the introduction of LID

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3.3. Model simulation conclusions and land use optimization strategies

3.3.1. Model simulation conclusions

- (1) The LID control technical measures have no obvious influence on the evaporation amount and the infiltration amount under the conditions of constant temperature, wind speed and land structure.
- (2) LID control technology measures can greatly control the total amount of surface runoff, and the effect is more obvious on light rain days.
- (3) After the development and construction of the cities, the surface runoff will be increased due to the increase of the surface impervious rate. However, the surface runoff may be reduced to some extent or even lower than before the development if the LID control technology measures are introduced reasonably.
- (4) The different proportion of urban functional land area will affect the surface runoff and urban rainstorm waterlogging disaster prevention and control, so the urban land area ratio has an impact on the construction performance of the sponge city.
- (5) The functional land of the city has little effect on the evaporation due to the impervious rate, but it has an effect on the amount of infiltration, surface runoff and total flood, and with the increase of impervious rate, the amount of infiltration decreases and the surface runoff increase, the total amount of floods increased.
- (6) Green land is more conducive to increase the amount of infiltration, reduce the total surface runoff, and improve the ability to control surface runoff; however, in the prevention and control of flood disasters in heavy rain, the green rate does not play a significant role; In the green space system layout, centralized layout and decentralized layout have their own advantages and disadvantages.

3.3.2. Land Use Optimization Strategy

The delayed water body can effectively improve the construction performance of the sponge city. The natural rivers and lakes or artificial excavation should be used as much as possible in the planning, but at the same time, the water density of the urban river network should be reasonably improved.

In the drainage planning, the rainwater should be discharged into the natural water body as soon as possible; when the funds are allowed and the planning is feasible, the rainwater pipe diameter should be increased as much as possible, and LID technical measures should be introduced;

Urban planning does not necessarily pursue high green rate; in the layout of green space system, centralized layout and decentralized layout have their own advantages and disadvantages.

4. Research Results and Applications

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4.1. Theoretical Results

There are mainly two theoretical results of this research: preliminary exploration of the performance evaluation method of sponge city construction based on land use planning perspective and empirical research, through the specific indicators of sponge city construction performance evaluation, and the application of sponge city construction performance evaluation model to form a set of methods to quantify the performance of sponge city construction, making the study of sponge city more rational; This paper propose a strategy to improve the performance of sponge city construction based on the perspective of land use planning.

4.2. Research applications

This paper focuses on the urban planning stage of sponge city construction, focusing on the overall planning land use planning level in urban planning. Through the construction and operation of the simulation model, this paper try to propose a method that can quantify and evaluate the performance of sponge city construction, and analyze it. The optimal scheme is selected through this method. This paper proposes a strategy to improve the performance of sponge city construction based on the perspective of land use planning, which can be used to optimize the scheme of the design stage of land use planning.

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