Sustainability and river management in Taipei City, Taiwan

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ABSTRACT. Sustainability issues in Asian metropolitan centers have attracted considerable attention recently, but most studies have focused primarily on providing a comprehensive comparison of economic, social, and environmental indicators in various cities. The interaction between nature and cities during the process of urbanization has been largely overlooked in the assessment of sustainability. This article presents a case study of Taipei city to investigate the challenges associated with sustainable development through an investigation of the relationship between Taipei City and Keelung River and a discussion of relevant policy implications.

KEYWORDS. ***Locality, urban sustainability, river management, Taipei City***

1. Introduction

The development of metropolitan centers has been an important research topic within globalization studies. A considerable number of studies have focused on characterizing and ranking cities globally, as well as touching on economic, spatial, and social topics related to the development of cities within the broader context of globalization (Friedmann et al., 1982; Friedmann, 1986; Hill et al., 2000; Knox et al., 1995; Lo et al., 1996; Sassen, 2000; Short et al., 1996; Taylor, 1997). Urban sustainability and related environmental issues in the development of Asian cities have increasingly attracted the attention of researchers (Douglass, 2000; Lo & Marcotullio, 2000; Lo & Marcotullio, 2001; Macotuillio, 2001; Ng et al., 2003). Douglass (2000) emphasized that overcoming issues related to environmental sustainability in Asian metropolitan centers is a formidable challenge to urban policy makers.

According to the 1987 Brundtland Commission, sustainable development can be defined as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs". In the planning and management of cities, sustainable development is broadly translated and recognized as the ability to make developmental choices that respect the relationship between the three "E's"-economy, ecology, and equity (Berke et al., 2006). Thus, sustainability is extensively examined in terms of balancing economic, ecological, and social indicators (Macotuillio, 2001; Ng & Hill, 2003). Researchers have clearly advanced our understanding regarding the sustainability of cities, and the impact of urban development on the natural environment has been widely examined. Nevertheless, the relationship between nature and cities during the process of urbanization has been largely overlooked in the assessment of sustainability, downplaying the process of city development at the local level and its impact on the natural environment, particularly with regard to rivers.

As argued in discourses related to locality (Held et al., 1999; Marcotullio, 2001), urban development has not progressed along a single path; rather, different localities have demonstrated contextually specific paths. Thus, more systematic research based on a variety of environmental cases in different countries is required to gain a better grasp of issues associated with the environmental sustainability of cities. This article adds to the environmental debate by exploring the local significance of the relationship between cities and rivers. As Barrow (1998: 171) argues that "Every river and its basin is unique, but there is adequate commonality of hydrological, geomorphological and ecological characteristics for rivers to serve as widely applicable, non-ephemeral, operational landscape units for planning and management, and for maintaining environmental quality in the pursuit of sustainable development" (Tundisi & straskraba, 1995; Biswas 1997). However, the issues concerning the planning and management of river basin development has rarely been discussed or analyzed in previous studies. This paper presents a

case study of Taipei City and examines the relationship between urban development and rivers, which is the subject of many urban and geographical investigations (Eden et al., 2000; Kelman, 2003; Kortelainen, 1999; Pfadenhauer, 2001; Pires, 2004; Ryan, 1998; van Diggelen et al., 2001). Emphasizing the local process of city development, this paper examines the challenges associated with the environmental sustainability of Taipei through an exploration of its relationship with its rivers. In so doing, this work goes beyond typical indicators of sustainability (environmental pollution, changes in land coverage, and conflicts in land use) by focusing on river related disasters and watershed management problems (Huang et al., 1997; Whong, 2001; Huang et al., 2003; Lee et al., 2008). Due to steep hillslopes and weak land use controls, the watershed in the Taipei area is associated with frequent flooding, debris torrents, and landslides during typhoon season, making it an integral part of sustainability issues in Taipei (Lu et al., 2001; Cheng et al., 2002).

The paper begins with a brief discussion on earlier developments in the Taipei Basin. We then explore the intense developments along the Keelung River (KR) watershed since the 1980s, followed by an examination of challenges to river sustainability in the KR watershed. River disasters and state intervention in the KR are further highlighted to explore the relationship between the city and the KR. Conclusions and policy implications are considered in the final section of this article.

2. Early development in the Taipei Basin and Keelung River (KR) watershed

Taiwan is situated in the west Pacific region and characterized as a mountainous island. It covers approximately 36,000 km^2, and two thirds of it is mountainous. It has 129 rivers, most of which are located alongside cities. Taiwan's rivers represent a significant component of the urban development and environmental processes.

