Chapter 12
Assessing Water Security at District Level: A Case Study of Bangkok, Thailand

A. Onsomkrit, M. S. Babel, V. R. Shinde, and V. P. Pandey

Abstract This study applies the water security framework in Bangkok city, Thailand at different spatial (five districts: Sathon, Lat Phrao, Nong Chok, Bangkok Noi and Nong Kheam) and temporal (2007–2014) scales. The framework consists of an index (water security index, WSI), five dimensions, ten parameters and twelve indicators. The five dimensions cover following aspects for a water-secure city: (1) Every person at household level can access easy piped water supply with sufficient quantity to meet basic needs and be of acceptable safe quality; (2) Water productivity of economic activities in the city is reasonably high; (3) Water-bodies in the city are not affected from pollution and contamination generated in the city; (4) Acceptable level of water-related disaster to people in the city that consider urban flood damage and rainfall variation; and (5) Water governance is effective for resource use, management, and capacity development. Results showed that the overall status of water security in the study districts are "moderate" level. We also found that some of the indicators and parameters were found inappropriate at district (or sub-city) level due to lack of data. This application demonstrates suitability of the framework at a city-scale rather than sub-city (or district), as data of a finer scale are lacking at sub-city scale and most of the actions to secure water are taken at the city level.

Keywords Bangkok · Framework · Index · Indicators · Water security

12.1 Introduction

Early societies arose along rivers and lakes because these natural assets provided significant water security for domestic use, irrigation, transport, fisheries, and power (from water wheels to hydropower). However, as population and water demands have grown, man-made infrastructure became necessary to supplement natural assets to maintain water security. There is evidence of dams built over 4,000 years ago to store water in ephemeral rivers (Fahhlbusch 2001 cited in Grey and Sadoff 2007).

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M. Babel et al. (eds.), *Water Security in Asia*, Springer Water,
https://doi.org/10.1007/978-3-319-54612-4_12

In countries with adequate wealth and technology, dams, wells, canals, pipelines, and municipal water supply systems have been built to provide storage and delivery functions much similar to the lakes, rivers and springs and treatment plants that provide the cleansing functions to wetlands and aquifers. From natural to man-made and from small-scale to large, a continuum of options has evolved to meet the challenges of water security (Grey and Sadoff 2007).

Awareness is growing that water is a scarce and precious resource, which must be carefully managed if frightening future water crises are to be avoided (GWP 2000). The world has recognized that secure livelihoods, strong economies, and sustainable ecological systems depend on the availability of water, and principles for its management have been internationally agreed (GWP 2000). The urgent challenge that remains is to translate these agreed principles into practice. In 1997 at the first World Water Forum, professionals from around the world agreed that a mass mobilization and awareness campaign was needed to alert people and politicians to the fragile status of the world's water resources (GWP 2000).

The concept of water security emerged in the 1990s and has evolved significantly since then (Cook and Bakker 2012). Held in 2000, the 2nd World Water Forum conceptualized the first definition focused to tackle the global water crisis by directing the need to work towards "water security" as an overarching goal. Therefore, the Global Water Partnership (GWP) introduced an integrative definition of water security which gave the definition as "water security at any level from the household to the global means that every person has access to enough safe water at affordable cost to lead a clean, healthy and productive life, while ensuring that the natural environment is protected and enhanced." On the other hand, Grey and Sadoff (2007) have defined water security as "the availability of an acceptable quantity and quality of water for health, livelihoods, ecosystems and production, coupled with an acceptable level of water-related risks to people, environments and economies". Also, Cook and Bakker (2012) showed that framings of water security have become more diverse, expanding from an initial focus on quantity and availability of water for human uses to water quality, human health, and ecological concerns. Thus, they proposed four interrelated themes that dominated the published research on water security: water availability; human vulnerability to hazards; human needs (development-related, with an emphasis on food security); and sustainability. However, the concept of water security remains largely unquantified (Lautze and Manthrithilake 2012 cited in GWP 2014), due to which developing and managing water resources to achieve water security remains at the heart of the struggle for growth, sustainable development, and poverty reduction (Grey and Sadoff 2007).

