

Study of Climate Change Adaptation Strategies for the Urban Design of Taichung City

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Abstract— Taiwan is an island located at the junction of the Pacific and Eurasian areas. It is deeply affected by the interactions between the ocean and atmosphere. Latitude, monsoon season and vertical terrain changes all play a significant part in impacting the climate of Taiwan. In addition to the urban heat island effect, floods triggered by typhoons and torrential rains lead to economic, environmental and life safety threats. Taichung City is located in the middle section of the island and plays a strategic role in transportation (north-south and east-west) and industrial developments. To its east is the Central Mountain Range, adjacent to Ilan and Hualien Counties. To its west is the Taiwan Strait. The city owes its diverse terrain to rivers running through it as well as underlying faults below. The landscape ranges from mountains, hills, basins, plateaus and plains, running from east to west, gradually receding into the sea. In the face of climate change and the impacts of torrential rain, Taichung needs to urgently restructure its existing rich and diverse green resources and blue ribbon resources for disaster prevention. By thinking green in regards to reconstructing Taichung's infrastructure, both ecological conservation and disaster prevention of the densely populated metropolitan area can be improved. This study focuses on the effects of climate change and how to avoid consequential damages, using Taichung as an example. Based on overall landscape spatial structures, it identifies Taichung's strengths and opportunities in facing climate change. Using water issues as a starting point, this paper identifies Taichung's land development orientation and landscape transformation for towns and villages. As Taichung is developing into a highly urbanized area, it proposes green disaster prevention planning and design and also explores how to develop a symbiosis of water adaptation strategies for the urban design of Taichung.

Index Terms— climate change, landscape ecological structure, green infrastructure, green disaster prevention, adaptation strategies for urban design

I. INTRODUCTION

In recent years, in consideration of climate change, nature conservation and sustainable development, Taiwan has started adapting to the climate change spatial transformation movement. However, current urban design and landscape

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related projects in various cities throughout Taiwan fail to dwell on environmental issues. They only address 3-D form and style controls for visible landscapes, such as buildings and open spaces and do not provide specific countermeasures for functional disaster prevention, much less overall urban environmental benefits. Using water resources as an example, a city's river or canal often constitutes its urban landscape and is an important element of blue/green ribbon space. More often than not, considerations were made purely from a hydraulic engineering perspective. By not thinking about an overall urban landscape corridor, the results have very little urban ecosystem benefits. Due to increasingly serious environmental threats, cross-domain integration and forward-thinking, design has become an increasing need. This study analyzes the landscape ecological structure of Taichung in exploring its natural advantages and re-development opportunities. It focuses on major storm water issues facing metropolitan areas and proposes cross-domain integration of urban and rural landscapes. Additional responsive design concepts discussed include rainwater storage, water retention infrastructure and low-impact development.

II. TAICHUNG LANDSCAPE ECOLOGICAL STRUCTURE AND LAND DEVELOPMENT ORIENTATION

Taichung is very fortunate to have a unique ecological landscape structure. Its early development was primarily due to its excellent geographical location and natural environment. From the eastern mountains to the western sea, the landscape consists of Syueshan (Snow Mountain), the Foothills, Taichung Basin, Dadu Tableland and the Coastal Plain. Counting from north to south, there are three rivers crossing the region: Daan River, Dajia River and Wu River. There are also more than a dozen interwoven streams in the basin area. All these constitute Taichung's geographical living blocks. The geographical landscape and ecological structure of Taichung include:

A. Irrigation by Three Major Rivers Basins

From north to south there are three river systems: Daan River, Dajia River and Wu River. They run from east to west, through the region and into the sea. The abundant and uniform river flow provides irrigation for the immense Taichung Basin all year long, giving birth to a variety of geographic units with diverse ethnic cultures and ecological resources.

B. Diverse Terrain Landscape Structure

Based on terrain landscape structure, the whole region can be divided into four parts. The eastern half area covers the southern end of Snow Mountain and upstream of the Dajia River Basin. The Taichung Basin (also known as Little

Taiwan) is formed from river alluvial and makes up the central part. West of the basin is the longitudinal Dadu Tableland. Even further west are the lowlands of the Coastal Plain.