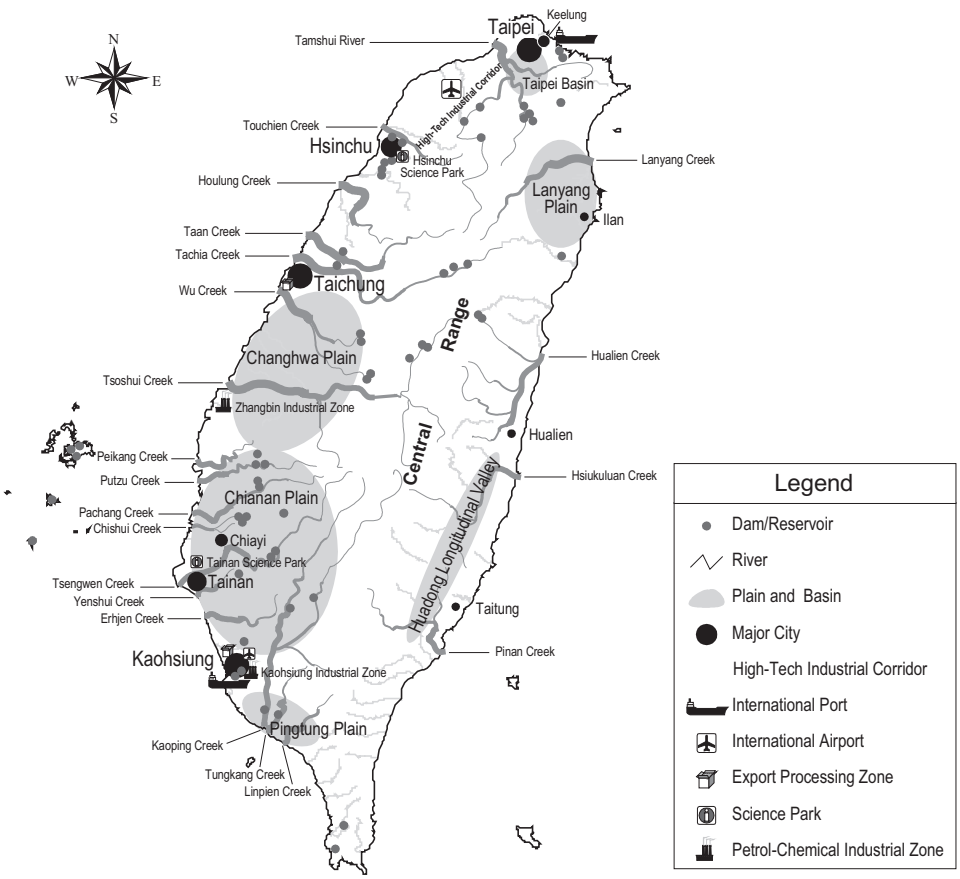

Figure 1. Cities and rivers in Taiwan

In northern Taiwan, the Taipei Basin comprises two important rivers: Keelung River and Tamshui River. According to historical literature, early economic development in the Taipei Basin centralized along the Tamshui riverside, particularly in the traditional districts of Taipei, or Barn-gar and Da-dau-cheng (Chou, 2007). The Tamshui river had hence functioned as the primary site for commercial transport of tea, rice and camphor, which were shipped through Tamshui River to markets in Mainland China. The river ports in Tamshui and Taipei (Da-dau-cheng) flourished as commercial cities during the Ching Dynasty. The areas surrounding the Keelung River (KR) were overwhelmingly agricultural land. Obviously, early development in the Taipei Basin was characterized geographically as two distinct river cultures. That is, the commercial Tamshui River and agricultural Keelung River.

Keelung River originates in the northeast mountainous area of Taiwan, flowing southwestward and crossing the Taipei Basin to meet Tamshui River at Guandu. Its length is 86 km and the river basin is 501 km^2. The elevation at the origin is approximately 500 m. Slow water flow below Nangang causes the river to meander across the Taipei Basin at nearly the same elevation of 40 m. Inundation has frequently occurred in midstream and downstream stretches of this river, which has resulted in agricultural development and created a large scale flood plain The midstream and downstream stretches of the river, and the land use in the major villages of Nauannuan, Hsichih, Nangan, Songshan, Zhongshan and Neihu was previously dominated by rice production. The KR accordingly served as an important resource for rural villages; agricultural production in paddy fields along the riverside, and for transportation to the outer world.

The agricultural heritage of KR was further deepened during the colonial period from the late 1890s. Colonial powers reinforced production by introducing hydraulic engineering. Nauannuan reservoir and associated Liukong irrigation system, and Chising irrigation system were established in the late 1920s to meet the demand for water for paddy fields in the Taipei Basin. Simultaneously, rice farmers organized self-regulated irrigation associations for managing the use of river water and maintaining the irrigation system (Ho, 1968; Hsieh, 1964). The irrigation associations and reservoir and irrigation engineering technology expanded the rural production of aquatic rice along the riverside. However, the KR watershed frequently faced serious threats from floods caused by typhoons. For this reason, agricultural lands along the riverside were not reclaimed entirely. In the colonial period, Nangan, Neihu, Zhongshan, Songshan, Shezi Island and Guandu plains were identified as flood plains in the downstream section of the KR. The KR functioned for irrigation, water supply, fishing, and transportation for neighboring villages. In spite of the threat of floods, flood prevention facilities along the riverbank of the KR were not established. These measures were only taken in urbanized areas of Tamshui Riverside (Taipei City Government, 1970). Flooding along the KR was considered acceptable for farmers in an agricultural society; however, these agricultural developments have been overwhelmingly improved since the Second World War due to rapid industrialization and urbanization in the Taipei Basin.

