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Case Report

Sustainable Urban Water Management in China: A Case Study from Guangzhou and Kunming

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Abstract: In China, the notion of a water sensitive city has gained popularity in urban water management as a result of the detrimental effects of flooding and pollution caused by developmental activities. Urban systems and their interrelationships are critical for long-term urban water management and water sensitivity. This article is a case study considering how a strength, weakness, opportunities, and threat (SWOT) analysis-based approach to urban water management interventions in Guangzhou and Kunming cities (China) enables decision makers to identify solutions for cities to become more water-sensitive and resilient. The similar difficulties and rewards with respect to the contexts of both cities were synthesized using SWOT analysis. The contextual SWOT analysis, in conjunction with the comprehensive inclusion of Sustainable Development Goals (SDGs) in intervention planning in these cities, revealed that a water-sensitive-cities approach requires the establishment of a comprehensively multi-objective rainwater management system; this approach would have the goals of reducing rainwater draining sources, controlling processes and adaptive measures, and governing the system to make it more resilient. The water strategy should be holistic and adaptive, capable of providing a broad range of ecological services and other social benefits consistent with the fulfilment of the Sustainable Development Goals, and adaptable to other Chinese cities seeking to achieve water sensitivity.

Keywords: sustainable urban water management; Chinese city; flooding mitigation; SWOT

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1. Introduction

China is accelerating its efforts to develop sustainable urban water management systems. Several pilot cities in China, however, have continued to face significant waterlogging over the years [1]. Due to a lack of connectivity between facilities, several cities' eco-logical rainwater collection systems have devolved into unclean water ditches, resulting in water pollution that has a severe impact on the economy, environment, health, and China's process of sustainable development [2]. From a sustainable development standpoint, the most significant difficulty confronting the Chinese urban water management is implementing the strictest ecological environment protection policy possible. Although China is the world's second largest economy, its home water-use efficiency, industrial water-use efficiency, and effective use of farmland irrigation water are all lower than those of advanced economies [3]. Another issue is that the overuse of local water supplies exceeds their renewable capacity [4].

To accomplish sustainable water management, the Chinese government first floated the idea of building a sponge city in 2012, and construction began in 2015 in a number of cities throughout the country [5]. The Sponge City interventions are comparable to those of other sustainable water management methods, such as Water Sensitive City (WSC), which focuses on infiltration and attempts to mitigate excessive rainfall through the deployment of blue green infrastructure (BGI) [6]. Sponge City advocates for natural storm water management practices that reduce runoff and help avoid pollutants from entering the runoff and, thereby, pollute the groundwater or other water resources [7]. Comprehensive procedures such as "seepage, retention, storage, purification, usage, and drainage" are used in the creation of Sponge Cities to mitigate the ecological impact of urban development and construction. This would have a beneficial effect by allowing for the absorption and use of 70% of rainfall locally [8].

Water sensitive cities are comprehensive and adaptive in nature, as they can give a diverse variety of ecological and socioeconomic benefits. Thus, in order to attain the best results, several processes must be combined to maximize returns. When the concept of WSC first gained popularity in China, the WSC construction prioritized engineering criteria over the decision-making processes, resulting in a lack of systematic planning and implementation [9]. However, following the formulation of the Sponge City strategy by the central government on 12 December 2013, some pilot projects for implementing the Sponge City construction, with financial support from the central government, were launched. As a result, Sponge City construction technology and methods are gradually being standardized, such as the Evaluation Standard for Sponge City Construction (GB/T51345-2018) approved in 2018. Thus, in countries such as India and China, Sponge City construction and other urban water management programmes are based on transition from grey infrastructure to a more flexible, resilient, and sustainable system [10,11].

The central government has only promised to provide financial assistance for three years, after which the private sector is expected to become the primary source of finance, because the private sector is thought to play an important role in the management of water projects in terms of long-term operation and maintenance [12]. However, few private investors are interested in the economic returns generated by the construction of Sponge Cities. They believe that Sponge Cities have greater social value. Currently, there are two stakeholders in the Sponge City Program: the government and the project manager. Economic analysis, from the government's perspective, compares all potential economic, environmental, and social impacts of the ongoing and future water conservation projects. The financial analysis compares the revenue and cost of the water project from the perspective of the project manager [13]. As a result, how investment sources or investment ratios affect the construction effect of Sponge Cities deserves further investigation.

Sponge City construction emphasizes the use of green squares, green roofs, and artificial ditches to capture and collect rainwater, allowing it to infiltrate and temporarily stay, and then using ecological filters along the river to filter the rainwater and purify the water bodies. Thus, the rainwater collected and purified can be used for green land irrigation, road cleaning, landscape water replenishment, and other purposes. Thus, it is critical to preserve the hydrological functions of the city's original natural water systems, such as rivers, detention ponds, ditches, and wetlands [14]. However, due to the severe hardening of urban land, it is thought to be reasonable to construct some artificial parks, lawns, and retention ponds. Guangzhou and Kunming, in particular, are densely populated cities, and the feasibility of building reservoirs is low. From a practical viewpoint, some permeable paving materials can also be used for the construction of urban hardened grounds, urban green belts and grass-planting ditches, thus, greatly reducing runoff generation [15].

The majority of the existing engineering standards are followed in the construction of Sponge Cities in China. According to the technological guidelines of BGI building in the corresponding cities, the area of Sponge construction in pilot cities must achieve a particular size in order to function properly. In Kunming, for example, the city must transform more than 80% of its built-up area into a Sponge City by 2030 in order to meet international standards. The planning agency will therefore implement BGI in locations where it is simple to construct BGI, without considering the real utility of these infrastructure facilities. In other words, the construction of a large number of BGI is solely for the purpose of meeting the requirements of the central government. From the standpoint of quality control and impact, the government will require that specific types of water pollutants be reduced to concentrations below a certain level in order to achieve environmental compliance. Many design units, on the other hand, will rely on the high efficiency of sewage treatment facilities to meet their discharge limits [16,17].