C. Unique Geographical and Climatic Conditions

The Taichung Basin has natural barriers on both sides: the Touke Mountains (westward extending mountains of the Central Mountain Range) and Dadu Tableland. They provide natural defenses against wind and natural disasters. The basin is oriented northeast to southwest and its river systems introduce a pleasant year-round monsoon climate. All these contribute to Taichung's unique conditions, making for plenty of sunshine and comfortable temperatures.

D. Settlement Development following River Geography

The settlement development process can be broadly divided into three regions: Mountain, Coastal and Suburb. The Mountain Region includes the eastern part of Dadu Tableland, between the Daan and Dajia Rivers. The Coastal Region consists mainly of the coastal areas west of Dadu Tableland. The Suburb Region occupies the area south of Taichung Basin, adjacent to Old Taichung, a part of the Taichung Metropolitan Area.

To research and analyze development context and future development orientation for Taichung, the overall landscape ecological structure must be classified and analyzed. Environmental conditions and resource potential of major topographical landscape areas can be explored to serve as an important reference for land conservation strategies. By taking into consideration its geographical terrain characteristics and settlement development context, Taichung's overall spatial structure can be divided into the following six regions:

1. Forest Ecology Green Screen: This region is located at the center of the Central Mountain Range Conservation Axis. With the exception of Shei-Pa National Park, the remaining area should have the objective of geographic landscape ecosystem preservation and basin headwaters conservation. With the Central Mountain Range as the core, resource conservation and usage planning should be expanded to include neighboring Miaoli's Taian Township to the north and Nantou's Renai and Xinyi Townships to the south.

- Strategy 1: From the perspective of land planning, establish development positioning and low environmental impact land-use patterns.
- Strategy 2: With the Central Mountain Range as the core, designate a national class scenic area for cross-county resource conservation and usage planning.
- Strategy 3: Designate protection zones in geologically sensitive areas, disaster-prone areas and reservoir watershed areas to carry out remedial actions for water, soil and forest.
- Strategy 4: Promote tours that integrate settlement culture, mountain climbing and various historical sites of industrial heritage.

2. Hill Valley Terraces: This region sits at the junction between the mountains and the metropolitan area, with a water system embedded in the sensitive hilly terrain. With several faults passing through, its disaster risk and ecological

impact is high. As a result, conservation of the whole forest ecosystem and extension belts are required to effectively control the development of the metropolitan area to create quality ecological urban and rural areas.

- Strategy 1: Emphasis on terrain landscape preservation and ecological protection of hill extension belts at foothills.
- Strategy 2: Restore the natural texture of diverse river systems and strengthen risk assessment at settlement junctures.
- Strategy 3: Development of line control for settlements at edge of tableland.
- Strategy 4: Highlight the diverse ethnic culture and develop quality ecological urban and rural areas.

3. Taichung Basin Alluvial Fan: This region remains as the main living area of Taichung. Effective control of the core area of urban development is required. Diverting the living area to surrounding satellite towns in order to develop a low-density city, is recommended.

- Strategy 1: Construct an open space system of accessible green river networks.
- Strategy 2: Use canal and stream textures to provide fast and convenient public transportation services, as well as comfortable and pedestrian friendly spaces.
- Strategy 3: Wuri core region is located at the most low-lying area of the basin. Being at the intersection of water and green resources, its future development should be re-established by overall ecological infrastructure positioning.

4. Laterite Plateau Barrier: This plateau is an important natural barrier which blocks the northeast monsoon and the sea breeze for the Taichung Basin and the western Coastal Plain. From north to south are the Houli Tableland, Dadu Tableland and Pakua Tableland extending to Changhua. It consists of a full range of miniature western coastal mountains coupled with natural river systems. With the Fazih River flowing alongside, and the Daan, Dajia and Dadu Rivers flowing through, it is geographically important, serving as [for serving the] major ecological islands and corridors between the alluvial plains

- Strategy 1: Treat cultural and historical development context and eco-geographical characteristics based on the miniature western coastal mountains (Houli Tableland, Dadu Tableland and Pakua Tableland).
- Strategy 2: Designate boundary buffer zones for developed areas and carry out landscape restoration.
- Strategy 3: Emphasize the ecological value of rivers and restore the original natural texture of rivers and canals.
- Strategy 4: Reconstruct quality green water infrastructures using parks and campuses as green nodes and roads and canals as green axes.

