

Strategic planning for Taipei sponge city

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Abstract. With the accumulation of industrial development and human development, the effects of global climate change are becoming more and more obvious, and because of the increasingly obvious warming phenomenon and impact, countries began to put their hand on global warming mitigation and adaptation measures and policies, hoping to reduce the negative impact of global warming on people's living and natural environment. This study explores the problems in global climate change and global warming, and aims to examine how to cope with variation of extreme climate and the highly populated environment in Taipei, and how to practice the concept of "Taipei Sponge Livable City" project as the main axis. First, this study elucidates the context of Sponge City concept, relevant academic research and case studies. This study then analyzes Taipei's water environmental changes, the implementation of policies and projects. By translating the planning concept into a tree-like structure, on the one hand, it can analyze the relevant policies and the works of the City Department; on the other hand, it can set up a sound direction and prospect for the Taipei Sponge City Policy. Moreover, by referencing to numerous Sponge City examples, this study can improve the water policy and continuously construct the "Sponge Livable City" for Taipei City.

1. Introduction

With the impact of global climate change becoming more pronounced, the impact of climate change on the global or regional natural and human systems is far more severe than the past. The issue of global warming has attracted growing attention worldwide. In addition to the major economic losses caused by global warming, global warming has far-reaching influences on the sustainable development of the environment and the society. Global warming is like terrorism, without borders. From Agenda 21 in 1992, Kyoto Protocol in 1997 to the Paris Agreement in 2015, it can be seen that international attentions have focused on the global warming issue.

The impact of climate change is more visible in urbanized areas, Ren *et al* set up temperature observers in rural China, small cities, central cities and large cities, comparing their values with the region's average temperature rise in the extreme climate, and found that the temperature rises most in largest cities, indicating that urban areas are more vulnerable to the impact of extreme weather [1]. Tayanç and Toros studied through four cities in Turkey and their adjacent rural sites of temperature monitoring results [2]. Their results indicate that cities' urban heat island effect is indeed higher than that in rural areas. Because of increasing population, frequent human activities, increased use of resources and complex uses of land demand, urban ecological environment will be changed, such as the increase of impervious pavement, high-rise buildings and asphalt in the face of sunlight heat storage, transportation, gas emissions, and so on. These phenomenons are why urban areas become



hotter; also make urban water cycle hindered and more vulnerable to climate change and extreme weather events.

On the other hand, there is a growing tendency for urban water circulation and water governance around the world, for example, the United States in the 1990s began to promote "low impact development" (LID) [3]. Germany promoted innovative flood prevention technologies in urban renewal plans in Hamburg port city (HafenCity) in 1997, which require roads and public spaces to be built over 7.6 meters on the platform of the climatic line [4]. Japan promoted the total water governance, and then put forward the "sum of water countermeasures" for the river basin because of rainwater runoff increase by rapid urbanization. Australia advocated "water-sensitive urban design" [5]. The United Kingdom proposed the "sustainable drainage system" [6].

To sum up, because climate change and water cycling regulation are more difficult in the high urbanized area, and the population is denser, if natural disasters happen, it may lead to life security and socio-economic significant losses. Therefore, urban areas should pay attention to whether the operation of urban water cycle and regulation system can be carried on the potential crisis caused by climate change. According to the statistics of Taiwan's Executive Yuan, the high urbanized areas of Taiwan are headed by Taipei, New Taipei City and Kaohsiung. Of them, Taipei is the capital city with an important development role for Taiwan's political economy, which is why Taipei was selected as the study area in this research.

In response to the extreme climatic variability and in conjunction with the densely populated residential environment of Taipei, this article adopts the "Sponge Livable City" concept for the framework of the overall strategic planning. Three visions for Taipei include "resilient water adaptation", "friendly water environment" and "activated water utilization". Based on the three visions, six strategies were proposed, including "sound urban water cycle", "improving flood tolerance", "diversified water use", "stable water supply and effective water", "ecological diversity aquatic habitat", "rich water recreation." Based on the visions and strategies, this study develops a promotion structure, organization and control pointers, trying to improve urban water circulation and achieve the goal of "sponge and livable city".