In general, water management methods in cities ignore sustainability concerns, there exists a lack of coordination with various end-users and stakeholders, a missed opportunity to develop locally and economically viable resources, and a lack of connectivity to the watershed [18]. This paper advocates for governments to incorporate the Sustainable Development Goals (SDGs) into their planning and implementation processes in a systematic and comprehensive manner. SDGs are the 17 global development goals established by the United Nations to provide a holistic and multi-dimensional view of different developments. The SDGs seek to address a wide range of complex issues confronting humanity, including gender inequality, climate change, water quality, education and environmental degradation. The related publications covering SDGs have historic significance for sustainable development in both developing and developed countries [19]. The 17 SDGs are the agenda's foundational elements; they represent an urgent call to action by all countries, developed and developing, to co-work together and develop the global network of peer-learning and partnership. Chinese cities continue to face social and environmental issues, which are not isolated; instead, they are part of a larger social and environmental disaster. These SDGs should be evaluated in light of this context. The 17 Goals are all interconnected, and it is expected that they will all be met by the year 2030 [20].

The SWOT analysis, which includes the elements of strength, weakness, opportunities, and threats, can provide an integrated view for planning a city's future water resource management. The SWOT analysis can assist decision makers in analyzing from the ground up (i.e., the bottom to top approach) in order to propose various management solutions that can increase the strengths, minimize weaknesses, optimize opportunities, and mitigate threats [21]. The case-study based approach is extremely useful for gaining an in-depth and multi-faceted understanding of different urban water management issues [22].

The purpose of this case-study based paper is to discuss the relevance and application of SWOT-based methodologies for WSC project selection in the Chinese cities of Guangzhou and Kunming [23,24]. These two cities share common issues with water quality and quantity, such as pluvial flooding and water pollution. The main goal is to create a water management plan that is typically sustainable in Chinese metropolitan areas.

The primary aim of this research is to identify the common problems and offer solutions to these problems in the process of sustainable urban water development in the cities of Kunming and Guangzhou (China). This study also determined the usefulness and application of SWOT-based methodologies for WSC project selection in these two cities. These two cities have common problems in water quality and water quantity such as pluvial flooding and water pollution. The main goal is to develop a plan for water management that is usually sustainable in Chinese metropolitan areas.

The objectives of this research through this case study-based application can be stated as follows: (i) to determine whether the existing BGIs are currently beneficial to the city's development and whether these existing BGIs are consistent with the city's planning; (ii) to use the Chinese cities of Guangzhou and Kunming as examples and compare the effectiveness of each step in the implementation of BGI through their different approaches; (iii) to ascertain if the SDGs (Sustainable Development Goals) can be achieved and to incorporate them into the SWOT analysis for the two cities; (iv) to investigate the relationship between governance and the water cycle in the two cities; and (iv) to identify and overcome BGI implementation barriers, as well as common challenges and opportunities in each city, and propose practically feasible recommendations that are conducive to sustainable urban water management to the different Chinese stakeholders.

2. Methodology

As stated in the introduction, the engineering aspects of Sponge City construction in China are well established, but not the resilient defence to climate change or the solution to the persisting water problems. The efficiency of sustainable urban water management, on the other hand, cannot be measured solely on the basis of flood control and runoff pollutant removal rates, because these hard metrics do not account for the efficiency and resilience required to deal with future climate hazards [25]. The gap between the efficiency of current Sponge City infrastructure and sustainable urban water management is supposed to be researched and identified using SWOT analysis, a qualitative analysis approach used to evaluate both the internal and external aspects in Sponge City strategy development [26].

Furthermore, the proposed research recommends the SDGs as a benchmarking criterion for evaluating the current state of urban water management, which can avoid the embarrassing situation of evaluating the effectiveness of Sponge Cities solely by engineering standards [27]. The Sponge City is designed to address urban water issues while also providing co-benefits such as reduced air pollution and urban heat island mitigation. The SDGs are recognized as the guiding principles for Sponge City construction because they focus on resolving social, economic, and environmental development concerns before developing a strategy for sustainable development.

The steps to conduct a SWOT analysis include identifying internal factors (strengths and weaknesses) and external factors (opportunities and threats), the priority of these impacts, and the subsequent relationships between these factors [26].

As the essential components of the holistic Sponge City construction are expected to be identified, this research focuses on the following areas of sustainable urban water management construction, including the urban drainage system, economics, society, ecology, and environment [28].

3. Case Study Cities in China

Guangzhou, formerly known as Canton, is Guangdong's capital city, located in southern China near the South Sea on the east bank of the Pearl River. There are around 1300 rivers and 108 ecological parks, which include forest, wetland, and geology parks. Guangzhou, which measures 7434.4 km^2 and has a population of 15.31 million, is one of China's first-tier cities and the Pearl River Delta's commercial hub. Guangzhou's GDP is expected to reach 2.5 trillion Yuan by the year 2020 [29]. Guangzhou's entire wetland area is 86,178 ha, including 39,286.4 ha of wetland near the sea and beach, which accounts for 45.6% of the total. The river wetland area is 10,804.9 ha, accounting for 12.5% of the total. The lake wetland covers 154.3 hectares, whereas the pool wetland covers 35.933 hectares, respectively [30]. The salinity of Pearl River water has remained low [31]. Yuzhu Pier's yearly average salinity is greater than that of upstream Zhongda Pier, which is 0.22 [32].

From April to November every year, Guangzhou's old town floods as a result of typhoons that bring heavy rainfall and strong winds throughout the rainy season. According to the Guangzhou Meteorological Service, the city's average cumulative rainfall from 1 March to 8 May hit 791.6 mm, a record high that was 42.9 mm higher than the historical record of 748.7 mm set in 1980 over the same period. The most recent period of extreme rainfall occurred on 19 April 2019. It attained a speed of 75.9 mm/h. Additionally, the water level in the Pearl River increased from 3.07 m to 3.28 m with the passage of the most recent powerful typhoon, 'Super Typhoon Mangkhut, international no. 1822, on 17 November 2018 [33]. According to data from the national climate center, the chance of spring rainfall increased by 24% in Guangzhou [34].

In Guangzhou, sewage is primarily transferred to municipal sewage treatment plants for centralized treatment via the urban pipe network's collecting system and sewage interception system. The drainage system encompasses 7440 km^2 and collects and treats more than 95% of the sewage. In the year 2018, the separate sewage and rainfall systems covered only 42% of Guangzhou, making them the system's weakest link. Additionally, 83% of sewage pipes are constructed for a one-year return time of rainstorm events, while other pipes in Guangzhou's central business district are only intended for a half-year return period, implying that the occurrence of severe rainfall easily results in floods [35].