5. Coastal Lowland Plain: This region is sandwiched between the mountains and the sea, with rivers within. It is a plain with rolling dwarf hills, lowland, and alluvial from three river basins. This region has the most natural geographical advantages. As such, there are traces of human activity from as early as prehistoric times. Today, however, the entire coastline has large areas of development, including Taichung Harbor, Taichung Power Plant, etc. Since the natural coast has completely disappeared, the only way of development is

restoration, from an ecological landscape architecture point-of-view.

- Strategy 1: In response to industrial and port area development and transformation, development of green industrial zones and green harbor is suggested for the future through surrounding ecological restoration.
- Strategy 2: Establish Gaomei Wetland as the major ecological core of the Coastal Plain; restore water networks and green ecological networks of the Dajia River Basin.
- Strategy 3: Highlight the cultural historic development context of the area, and recover quality living settlements near river banks and hills.
- Strategy 4: Restore organic rural landscape textures for rivers, farmland, waterways, field forests and river terraces; strengthen flood detention functions of agricultural lowlands, from the perspective of watershed disaster prevention.

6. River Basin Corridor: Cut off by rivers and the terrain, landscape and urban units are scattered and independent, preserving the original natural and cultural texture and characteristics of individual settlements. In the future, making good use of environmental characteristics to build a sound ecological structure can bring scattered units closer. Green infrastructure development strategies include:

- Strategy 1: Use river corridors to link landscape ecological units and scattered towns and settlements in Taichung.
- Strategy 2: Use the river basin ecological axis to guide future development of Taichung.
- Strategy 3: Emphasize water catchment and water resources for preservation of land and settlements.
- Strategy 4: Restore natural textures and functions of rivers and canals within metropolitan areas.

III. THE THREAT OF CLIMATE CHANGE AND CHALLENGES FOR TAICHUNG

According to the Fourth Assessment Report from the Intergovernmental Panel on Climate Change (IPCC), the frequency of heavy storms in most parts of the world is predicted to increase in the future. The proportion of stronger typhoons may rise in the Pacific Northwest, and the intensity of the accompanying wind and rain may also increase. In addition, East Asia may see more arid days. Taiwan is located in the East Asia climate zone and within the Pacific earthquake fault zone. The island terrain coupled with high mountains and swift waters, greatly increases its disaster risk. According to statistics from the National Disaster Prevention and Rescue Center, Taiwan's mean temperature and sea level rose faster than the global rate of change, which shows that the effects of climate change on Taiwan has been very significant. The intensity of Taiwan's average seasonal rainfall is increasing; more obvious in northern Taiwan than in the south. The number of days without rain has increased year by year. Flooding and landslide disasters are closely related to extreme amounts of rain. Their intensity has grown in recent years in the areas west of the Central Mountain Range, with little to no change in the areas east of the range. The main cause of disasters from a typhoon is the extreme precipitation. Over the past decade, the frequency of typhoons with large

amounts of rainfall has more than doubled compared to that of the previous three decades.

Taichung is located in the middle of Taiwan's western plains, from east to west, the long and narrow area is about 100 kilometers in length with a terrain elevation difference of about 3,800 meters. The terrain covers mountains, hills, basins, plateaus and plains, with three major river basins. As a result, the distribution of natural disasters is different. Landslides account for the major disasters in the eastern half while wind and water trouble the western half. The metropolitan region's major disasters occur during the rainy season or typhoon period; the frequent and high intensity rainfall over a short period of time overwhelms the storm drain systems and causes flooding in parts of the region. In higher regions, river mudslides can occur due to erosion and debris. According to the Water Resources Agency's flood prone areas map, the Wuri area is the most low-lying area and has the highest risk of flooding in Taichung, along with scattered locations in the western estuary lowlands.

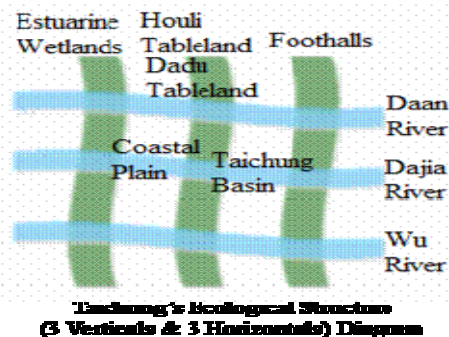
The 921 Earthquake caused severe damage in Taichung, mainly due to the Chelungpu fault passing through the edge of the Taichung Basin. The entire Taichung area has two geological fault belts: the Changhua Fault near the western Coastal Plain, and the Chelungpu Fault along the edges of Taiping and Wufeng Hills. The faults cause geological instability and fragility, but also provide natural tourism resources such as geothermal and hot springs.

