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REVIEW

Exploring sustainable solutions for the water environment in Chinese and Southeast Asian cities

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Abstract Water is essential for human activities and economic development, and the water environment significantly influences ecological balance and global climate. China and Southeast Asia are the most populous areas in the world, and their water resources are deteriorating day by day. We focus on five representative cities such as, Beijing, Jakarta, Hanoi, Kathmandu and Manila to investigate water-environmental problems with the ultimate goal of providing recommendations for sustainable urban water management. The study found that (1) the water environment of all cities has been polluted to varying levels, while the pollution has improved in Beijing and Jakarta, and the situation in other regions is severe. (2) The aquatic biodiversity has reduced, and its pollution is mainly caused by organic pollutants and decreasing river flow. In addition, numerous people live in megacities without access to clean surface water or piped drinking water, which greatly increases the use of groundwater. Further, frequent floods in the world leads to serious damage to urban infrastructure and further deterioration of water environment quality. To address these problems, countries and organizations have begun to construct wastewater treatment plants and develop water-saving technology to ensure healthy and sustainable development of water environment. The results and practical recommendations of this study can provide scientific insights for future research and management strategies to address water quality challenges during ongoing policy debates and decision-making processes.

Keywords China · Southeast Asia · Sustainable solutions · Urban development · Urban water environment

Yong Mu and Pingping Luo contributed equally to the manuscript.

INTRODUCTION

Without changing current water consumption and pollution levels, almost half of the world's population will face severe water stress by 2030, damaging the well-being of millions of people (Programme 2016). Population growth and urbanization have degraded water quality, and many countries and areas are challenged by water shortages. Therefore, properly managing the water environment is crucial for ensuring sustainable socioeconomic development worldwide (Alcamo et al. 2007; Bartram 2010). More than half of countries have been impacted by a deterioration in the water environment, especially in developing countries. In particular, Southeast Asian countries and China, as one of the most populous regions in the world, have abundant water resources but unevenly distributed, and face significant water environment stress due to problems such as substandard sewage treatment, and flood disasters. As these problems have become increasingly prominent, few large-scale researches and investigation have been done to develop sustainable solutions that address the increasingly dire water environment problems.

Global studies on water pollution have been undertaken, focusing on the sources of global water pollution, such as oil exploration, ocean transportation, and petroleum-contaminated wastes (Le et al. 2017; Keeler et al. 2019; Zhang et al. 2020a). Experience has shown that in the context of globalization, a variety of factors, including economy, politics, culture, and population, are closely related to water environment problems (Johnston 2011; Elvanidi et al. 2017; Nagabhatla et al. 2020). At the same time, global attention has turned to the impact of agricultural development on water quantity, water use efficiency and allocation (Mateo-Sagasta et al. 2017). In addition, studies have shown that severe natural disasters related to weather and floods are increasing and will impose a greater cost burden on the economy in the future (Kundzewicz et al. 2014; Kron 2015). Some work has also clarified the importance of water environment protection in terms of sustainable development goals and global water balance (Sood 2017). Further focus is essential given the prominence of these issues on global development.

Southeast Asia and China account for more than 1/3 of the world's population, and many experts have focused on the water environment conditions in part of region. For example, from perspective of water quality, to explore ways to improve the water environment situation, one study was conducted to assess the groundwater-surface water quality trend in Jakarta, Indonesia (Delinom et al. 2009; Amira et al. 2018). The study generated an overview of water quality for Jakarta using a spatiotemporal trend analysis of water quality; however, the study did not consider the groundwater environment (Luo et al. 2019). Further, from perspective of water quantity, a number of water usage surveys have been completed to investigate recent trends, as well as the main factors and challenges impacting water demand of Hanoi in Vietnam (Bui et al. 2012; Bao et al. 2013). To explore ways to relieve shortage water resources in Manila, Philippines, studies have investigated groundwater supplies and sustainable development approaches (Munasinghe 1993; Clemente et al. 2001; Kooy et al. 2018). From perspective of water disaster, previous studies have also investigated the Bagmati River in Kathmandu, where flooding is a common occurrence leading to serious damage to urban infrastructure, personal safety and further deterioration of water environment. Those studies have described the probable causes of flooding in the central basin and summary major past flood events and impacts (Dhital and Kayastha 2013; Tbca et al. 2020). These past studies highlight the importance of identifying the state of the water environment in the most populated cities in China and Southeast Asia.