Kunming is the provincial capital of Yunnan, and its beautiful tourist attraction is the Dian Lake. It features the characteristic low-latitude plateau mountain monsoon climate, in which the temperature is controlled not only by the season, but also by its elevation. The metropolitan region is located north of Dian Lake and is flanked on all sides by hills and mountains, transforming it into a flat ground [36]. Precipitation is concentrated in Kunming from May to October every year, with the majority of rainfall falling in the low elevation area [37]. The main urban region is prone to heavy rain and flooding due to the effect of the southwestern warm and humid airflow, mountain barriers, and uneven rainfall [38].

Dian Lake is a key supporter of economic development in Kunming, a well-known tourist destination. In the spring season, flocks of red-billed gulls flocks in from the northern seas to seek refuge from the chilly winds. In recent years, the favorable economic climate and inexpensive housing prices have attracted an increasing number of young talents. The overall population is >4.3 million in the year 2021, with a third of the population made up of migrating citizens, resulting in new environmental pressures. The Dian Lake is a 330 km^2 plateau based freshwater lake in China. It is also the confluence of 35 rivers. Dian Lake is positioned at the lowest elevation; hence, it receives the most of the water from the urban area. As a result, it is critical in resolving several urban water-related issues. The adjustment function, on the other hand, is harmed by the aquatic plants that blanket the surface as a result of eutrophication [36].

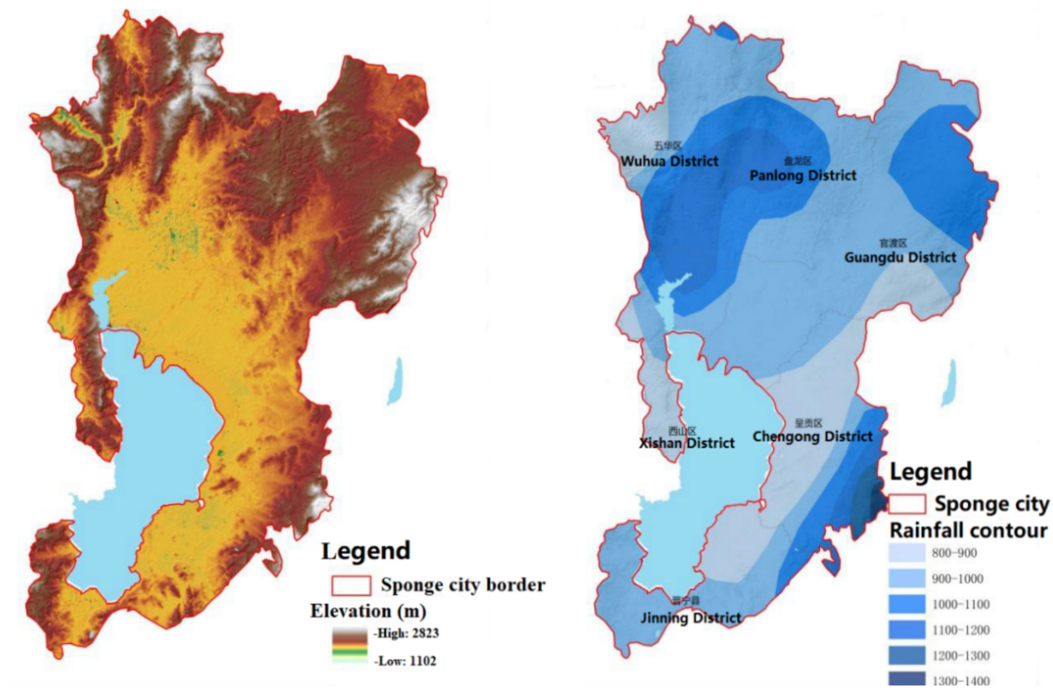
3.1. Concerns Regarding Water Quantity

Water scarcity, which results in urban pluvial floods, is a frequent occurrence in the cities of Guangzhou and Kunming. Although Guangzhou's drainage system has been built, certain districts continue to be inundated by pluvial floods when it rains excessively. When urban floods occur, they pose a threat to public health, infrastructure, and economic viability, particularly in older towns. For instance, on 22 May 2020, several metro stations and roads were flooded, forcing the closure of several lines, and trapping several ambulances on the road. Additionally, the combined drainage system is only 50% complete, and the drainage system in older municipalities is insufficiently maintained. Additionally, historic roads and structures must be preserved, making it difficult to modify the city's drainage system. Additionally, upstream drainage improvements have resulted in fresh flooding in the downstream areas [39].

Urban flooding has been a frequent occurrence in Kunming in recent years, occurring virtually every year. On the one hand, both the unique geographical location and the uneven distribution of rainfall will place a major constraint on the urban drainage system. Extreme precipitation occurs regularly in Kunming, and the heavy rainfall is concentrated in the lower elevation area (Figure 1), making drainage problematic during water logging and flooding. On the other hand, when urbanization accelerates, the land structure becomes more hardened, resulting in a rising runoff coefficient, increasing the risk of urban flooding.

3.2. Concerns Regarding the Water Quality

Guangzhou has a significant number of dispersed pollution producing factories and industries, a high energy consumption rate, a high level of pollution, and widespread manufacturing units. Although the 147 rivers had been largely cleaned, the water quality remained unstable, with a potential of reverting to dark and odorous conditions [40]. The river's poor water quality puts a strain on Guangzhou's water management. Although each river has its own 'River Management System,' the implementation of proper supervision and a methodical strategy for treating the contaminated rivers are rather ignored. The treatment of black and odorous rivers is independent, and the upstream and downstream rivers still lack coordination within the River Management Systems [41]. Guangzhou's treatment plan also lacks technical procedures for ecological rehabilitation. The majority of river courses have hardened bottoms and shorelines, and the river's ecological potential for self-purification is insufficient.



(a) (b)

Figure 1. Map showing: (**a**) the elevation, and (**b**) the rainfall distribution in Kunming (adapted from Ref. [39]).

Additionally, the wetlands in Guangzhou are polluted by human-related activities. Some wetlands have been transformed into eco-natural parks in recent years for the sake of amusement and tourism. Haizhu Wetland is one of the largest hybrid wetland systems in the world, consisting of rivers, lake wetland, and orchard. Numerous negative actions on the part of some people (e.g., the tourists) have resulted in significant damage to the wetland's environment, including flowers and the grassland. Apart from the wetland, there are several residential areas in the urban region; thus, the wetland is under pressure to discharge polluted wastes; additionally, the fruit bearing trees are grown using fertilizers and insecticides in this wetland area [42].