2. Literature review

2.1. *Sponge city*

Under the challenge of climate change, extreme climate pressures on urban environment are more severe, causing highly developed cities like impervious cement jungle. Urban water environment faces numerous challenges, including extreme rainfall, heat island effect, insufficient water retention capacity, long-term water resource risk, reducing urban ecological habitat and the increasing hydrophilic demand. In view of global climate change, urban flood has become a global concern in recent years, because it has a serious negative impact on the city [7-10].

There are many water-related problems, such as water shortages, water pollution, floods, and degradation of aquatic habitats and they constitute a large and complex urban development issue, requiring a comprehensive solution, as well as seamless coordination between different processes and construction units [11].

According to the Taiwan Sponge Alliance (2018), "sponge city" first appeared in 2012. The concept of sponge city is similar to the concept of LID, which is actively promoted in numerous countries worldwide. Sponge city emphasizes that all human-made impervious pavements will be changed into permeable surfacing. For a long time, dense population has gathered in the city, the construction and the road obstructs water movement and the ecology, making urban environment become artificial and impermeable and further isolated from the nature. Sponge city aims to transform the city to absorb the water and filter the air, like a super large sponge, in order to achieve flood and drought control, cooling, carbon sequestration and other benefits. Sponge city aims to solve urban water and ecological problems, in order to move toward low-carbon and sustainable cities [12].

2.2. Related research

Che *et al* reviewed experiences and practices of sponge city in various countries [13]. These authors also explored the theory and method of rainwater management, and put forward the constructive direction. Furthermore, they pointed out that sponge cities in the United States include three concepts: management measures, LID and green infrastructure. In Germany, drainage engineering and delayed storage engineering are the keys to the development of sponge city. New Zealand and Japan set up sponge cities from national laws, regional rules and operation management directions. Experimental sponge city projects in China have drawn three successful key strategies: water resource drainage or stagnation in the source, process deceleration in the transmission and flexible end-pipe user adaptation [11]. Yang and Lin proposed that elastic city, LID and sustainable resource management are the core ideas of sponge city. Sponge city and ecological city, low-carbon cities are closely linked and complementary [14].

According to the scope and area of urban planning, Lin divided sponge city into large sponge and small sponge [15]. Large sponge cities refer to larger planning areas, therefore, more time and funds are needed. Large sponge cities mainly concentrate on public investment, such as reservoirs (including artificial lakes), estuary weir. A small number of large sponge city projects can be developed, using the public private partnership (PPP) pattern. Small sponge cities use small areas as a unit, such as the size of Taiwan's urban planning area. Planning items include roads, greenery and parks and planning time and funds needed are relatively low. Moreover, small sponge cities can be developed using public investments or public and private partnerships (PPP) in parallel.

Sponge city faces some predicament and challenges, for example, the construction costs are huge, the operation and management is complex. Therefore, constructing sponge city should conform to the natural resources and the humanity development, and under the premise of considering the socio-economic development and the environmental harmony [15]. Cui *et al* suggested that the practice of sponge city is mostly confined within urban boundary and lack of coordination and cooperation across city boundary [16]. When LID was emphasized, we may ignore the update of old equipments is difficult, so it is necessary to strengthen the systematic linkage, the related basic discourses and the engineering construction technology for the construction of sponge city.

Xia *et al* pointed out that the rainwater management is based on the concept of rapid emissions - grey infrastructure (such as drainage networks and water tanks) [17]. This approach is costly and difficult to catch up with rapid urban sprawl, and ignores green infrastructure (such as rivers, lakes and wetlands). The construction of sponge city is still limited to LID methods, only focusing on source control measures while ignoring key functions of the surrounding landscape (mountains, rivers, wetlands, forests, farmland and lakes, etc.). The application of the integrated urban water supply system and its supporting technologies, such as urban water systems, urban hydrology, environmental science, social science and ecological landscape, is relatively weak and needs further improvement. In addition, the lack of sponge city planning and demonstration areas is a considerable problem.