3. Globalization-driven urbanization in the KR watershed since the 1980s

Industrialization and associated urban development in the KR watershed occurred primarily in the cities of Taipei and Keelung. In 1968, the manufacturing employment in the Taipei-Keelung region reached 194,000, accounting for 40.4% of Taiwan's manufacturing sector, with a GDP of NTD 53.4 billion, or 63% of Taiwan's total GDP (CIECD, 1971). Due to their location adjacent to the Keelung sea port and the capital, Taipei, industrial zones along the river KR also emerged

as a significant part of the industrial development in the city region, including Nuannuan, Badoo, Qidoo, Liudoo and Wudoo in Keelung City, and Nangang, Neihu, Songshan, Zhongshan, Shihlin and Peitou in Taipei City (Hsin, 1978). The Liudoo industrial district in particular, including 60 hectares in Keelung City, was included in the early industrialization designated by the central state as an exemplar industrial zone for attracting FDIs in the 1960s (CIECD, 1969: 121). Food processing, consumer electronics, chemicals and other manufactured products rapidly expanded in the KR watershed as an integral part of Taiwan's export-oriented industrialization development. Industrial development in the watershed played an essential role in Taiwan' s industrialization. Despite being dominated by mountains, the KR watershed experienced rapid industrial growth, in which industrial zones, cargo yards and thousands of factories were scattered along the river. Rapid industrialization fuelled vibrant growth in the industrial economies in the watershed, shifting the KR region from early dependence on agriculture to the manufacturing sector.

However, pressure on urban development increased in the late 1980s, when Taipei City increasingly faced mounting competition from Hong Kong, Seoul, and Singapore (Chou, 2005). As the capital city and only world class city in Taiwan (Wang, 2003; Wang, 2004; Kwok, 2005), it required reconstruction and expansion of its economic base to further strengthen its global ties with the growing markets of Asia-Pacific, and to develop into a truly international metropolis. A 153 ha international financial center in Xinyi was created from a military factory brownfield of the KR to reformulate the city of Taipei as a new 'Manhattan' for financial services, serving as entrepreneurial headquarters. An 8.1 hectare industrial zone in Nangang (along the KR) was reorganized in 1996 as an economic trade park to stimulate the software and bio-tech industries within the city. Because urbanization in the Taipei Basin had reached saturation point in the mid 1980s, further land reclamations from the KR became unavoidable. Pressure from urbanization caused Taipei to launch an ambitious reclamation of the KR to create a new area for industry and urban development. In the 1990s, the meandering waterway through Taipei City was artificially redirected to form a straight line, complete with riverbanks and 10 water pumping stations. The length of the river in Taipei city was shortened by 5.3 km in the Neihu area of Taipei City. More than 500 hectares of land reclaimed from the river was first designated light industrial, and was recently transformed into the Neihu Science Park to serve as a strategic space for high-tech industrial developments in the globalization of Taipei (Chou, 2005). The reclamation project was seen as the most significant achievement in the recent urban development of Taipei (Huang, 2001: 118). On the flood plains, Shezi Island (323 hectares) and Guandu (924 hectares) have faced increasing developmental pressure to serve as a city sub-center since the late 1980s. Through the remodeling of traditional industrial zones, the redevelopment of military land, and the reclamation of land from the river, further urbanization and industrialization in the KR

watershed has generated a considerable number of new businesses and jobs, and provided a kick-start to renewed expansion. The KR watershed recently began to serve as the strategic center from which Taipei city is attempting to accommodate globalization spatially.