Despite widespread acknowledgement of the problems described above, few studies have systematically reviewed the water environment problems in Southeast Asia and China, and proposed approaches to address them. Most previous studies about the water environment have focused on a certain country or a limited region (Botequilha-Leito and Díaz-Varela 2020; Zhang et al. 2021). This study uses previous research to generate a systematic overview of the water environment situation in five cities in Southeast Asia and China (Fig. 1). The main objective of this paper is to study the surface and groundwater environment to develop effective water environment policies and improve infrastructure in the face of these challenges by comparing different water environment conditions. This paper therefore solves the following research problems. First, what is the current situation of water environment and possible development trend in the future? Second, compare the measures of different countries to deal with water environment problems, and provide ideas for global urban water environment governance. Third, what are the implications for global sustainable development through the study of water environment in Southeast Asia and China? Therefore, the result of this research provides an analytical foundation for stakeholders to better understand water environment in their cities, and develop strategies for future sustainable urban water management.

METHODOLOGY

Figure 2 shows the research framework of this paper, which mainly includes two parts: case study of urban water environment (Troubles) and classification and induction of urban water management schemes (Solutions). The first part takes the representative cities in Beijing and Southeast Asia as an example (Beijing, Jakarta, Hanoi, Kathmandu, Manila). In section "Overview of urban water environment", analyses and studies the impact of several factors on surface water, flood disaster and groundwater environment by consulting relevant historical data (Contents in the left dashed box). The second part mainly studies the measurements put forward by different cities for water environment problems. In section "Implications and solutions for sustainable urban water management", the similarities and differences of water environment problems in different cities are classified and analyzed. Finally, we rethink the water environment problems and solutions of representative cities, and expect to put forward sustainable water environment management solutions suitable for Asia and even the world.

OVERVIEW OF URBAN WATER ENVIRONMENT

Geographical and hydrological environment of the megacities studied

This study focuses on five megacities in Southeast Asia and China: Beijing, Jakarta, Hanoi, Kathmandu, Manila (Fig. 1).

Beijing

Beijing(39.4° to 41.6° N and 115.7° to 117.4° E), the capital of China, is located in the north of the North China Plain and is surrounded by the Gully, Chao Bai, North Canal, Yong Ding and Duma River from east to west. Particularly, Beijing plays an indispensable role in economic, political, and cultural of China. The city covers