Shao *et al* used the information engineering perspective to analyze the sponge city [18]. They proposed that sponge city planning should be based on the data of underground pipe network information, hydrologic network information and urban planning, and put forward the data integration scheme of sponge city from the technical aspect, to integrate urban flood control, sewage and natural water treatment technology under the concept of LID. Wang *et al* further elucidated Chinese people's understanding and knowledge of urban flood and sponge city construction, and tested the public's willingness to support the sponge city by paying water surcharge and issuing credit securities [9]. Their study found out that most respondents were aware of urban floods and sponge cities, and supported the construction of sponge cities, with residents' thinking that government subsidies and public-private partnerships should be the main source of funding for sponge cities. However, respondents also accepted the domestic water price of the 17% as a sponge city construction surcharge. At the same time, the government issued a willingness to pay for the construction of the sponge city's credit securities (WTP) is 55% of the average annual capital surplus. Their study also found out that occupation, education and income were the main variables that affected respondents' WTP for the

sponge city initiative. Although a certain amount of water price increasing will be accepted by the public, the government should consider and promote the design of a more reasonable public-private partnership to overcome financial deficiencies and to ensure sustainability of the sponge city.

2.3. Case study

2.3.1. New Taipei city, Taiwan: permeable city. In order to implement the concept and ideal of "Permeable City", to improve the rate of impervious pavement, to reduce the flood occurrence and further to achieve the goal of urban water environmental protection through facilities such as rainwater storage and detention and water conservation, the New Taipei City Government launched the "Realizing Permeable City Project" in 2013. This Project analyzed the current situation and changes of water permeability in urban planning areas, and put forward the relevant laws and regulations, to practice permeable city policies.

The New Taipei Government set up a permeable demonstration zone with a view to alleviating the flooding problem and demonstrating the water permeable method to promote its effectiveness. According to the law, new development buildings in the urban planning area must provide rainwater storage facilities and standardize the development of public facilities and construction sites have to set up the water permeable and water-holding facilities, so that the ratio of water retention will meet the required standard.

2.3.2. Kaohsiung: eco-city and green building. Based on the environmental characteristics of Kaohsiung City, the Eco-City and Green Building Plan integrates numerous professionals, combined with the eco-city design technology, and used four operational guidelines, including "responding to climatic climate", "forming specific material spatial system", "extending the historical value of regional culture", "facing the influence of globalization and the need of urban competition", to design eco-city strategies; for example, building a self-assessment system to begin the development of eco-cities. The concept of self-assessment system is the standardization and embodiment of eco-city design strategies, which are related to local and public life, concise and easy to understand. The Government can adopt appropriate indicators to examine the gap between current situation and development visions or to seek improvement strategies.

Self-assessment indicators correspond to the climatic characteristics in Kaohsiung, like strong sunshine, high temperature and humidity, windy weather, as well as areas of high density, severe heat island effect, and industrial pollution emissions. Ten indicators include green, water, biological microclimate, energy, green transportation, resource recycle, digitalization, land use, pollution and heat island. These indicators combine the established "Sustainable Taiwan" assessment system and the "Kaohsiung and Pingtung sustainable development" indicators, and try to add the "shading", "wind", "energy saving", "resource recycle", "water management" and "green quality" and other practices, as the foundation for objective assessment.

These autonomous regulations are designed to promote eco-city, create a green building environment and a healthy quality of life, also promote green economic industry, and achieve the goal of reducing carbon and disaster. Buildings according to the use of categories and size classification need to comply with the relevant norms, such as setting roof solar power facilities or roof greening, waste disposal facilities and storage space, provincial water equipment and green equipment, rainwater or living miscellaneous drainage and recycling facilities, and so on.