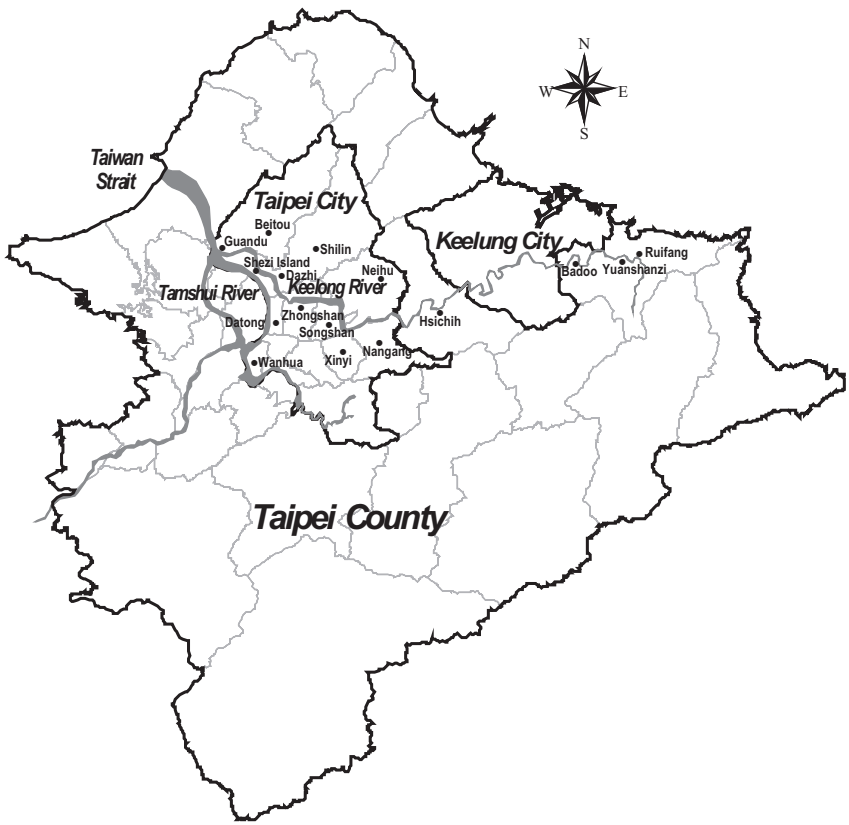

Figure 2. Taipei Metropolitan Area and its rivers

The spatial restructuring process in Taipei City also stimulated an urban explosion in the neighboring slope lands of the KR watershed in Taipei County. In 1987, Taipei City announced the Xinyi Project to build an international trade center. This accelerated subsequent urban development toward the eastern side of the city, and stimulated land speculation in Xinyi, Neihu, and Nangang. At the same time, the eastward development of Taipei City expanded land development into the fringe townships of Taipei County, resulting in a dramatic population explosion in Hsichih city from 55,736 in 1976, to 170,765 in 2003, an increase of approximately 115,029 people (Table 1). The increasing importance of Hsichih within the KR watershed is

illustrated by the fact that its population grew by approximately 91,472 between 1986 and 2003, while Taipei city increased by only 51,958, and Keelung city by 42,628. In fact, Ruifang decreased by 12,818 during the same period. Hsichih is a city of 7126 hectares, of which some 1300 hectares (20%) are classified as urban land. This implies that more than 80% of the remaining areas are reserved as natural protection areas because of their steep slopes (> 30%) in which development is discouraged. Hsichih is located on the eastern side of Taipei city, linking Taipei city and the international airport by two important freeways. The boom of Hsichih owes much to its convenient transportation and to the operations of land speculators, who increasingly considered Hsichih an investment locale since the 1980s (for a detailed study see Cheng, 1996). In response to growing developmental pressures, the local government expanded its urban development plan by 600 hectares in the 1990s (CEPD, 1999). With loose land use control, the new high-rise buildings in Hsichih were estimated to house 92,862 by 2000 (United News 2000/12/3). These developments left the city exposed to the threat of flooding, since many high-rises had been developed by speculators along the KR riverside without any investment in flood control infrastructure.

4. Land use and river sustainability challenges in the KR watershed

The above intensified industrialization and urbanization resulted in significant land use changes in the KR watershed. By 2000, 1,407 hectares of industrial zone had been developed in Wudoo, Nangang and Neihu to meet the spatial requirements of the manufacturing investment. Above all, industrialization brought urbanization to the watershed. As illustrated in Table 1, the population in the watershed reached 2.56 million in 1976, and further expanded to approximately 680,000 between 1976 and 2003. The city region had a population of approximately 3.24 million in 2003. In 2000, the urbanized and industrial areas in the watershed were estimated to be 335,691 hectares and 1,407 hectares, respectively.

Table 1. Urban and industrial land uses in the watershed of Keelung River

	Urbanized areas in 2000 (hectares)	Population growth			Industrial zones in 2001 (hectares)	
		1976	1986	2003	A	B
Taipei city	27,180	2,089,288	2,575,180	2,627,138	480	8
Keelung city	7,147	342,544	349,616	392,244	564	30

Ruifang	63	71,867	58,622	45,804	11	38
Hschih	1,301	55,736	79,293	170,765	276	-
Total	335,691	2,559,435	3,062,711	3,235,951	1,331	76

Source: Urban and Regional Development Statistics R.O.C 2000, Taiwan-Fuchien demographic fact book, R.O.C. 2004, Development and management of industrial zone 2001.
Note: A represents industrial zones developed by local governments. B represents industrial zones developed by the central government.