Neonicotinoids (Neonics) have been the world's most extensively utilized insecticides in recent years. Neonics are emerging pollutants in drinking water due to their hydrophilic nature. The total amount of neonicotinoids in surface water ranged from 92.6 to 321 ng/L, with a geometric mean (GM) of 174 ng/L, according to an assessment of the residual level of neonicotinoids in the Guangzhou part of the Pearl River [43]. The drinking water treatment plants are capable of only removing roughly 50% of neonics from surface water. The western and frontier river routes of the Guangzhou section of the Pearl River that acted as a water resource were more contaminated with neonicotinoids than the rear river routes, as a result of receiving more effluents from WWTPs and being subjected to extensive commercial and human activity. Hence, the metropolitan area of Guangzhou may suffer from moderate pollution and pose major ecological problems [44].

Water quality has also been a problem in Kunming, following the deterioration of Dian Lake's water quality. The reasons for the reduction in water quality are industrial and domestic discharges, as well as the agricultural land occupying a wide area due to Kunming's other significant economic activity—landscaping-plants import and export [45]. Anew, the residents' poor public participation increases the community's resistance to solving urban water problems. A classic example is that the tourists toss debris into rivers, clogging the channels and impairing the drainage system's performance.

Kunming and Guangzhou continue to face social and environmental concerns, and the issues are not isolated but are part of a larger social and environmental catastrophe. In the future, a metropolis with a blue-and-green environment that is hospitable to both humans and animals is expected.

4. Linkages between the Urban Water System in Guangzhou and Kunming

Many stand-alone ecosystem services are now provided by a combination of more distantly linked ecosystem services (e.g., the constructed waterways) that transfer water to cities and agriculture wetlands. These services are also linked to drinking water treatment plants, manufacturing industries, and recreational sites, and they are made up of a variety of interconnected physical elements and infrastructures (e.g., water treatment plants, water and sewerage infrastructures) [46]. The cities' numerous water systems are designed to be interconnected. If a single component cannot be resolved in its whole, the entire city water system will become entangled in a vicious spiral. The amount of sewage produced is proportional to the amount of water consumed. Due to Guangzhou's growing population, the more water that is consumed from the water supply system, the greater the pressure on the drainage and sewerage systems. Additionally, because many pipes are located beneath roadways, pipeline maintenance may clog roadways and disrupt traffic. Residents and farmers in Kunming's urban areas receive their water from neighboring reservoirs, which are surface water resources. While the natural water supplies are plentiful, insufficient water conservation facilities are less likely to deal with extreme dry seasons in specific years, affecting the urban water supply problem. As a result of the drainage system's development, the number of separate drainage systems has increased, which benefits both the river and wetland water quality. Rainwater flows directly into the river, therefore, it is possible to ensure that all sewage is directed to sewage treatment plants and subsequently to the wetland following its treatment. Additionally, it helps to alleviate the demand on sewage treatment by reducing wastewater production.

Due to advancements in ecological technology at sewage treatment plants, the outflow water quality can be enhanced, thereby reducing water pollution in wetland areas (Figure 2). Additionally, employing fewer insecticides and planting organically grown crops/plants can help improve the wetland's water ecology. Finally, fostering collaboration between private businesses and the government to manage a wetland and conduct research on biological and ecological technologies can alleviate economic pressure and spur innovation. Additionally, the stakeholders in this region include not only individuals and government, but also businesses. Thus, when the relationship between the city's components is considered, development can proceed on the predicted path.

From a shared beneficial perspective (Figure 3), the benefits of collaborative projects manifest not only in terms of science, technology, and the environment, but also in social, economic, political, and climate-related dimensions. For instance, incorporating steps to mitigate urban heat island impacts into Sponge City building might promote public participation, hence, consolidating funds for public-private partnerships. The water sensitive city construction in Kunming and Guangzhou has several benefits, including the reduction of water pollution, the purification of sewage by natural processes, and the effect of natural purification on biodiversity. Floodwaters have an adverse effect on people's daily lives and economic activity, impeding social development and policy execution.

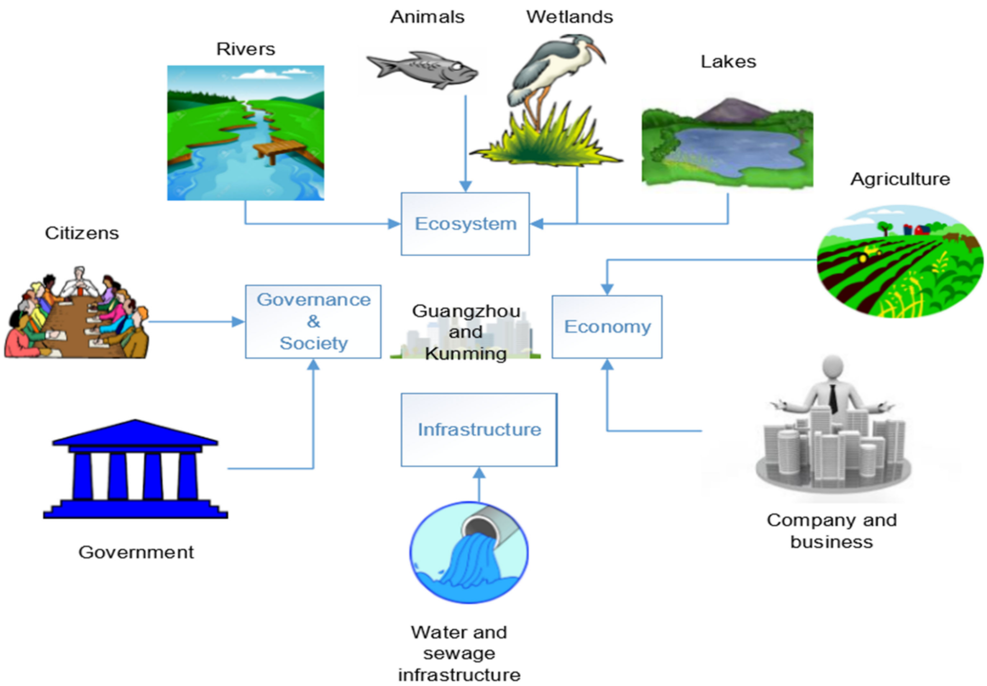


Figure 2. The linkages of urban water management.