2.3.3. The Netherlands: room for the river. The recent water policies in the Netherlands began in 1953, to start the Delta Plan in response to the floods. The Delta Works started in 1958, about 40 years later the Dam Delta completed. Since 2003, the Netherlands have begun the land reform planning, expropriating the river banks as a flood plain. The Government decided to restructure lands by adopting the concept of "Making Room for the River" [19].

The Netherlands has been promoting national land use planning based on the "Building with

Nature" principle since 2003, and put out the concept of "Returning the Land to the Sea" and "Living with the Water" as the basis of the coastal adaptation plan, and adopted sustainable, no-regret and resilient adaptation measures. The main practices include using land use change, urban planning and urban design to increase water storage space. Adopting land use control, urban planning and urban design practices to return the space to nature, and increasing rivers' retention space not only reduce the risk of flooding, but also take into account the supporting measures and policies for water governance [20,21].

The Netherlands has initiated a three-step strategy for water management since the beginning of the 21st century: storage, buffering and drainage. To do this, water resources need more storage spaces. The National Space Planning Memorandum has formally confirmed these water recommendations [22].

The water governance projects and cases differ due to different characteristics of each river, the basin situation and the riparian land use. However, the basic water measures, including reducing flood plains, the relocation of embankments can make the riparian plain a wider area to carry the flood, and make the flood flow rate slow down to prolong the people's response time and reduce the impact of disasters. Additionally, deepening the stream bed level in summer, increasing the water storage space, improving the waterway, reducing the barrier of dike or pier can increase the capacity of the river and strengthen the hardware facilities such as dike, so that people can safely coexist with water [23].

2.3.4. Australia: water-sensitive urban design (WSUD). Australia has had water resource problems for a long time. Due to the insufficient rainfall and continuous desertification, the rainfall becomes precious in Australia. However, with more concentrated rainfall resulting from the climate change, flooding has become more frequent than before. Therefore, the concept of "water sensitivity" is used to plan and design urban land use rather than the idea of overpowering-the-nature. This concept considers carefully of water sensitivity in urban planning and design and is the best practice for Australia to face the aforementioned problems [24].

Water-Sensitive Urban Design (WSUD) is based on the premise that the process of urban development and reconstruction needs to fully explore the sustainable water environment. WSUD refers to the integrated design of urban water recycling, including water supply, waste water, rainstorm and groundwater management, urban design and environmental protection. WSUD represents water and related environmental resources and water infrastructure in urban planning and design. The goal of WSUD is to manage all water streams as resources, because they can have qualitative and quantitative impacts on land, water resources and biodiversity. WSUD can be applied at all levels of urban water governance, that is, community, institution and government [5].

Through the rain and flood treatment, the interaction between landscape ecology and humane society, as well as the multi-objective comprehensive planning, WSUD can make urban development more aesthetic. The benefits of WSUD include environmental protection, social equity and economic development, thus achieving the ultimate goal of sustainable development. The porous paving system is an important approach of WSUD. To reduce the urban runoff and velocity of rainwater, the original impervious pavement can be changed to a pavement which allows runoff to seep into the soil. Another approach is rainwater gardens (rain piggy), it is usually designed as a concave or shallow depression, to collect urban rainwater, minimize the runoff and flow velocity caused by impervious surfacing, and to bring rainwater into the soil, while in infiltration process. The effect of purifying water quality is achieved by soil and plant roots.

2.3.5. The United States: LID. In the late 1990s, Seattle, Washington, Portland, Oregon and George Prince, Maryland, US began to advocate low impact development (LID), which is to reduce the risk of water pollution by reducing storm runoff. In 1998, Prince George County won the first prize for the National Excellence Award for the Urban Storm Management program by the Environmental Protection Agency (EPA) in a LID program. In 1999, the EPA completed the LID guide, which was extended to other states in the US [3].