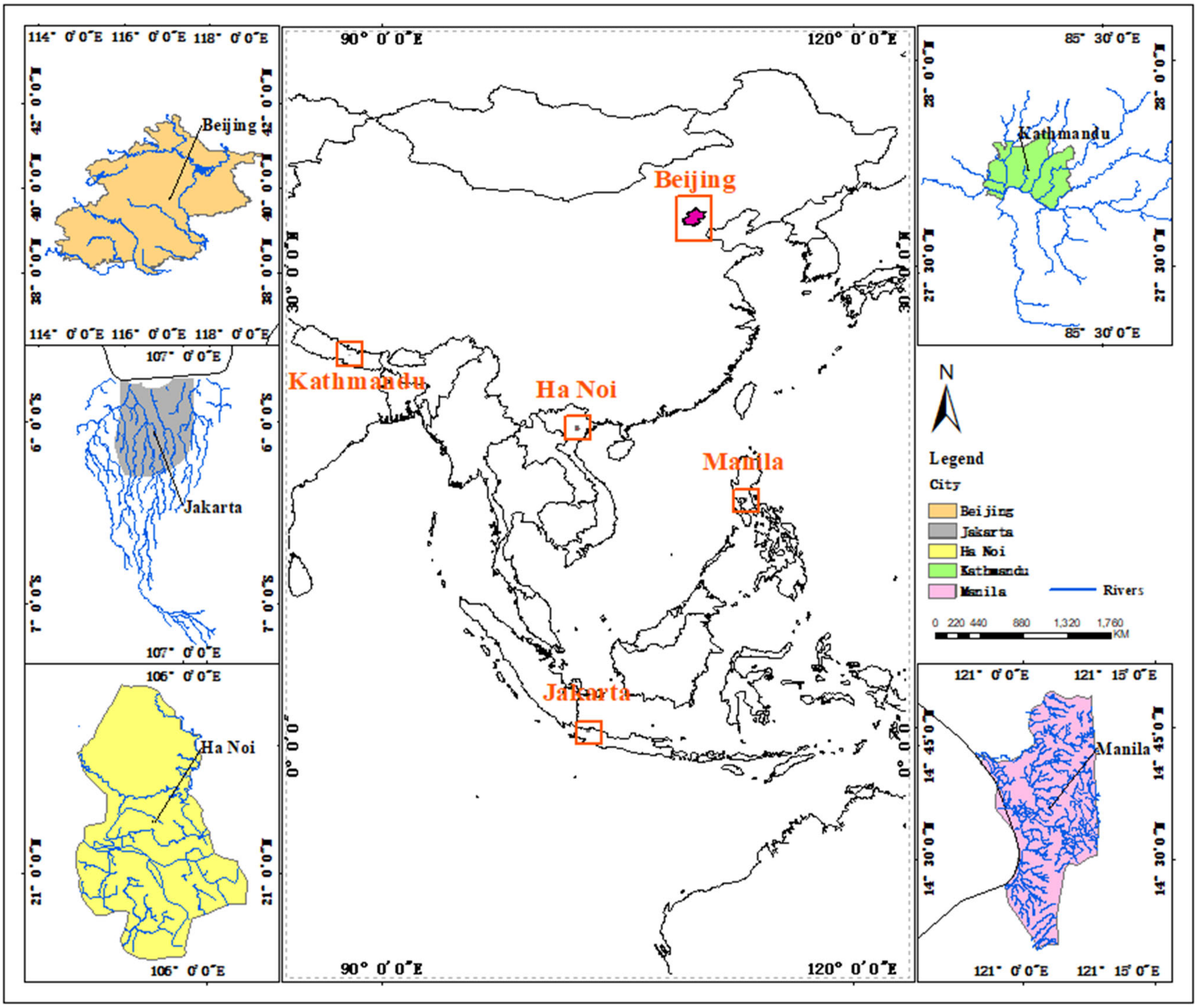

Fig. 1 Geographical location and main river distribution of the five cities

approximately 16 410 square kilometers. Precipitation is the primary source of surface water and has gradually decreased since the late 2000s because Beijing's climate has become warmer and drier (Liu et al. 2010). Physiographically, "three gradient terrain" is a general description of the characteristics of Chinese topography. The terrain in the west is generally high, while the terrain in the East is low (Hao et al. 2018). Beijing is located in the third gradient in the East. Therefore, under extreme rainfall conditions, it leads to urban waterlogging, mountain landslides and debris flows, as well as human life and property losses.

Jakarta

Jakarta (6° 10′ S, 106° 49′ E), the largest city in Indonesia, is generally known as the Special Capital Region of Jakarta. Officially, the Jakarta Special Region covers 662 km^2 of land area and 6977 km^2 of sea area. The city is the economic, political, and cultural capital of Indonesia, and is administratively equal to a province with five key geographically-defined areas (Luo et al. 2019; Jensen and Khalis 2020). Jakarta is located on the northwest coast of Java Island at the mouth of the Ciliwung River on Jakarta Bay, which is an inlet of the Java Sea. In terms of topography and climate, Jakarta lies in a low, flat area, ranging from − 2 to 50 m below/above sea level (BSL/ASL), with an average elevation of 8 m ASL (Takagi et al. 2016). Approximately, 40% of Jakarta is below sea level, particularly in the northern areas, while the southern parts are comparatively hilly (Voorst and Roanne 2016). Several rivers flow from the Puncak highlands to the south of the city, and across the city northwards towards the Java Sea. The most important river is Ciliwung River, which divides