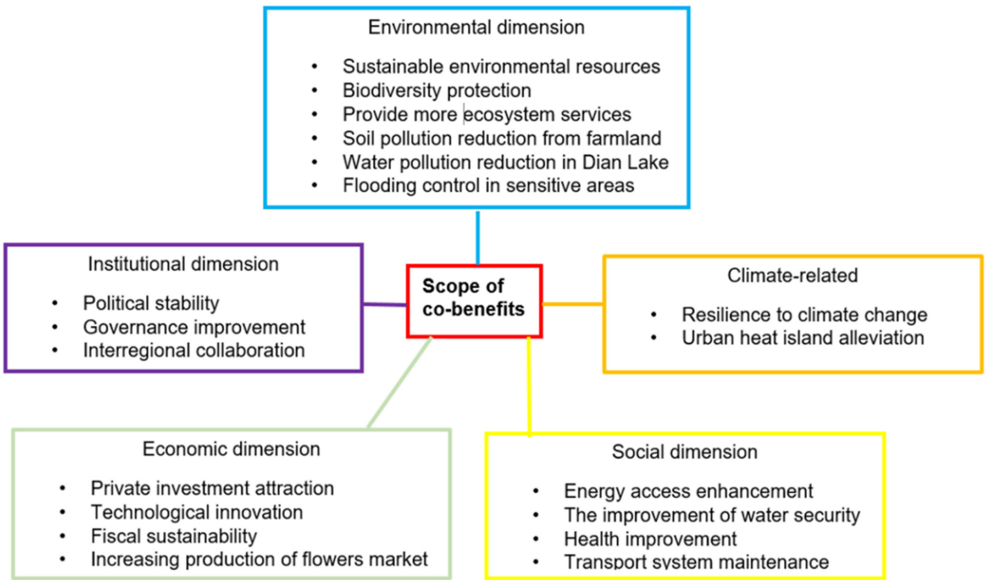


Figure 3. Co-benefits of water sensitive city construction.

5. SWOT Analysis in the Two Cities

5.1. SWOT Analysis in Guangzhou City

In order to develop a viable plan for Guangzhou, a SWOT analysis was undertaken to ascertain the potential advantages, disadvantages, opportunities, and threats associated with the creation of the water-sensitive metropolis, as shown in Table 1. Interestingly, Guangzhou is already a water cycle city, with a fully operational and reliable drinking water infrastructure. Each river is managed by a number of river managers. However, the population is growing, and the available land is diminishing. Additionally, Guangzhou's climate is a monsoon maritime clime, which experiences frequent typhoons and intense rainfall. The more water that is drawn from the public water supply, the greater is the pressure on the sewerage system. Planning and implementation have become increasingly challenging due to a lack of data and funding. The water system's governance lacks coordination, cohesion, and public participation, and the economical standards of different residences also vary (e.g., low, medium and high class). As a result, Guangzhou has great potential to become a water-sensitive metropolis by overcoming these shortcomings and risks. It is more cost-effective and time-efficient to install blue and green infrastructure alongside buildings during urban water regeneration. Additionally, exchange programs and peer-to-peer learning can help students and early-stage researchers to acquire the cutting-edge technology in this field.

Table 1. SWOT analysis of the current condition in Guangzhou for Sponge City construction.

Strength	Weakness
• River Manager Plan • The completed drainage system and treatment plants • Good economic condition • Water cycle city • Steady water supply	• Large population • Shortage of Land • Typhoon and high rainfall intensity • Public attendance shortage
Opportunity	**Threat**
• Urban renewal circle • Socialist system • Exchange study to foreign countries	• Missing data • Compensation for house relocation • Lack of coordination and unity • Difference in standards • Shortage of investments • Unpredictable climate change

Table 2 provides a more in-depth examination of the relevant factors in Guangzhou. The unpredictable climate changes pose a threat to the drainage system and the environment. The existing drainage system is complete, but it cannot adapt to climate change and no longer meets the requirements. Simultaneously, high rainfall intensity caused some cascading effects, such as low concentration and unstable inflow in combined sewage system to water treatment plants, resulting in low treatment efficiency. The urban renewal cycle is an opportunity, but repeated road excavation and backfilling in the same location should be avoided in the future.

Table 2. SWOT analysis in Guangzhou.

	Strength	Weakness
Urban drainage system	• Completed drainage system • Existing drainage management regulation • The separate drainage system in the new area • Almost Confluence channel sewage diversion	• Sub-standard construction and irregular construction process because of building too fast • The capacity does not meet requirement • Sedimentation in reinforced concrete pipes • Inability to cope with extreme weather
Water pollution treatment system	• The sewage treatment capacity can reach 7.66 million t/day • Centralized collection of domestic sewage reached 80% • The urban sewage treatment rate reached 97% [47]	• The rate of sewage and rainwater diversion in old town is low • Unstable inflow concentration

Table 2. *Cont.*

	Strength	Weakness
Economy and society	• Total GDP rank 4th in China • Abundant experienced talent team • Increased education level	• Repeated construction and investment waste • Residents' low participation in the decision-making process
Ecology and environment	• Various high-quality wetlands • High environmental quality • Many pocket parks	• Poor river water quality during rainy day
	Opportunity	**Threat**
Urban drainage system	• Urban renewal cycle • Various design company • Increasing economic investment	• Hardened ground • Increase in extreme rainfall • Low community resilience • High building density
Water pollution treatment system	• The separate drainage system construction • Wetlands to treat wastewater • Government highly value environment treatment • Upgrading of drainage units to standard	• Sewage and rainwater diversion construction unfinished in old town • Wrong mixing of rain pipes and sewage pipes
Economy and society	• Central government support • City to city learning • Joining of young people • New technological assessment	• Excessive population growth • Increasing price of raw materials
Ecology and environment	• Increased social attention • National policy support • Advancement of civil construction philosophy	• Climate change

5.2. SWOT Analysis for Kunming City

To build a plan that is appropriate for local city growth, a SWOT analysis was undertaken to ascertain the potential strengths, weaknesses, opportunities, and threats associated with the creation of the Sponge City, as seen in Table 3. Additionally, Sponge City is associated with a variety of factors, including urban drainage systems, water pollution treatment systems, the economy and society, and ecology and the environment. Table 3 summarizes the SWOT analysis in the key sectors and this information serves as a foundation for a more in-depth analysis provided in the next sections.