Furthermore, scale is also critical in assessing water security because of the scalar variability of hydrology, as illustrated by a study (Vorosmarty et al. 2010 cited in Cook and Bakker 2012). Cook and Bakker (2012) argued that different disciplines tend to focus on different scales. Development studies tend to use national scales, hydrologists often focus on watershed scales from the regional to the national, and social scientists regularly work at the community scale (Cook and Bakker 2012). Moreover, water security assessment at the national scale can mask significant variations in security at the local scale (Vorosmarty et al. 2010 cited in Cook and Bakker

2012). Dun et al. (2009) also stated that indicators are often site-specific or framed for a specific scale that may not be transferable to other scales (e.g. national or international level indicators may not be sensitive enough to identify water issues at a local level) (GWP 2014). Thus, this study aims to apply the water security framework to assess status of water security at the district scale of Bangkok city, Thailand.

12.2 Water Security Assessment Framework

From a previous study, Onsomkrit (2015) established the water security framework at city scale that defines water security as–*Every person at household level can access easy piped water supply with sufficient quantity to meet basic needs and be of acceptable safe quality; Water productivity of economic activities in the city is reasonably high; Water-bodies in the city are not affected from pollution and contamination generated in the city; Acceptable level of water-related disaster to people in the city that consider urban flood damage and rainfall variation; and Water governance is effective for resource use, management, and capacity development*. The framework consists of an index (Water Security Index, WSI), five dimensions (reflecting the definition), ten parameters and twelve indicators to measure the dimensions that are showed in Fig. 12.1. This framework was developed by using DPSIR (drivers, pressures, state, impact, and response) framework and SMART (specific, measurable, actionable, relevant, and time-bound) criteria. Moreover, a scoring system from 1 (water insecurity) to 5 (very high-water security) was employed to represent and interpret the water security situation. Equal weight was also applied for this framework. Different weights to dimensions, parameters, and indicators can be given based on their importance in a particular city. Multi-criteria decision analysis techniques such as Analytical Hierarchy process can be applied to define the weights to the indicators, parameters, and dimensions. The methodology of this study is based on water security framework from Onsomkrit (2015), which has been applied to assess water security status at district level.

12.3 Study Area

This study considers a small spatial scale (district level) in Bangkok, Thailand. The districts include Sathon, Lat Phrao and Nong Chok (east of Chao Phraya river), and Bangkok Noi and Nong Kheam (west of Chao Phraya river) as shown below in Fig. 12.2. The summary of characteristics of the selected districts is given in Table 12.1.