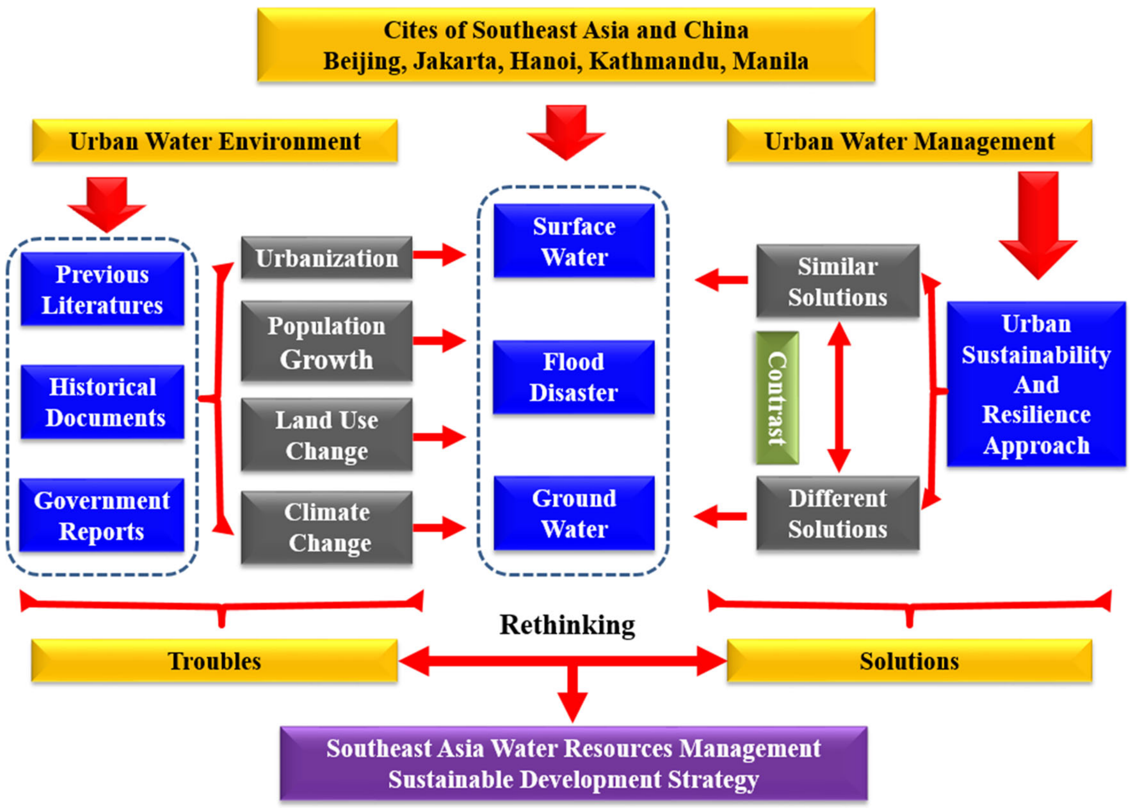

Fig. 2 Research framework for assessing and analyzing sustainable solutions for water environment management in Southeast Asia

the city into western and eastern principalities (Irawan et al. 2015). Physiographically, Ciliwung River is divided into three segments: upstream, midstream, and downstream. The riparian area in the midstream is the largest area, covering more than 60% of the total riparian area. The Ciliwung River receives a high annual rainfall (1500–3200 mm/year). The most rainfall occurs from November to March; the least falls in May to September (Noviandi et al. 2017).

Hanoi

Hanoi (20° 53′ to 21° 23′ N, 105° 44′ to 106° 02′ E) is the center of Northern Delta area in Vietnam, and is the political, economic, cultural, and scientific capital of the country. After its administration boundary was expanded in August 2008, Hanoi spanned an area of 3324.92 km^2. The climate in Hanoi is typical of the Northern Area, and is a humidified sub-tropical area: hot in the summer, rainy and cold in winter, with less rain in the early season and with light rain in late season. The hot summer season lasts from May to September, with high intensity rainfall and an average temperature of 28.4 °C. Winter lasts from November to March, with an average temperature of 20.5 °C (Kuroda et al. 2017; Mu 2020). The river network inside and across Hanoi is abundant and dense, including the Red, Da, Day, Nhue, Tich, and Ca Lo River. The Red River is the largest river in the northern, with a total river basin area of 155 000 km^2. It is 556 km long with 118 km running across Hanoi. Its average annual flow is 2640 m^3/s and has a water yield of 83.5 million m^3 (Tran and Nguyen 2018).