As urbanization intensified, the KR waterway in Neihu was invaded by 45 meters to create a 14.3 hectare landfill site, which served as a landfill for Taipei city between 1968 and 1985. It polluted the river, influenced the flow, and became known as the landmark, "Garbage hill on the riverside." Land use neighboring the KR waterway was either dominated by NIMBY (not in my back yard) activities of car repair shops and garbage recycling, or served as cargo yards, city arteries, and freeways with high bridges. Urbanization eventually caused serious pollution in the KR, and translated it into an urban waste water processor due to insufficient investment in sewage systems (Huang et al., 2003; Whong, 2001). Because most industrial waste and sewage effluent was discharged directly into the KR with very little treatment, concentrations of heavy metal sediment was observed in the KR drainage basin (Huang et al., 2003). The contaminated length of the river reached 68 kilometers (74% of the total length) in 1991, whereas it was only 45 km (52%) in 1985 (Whong, 2001). These drastic alterations in the ecological structure of the river resulted in the loss of the vast majority of fish. Above all, slope-land development in the KR watershed was increasingly transferred to residential communities, graveyards, and recreation parks. Road construction and inappropriate land development in the upland hillslopes of the watershed accelerated the occurrence of landslides and debris flow. The spatial consequence of intensified urbanization in the KR watershed also resulted in a dramatic change in its land cover. Since the late 1980s, adjacent forest cells were reduced by 78% (from 17,748 cells to 3,819 cells). The number of cells of less than 100 m2 were reduced by 70% from 7,000 cells to 2,000 cells, while those between 100 m2 and 1 hectare were reduced by 81% from 7860 cells to 1482 cells (Whong, 2001:78). This huge loss of forest considerably increased surface runoff, making natural disasters inevitable in the urbanized KR. With steep hillslopes and weak land use controls, the KR watershed was afflicted with frequent severe flooding, debris torrents, and landslides, becoming a serious watershed management problem during the typhoon season (Lu et al., 2001; Cheng et al., 2002). It is in the above context of urbanization that Hsichih became the primary target of attack by typhoons and the river due to over development (Ying, 2001).

5. River transformation and management policy in the KR watershed

As previously mentioned, since the 1960s, Taiwanese industrialization was centered on enormous economic activity and population growth in the greater Taipei metropolitan area, which changed the relationship between the city and nature. Hsinshan, Nuannuan, and Feitsuei reservoirs were completed in the early 1980s, and river water in Keelung and Tamshui was transferred to meet the water requirements of the Taipei metropolitan area. This development was associated with a changing relationship between KR with its proximal hinterlands in its midstream and downstream stretches. Water was increasingly separated from urban settlements in the KR watershed. Landowners, factory investors, and land speculators moved into the watershed to replace rural communities. Factories and residential communities expanded in the mid/downstream stretches of the KR as industrialization and urbanization intensified around the riversides of Hsichih, Nangang, Neifu, Songshan, Zhongshan, Shihlin, and Peitou. Agricultural land was reformulated to meet the requirements of manufacturing and urban development. Water resources for irrigation were destroyed and the rice culture of the river disappeared. The KR no longer functioned as a supply of water for urbanized areas, and was replaced by the Feitsui Reservoir, in the midstream section of the Tamshui River. Above all, as a result of the intensified riverside land reclamation, Taipei City was increasingly exposed to the threat of serious flooding. As the then Mayor Lee Teng-hui argued in 1981,

> *'most of the residential structures in Taipei have an elevation of three to six meters above sea level, and in some low-lying districts, houses are even below the level of high tides. . . . the rivers—Hsintien, Tamsui and Keelung—which traverse Taipei City are silted up, and their beds are becoming higher and higher. When floods occur, the water levels of these rivers rise quickly due to a lack of proper drainage of the city. As a result, the citizens of Taipei often suffer damages from deluges' (Lee, 1981: 12).*

The river has accordingly faced growing pressure from urbanization to provide land for the expanding city, making it an important target for discipline due to its threat of flooding.

In fact, in the 1960s, the government prepared a long range plan for comprehensive flood protection in the Taipei Basin (Taiwan Province Government, 1963). According to a report by a planner (Darling et al., 1964), improvements in channels and levees were identified as the most feasible means of obtaining a desirable degree of protection for the Taipei Basin. It was also emphasized that the 200-year flood is the minimum discharge design that should be considered for this densely populated metropolitan area (Corps of Engineers USA, 1965; Darling et al., 1964).

The plan was statutorily approved in 1964 as the Flood Control Plan for Tamsui River (FCPTR), and was further revised as the Flood Control Plan for Great Taipei Area in 1971 (for a detailed discussion on the planning evolution see Ying, 2001: 22-32). It was finally carried out between 1982 and 1996, costing approximately NTD 104.6 billion. Fifty water pumping stations and riverbanks approximately 12 m high and approximately 100 km long were completed.

The state-led flood control plan did not include ecology based flood control strategies using the preservation of wetlands and flood plains, because this would have impeded on land reclamation projects by the riverside. Instead, it was under the belief that 'people beat nature' and efforts to preserve land reclamation that the circumference strategies of building riverbanks and water pumping stations have been adopted as the primary solution to dealing with the threat of flooding from the KR.

6. Disastrous results of river management and state response in the KR watershed

The state-led strategy of flood control projects based on the hydrological engineering did not fully control the river to play the functional role set by the state. With the contribution of tropical typhoons, annual precipitation in Taiwan can be as high as 2500 mm. In an average year, the tropical weather in the west Pacific region generates approximately 27 typhoons, 3–4 of which significantly influence Taiwan (Cheng, 2000: 13). Due to the powerful forces of annual typhoons, the KR has repeatedly caused disastrous flooding in neighboring urban settlements (Table 2).