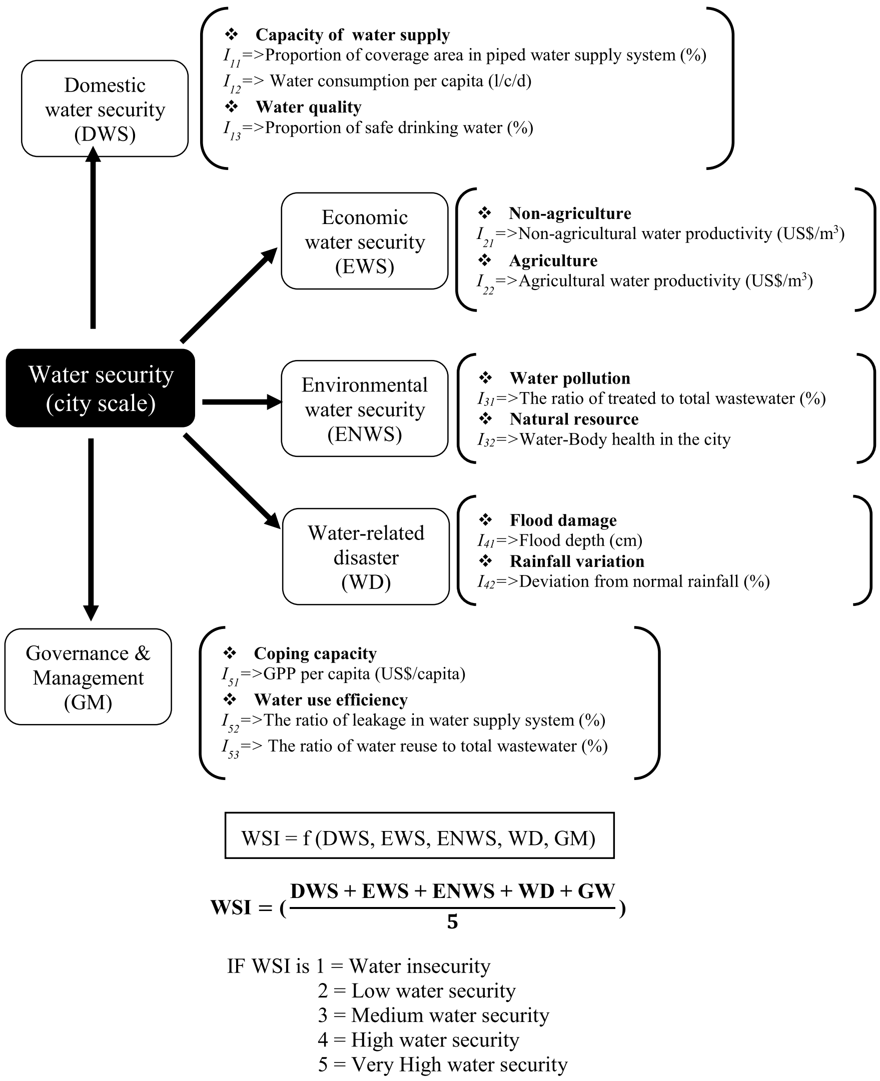

Fig. 12.1 The overall water security framework at city scale (*Source* Onsomkrit 2015)

12.4 Results and Discussion

The water security index is calculated for the five selected districts of Bangkok. The temporal scale of the study was eight years, from 2007 to 2014. The values of each indicator have been presented in Table 12.2. Some of the data was available at provincial level and hence such values were assumed to be same for the districts within a province. The results of application of the framework at district level, as

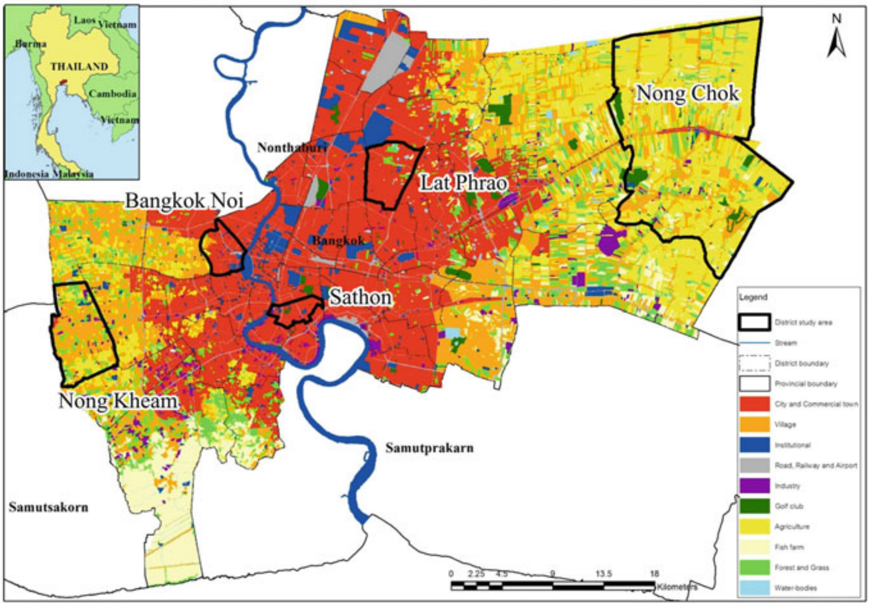

Fig. 12.2 Selected districts for assessing water security status

shown in Fig. 12.3, indicates that the level of water security of selected districts is of moderate level over the 8–year period. Sathon, Lat Phrao, Bangkok Noi and Nong Kheam have fluctuating trends over the years while for the Nong Chok district, there is a slight increase in water security status compared to the other four districts.

Firstly, the *domestic water security dimension* in each district shows a high level of water security. The indicators of coverage area in water supply system and proportion of safe drinking water in each district has the same trend over the years. This dimension varied according to water consumption per capita per year. In Sathon, Lat Phrao and Bangkok Noi, which has the most urban area coverage relative to its total, people may use more water than in rural areas. Nong Chok and Nong Kheam districts have lesser extent of urban areas which might lead to people using less water from piped systems, but more from other sources such as groundwater and rainwater.