In the past 40 years, the increase rate of impermeable pavement has exceeded the population growth rate 500%. The Best Management Practice methods typically use traditional hardware engineering to identify basic management facilities of the site (such as storage slots) [25]. The concept of LID practices tries to maintain the characteristics of natural hydrological cycle of the area in the land development. Especially when the land use pattern change into roads, squares, parking lots and buildings and other hard pavement, it will inevitably change the original hydrological flow, so that peak flow increases, the time of the flow shortens. Consequently, the LID approach must be adopted to do source control and to keep water stay rather than rushing to drain it. Source control focuses on infiltration, trying to maximize the amount of rainwater infiltration, so that the surface runoff and pollution concentration can be reduced.

Water and land should be developed harmoniously, based on the new ecological soft engineering, the LID practice can mitigate the harmful effects of urbanization on the environment, especially when impervious surfaces replacing natural or porous media. A successful LID requires owners, developers, urban and regulatory agencies to participate in a comprehensive planning process, and each stakeholder can play an important role [25].

3. Methods and the study area

3.1. Methods

In this study, the grey literature was adopted to review the related literature. Grey literature includes internal reports and research reports of various government agencies not publicly published. Therefore, this study will analyze the grey literature and historical reports related to water conservation governance in Taipei City, and will elucidate visions, strategies and supporting measures of building a sponge and livable city.

3.2. Study area

3.2.1. Water environment change in Taipei City. Taipei belongs to the Tam-sui River watershed, with a mainstream length about 158.7 kilometers, watershed area approximately 2,726 square kilometers. The Tam-sui River system has three major tributaries: the Keelung River, the Da-han River and the Xin-dian River. The main stream (that is, the largest tributary) is Da-han River.

The population of Taipei City is about 275million, and the population density is the highest in Taiwan. Taipei City is dense and urbanized, accompanying with waste heat emissions, cement and less green cover, resulting in the urban heat island effect. The possible impacts of urban heat island effect are extensive, including: increase of energy supply pressure, decrease of sunshine hours, decrease of relative humidity, change of rainfall pattern, reduction of available water resources, increase of urban flood probability, impact on air pollution monitoring, and confusion of global warming signals [26,27]. At the same time, intensive urban development increases the impermeable areas, which limits the capacity of waterway flood control and increases the surface runoff, impacting on urban flooded areas. Regions with more population and higher density have greater demands for transportation, and the planning and adaptation of land use and subsistence infrastructures should take into account the problems brought about by the extreme climate caused by climate change. Additionally, the concentration character of the population distribution in Taipei is likely to have a serious impact on extreme events such as typhoons and torrential rains [28].

The expansion and improvement of the water supply and the development of the reservoir due to urban growth of Taipei City, the Government completed the Emerald Reservoir in 1987 as expected to bring convenience to the residents of Taipei. With regard to the sewage treatment, Di-hua Sewage Treatment Plant and Nei-hu Sewage Treatment Plant produce the maximum daily use of 30,000 cubic meter for reclaimed water. If we can make good use of the water in the sewage treatment plant as a reusable water source, we can not only diversify the water supply, but also reduce the demand of traditional water resources and make use of it effectively.

3.2.2. Water governance history. Taipei City's overall flood control and drainage management began in 1960. Ministry of Economic Affairs proposed the "Taipei Flood Control Plan" in 1973, which intends to build embankments along the Tam-sui River and its tributaries. Following the approval by the Executive Yuan of the "Taipei Flood Control plan" in the same year, the overall flood control plan for Taipei was developed on the basis of the coastal embankment method and the principles of river regulation and river management.

For the exclusion of urban rainwater, Taipei Government set up pumping stations at the low-lying areas and at the exits of the drainage routes, aiming to remove runoff from the urban areas which cannot be discharged by gravity when the water gate is closed. The construction of the sewer in Taipei began in 1896, and till 2010, the implementation rate of Taipei Rainwater Drainage System reached 96.66%. As for the overall sewerage construction in Taipei, it was funded by the UN World Health Organization and the United Nations Development Fund and finished "Taipei Sanitary Sewerage System Structure Plan" in 1973. Whether sewerage diversion should be adopted or sewerage confluence should be adopted? Whether centralized treatment should be adopted or district treatment should be adopted? After taking into account water pollution and construction costs and other factors, the Taipei Government determined to use sewage diversion and sewage centralized treatment.