Kathmandu

Kathmandu (27° 32′ to 27° 49′ N, 85° 11′ to 85° 31′ E, 1300 m ASL), the capital of Nepal, is an intermountain basin lies the central development region of Nepal. Kathmandu Valley civilization originated from the sacred Bagmati River and has a history of more than 1200 years. Geographically, Nepal's terrain is very unique because the contrast of the terrain varies from 64 to 8848 MASL in a very short distance (about 150 km) from the Terai plain in the south to the Himalayas in the North (Dhital 2015). The impact of geographical and topographic diversity is reflected in different climatic conditions from tropical humid to alpine climate. The average maximum and minimum temperatures in Kathmandu remained high from June to August and low from December to February. From 1971 to 2011, the temperature trend of the Valley shows a continuous average heating rate of 0.033 °C per year, with an average maximum temperature rising by 0.043 °C per

Table 1 Population ranking of five cities

2010			2020			2030		
Rank	City	Population	Rank	City	Population	Rank	City	Population
1	Beijing	16 441 252	1	Beijing	20 462 610	1	Beijing	24 281 912
2	Manila	11 887 189	2	Manila	13 923 452	2	Manila	16 841 340
3	Jakarta	9 625 579	3	Jakarta	10 770 487	3	Jakarta	12 686 756
4	Hanoi	2 811 020	4	Hanoi	4 678 198	4	Hanoi	6 361 522
5	Kathmandu	964 802	5	Kathmandu	1 423 515	5	Kathmandu	1 939 077

Sources from: https://worldpopulationreview.com

year and a minimum temperature rising by 0.02 °C per year (Chhetri et al. 2020; Zhu 2020). Similarly, precipitation in Kathmandu is generally concentrated on time and space scales. During the period from June to September, 80% of the rainfall occurred where the valley obtained an average annual rainfall of 1500 m (Adhikari et al. 2019a).

Manila

Metropolitan Manila (14° 40′ N, 121° 3′ E), known as the National Capital Region (NCR), is the capital of the Philippines. It is bounded by the Manila Bay in the west, the Laguna de Bay in the southeast, the Sierra Madre Mountain Range in the east, and the fertile plains of Central Luzon in the north. Located at the mouth of the Pasig River, Metro Manila is generally flat, with an average elevation of 10 m in the west. Metro Manila has a total land area of 63 600 ha, representing approximately 0.21% of the country's land area (Kumar et al. 2018). Metro Manila has a tropical wet and dry climate that borders on a tropical monsoon climate. Like the rest of the Philippines, it lies entirely within the tropics. The average temperature during the cold months of December to February is 26.1 °C; the average temperature during the hot months of March to May is 28.8 °C (Yumul et al. 2011). During the monsoon season, manila metropolis is affected by tropical cyclones and extreme floods, which usually paralyzes the city's socio-economic activities. In addition, by 2025, land subsidence will lead to a relative increase of 0.4 m (Uprety et al. 2017). These topographical and climatic conditions, coupled with inadequate drainage facilities, have led to frequent flood events and seriously damaged the water environment (Philippine Atmospheric 2011).

Urbanization and population

The population of the five major cities has increased rapidly since they are the centers of financial, commercial, medical, educational and political activities and services. According to the data of world population review, the population density of Beijing is 20.46 million in 2020, ranking first among these cities, and it is expected to reach 24.28 million in 2030 (Table 1, Fig. 3).

The explosive growth of population poses a challenge to the sustainability of the quality and quantity of urban surface water and groundwater. As the city with the fastest population growth, Beijing's demand for water resources has greatly exceeded its supply. Therefore, the government has taken countermeasures to adjust the water structure and increase the supply through the South-to-North Water Transfer Project. For Manila, the second most populous city, a large number of private wells are used for domestic water, resulting in ground subsidence and seawater backflow. Jakarta's water environment is even worse, and 45–90% of its groundwater resources have been polluted.

Current situation of surface water environment

Beijing

There are 5 main rivers in Beijing, including the Gully River, Chao Bai River, North Canal, Yong Ding River and Duma River from east to west, which belong to five major river systems in the Hai He River basin. Beijing has more than 100 rivers of different sizes with a total length of 2700 km, and more than 120 lakes and reservoirs (Zhang 2017). The total storage of the reservoir exceeds 2 billion m^3, mainly including Miyun, Guanting, Ming Tombs, Haizi and Huairou (Zhongshan 2010). Precipitation is the primary source of Beijing's surface water. Beijing is located in a semiarid and semi-humid area, which is not rich in water resources. From 1999 to 2011, precipitation was 481 mm, which is 17.8% less than the precipitation of 585 mm in the 44 years between 1956 and 2000 (Wang et al. 2015a). In response to the decrease in precipitation, the volume of available water resources decreased by 44%, to 2.1 Gm^3 by 2011, although 3.75 Gm^3 of water accumulates each year. The volume of river flowing into