Secondly, for the analysis of *economic water security dimension*, the study was used with the same value in different scales because of data availability. This study assumed that each district has same status of economic water security. Sathon and Bangkok Noi has a very high score of water security because these districts only have non-agricultural economic activity. Lat Phrao, Nong Chok and Nong Kheam have non-agricultural and agricultural economic activities, due to which these districts experience fluctuations according to agricultural water productivity.

Thirdly, the *environmental water security dimension* in selected districts shows low water security levels, except for some years in Sathon. The indicator of the ratio of treated to total wastewater at Sathon is the highest over the years because this

Table 12.1 Summary of characteristics of selected districts of Bangkok, Thailand

Characteristic	Sathon	Lat Phrao	Nong Chok	Bangkok noi	Nong Kheam
Location within Bangkok	Inner area of Eastern part	Middle area of Eastern part	Outer area of Eastern part	Inner area of Western part	Outer area of Western part
Area (km^2) (% of total area in Bangkok)	9.33 (0.59%)	21.86 (1.39%)	236.26 (15.06%)	11.94 (0.76%)	35.82 (2.28%)
Population (persons) (% of total population in Bangkok) (2013)	83,898 (1.48%)	122,441 (2.15%)	159,962 (2.81%)	117,503 (2.07%)	151,877(2.67%)
Density (person/km^2) (2013)	8,996	5,601	677	9,837	4,239
BOD (mg/L)/DO (mg/L) of canals in districts (average value in 2013)	18.36/0.14	7.63/0.58	3.55/3.54	7.36/2.96	4.97/2.69
WWTP (% of coverage area/Capacity of treated (m^3/day)	1 plant (100%/200,000)	–	–	–	1 plant(around 30%/157,000)
Economic activities	Non-agriculture	Non-agriculture and Agriculture	Non-agriculture and Agriculture	Non-agriculture	Non-agriculture and Agriculture
Urban flood occurrences (Maximum flood depth (cm)) (2013)	2 (20 cm)	3 (15 cm)	–	1 (15 cm)	1 (20 cm)

BOD = Biochemical oxygen demand; DO = Dissolved oxygen; WWTP = Wastewater treatment plant

Table 12.2 Values of Water Security Indicator in selected districts of Bangkok, Thailand

No.	Indicators	Unit	Spatial scale	Year							
				2007	2008	2009	2010	2011	2012	2013	2014
1	Proportion of coverage area in water supply system (**I_{11}**)	%	Sathon [E]	96	100	100	100	100	100	100	100
			Lat Phrao [E]	96	100	100	100	100	100	100	100
			Nong Chok [E]	96	100	100	100	100	100	100	100
			Bangkok Noi [W]	96	100	100	100	100	100	100	100
			Nong Kheam [W]	96	100	100	100	100	100	100	100
2	Water consumption per capita (**I_{12}**)	l/c/d	Sathon [E]	211	210	204	205	198	205	205	206
			Lat Phrao [E]	256	254	255	257	244	253	253	256
			Nong Chok [E]	129	136	141	149	149	160	165	177
			Bangkok Noi [W]	253	252	255	263	270	286	282	291
			Nong Kheam [W]	151	150	149	152	155	163	166	170
3	Proportion of safe drinking water (**I_{13}**)	%	Sathon [E]	100	100	100	100	100	100	100	100
			Lat Phrao [E]	100	100	100	100	100	100	100	100
			Nong Chok [E]	100	100	100	100	100	100	100	100
			Bangkok Noi [W]	100	100	100	100	100	100	100	100
			Nong Kheam [W]	100	100	100	100	100	100	100	100
4	Non-agricultural water productivity (**I_{21}**)	US$/m^3	Sathon [E]	240.0	260.4	254.4	289.3	341.6	354.0	381.8	362.2
			Lat Phrao [E]	240.0	260.4	254.4	289.3	341.6	354.0	381.8	362.2
			Nong Chok [E]	240.0	260.4	254.4	289.3	341.6	354.0	381.8	362.2
			Bangkok Noi [W]	240.0	260.4	254.4	289.3	341.6	354.0	381.8	362.2
			Nong Kheam [W]	240.0	260.4	254.4	289.3	341.6	354.0	381.8	362.2

(continued)

Table 12.2 (continued)