Table 3. SWOT analysis of the current condition in Kunming for Sponge City construction.

Strength	Weakness
• Completed water network distribution • Suitable climate and weather for plants • Improved infrastructure system	• Uneven rainfall • Low public awareness • The lower location of the urban area
Opportunity	**Threat**
• Policy support • Matured technology • Governmental and social investment • New urban areas are under construction • Exchange study to foreign countries	• Data missing • House re-movement and relocation compensation • Increasing population and migration • The change of land use of urbanization • Unpredictable climate change • The agricultural sewage discharges

According to the SWOT analysis, Kunming's natural conditions are favorable for Sponge City implementation. For instance, a water network and favorable weather conditions are advantageous for stabilizing the soil structure and establishing a green drainage system. However, the weakening factors, such as uneven precipitation, are uncontrollable. As a result, the government should place a greater emphasis on urban planning. Table 4 provides a more detailed review of the pertinent factors. The present drainage system is a mixed system for the urban drainage system and infrastructures. During the rainy season, the sewer overflows into the natural environment. The drainage system in the newly constructed metropolitan area is distinct. Additionally, new technology may enable real-time monitoring of pipeline conditions. Engineers can monitor changes in the pipe and react to improve the efficiency of floods water disposal via computers or mobile phones.

Kunming's wastewater treatment plants have a limited capability for water pollution treatment. The city's entire sewage system empties into Dian Lake, especially during the rainy season. Untreated water, a substantial proportion of mixed sewage escapes directly into the river and flows into Dian Lake. The Kunming government has recommended that engineering technology, biotechnology, information technology, and automated control should be used to manage the river basin's water environment in its entirety, including monitoring source pollution and fully repairing river channels and estuaries.

Table 4. SWOT analysis in Kunming.

	Strength	**Weakness**
Urban drainage system	• The separate drainage system in the new area • Kunming's developed a water system that can carry runoff and rainwater • Complete flood warning system	• Inadequate supervision of leakage • Disordered drainage systems in agricultural areas • The sensitive urban area is a combined drainage system • Inability to cope with extreme weather
Water pollution treatment system	• Sewage treatment plants of different nature • 27 sewage treatment plants in the Dian Lake Basin • Complete local sewage treatment standards	• Insufficient sewage treatment in agricultural areas • The low sewage collection rate in the main urban area, only about 81%
Economy and society	• The trade center of Southeast Asian countries • Good economic foundation • Increased education level	• Low overall education level • Residents' low participation in the decision-making process
Ecology and environment	• Suitable weather and climate for the growth of various plants • High environmental quality	• Poor water quality
	Opportunity	**Threat**
Urban drainage system	• Advanced technology that can monitor the pipeline conditions in real-time • High building efficiency • Increasing economic investment	• Hardened ground • Uneven precipitation • Low community resilience • Different companies have different construction effects • Rapid population growth
Water pollution treatment system	• The separate drainage system in the new construction area • Ecological methods to treat wastewater • Various technologies combine to treat wastewater	• In the rainy season, high overflow rate of combined sewage, about 90% • Dian Lake carries more massive sewage discharge

Table 4. *Cont.*

	Opportunity	Threat
Economy and society	• Supports from developed transportation on trade • Geographical advantages • Joining of young people • New technological assess	• Excessive population growth • Increased employment pressure
Ecology and environment	• Increased social attention • National policy support	• The impact of increasing pollutants on ecology • The impact of increasing pollutants on ecology • Climate change and urban heat island effect

6. Water Sensitive Solutions for Guangzhou and Kunming

6.1. Solutions for Guangzhou

For river managers, each river must be more methodically managed, and regulation and monitoring must be improved. Additionally, the government should promote high-level ecology-oriented education connected to rivers and wetland water treatment, which can result in the development of new ecological technology and environmental education for all citizens. Finally, but certainly not the least, the government can invest more money in developing new and innovative wastewater treatment and nature-based technologies, as well as encourage private sector investment that not only benefits from the new technology but also alleviates the economic pressure [48].

Water sensitivity must be considered in order to make Guangzhou liveable. Guangzhou's urban flood risk management is the most important concern. Prior to a period of high rainfall, it is vital to conduct risk assessments and prepare, as well as to implement some flood prevention measures. Additionally, it is advantageous to have diverse flood mitigation measures in different risk zones, and flood resilient technology can be created incrementally, while conforming to Guangzhou's current urban structure and design. Additionally, a more stable and high-quality urban water service is vital in the event of a future flooding event in Guangzhou. To make Guangzhou more beautiful, liveable, and dynamic, and to achieve the SDGs, the following action plans must be developed.

6.1.1. Improvement in Flood Protection Level

Firstly, the rain and sewage diversion systems should be strengthened to reach 90% within the next five years. Pipes both inside the structure and beneath the earth should be upgraded, and warning systems should be installed. Concerns should be raised about the possibility of the problem spreading to another part of the city as the capacity increases. As a result, it is necessary to expand the monitoring network, create simulation models of the Guangzhou sewer network and basin models with other city systems, and fully implement and address the issues of "seepage, retention, storage, purification, usage, and drainage". Secondly, a flood risk map is required for Guangzhou in order to identify areas prone to flooding and to build community resilience in these areas through education and governance. Collecting data from Guangzhou stakeholders, such as GIS spatial data, drainage system data, and social data, and then creating a 1D/2D model of the flood region and analysing the different possible hazards and vulnerabilities in the flood area to create a flood risk map of Guangzhou, can aid in flood risk analysis.

Based on Guangzhou's risk map, and by combining the weather forecast system, the early warning system, and evacuation plans for residents in the high-risk zone, priority will be given to setting up the weather forecast system, the early warning system, and evacuation plans for residents in the high-risk zone. For instance, temporary flood barriers on the perimeter can be built in front of metro station entrances prior to raining, based on early warning systems. Additionally, a nature-based solution for flood protection can be constructed by utilizing urban renewal cycles for the rehabilitation of older areas. Natural solutions, such as green roofs and natural retention ponds, should be considered throughout the development stage of the new region.