Taiwan's west coast faces a rising sea level and coast-land loss. Although Taichung Port and the Taichung Power Plant have barriers, the disaster risk, environmental pollution and ecological impact on these industries is relatively high. According to a 2001 report by Ching-Piao Tsai and Chun Lin, the main problems facing the Taichung coast are from the gravel and sand mining of the Daan and Dajia Riverbeds, as well as problems arising from the construction of large-scale structures.

IV. LAND CONSERVATION AND USAGE STRATEGIES FOR TAICHUNG IN FOR COPING WITH CLIMATE CHANGE

Extreme climate certainly plays an important role in Taichung being hit hard by calamities. However, poor land usage that fails to comply with the restrictions of natural and geographical conditions are probably the main cause. Taichung's land usage development should use its natural geographical landscape ecology structure as the primary key for more adaptive land conservation and usage strategies.

1. Use "Three Verticals and Three Horizontals" Natural Landscape Defense Regeneration to Construct Taichung's Life-Support System



Landscape defense is built on a comprehensive water and green resource ecology structure. The general ecological pattern of Taichung is shaped by three vertical and three horizontal landscape textures. The three verticals are natural green veins, including the Foothills, Dadu Tableland and the Coastal Plain; while the three horizontals are the three basins running through Taichung, namely, Daan River, Dajia River and Wu River. We must re-examine the ecological bases and functions of the “three verticals and three horizontals” from the perspective of land conservation to promote urban and rural green infrastructure facilities.

Historical Districts:

- Use urban renewal to build green infrastructure facilities
- Transform park land into ecological disaster prevention green land
- Improve sidewalks and reconfigure water network systems
- Emerging Urban Areas:
- Conform to ecological infrastructure
- Construct an open space system of river accessible green networks
- Promote a healthy city with disaster prevention capability as a basis to enhance international competitiveness

2. Green Disaster Prevention Oriented Reconstruction for Taichung's Green Infrastructure

Taichung City is located at the heart of the national spatial framework, the “Western Growth Management Axes”. The axes mainly consist of Zhongshan Freeway, the High Speed Rail and the North-South Railway. Both Zhongshan Freeway and the High Speed Rail pass through Taichung along the Fazih Riverbank, while the North-South Railway cuts through Taichung along Beitun Road and Fuxing Road. With these two major axes, Taichung provides intercity transportation for the entire western corridor. In the future, along with playing an important role in the western transportation network, Taichung should focus on ecosystem preservation and disaster prevention for river systems, instead of just concentrating on intercity transport.

In addition, the three major river systems and dense water networks will play a vital part in future disaster prevention. By adopting a three-level system of basin, regional and metropolitan, along with a recyclable water resources usage system, green disaster prevention oriented reconstruction can be implemented on Taichung's green infrastructure, allowing for effective water diversion, retention, and usage.

3. Strengthen Coastal and Wetland Ecological Preservation Roles and Functions

From a regional ecological preservation viewpoint, the coast and nearby wetlands are the first and last, lines of defense. They also account for the best natural conservation zone for ecological habitat and human settlement. They can effectively reduce the threat of storm surges and tsunamis and can also act as pollution buffers. Coastal management policy outlines and integrated coastal management plans are needed and should be based on coastal area resources and ecological conservation objectives. It should serve as the basis for the regional planning and management of counties and cities, development permits and environmental impact assessments

The wetland area reduction crisis should be actively addressed. Conservation and restoration work on the Gaomei Wetland and Dadu Estuary Wetland should proceed without delay. In addition, the hardware and software quality of the environmental education facilities for both wetlands should be upgraded to international environmental education services standards. Additional environmental education sites and facilities can be added beyond the perimeters of the core protected areas. The promotion of environmental education should be carried out without affecting habitat functions. The regional impact of industrial pollution should be fully monitored as well.