No.	Indicators	Unit	Spatial scale	Year							
				2007	2008	2009	2010	2011	2012	2013	2014
5	Agricultural water productivity (**I_{22}**)	US$/m^3	Sathon [E]	NA	NA	NA	NA	NA	NA	NA	NA
			Lat Phrao [E]	0.20	0.31	0.37	0.46	0.34	0.24	0.24	0.43
			Nong Chok [E]	0.20	0.31	0.37	0.46	0.34	0.24	0.24	0.43
			Bangkok Noi[W]	NA	NA	NA	NA	NA	NA	NA	NA
			Nong Kheam[W]	0.20	0.31	0.37	0.46	0.34	0.24	0.24	0.43
6	The ratio of treated to total wastewater (**I_{31}**)	%	Sathon[E]	65	60	43	68	100	95	66	62
			Lat Phrao[E]	0	0	0	0	0	0	0	0
			Nong Chok[E]	0	0	0	0	0	0	0	0
			Bangkok Noi [W]	0	0	0	0	0	0	0	0
			Nong Kheam [W]	21	22	22	20	20	20	21	18
7	Water-Body health in the city (**I_{32}**)	0–100	Sathon [E]	8.5	11.7	3.8	4.4	0.6	4.6	0.6	4.5
			Lat Phrao [E]	7.7	16.8	6.8	8.5	6.8	9.3	5.2	3.3
			Nong Chok [E]	46.5	47.1	49.4	54.6	47.9	53.3	49.0	41.1
			Bangkok Noi [W]	40.6	38.5	40.7	29.9	41.5	34.0	33.5	32.4
			Nong Kheam [W]	33.3	29.9	27.9	31.1	35.2	33.8	29.2	22.9
8	Flood depth (**I_{41}**)	cm	Sathon [E]	20	30	30	30	30	20	20	20
			Lat Phrao [E]	10	–	–	–	15	–	15	–
			Nong Chok [E]	–	–	–	–	–	–	–	–
			Bangkok Noi [W]	15	–	20	20	20	15	15	20
			Nong Kheam [W]	–	–	18	25	–	–	20	20

(continued)

Table 12.2 (continued)

No.	Indicators	Unit	Spatial scale	Year							
				2007	2008	2009	2010	2011	2012	2013	2014
9	Deviation from normal rainfall (**I_{42}**)	mm	Sathon [E]	17.2	25.5	55.6	42.6	52.4	17.8	16.3	−12.9
			Lat Phrao [E]	17.2	25.5	55.6	42.6	52.4	17.8	16.3	−12.9
			Nong Chok [E]	17.2	25.5	55.6	42.6	52.4	17.8	16.3	−12.9
			Bangkok Noi [W]	−19.3	4.9	3.9	−10.9	7.4	0.4	−19.2	7.7
			Nong Kheam [W]	−19.3	4.9	3.9	−10.9	7.4	0.4	−19.2	7.7
10	GPP per capita (**I_{51}**)	US$/capita	Sathon [E]	10,517	11,074	10,507	11,818	13,073	14,042	15,191	13,922
			Lat Phrao [E]	10,517	11,074	10,507	11,818	13,073	14,042	15,191	13,922
			Nong Chok [E]	10,517	11,074	10,507	11,818	13,073	14,042	15,191	13,922
			Bangkok Noi [W]	10,517	11,074	10,507	11,818	13,073	14,042	15,191	13,922
			Nong Kheam [W]	10,517	11,074	10,507	11,818	13,073	14,042	15,191	13,922
11	The ratio of leakage in water supply system (**I_{52}**)	%	Sathon [E]	31.6	29.1	28.6	27.3	25.5	24.5	21.8	21.1
			Lat Phrao [E]	23.0	19.4	19.5	19.5	19.2	18.2	16.9	16.3
			Nong Chok [E]	23.3	21.2	17.4	16.5	17.4	15.0	13.3	12.5
			Bangkok Noi [W]	35.1	36.1	34.7	30.6	33.2	30.4	31.5	28.9
			Nong Kheam [W]	34.4	31.5	30.1	29.7	32.4	31.7	34.9	31.1
12	The ratio of water reuse to total wastewater (**I_{53}**)	%	Sathon [E]	9.5	8.5	11.6	7.8	11.8	13.2	10.5	10.3
			Lat Phrao [E]	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
			Nong Chok [E]	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
			Bangkok Noi [W]	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
			Nong Kheam [W]	0.2	0.3	0.3	0.3	0.3	0.3	0.4	0.3

Note [E] = District is in eastern part and [W] is District is in western part of Bangkok