6.1.2. Steady and Good-Quality Urban Water Services

Real-time automated control and monitoring systems, such as Supervisory Control and Data Acquisition (SCADA), should be implemented in the water service system, at the source, water and wastewater treatment plants, and other networks to reduce the need for human labor during a pandemic [49]. Automatic monitoring of key water quality parameters, particularly virus concentrations, in lakes and rivers to ensure good water quality should also be initiated at the regional levels [50]. This will serve as a criterion for determining the appropriate level of disinfection achieved at water treatment plants. Real-time automated central control of the processing flow and dose at treatment plants can help in reducing the workers workload, while providing a consistent supply of high-quality water [50].

In order to maintain acceptable water quality, the microbial communities present in the water, particularly the virus, should be monitored on a daily basis. To ensure adequate water quantity, the water supply network should be continuously monitored using sensors to determine the residential water demand as a control signal [51]. Additionally, to prevent pipe corrosion, an automatic monitoring system for water quality and pipe condition should be implemented. When wetland treatment is used as a final step in the sewage treatment process, real-time automated control and monitoring can assist engineers in determining the current state of the wetland and managing it more effectively. Computer-based management will become increasingly prevalent in urban service systems in the future. Additionally, citizen science has the potential to boost participants' knowledge and understanding of different water issues, thereby, increasing participants' confidence in both the water's quality and the importance of the water business [52]. Additionally, citizen participation in monitoring can boost individuals' willingness to pay for improved water quality.

6.1.3. Updating the Laws and Strengthening the Supervision

New regulations and environmental governance related legislation should be introduced. For instance, individuals or enterprises who release untreated water into rivers should be penalized, as should excessively fishing and illegal aquaculture farms. The Environmental Protection Law, which went into effect in China in 2015, added some new penalties for enterprises that violate environmental laws and increased the responsibility for illegal pollutant discharge, effectively resolving the problem of "low cost of law violation" [53]. According to a recent statistic, there were 503 consecutive daily punishment cases nationwide in the first half of 2017, with a fine of 610 million yuan, up 131% from the same period in 2016, indicating that ecological and environmental protection laws are becoming more useful and playing a role [53]. From 2016 to 2017, strict environmental enforcement directly contributed to the resolution of over 80,000 environmental issues, including garbage, stench, oil fumes, noise, black and smelly water bodies, and pollution from "scattered and dirty" enterprises [53].

To ensure that stakeholders have access to the most up-to-date water information, the Combined Water Information Sharing (CWIS) Platform is beneficial. CWIS is a new web-based information-sharing platform for water management that is linked to a collection of simulation models. CWIS simulates systems that affect urban water management interactions, providing insight into how certain activities affect other parts of the system. It can be used as a communication tool for data sharing and to assist in strategic planning for urban water management across multiple catchments [54]. This platform comprises of a database and a variety of data visualization tools that enable users to visualize the physical space of a city in the same way as GIS does, as well as its logical spatial and non-spatial component elements and their relationships via a system viewer.

6.1.4. Encourage Private Investment

The government should support private sectors investment, in order to benefit from new technology and alleviate economic pressure. For instance, the government can cooperate with a technological software company to develop a mobile application for the public to download information on the flood risk map and an early warning system. This program, which utilizes a global positioning system, can alert individuals in advance of flooding and implement certain flood mitigation steps to assist them in preparing. Additionally, advertisements can be inserted in this program to generate revenue by selling the firm or government's professional edition [55]. Additionally, the Guangzhou government may provide preference to construction companies who are willing to construct commercial buildings such as shopping malls with BGI-compliant features such as green roofs and green walls [56].

6.1.5. Grow Eco-Friendly Fruit Bearing Trees

The planting of fruit bearing trees is also recommended as well as the use of their fruit as food for wild animals, by restricting agricultural techniques such as weeding, fertilization, pruning, and fruit plucking, and by creating a natural habitat and foraging area for wildlife. Additionally, applying insecticides should be applied whenever required and the dead branches and bad fruit should be removed in order to prevent insect disasters.

6.2. Solutions for Kunming

To transform Kunming into a harmonic water-sensitive metropolis, it is vital to address the twin challenges of flooding and water pollution, the primary drivers of which are unabated rainfall and development. Based on the results of SWOT analysis, the current urban water management situation in Kunming may have a gap to reach the Sponge City concept. Increasing the flexibility of water management can promote the transformation of urban planning and construction, thereby, reducing the risk of rainwater runoff pollution and drainage system pressure in advance. It is also recommended to enhance the water ecological environment in the Dian Lake Basin and provide the population with sustainable and adaptable living circumstances. However, decision-makers, developers, and financial backers should take the local ecosystem into account while implementing all the measures. As a result, it is critical to advance a holistic strategy that generates benefits and expands the options for resolving different water issues.

The strategy should establish norms and direct development for the city that also maximizes co-benefits for the citizens. Thus, sustainable development in Kunming should be viewed as a macro-scale endeavour, water quality improvement as a middle-scale endeavour, and development of Dian Lake as a micro-scale endeavour. These ideas should be in response to Kunming's water-sensitive city strategy and will serve as guidance for the economic and environmental development. This section is divided into four distinct categories of approaches: asset management, technology, uncertainty, and community resilience [57].

6.2.1. Approaches in Asset Management

In terms of asset management, drainage systems deteriorate as a result of aging, high demand, overuse, and inadequate maintenance, and rehabilitation is typically neglected until a catastrophic failure occurs [58]. As a result, recovery is both difficult and costly. Thus, a faulty drainage system will impair the operation of other critical infrastructures, including the water supply system, healthcare system, and environment. Indeed, Kunming's waterlogging problem is serious enough that it has a detrimental effect on traffic, living standards, and even economic services, to the point that economic losses may exceed the building and maintenance costs. Thus, drainage and sewerage system assets are allocated considering the whole decision-making life cycle, which includes engineering, planning, construction, operation, and maintenance [59].

Kunming is also embroiled in a hindering situation of municipal planning and land availability for commercial activities. Because some unmanaged natural wetlands have gradually become commercial land, the cities' hydrological functions will suffer as a result of a lack of green space. Even the land that was originally allocated for the sewage treatment plant to be built on is now constrained. Therefore, during the feasibility analysis of Sponge City construction, reasonable urban planning should also be considered [60].