4. Discussions

In light of the impacts of climate change and extreme weather events, the development of water environmental policy in Taipei is becoming difficult in the aspects of ecological sustainability, flood control safety and urban development. It is hope that through numerous engineering and management tools, the open government policy, public participation and public-private partnerships, road permeability can be implemented, urban green coverage ratio can be improved, green roof concept can be promoted, capacity of urban storage detention can be increased, the sewage treatment can be upgraded, and reclaimed water can be reused. Consequently, Taipei City can have the ability of infiltration, water retention, and regulation of urban microclimate. When facing extreme weather events, Taipei can have enough capacity for dealing with disasters and achieving resilience. By so doing, Taipei can achieve the Sponge City goal for providing stable and diverse water resources, establishing amiable water environment and providing a rich variety of water environment. Based on the policies of Taipei City Government and research results of this study, visions and goals, strategic framework and supporting measures of building a sponge and livable city for Taipei are summarized as follows:

4.1. Resilient water adaptation

The vision of resilient water adaptation emphasizes control and adaptation of water when it is too much. When facing the water drainage and flood control of the Tam-sui River in Taipei, intelligent disaster prevention strategies should be adopted in the hope that the idea of living with the river and hydrologic regulation can be achieved.

4.1.1. Sound urban water cycle. The improvement of urban water circulation mainly focuses on promoting the infiltration and greening of public facilities and constructions from the private sectors, so as to improve the water retention of the construction site from two aspects, one is to increase the permeability of surface water and the other is to increase the green area. Permeable pavement has good water permeability and moisture and can improve the ecological environment of urban surface. While taking into account the requirements of human activities and reduction of the environmental damage of the non-permeable pavement to the ecological environment, permeable pavement design can further help achieve the goal of "symbiosis with the environment". The design of permeable pavement is the most important factor affecting surface permeability. If a construction site uses a large number of impermeable pavements, it is easy to make the landing rainwater become runoff and discharge from the site, resulting in poor water retention. Pavement design is the best way to control water retention of the construction site. However, increasing the permeability of surface water will

also need to consider the infiltration capacity of the building site, as well as the tolerance of the rainwater sewer system in Taipei. The Government should analyze more practical and diversified implementation alternatives to achieve the target of rain water storage capacity.

The LID method should be adopted to increase the tolerance capacity for floods and the capacity for rebuild, and further to construct a resilient city. There are many ways to practice the design of LID, including vertical greening, rain garden, plant retention trough, water permeable pavement, green street, grass ditch and grass drainage, and planting roof cover. These greening facilities provide many environmental and social benefits, including heat insulation, mitigation of heat island effect, rainwater harvesting and provision of elegant space for social gatherings.

4.1.2. Improving flood tolerance. In response to climate change, it is important to upgrade and review urban drainage systems, the flood control capacity of river and continuously promote the slopeland management, the treatment of the geologically sensitive areas, the planting, the setting of the flood regulation facility, and the sewer layout of rainwater side ditch and so on. In addition, the contingency and substitution measures will be established to a certain extent by means of engineering measures to continuously upgrade the flood control and drainage protection standards and to eliminate the threat of volatile areas. To enhance the flood tolerance, the main focus is on watershed countermeasures and intelligent disaster prevention. In the watershed countermeasure, the main aim is to continue the flood control plan, to manage the flood water in the flood area, and to carry out the maintenance and management of the facilities in order to play its proper function.

4.1.3. Key point. Through strategies of upstream water conservation planning, midstream flood reduction, and downstream flood control, it can further enhance the flood control capacity of Taipei City, such as the constructions of "Wen-shan District Overall Drainage Improvement Plan", "Jin-rui Water Conservancy Park".