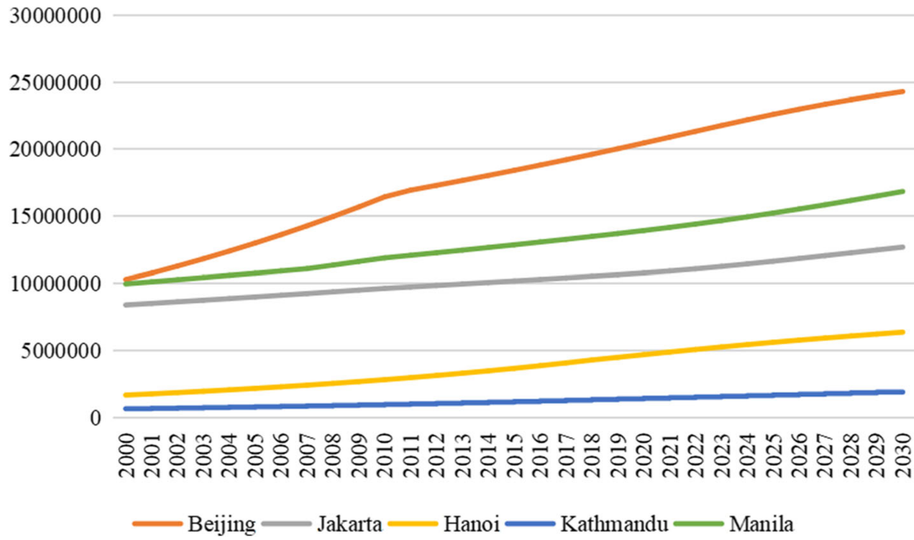

Fig. 3 Population of megacities in Southeast Asia and China

Beijing has also been declining due to extensive upstream water use. River water volume inputs have declined by 76.8% to only 0.49 Gm^3 in 2011 (Sun 2013).

To alleviate the stress on the water environment caused by the growing water demands, waters originally reserved for emergencies have been accessed since 1999. For example, withdrawals from the Mi Yun and Guan Ting Reservoirs have accounted for almost 90% of Beijing's surface water use. The large withdrawals had depleted the storage volume of the two reservoirs by 2 billion m^3 by the end of 2013 (Wang et al. 2015b). By the end of 2018, the city's surface water resources were 1.431 billion m^3 and the total water resources were 3.546 billion m^3. The inflow was 819 million m^3, and the outflow was 2.065 billion m^3. In 2018, the city's total water supply was 3.93 billion m^3 (Fig. 4), essentially meeting domestic, industrial, and agricultural water consumption demands (Affairs 2018).

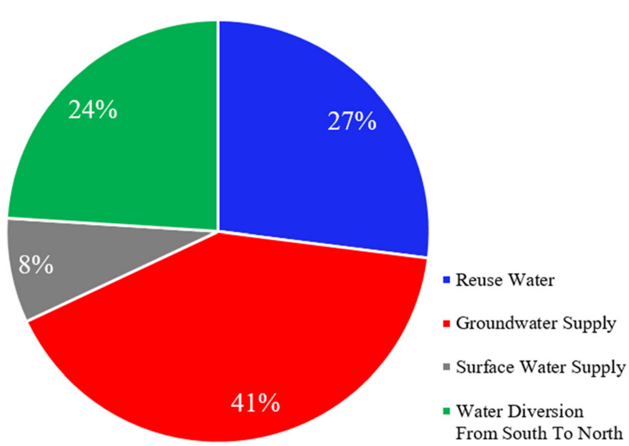

Fig. 4 Proportion of different water sources in 2018

The total sewage discharge from the city was 2.04 billion m^3, and the sewage treatment capacity was 1.90 billion m^3 resulting in a treatment efficiency of 93.4%. Surface water resources in the city have been monitored for quality since 2018 (Affairs 2018; Lyu et al. 2019). One 2,545.6 km long river has met China's Class II class standard (COD $\leq$ 15 mg/L, $BOD_5 \leq 3$ mg/L, TN $\leq$ 0.5 mg/L, TP $\leq$ 0.1 mg/L) for a length of 1142.5 km; the Class III class standard (COD $\leq$ 20 mg/L, $BOD_5 \leq 4$ mg/L, TN $\leq$ 1.0 mg/L, TP $\leq$ 0.2 mg/L) has been met in a 323.4 km long river (Zhang et al. 2020b). The vegetation richness around the river is higher compared to other rivers, and the degree of human disturbance and destruction is lower.