Table 2. Disasters associated with Keelung River

Typhoons	River disasters				State interventions
	Inundation depth (meters)	Raining hours	Influenced cities	Inundation (hectares)	
Lynn (1987.10.24)	3.0	48	Hsichih Taipei	609.6	-
Herb (1996.7.31)	0.1–3.0	7–24	Major cities in Tamshui watershed	-	Reduce the maximum slope for land developments from 55% to 40% across the island.

Winny (1997.8.18)	0.2–0.3	7	Hsichih Taipei	141.1	-
Anb (1997.8.29)	0.2–1.0	15–10	Hsichih Taipei	197	
Zeb (1998.10.15)	0.5–4.0	10–16	Hsichih	291	Announce Phase I of the Flood Control Plan for the upstream KR, (USD 348.5 million) to deepen waterways and construct riverbank and pumping stations in Hsichih and Ruifang.
Babs (1998.10.26)	0.5–3.8	5–8	Hsichih	286	
Xangsane (2000.11.1)	0.5–7.5	10–16	Hsichih Keelung	441	(1) Announcement of the Comprehensive Plan of Flood Control for the upstream KR to replace the Phase I of Flood Control Plan. (2) Reduce the maximum slope for land developments from 40% to 30%.
Toraji 2001.7.30)	-	-	Hsichih	800	(1) Facilitate the Comprehensive Plan of Flood Control and initiate flood control projects costing USD 3 billion. (2) Approve a special law for control of the KR.
Nari (2001.9.16–18)	1.5–8.5	16	Hsichih Taipei Keelung	800	

As mentioned above, the riverbank and pumping stations in the downstream areas of KR, or the Taipei basin were completed in 1996. These measures were implemented to protect the economic heart of Taipei from inundation disasters. However, the flood threat moved up to Hsichih in the midstream section, which had been developed by land speculators as a satellite town. Hsichih was inundated in nearly every typhoon, due to overdevelopment and a lack of

investment in flood mitigation infrastructure. During Typhoon Winny in 1997, the inundated area reached 141 hectares, and 200 households of Lincoln Mansion in Hsichih were destroyed in violent debris flows and mudslides, in which 28 people were buried alive. Two weeks later, Taipei and Hsichih were flooded again due to Typhoon Anb. The inundated areas expanded to 197 hectares. Such disasters reoccurred in 1998 with typhoons, Zeb and Babs. Hsichih city was inundated twice again within two weeks, submerging approximately 300 hectares and claiming 3 lives. More recently, Toraji and Nari typhoons ravaged Taiwan, claiming 185 lives with more than 100 people missing island wide. Hsichih was again submerged twice, breaking records for inundation.

Such disasters have repeatedly occurred during typhoon season, attracting national attention to the issue of urban over development in the KR watershed the policy of allowing land development on hillslopes (Table 2). The severe debris of Typhoon Herb in central Taiwan forced the state to reduce the maximum slope for developments from 55% to 40% in 1996 (for detailed analyses on Herb see Lin et al., 2000; Chen et al., 2001). The threshold was further reduced to 30% following Typhoon Xangsane. In response to typhoon Zeb and Babs in 1998, the state was forced to announce Phase I of the flood control plan for the upstream KR, at a cost of USD 348.5 million to deepen the waterway and construct riverbanks and pumping stations in Hsichih and Ruifang. Nevertheless, typhoons Toraji and Nari again smashed the river control projects in 2001, seriously damaging Taipei city, Hsichih and areas of Keelung. On the one hand, the government continued its 200-year flood control policy by raising river embankments in response to the record breaking weather in the Nari disaster. The standard for river embankments to deal with peak water flow was increased from 3,600 tons to 5,200 tons per second. Moreover, in 2002, in desperation, a special law was enacted to bring the KR under control, and a budget was swiftly passed for the construction of embankments and a flood diversion program. Four flood control programs were launched following Typhoon Nari. The entire KR control project cost approximately USD 3 billion and aimed to (1) construct flood control dams in upstream Pingsi village, (2) facilitate the construction of embankments in the KR watershed, (3) carry out flood-diversion projects in the Yuanshanzi and Badoo areas, and (4) complete a river tunnel at Yuanshanzi to intercept floodwater upstream and guide it directly into the Pacific Ocean, which is estimated to reduce the water level of KR by 1.5 m. The government has used river engineering and technology to suppress and control the KR. Nevertheless, achieving urban sustainability in the watershed is still uncharted and in Sept. 2004, Hsichih was seriously inundated by Typhoon Haima.