On the public side, it will be great to let the potential disaster information more transparent through water condition APP, related security refuge maps and so on. Moreover, the Government should hold pre-disaster education advocacy, disaster prevention drills and aim to build public awareness of disasters, concept and ability of disaster avoidance. Through public-private concerted efforts, it is important to minimize the damage, create sustainable cities that are resilient and can meet challenges in the future. In addition to establishing relative rules, such as building development is above a certain scale, the 4% development of the water needs to be replaced by rainwater use. Moreover, the following efforts should be encouraged: environmental impact assessments for building a livable and sustainable city, for example, for developments above a certain scale, at least 4% of the water needed should be replaced by rainwater and the implementation of various rainwater infiltration measures to reduce the amount of runoff after development should be adopted.

4.2. Sustainable water use

The vision for sustainable water use focuses on how to allow the existing water resources in Taipei to be recycled when the water is too little. Therefore, Taipei City adopts two goals for sustainable water use: "Stabilizing water supply for effective water use" and "Diversified water use", hoping to improve the efficiency of sewage treatment, the purification of raw water turbidity and to make the water quality of Taipei be reused through purification.

4.2.1. Stabilizing water supply for effective water use. The promotion has two projects: "Conservation Management of Reservoir Catchment Areas" and "Reservoir Renewal Improvement and Siltation Treatment", in order to reduce the storage of silt in catchment areas and to exclude some silt by applying fortification and silting facilities.

In view of the precious water resources, in addition to promoting the stable supply of water resources, water conservation is an indispensable measure for sustainable water resource utilization. Taipei City gradually promotes water-saving plans and water-saving advocates to reduce water

consumption. Current daily water consumption per person in 2007 was 352 liter, and reduced to 330 liter in 2015 [29]. According to the domestic water consumption survey of the Ministry of Economic Affairs in 2016, the average daily consumption of people in Taiwan is about 276 liter, and Taipei is the city with the highest consumption, about 333 liter. It is expected to start from the tap water users and institutions to promote water-saving measures and counseling.

4.2.2. Diversified water use. For a large number of urban residents using water, water is a valuable resource. In addition to curbing the waste of water, how to achieve rationalization of water conservancy and to establish water-saving water use need to be recognized and implemented.

During recent years of urbanization and industrialization in Taiwan, most urban planners or construction experts treated rainwater as a shelter from rainwater (impermeable pavements) and tried to expulse them from buildings. As a result of this conceptual design, the existing urban buildings lack rainwater storage capacity, infiltration and evaporation, and resulted flooding, urban heat island effect or urban water pollution problems. Architects, engineers and scientists should therefore reconsider the relationship between building and rainwater.

Rainwater is the main inducing factor for the potential crisis of slopeland and other disasters. Additionally, there are many reasons for the improper use of land, such as the development of upstream hillside areas, the filling of river valleys and the encroachment of rivers. Solutions should be returned to land management, if only relying on the river embankment, the continuous increase in the way to solve the bar, its potential risk of a dam burst and follow-up maintenance management fee is also huge, not only contrary to natural principles but also economic benefits. Therefore, the sound water cycle concept, "Let the rain return to the Earth", should be an alternative way of thinking.

4.2.3. Key point. The Government promotes reuse of reclaimed water in sewage treatment plants, and reclaimed water can provide for environmental water use, such as road cleaning and cooling. Improving the water quality of reclaimed water (upgrade water quality), and setting up rain piggy in the park or setting rainwater storage pool for ecological and landscape construction should be advocated.

4.3. Friendly water environment

Taipei City locates in the Tam-sui River basin, as people pay more attention to leisure activities and quality of life, to create a friendly and high-quality hydrophilic environment become the Government's important task. The vision of a friendly water environment is that residents can enjoy friendly hydrophilic environment, recreational facilities and the benefits of coexistence with the water and various hydrophilic activities.