6.2.2. Approaches in Technology

In terms of technology, depending on the flood situation, a combination of natural and technological/man-made measures should be considered as a strategy for mitigating flood risk. For example, in Kunming, the sensitive area is in the city centre, which has a prosperous economy and a dense population. As a result, it is less likely that green methods will be adopted on a large scale [61]. To make flood risk mitigation holistic, natural (such as introducing green roofs) and non-structural (such as improving policy) methods can compensate for the limitations of structural approaches (such as building drainage networks with good performance, reservoirs, and pumping stations).

Additionally, real-time control technology can be used to update the drainage system's operation, which can determine the water level in real time and modify it via weirs or gates. Similarly, sensor technologies can be used to determine the internal condition of pipelines and to investigate sewer leakage [62]. At the same time, some data-driven models are becoming increasingly popular for simulating the current drainage situation and even predicting whether the future drainage system will be capable of avoiding urban floods. The real-time hydrological and hydrodynamic data can be used as input data and boundary conditions for these data-driven models, which will simulate the effectiveness of BGI and reflect the impact of Sponge City construction on climate change. When an urban flood occurs, it is necessary to estimate the losses, both intangible and tangible. This type of estimating method can be used to determine the effects of urban flooding on buildings and people, both directly and indirectly [63].

6.2.3. Approaches in Uncertainty

There are uncertainties associated with moderate climate change and an unexpected pandemic outbreak such as COVID-19. While flexibility and robustness are often regarded as excellent ways to deal with uncertainty in urban planning, the tough part is figuring out how to use them in practice. Throughout the coronavirus outbreak, many people expressed concern about society's ability to function regularly and offer critical social services. Water supply and drainage systems have also received a lot of attention. In Kunming, despite the economic crisis, water and energy supply services continue to operate smoothly, owing to the gradual digitization of social services, which may become a popular trend in the future. For instance, real-time control can regulate the water level automatically, obviating the need for manual adjustment. This implies that advanced technology can enhance infrastructure's adaptability, allowing it to quickly recover from unknown or unexpected changes [64].

6.2.4. Approaches in Community Resilience

The term "resilience" has been commonly used in recent years while discussing the creation of water-sensitive cities, particularly when referring to blue-green infrastructure, and resilience also includes ecosystems and the communities. The resilience of an ecosystem is a natural regulatory function, and it can be difficult to manipulate artificially, at times. However, community resilience refers to a community's ability to continue essential activities in the face of adversity, as well as its ability to recover rapidly following a calamity. Because it is a community-based, self-adaptive, and self-recovery process following a disaster, it is virtually entirely influenced by human activities [65].

On the one hand, it is worthwhile debating the community's flexible development plan in terms of traffic accessibility, increasing the number of blue-green infrastructures, and expanding the flexibility of the community's public spaces in order to activate the vitality of community space [66]. On the other hand, community resilience is also influenced by the decision-making process, as it is contingent upon local community engagement and the local municipalities/departments. The more residents or their representatives participate, the more government representatives will understand their demands, and the more satisfied citizens are, the more authorities will be able to urge them to participate in the process of resolving the associated problems. For instance, if the government is actively involved in resolving the flood in their town, they will not refuse to clean the channels [67]. One outcome of decision-making and governance is community resilience. The most effective strategy to strengthen community resilience is to give evaluation tools that enable residents to participate in the decision-making process.

6.3. Suggestions for Overall Chinese Urban Water Development

To begin, the existing national and river basin-level water governance organizations' status and responsibilities should be enhanced, and their involvement in ecosystem conservation should be enlarged. Second, the scope of policy coordination across several agencies, authorities, and departments remains unclear [57]. Third, human beings and ecosystems' adaptability should be further enhanced to enable them to deal with future threats and challenges, such as the increased use of green infrastructure to manage floods, water pollutant discharge permit trading, and other financial mechanisms for non-point source pollution reduction. Fourth, increasing reliable data and information exchange is required in order to optimize China's capacity and degree of water governance decision-making in order to assure its scientific/technical quality and public participation [68]. The construction of a national platform for sharing water-related information will aid in the coordination and cooperation of many agencies and will foster innovation in the water sectors.

7. Scope for Contribution towards the Sustainable Development Goals (SDGs)

To address water scarcity and water quality issues in Chinese cities, a comprehensive and adaptive strategy is needed. This strategy should focus on providing a wide range of ecological services and other social benefits, while also meeting the mandate of the SDGs, such as the possibility of achieving multiple SDGs in Kunming and Guangzhou, respectively (Table 5).

Table 5. The response of urban water development to SDGs in Guangzhou and Kunming.

Problems	Scope for Guangzhou	SDGS for Guangzhou
Urban flooding	• Improvement to the flood's protection level	#SDG3, #SDG15, #SDG14 and #SDG6
Poor water quality	• Steady and good-quality urban water services • Update laws and strengthen supervision	#SDG3, #SDG14, #SDG6 and #SDG15
	Scope for Kunming	SDGS for Kunming
Urban flooding	• Increase in asset management • Improvement in technology to compensate for the limitation of structural solutions	#SDG3, #SDG7, #SDG9, #SDG11, #SDG12, #SDG13 and #SDG17
Poor water quality	• Increase the flexibility and robustness to cope with the uncertainty. • Increase the community resilience to improve the participation	#SDG3, #SDG6, #SDG9, #SDG13, #SDG14 and #SDG17

8. Conclusions

This research aimed at identifying common problems and suggesting interventions using SWOT-based methodologies for water-sensitive city projects in the cities of Guangzhou and Kunming. These cities continue to face urban flooding and poor water quality as a result of climate change, population growth and inadequate coordination between the different stakeholders. The current status and the urban water management interventions in these cities were analysed using SWOT methodology; their contribution to global initiatives such as the SDGs were also determined. The analysis revealed that a comprehensive multi-objective rainwater management system must be established in Guangzhou and Kunming through the use of advanced sensors, intelligent process control systems, smart technologies and good governance in order to achieve reductions in rainwater discharge. More research, coordination among the stakeholders and contextualisation in a systematic manner is necessary to solve problems at the grassroot level. Cities in China with urban water management challenges should consider the proposed SWOT analysis to comprehensively address the SDGs, and adapt them to the local environment, in order to achieve long-term economic and environmental performance of the cities.

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