7. Conclusions and policy implications

According to Hall (2002: 281), sustainability in the literature can mean nearly anything the author wants it to mean. He borrows the celebrated phrase of Wildavsky (1973): 'if planning is everything, maybe it is nothing, and states that 'if sustainability is everything, maybe it is nothing.' Unlike the mainstream approach of comprehensively comparing city indicators, the paper examines the environmental sustainability of a world-class city by observing the process of dealing with environmental issues at the local level and the relationship between the city and nature (river). It has been recognized that the most significant issue here is the process of urban development driven by the globalization. Globalization has intensified urban development in the Taipei Basin toward the KR watershed and hydrological engineering has increasingly been the primary approach to flood control. The government has adopted the basic tenets of 'man over nature, in the acceleration of engineering efforts to bring the KR under control. However, this approach has intensified conflict between the city and the river with repeated disasters punctuating the need for environmental sustainability in the KR watershed.

Management of the KR watershed is at a crossroads, and requires new policies to reconstruct the relationship between urban development and the river. Obviously, if river engineering is to have more room and function effectively, it cannot be implemented in isolation from policies governing land use. A watershed such as the KR, with hydrologic extremes and unfavorable physiographic and geologic conditions requires symmetry in policy, such that nature and society are treated as necessary counterparts to policy. Bias in policy to suppress the river must be remedied to reincorporate the natural interests of the river. Above all, a more holistic approach must be adopted to emphasize the importance of the drainage basin as a natural environmental unit with which to construct an integrated management policy for changes in land use. Human action in the KR watershed must be extensively curtailed through the introduction of new initiatives dealing with the management of urban growth, the restoration and protection of forests, and above all strict controls on land development in hillslope areas to mitigate natural repercussions from human-induced hazards.

References

Barrow, C. J. (1998). River basin development planning and management: a critical review. *World Development*, 26(1), 171-186.

Berke, P. R., Godschalk, D. R., Kaiser, E. J., Rodriguez, D. A. (2006). *Urban Land Use Planning*. Urbana and Chicago: University of Illinois Press.

Biswas, A. K. (1997). *Water Resource: Environmental policy, management and Development.* New York: McGraw-Hill.

Chen, K. S., Wang, J. T., Mitnik, L. M. (2001). Satellite and ground observations of the evolution of Typhoon Herb near Taiwan. *Remote Sensing of Environment,* 75, 397-411.

Cheng, T. S. (1996). *Monetary City.* Taipei: Juy Liu Press.

Cheng, J. D., Lin, L. L., Lu, H. S. (2002). Influences of forests on water flows from headwater watersheds in Taiwan. *Forest Ecology and Management, 165*, 11-28.

Cheng, L. F. (2000). Typhoons in this year. *NAPHM Newsletter*, 2, 13-16.

Chou, T. L. (2007). Taipei, an Anti-communist Capital, a City Dependent on a Developing Country. *Space, 481*, 56-61.

Chou, T. L. (2005). The transformation of spatial structure: from a monocentric to a polycentric city. *Globalizing Taipei* (pp. 55-77). Reginald H. W. K. (Ed.). London: Routledge.

Council for Economic Planning and Development (CEPD). (1999). *Urban and regional development statistics*. Taipei: Urban and Housing Development Department.

Council for International Economic Cooperation and Development (CIECD). (1969). *Annual Report of Council for International Economic Cooperation and Development.* Taipei: CIECD.

Council for International Economic Cooperation and Development (CIECD). (1971). *Drafts on Hsinchu-Miaoli Regional Plan.* Taipei: CIECD.

Corps of Engineers USA. (1965). *Report on review of Taipei area flood control planning phase II.* Taichung: Water Conservancy Agency, Taiwan Province.

Darling, W. D., Buswell, J. M. (1964). *Preliminary review of flood protection plan for Tam-shui river, Taipei Plain,* Taiwan. Taichung: Water Conservancy Agency, Taiwan Province.

Douglass, M. (2000). Mega-urban regions and world city formation: globalization, the economic crisis and urban policy issues in Pacific Asia. *Urban Studies, 37*(12), 2315-2335.

Eden, S., Tunstall, S. M., Tsapsell, S. M. (2000). Translating nature: river restoration as nature-culture. *Environment and Planning D, 18,* 257-273.

Friedmann, J. (1986). The world city hypothesis. *Development and Change, 17*, 68-83.

Friedmann, J., Wolff, G. (1982). World city formation: an agenda for research and action. *International Journal of Urban and Regional Research, 6*(3), 309-344.

Hall, P. (2002). Planning: millennial retrospect and prospect. *Progress in Planning, 57*, 263-284.

Held, D., McGrew, A., Goldblatt, D., Perraton, J. (1999). *Global transformations, politics, economics and culture.* Stanford: Stanford University Press.

Hill, R. C., Kim, J. M. (2000). Global cities and developmental states: New York, Tokyo and seoul. *Urban Studies*, 37(12), 2167-2195.

Ho, S. P. S. (1968). Agricultural transformation under colonialism: the case of Taiwan. *The Journal of Economic History, 28*(3), 313-340.

Hsieh C. M. (1964). *Taiwan-ilha Formosa: A Geography in Perspective*. London: Butterworths.

Hsin, W. G. (1978). *Review and improvement program of industrial order in Taipei City.* Taipei: National Chung Hsing University GIUP.