Furthermore, low-carbon travel should be promoted to address coastal tourism impacts. Natural and cultural landscapes like Qingshui District Niumatou Cultural Site, Aofengshan, Dajia River, Daan Coastal Recreation Area and Taichung Port Art Center can be integrated for into overall coastal planning. Low-carbon transportation, wetland environmental education and local industrial cultural experiences can be used to form a diverse and coherent stretch of coastal eco-tourism for Central Taiwan.

4. Vision of a Better Life Based on Ecological Urban Development

The future development of Taichung's metropolitan area should be geared towards a multi-core living circle model, instead of the centralized, high-density development in the past. Urban development lines can be regulated through effective land usage controls while buffer zones can be set-up on lands which surround the major urban planning area. Urban planning can be decentralized, multi-style, adaptive to natural geographical textures, showing local cultural characteristics and also take quality of life into consideration. Such is the case in developing Taichung's satellite towns of Fengyuan, Wuri, Daya and Tanzi.

The forest area to the east is the reservoir catchment area. Besides its topographical constraints, the region is eco-rich, environmentally sensitive and a disaster-prone zone. Individual and sporadic development of industrial and residential units should be avoided. For settlements that are located within disaster areas, a comprehensive disaster warning system and industrial counseling program should be in place.

5. Overall Regional Thinking to Achieve National Land Aesthetics

After the inclusion of Taichung County, Taichung's visionary structure should be based on integration of cross-domain resource systems for long-range regional development and land conservation. In mountain and forest areas, the Central Mountain Range Conservation Axis should link to adjacent protected area resources; while in the coastal zone, the goal should be to construct Taiwan's Western Coastal Wetlands Conservation Axis, and conduct estuary wetland preservation and natural coastal restoration. A platform from which to implement urban and non-urban land controls and other supporting measures in the surrounding buffer zones should be established in conjunction with the relevant authorities.

Although developed as an artificial harbor, Taichung Port should still adopt a green harbor as its future goal, becoming a flexible, diverse and environmentally friendly development. It should take ecological redemption and environmental

responsibility and work together with the surrounding farming and fishing villages and schools for wetland and coastal protection work.

6. Use Wetland Conservation to Promote International Exchanges

Wetland conservation has quickly become the current international trend. Through more aggressive wetland conservation actions and by strengthening contact and cooperation with international wetland conservation organizations like the United Nations' RAMSAR, Taichung's Gaomei Wetland will have the opportunity to upgrade to an international wetland. Historical tours beginning at the Dajia River can be developed to really enhance international visibility. By using wetland conservation as a starting point and river corridor ecology restoration as the main content, Taichung's green disaster prevention capability can be soundly built-up.

V. GREEN DISASTER PREVENTION DESIGN FOR CROSS-DOMAIN INTEGRATION OF URBAN LANDSCAPE

In order to effectively respond to extreme climate change, green disaster prevention systems and thinking should be incorporated into urban environment construction. Using green infrastructure design techniques to mitigate the effects of disasters, such as storms, gales, heat waves and floods, can reduce the risk of exposure to urban disasters. Green disaster prevention design includes: designating urban green spaces and urban forests, constructing green roofs and ecological drainage systems, improving parking lot permeability for water retention, setting-up rain gardens, improving the pavement systems for city squares and streets, building urban green network systems, as well as preserving urban waterfronts.

In recent years, under pressure from global climate change, Taichung has faced threats from extreme weather such as typhoons, rainstorm floods, and droughts. These greatly impacted water resources and supply, directly affecting agriculture and environmental protection. The development of Taichung was nurtured by three major rivers flowing from east to west, and more than a dozen other rivers flowing in radial directions. Therefore, urban and rural planning is bound to proceed from the water system and its adjacent riverbanks. The waterfront should be tidied, restoring its ecological function, and urban activities extended to the waterfront. Using point, line, and plane to strengthen the entire water network, it can serve as a flood prevention waterway and also a blue and green belt open space system for urban activation

1. Water Environment Catalyst Program - Blue Wings and Green Petals Ecological Chain

Threats can be an opportunity for change. Wuri is located at the junction of Fazih River, Wu River and Mouluo River. The low-lying terrain is at risk of being easily flooded by torrential rain. It is also the rendezvous point of water and mountain systems, as well as the midpoint of Taichung, Changhua and Nantou. These unique natural, geographical and regional conditions make it a potential link for Central Taiwan living circles. Facing the pressures of global climate change, a core contemporary environmental issue is sure to be one of water resources. Thus, Wuri should be at the center of the conceptual water city, linking water and green belts in

response to cross-regional integration ideas. Planning concepts include:

- An ecological chain formed by Blue Wings (Wu River, Dadu River, Fazih River and Mouluo River) and Green Petals (Dadu Tableland and Pakua Tableland).
- Construct Wuri to be a model of a sustainable water city, providing cross-regional integration services.
- Construct green living circles for the Golden Triangle Region (Taichung, Changhua, and Nantou): providing cross-domain green transportation, cross-domain green land networks and green tourism system services.

2. Establish Three-Ring Ecological Defense Lines for Taichung

From its earliest days, the Old Taichung metropolitan area was developed using a single-core model. With the train station at the core, a radial road network was formed around it, resulting in a highly centralized urban expansion and poor environmental quality. Luckily, there are river systems like Lu Creek, Leo Creek, Mei Creek, Mayuantou River, Fazih River, Dali River and Han River all over the Taichung Basin. They flow transversely from the northeast to the southwest into Wu River, forming a natural wind corridor, effectively regulating the urban heat island effect and micro-climatic conditions.

In the face of today's changing climate, Taichung needs to restructure after having gone through intense urban development. It is necessary to construct new urban growth control lines from existing urban textures, serving as vital defenses of for disaster prevention. Cross-domain integration for Taichung should be built on the context of three-ringed ecological defense thinking. The three rings are Taichung greenways, Taichung living circle roads and the Taiwan Railways Ring System. The middle ring is proposed to connect with the existing water system, improve open space systems and storm water management systems and to establish an adaptive water resources system around the core metropolitan area.

3. Re-Link Waterfront Landscape and Culture through Water Resources Retention and Adaptation

Communities with abundant resources along the downstream segment of Wu River should be integrated and important strategic points along Wu River should be selected based on geographical location and cultural value; from Nantun, Wuri, Dali, Wufeng and all the way upstream to create a green waterfront chain. The design technique will use the river as the core and re-examine human waterfront settlements with cultural context along the Wu River through water resources retention and adaptation. Using a blue and green system, this chain of historical and cultural-value and ecological disaster prevention can be integrated.

4. Create Capillary-like Storm Water Management System

Facing threats from water, Taichung is striving to find the most beneficial way of urban development, rather than building dikes, thus seeking to create a win-win situation. Among the many flood mitigation strategies, flood detention facilities provide an important buffer for water resources

regulation. Taichung currently has many flood detention ponds, such as the Central Taiwan Science Park, Precision Machinery Park, Intercontinental Baseball Stadium, Shuinan Airport, Park #71 of the 12th rezoning (ecological retention pond), Tanzi Tzu Chi Hospital, etc., all located in the periphery of the living circle roads. This project is expected to use the Middle Ring. Through water intercepting waterways, flood detention ponds, campus ecology islands, rain gardens, and other techniques, a capillary-like storm water management system will be created for Taichung's metropolitan area, weaving a complete water resources protection mesh.

VI. CONCLUSIONS AND RECOMMENDATIONS

Water Symbiosis Adaptation Strategies for Urban Design

Over the years, numerous floods have caused significant damage to settlement environment as well as loss of life and property. Currently, domestic sectors are actively confronting flood issues; flood regulation has become the focus of government land management. Engineers have also begun to reflect on the problems arising from traditional flood control methods of river straightening and waterway channelization. Facing harsher climatic conditions in the future, a city's competitiveness and survival will be based on achieving symbiosis with water: effectively dispersing, retaining and relieving water resources. The following recommendations are proposed:

(A) Symbiosis with Water and Diversified Water Retention

River management is not only a flood control project of the river itself, but should start from the source and expand to the entire watershed, catchment areas and even the entire flood plain. From a land resources conservation point-of-view, using dispersed and diversified water storage, interception and retention, can help to achieve multiple objectives of flood control, water resources usage, ecological conservation and urban water environment construction. Water-sensitive urban design places an emphasis on water dispersion, small-scale measures, and prolonged timing. Its goal is to indirectly achieve urban flood mitigation by runoff reduction and permeability increase.