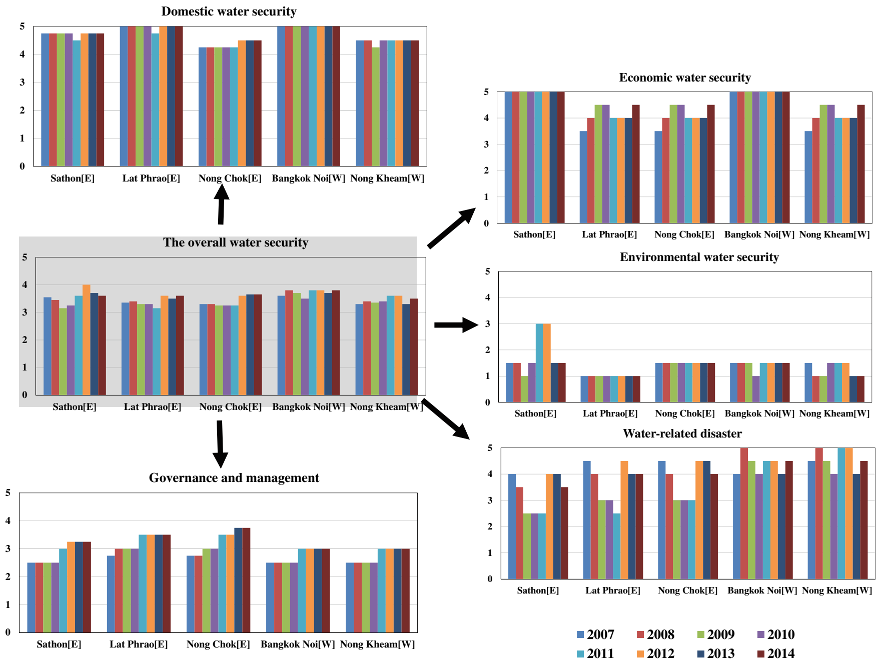

Fig. 12.3 Water Security Index of five selected districts in Bangkok

district has a Wastewater Treatment Plant (WWTP) covering the entire area. The indicator of water-body health in the city at Nong Chok has the highest value over the years because this district has less urban area and less population density that affects the wastewater generated in the area. However, water security in each district is still low because water quality of natural water sources in each district has seen an increased deterioration due to population growth and economic development and inadequacy of resources to treat wastewater.

Fourthly, for the *water-related disaster dimension*, the value of each indicator in selected districts has a fluctuating trend over the years. The level of water security varied from low to high. The score of this dimension in Sathon is the lowest among the five selected districts. Also, districts in western area (Bangkok Noi and Nong Kheam) have a higher score than districts in eastern area.

Finally, the fifth dimension–*Governance and Management*–includes three indicators to reflect management capacity. The score of GPP per capita, as the first indicator, shows high level of water security over the years. The leakage in water supply system of Sathon, Lat Phrao and Nong Chok districts increased slightly over the years while the leakage in Bangkok Noi and Nong Kheam has the same trend over the years. The score of the water use indicator in each district is same as water security/insecurity level over the years. Although water reuse in Sathon is of the highest magnitude, this value also ranks in the level of water insecurity. Hence, this dimension varied according to the leakage in water supply system and the ratio of water reuse in the respective district.

12.5 Conclusions

The overall status of water security in the selected districts has been at a moderate level over 8 years. Furthermore, the result of the study shows that the domestic water security dimension is of the highest level while the environment water security dimension is of the lowest level in each district. By applying the framework at different spatial scales, it was found out that the city scale can mask significant variations in water security situation at the district scale. The study also found that some of the indicators and parameters were found inappropriate at district (or sub-city) scale due to lack of data. Hence, this framework could be better to apply at a city scale and not at a sub-city (or district) scale because there is a lack of finer–scale data and most of the interventions of water security are implemented at the city scale.

Acknowledgements The authors would like to acknowledge the financial support provided by the Asia-Pacific Network for Global Change Research (APN) and the Asian Institute of Technology, Thailand, to conduct this research. The authors would also like to thank the Metropolitan Waterworks Authority, the Department of Drainage and Sewerage, the Department of Groundwater Resources, the Royal Irrigation Department, the Thai Meteorological Department, the National Statistical Office and the Office of the National Economic and Social Development Board for providing important and valuable data for the research.

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