Huang F. –S. (2001). *Oral history of Taipei Municipality by mayors and councilors*. Taipei: Taipei City Council.

Huang, S. L., Wong, Z. H., Chang, T. C. (1997). Construction and evaluation of city sustainability in Taipei. *City and Planning*, 24(1), 23-42.

Huang, Y. M., Lin, S. (2003). Consequences and implication of heavy metal spatial variations in sediments of the Keelung River drainage basin, Taiwan. *Chemosphere, 53,* 1113-1121.

Kelman, A. (2003). *A River and Its City.* Berkeley, C.A.: University of California Press.

Knox, P. L., Taylor, P. J. (1995). *World Cities in a world System.* Cambridge: Cambridge University Press.

Kortelainen, J. (1999). The river as an actor-network: the Finnish forest industry utilization of lake and river systems. *Geoforum*, 235-247.

Kwok, R. Y. W. (2005). (Ed.) *Globalizing Taipei.* London: Routledge.

Lee, T. H. (1981). *Development Plan for Taipei City.* Taipei: Taipei City Government.

Lee, Y. J., Lin S. J., Huang, C. M. (2008). Construction and Application of Taipei's Sustainable Development. *Journal of Architecture, 65,* 1-26.

Lin, M. L., Jeng, F. S. (2000). Characteristics of hazards induced by extremely heavy rainfall in central Taiwan: Typhoon Herb. *Engineering Geology, 58,* 191-207.

Liu C. L. (1975). Hydraulic constructions in recent 30 years. *Economic construction after the war.* News Agency of Taiwan Provincial State (Ed.). Taichchung: Taiwan Provincial State.

Lo, F. C., Marcotullio, P. J. (2000). Globalization and urban transformations in the Asia-Pacific region. *Urban Studies, 37(1),* 77-111.

Lo, F. C., Marcotullio, P. J. (2001). *Globalization and urban sustainability of cities in the Asia-Pacific region.* Tokyo: United Nations University Press.

Lo, F. C., Yeung, Y. M. (Eds.) (1996). *Emerging World Cities in Pacific Asia.* Tokyo: United Nations University Press.

Lu, S. Y., Cheng, J. D., Brooks, K. N. (2001). Managing forests for watershed protections in Taiwan. *Forest Ecology and Management,* 143, 77-85.

Marcotullio, P. J. (2001). Asian urban sustainability in the era of globalization. *Habitat International, 25(4),* 577-598.

Ministry of Economic Affairs (MoEA). (1970). *Reports of Flood Prevention Plan in Taipei Area.* Taipei: Water Conservancy Planning Council.

Ng M. K., Hills, P. (2003). World cities or great cities? A comparative study of five Asian metropolises. *Cities, 20(3),* 151-165.

Pfadenhauer, J. (2001). Some remarks on the socio-cultural background of restoration ecology. *Restoration Ecology, 9,* 220-229.

Pires, M. (2004). Watershed protection for a world city: the case of New York. *Land Use Policy, 21,* 161-173.

Ryan, R. T. (1998). Local perceptions and values for a Midwestern river corridor. *Landscape and urban planning, 42,* 225-237.

Sassen, S. (1991). Global City: *New York, London,* Tokyo. Princeton, NJ: Princeton University Press.

Short, J. R., Kim, Y., Kuu, M., Wells, H. (1996). The dirty little secret of world cities research: data problems in comparative analysis. *International Journal of Urban and Regional research, 20*(4), 297-716.

Taipei City Government. (1970). *Brief History of Taipei Urban Development.* Taipei: Archives Councils Press.

Taiwan Province Government. (1963). *Survey and Report of Flood Control Plan for Tamsui River System.* Taichung: Water Resources Management Bureau, Taiwan Province.

Taylor, P. J. (1997). Hierarchical tendencies amongst world cities: a global research proposal.

Cities, 14(6), 323-332.

Tundisi, J., Straskraba, M. (1995). Strategies for building partnerships in the context of river basin management: partnerships in the context of river basin management: the role of ecotechnology and ecological engineering. *Lackes and Reservoirs: research and management, 1(1)*, 31-38.

van Diggelen, R., Grootjans, Ab P., Harris, J. A. (2001). Ecological restoration: government of the art or government of science? *Restoration Ecology, 9,* 115-118.

Wang, C. H. (2003). Taipei as a global city: a theoretical and empirical examination. *Urban Studies, 40(2)*, 309-334.

Wang, J. H. (2004). Wold city formation, geopolitics and local political process: Taipei's ambiguous development. *International journal of Urban and Regional Research, 28*(2), 384-400.

Whong, Y. L. (2001). *Watershed planning based on the management of ecological system: a case study on Keelung River.* Taipei: Master dissertation of Graduate Institute of Resource Management, National Taipei University.

Wildavsky, A. (1973). If planning is everything maybe it's nothing. *Policy Science*, 127-153.

Ying, W. Z. (2001). *Flowing hope/disaster: political economy of Keelung River flood control project*. Master dissertation of Graduate Institute of Building and Planning Institute, National Taiwan University.