In order to implement this and actively achieve the goal of a sustainable city with comprehensive water retention, relevant regulations and incentives must be adopted and both public and private sectors must cooperate as well. For example, the March 2012 RDEC compilation "Urban Flooding Issues Discussion and Countermeasures Due to Climate Change" proposed flood management for five metropolitan areas. For the emerging metropolitan area of Taichung, its water resources adaptation measures are as follows:

1. For the currently booming new development areas, promote "Plain Residential Water Retention and Drainage System Overall Planning and Installation Mechanisms (with Incentives)". Using a drainage block as a unit, calculate allotted flow volume, evaluate suggested storage and infiltration capacity for each drainage block and provide incentives for base site water retention.

2. Promote "Public Facilities Reserving Lands Storage and Infiltration Facility Setup Standards", the main contents of which include:

- 1) Relax water storage and retention facility and set up flexibility for land reserved for public facilities.
- 2) Propose land suitable for storage and infiltration design specifications, priority areas and assessments.
- 3) Propose water retention development guidelines for land reserved for public facilities and base site water retention applicable targets.

(B) Shuinan Ecological Economic and Trade Park – A Specific Response to Wind and Water Climate Change Issues

In recent years, several large-scale development projects in Taichung have actively adopted urban design strategies to respond specifically to climate change issues. For example, Shuinan Ecological Economic and Trade Park, as one of the three flagship development zones (the other two being New Civic Center and Taichung Railway Station), is pivotal to the overall effectiveness of Taichung's urban development. The city government has proposed a few very forward-looking, thematic urban design ideas and addressed specific climate change adaptation strategies, including:

- Increase public open space systematically: retreat 4 to 6 meters along roads and open for public use; key base sites are concentrated, leaving open space for public use.
- Increase public events and public services: set-up a number of cultural facilities and public buildings in the region, such as the Movie Museum, Taiwan Tower and Second Cultural Museum;. require Ensure that a certain proportion of floor space must be designated for semi-outdoor corridors and shops along the street, providing public services and living functions and avoid purely luxurious mansions.
- Increase public transportation: strengthening public transport, including transfer stations, local shuttles and bicycle systems.
- Use wind and water as the main axes of passive energy saving for the urban environment:

Wind:

Connect and concentrate open space to form urban wind corridors.

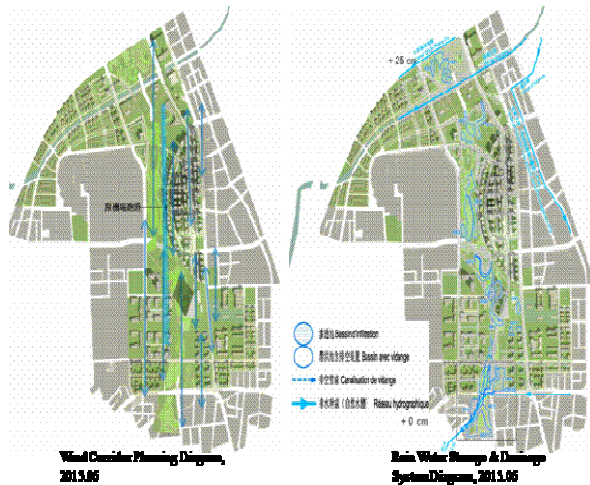
Retreat buildings along north-south roads to form urban wind corridors.

Integrate public and private open space as a continuous belt to form urban wind corridors.

Water:

Drain the development base site storm water to Chintzuiyuan for flood retention and disaster prevention; it will increase the infiltration of rain water, allowing water retention.

For large-scale development base sites and base sites with more than 20% volume transfers, rain gardens must be set up.



(C) Conclusion - Building Taichung into a Green Water City

Previous building site environments were often developed using impervious pavement design, resulting in the loss of good water absorption, infiltration and retention capacity of the earth. It weakened plant nourishment capacity and water evaporation, deprived the land of its natural climate regulation function, and aggravated the urban heat island effect. In addition, past urban flood control concepts were mostly to discharge rain water within the building site to adjacent land or into the urban public sewer system as soon as possible. It resulted in a heavy burden on urban public drainage facilities and caused flooding in low-lying areas after heavy rainstorms. Therefore, a review of building site water retention capacity becomes the basic requirement for water resources adaptation. A site with high water retention capacity can facilitate the water cycle of the land, improve the ecological environment, regulate micro-climate and ease the urban heat island phenomenon.