Jakarta

There has been rapid development of Jakarta's River Basins, from the upstream to the downstream area, leading to a population explosion. Development around the Ciliwung River Basin has led to a degradation in the land's natural ability to store water, increasing erosion and runoff and decreasing the protection of the ground surface. Water resource usage from the Ciliwung River has not yet reached a positive level. For example, clean water usage in Jakarta reached 413 million m^3 a year, but supplies from the district water utility's reservoirs are limited to 200 million m^3 each year. The remaining needed 213 million $m^3$of clean water come from available groundwater (Kooy et al. 2018; Rian et al. 2018). Another problem is pollution from different sources; an increased amount of waste has entered the upstream area of the riverbed from industries, households, and land usage. According to statistics, more

Table 2 River Pollutant Index

Quality status	Pollutant Index					
	2004 (%)	2005 (%)	2006 (%)	2007 (%)	2008 (%)	2009 (%)
Good	0	0	3	0	0	0
Low polluted	3	5	9	0	0	9
Moderate polluted	16	16	10	6	12	9
High polluted	81	79	78	94	88	82
Total	100	100	100	100	10	100

than 50% of shallow wells are polluted by *E. coli*. from domestic wastewater and more than 10% of shallow wells are also polluted by iron and manganese (Luo 2015). Based on the monitoring data collected during 2004–2009, the estimated total weight of biological oxygen demand (BOD) and carbon oxygen demand (COD) entering the Ciliwung River Basin reached 33.8 and 73.8 tons an hour, respectively. Although the percentage of polluted river water has decreased, the river water in Jakarta is still seriously polluted (Table 2) (Luo 2015; Rukmana 2015).

Hanoi

Hanoi's demand for clean water is increasing daily, and a series of challenges are damaging the fragile water environment. The main sources of pollution in the urban are as follows. Domestic wastewater from residential areas and commercial services is estimated at 723 000 m^3/day, with wastewater making up approximately 600 000 m^3/day, and wastewater from hotels and commercial center tourism making up 123 000 m^3/day. The total volume of wastewater from industrial parks, industrial clusters in Hanoi is estimated at 80 000 m^3/day. The total volume of medical wastewater discharge is approximately 6000 m^3/day (Pham Ngoc BAO 2013). Water quality is impacted by organic pollution, eutrophication, high levels of microbial contamination, and signs of heavy metal pollution (Fe, Cr_6^+). Wastewater at the hospital is made up of organic pollution and high levels of nutrients (NH_4^+). In particular, total coliform has been detected at a high level and microorganisms that cause infectious diseases, such as Salmonella and Cholera, have been found in the effluent from some hospitals (Li et al. 2017; Bui et al. 2018). In addition, wastewater discharge points at some industrial end points have included organic nutrients and toxic heavy metals, such as Hg, As, Cr, and Mn.

Kathmandu

Over the past 40 years, Kathmandu has been transformed, due to rapidly expanding urban sprawl, growing traffic congestion, polluted air from vehicles and brick factories, and degraded streams and rivers. The average BOD in the rivers has ranged from an average of 20 to 30 mg/L, with total coliform are as high as 104–105 MPN/100 mL (Fig. 5) (March 2009). The DO level of the Bagmati and Buriganga rivers is declining at an average annual rate of nearly 0.3 mg/L/year. This has led to a decline in aquatic biodiversity, particularly in rivers. For example, approximately 10 years ago, the upstream area of the Bagmati River had more than 36 species of fish; now, about a dozen species are seen exiting in the river and important fish species (e.g., *Puntius* sp., *Danio* sp., and *Esomus* sp.) no longer exist upstream (Jha 1995; CBS Central Bureau of Statistics 1998). City sewage systems are inadequate and poorly maintained, and are generally directly connected to the rivers in the valley. The direct and indirect discharge of untreated domestic liquid waste into the river is a major factor responsible for the water pollution (Parmeshwar et al. 2016).