4.3.1. Ecological diversity aquatic habitat. In order to implement environmental protection, the Government should not only protect the existing urban forest, but also reforest at the same time to create a natural environment. By so doing, birds, insects and fishes can have appropriate habitats, and can restore the wild natural ecology and human coexistence. In maintaining the balance of urban water environment, greening is the basic measure of intercepting rainfall and increasing rainwater retention, which delivers many benefits.

4.3.2. Rich water recreation. The Taipei Sponge City Project aims to create recreational and leisure spaces on the water edge ecological rehabilitation. Also, related ancillary facilities are mainly hydrophilic types, and waste irrigation channels should be managed to recover. In particular, the irrigation waterways that flow through urban areas can create and activate hydrophilic spaces and improve urban water circulation systems by matching landscape and hydrophilic facilities, and try to improve and rehabilitate the farmland drainage network system, make the urban water environment space greatly improved

4.3.3. Key point. This project promotes wild stream ecological classroom, increases living spaces and so on, and minimizes the use of impervious concrete. In people's hydrophilic areas, this project uses the original block stone materials to overlap the hydrophilic valley, the small waterway, the hydrophilic path, the bank protection, the level terrace, and the fish ladder and so on. Let the stone blocks maintain the permeable crevice, so that they can create a vitality habitat for the stream environment. The hydrophilic activities in riparian water make hydrophilic water a part of people's daily life, and according to different seasons, the government launches numerous activities suitable for various ethnic groups. The development of the riverside bike roads have a lot of theme routes, such as landscape, wetlands, flower, light carving, weddings, history and so on.

5. Conclusions and suggestions

Urban floods are considered to be the most influential disasters. Previous studies pointed out that in various environmental risks, floods are highly correlated with climate change, and urban floods have become a global concern in recent years in the context of global climate change, which has had a serious negative impact on the city [7-10].

The purpose of this study is to explore the extreme climate and to cope with the densely populated environment of Taipei. Furthermore, through the introduction of international trend of climate change adaptation, this study elucidates how to implement the Taipei City Sponge and Livable City Program, so that Taipei can adjust flexibly in response to climate change, global warming and extreme climatic events.

Based on the analyses of the history and policies of water governance in Taipei City, the concept of sponge city, the promotion framework and the case studies at Taiwan and abroad, this study sorted out the practical strategies and work guideline of Taipei Sponge city. It is hoped that under the three major goals: resilient water adaptation, sustainable water utilization and friendly water environment, and coordinate with the relevant measures so that it can improve the urban water cycle, improve flood tolerance, use water in multiple active, supply water stably, stay ecologically diversified aquatic habitats, make rich water recreational activities. Moreover, through public-private partnership, professional water conservancy projects and applications, international trends and case studies, Taipei Sponge City concept can gradually be implemented.

Taiwan has about 80% of the population live in the urban planning areas. In Taiwan, urbanization is quite obvious, coupled with the challenges of climate change and global warming. Taiwan should carefully put the extreme climate impacts into the focus of governance. Sponge city governance includes different sectors, for example, related to engineering technology, water prices, environmental protection and so on, which need more co-ordination between different government units. Also in response to the Australian's WSUD, the planning aspects contain environmental protection, social justice and economic development. In the future, Taipei sponge city governance should pay more attention to the flexible cooperation of various departments.

This study only aims at the present Taipei sponge and livable city policies and the cases worldwide. Follow-up studies can base on the abovementioned ideas to select a region for demonstration areas. They can be roads or green parks etc. as a planning project to establish a small-scale sponge city demonstration zone. The planning time and funds are little and the demonstration area can be developed by public investments and public-private partnership. With regard to the city-scale practice, it can refer to the Netherland Water Governance Methods and Cases, according to the characteristics of each river, river basin and land use differences. Follow-up studies can compare the rain environment, sponge city concept discussion and extent of practice in different districts of Taipei City.

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