Prior to the merger of Taichung County and Taichung City, economic and industrial development has been the primary high-density development of the older core area of metropolitan Taichung. Major public investments are also concentrated in that area. Now that the merger has taken place, the whole of Greater Taichung should be taken into consideration when it comes to urban development. For the already highly developed metropolitan areas, water retention planning and waterfront green belt transformation should be used to improve urban health. The surrounding green satellite cities, including the Fengyuan and Wuzi regions, should be simultaneously developed using a complete river corridor belt to adjust urban open space constitution and improve disaster prevention capabilities.

In addition to promoting a low-carbon city, Taichung has been actively boosting community awareness of environmental protection, energy saving and low-carbon concepts of urban and rural planning. Included are the promotion of community organic agriculture, green industry, green living circles, ecological communities and ecological urban planning. For example, in recent years, many downtown green corridors were planned and completed, including Calligraphy Greenway, Chinmei Park Lane, Jing Guo Parkway, etc. In addition, old parks were transformed into flood detention parks, idle spaces were transformed into

art performance spaces, and new development buildings were retreated from the road to produce wider green belts through urban design measures. In the future, incentives will be considered to produce more urban open spaces, and fully accomplish systematic water retention, water drainage and water resources recycling objectives.

REFERENCES

- [1] Adger, W.N. (1999): Social Vulnerability to Climate Change and Extremes in Coastal Vietnam. *World Development* 27 (2), pp. 249-269.
- [2] Blaikie, P., T. Cannon, I. Davis and B. Wisner (1994): *Risk. Natural hazards, people's vulnerability and disasters*. London, Routledge (2nd ed. 2003).
- [3] Bohle, H., Downing, T. and M. Watts (1994): Climate change and social vulnerability. *Toward a sociology and geography of food insecurity*. *Global Environmental Change* 4 (1), pp. 37-48.
- [4] Boland, J.J. (1997): Assessing Urban Water Use and the Role of Water Conservation Measures under Climate Uncertainty. *Climatic Change* (37), pp. 157-176.
- [5] Burton, I., Huq, S. Lim, B. Pilifosova, O. and E. Schipper (2002): From Impacts assessment to adaptation priorities: the shaping of adaptation policy. *Climate Policy* 2, pp.145-159.
- [6] Button, K. (2002): City management and urban environmental indicators. *Ecological Economics* 40 (2), pp. 217-233.
- [7] *Challenges for Research, Assessment and Decision Making*. Airlie House, Warrenton, Virginia. Environment and Natural Resources Program, Belfer Center for Science and International Affairs (BCSIA), Kennedy School of Government, Harvard University. Cambridge, MA.
- [8] Joao Reis Machado & Jack Ahern(2003): *Environmental Challenges in an Expanding Urban World and the Role of Emerging Information Technologies*.
- [9] O'Brien, K. and R. Leichenko (2000): Double Exposure: Assessing the Impact of Climate Change within the Context of Economic Globalization. *Global Environmental Change* 10 (3), pp. 221-232.
- [10] Pauleit, S. and F. Duhme (2000): Assessing the environmental performance of land cover types for urban planning. *Landscape and Urban Planning* 52, pp. 1-20.
- [11] Rosenzweig, C. and W.D. Solecki (eds.) (2001): *Climate Change in a Global City: The Impacts of Potential Climate Variability and Change in the New York Metropolitan Region*. New York, Columbia Earth Institute.
- [12] Peter Hall, 1988, *Cities of tomorrow : An Intellectual History of urban planning and design in the twentieth century* /Peter Hall-Updated ed., Blackwell
- [13] Monica Kuo (2000), *Parks and Green Spaces Development Plan Operating Manual*, Parks and Green Spaces Quarterly, Issue No. 3, p. 34.
- [14] Monica Kuo (2000), *New Roles for Urban Parks during Environmental Changes*, Parks and Green Spaces Quarterly, Issue No. 2, p. 15.
- [15] Monica Kuo (2001), *Taiwan Park and Green Land Resources Policy Outlook*, Parks and Green Spaces Quarterly, Issue No. 1, p. 14.
- [16] Monica Kuo (2003), *Water and Green Network Planning and Practice*, Jan's Bookstor