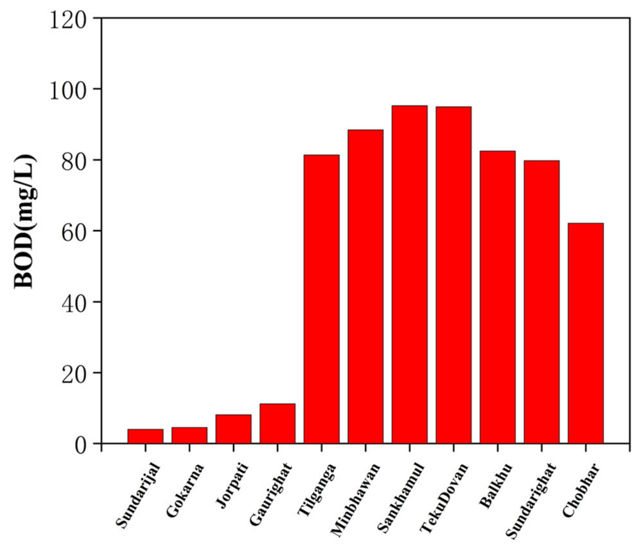

Fig. 5 BOD level in average at different locations of Bagmati in 2008

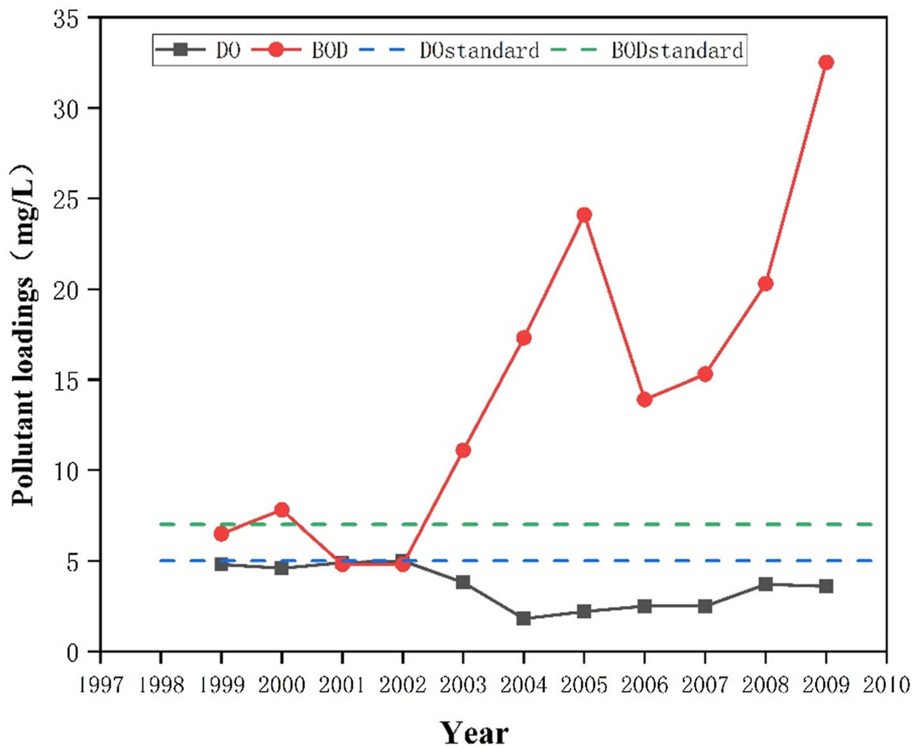

Fig. 6 Water quality of the Pasig River from 1999 to 2009. *DO* dissolved oxygen, *BOD* biochemical oxygen demand

Manila

However, most rivers and waterways in Metro Manila are heavily polluted due to rapid urbanization and population explosion. Domestic waste accounts for approximately 60% of the total pollution in the Pasig River, with the rest originating from industrial wastes (33%), such as tanneries, textile mills, food processing plants, distilleries, chemical and metal plants, and from solid waste (7%) dumped into rivers (Iliman 1992; Munasinghe 1993). As of 2013, 6296 wastewater generating establishments were registered with EMB. More than 300 000 people living in the vicinity have benefited from these projects. However, EMB reported that it monitored 19 bathing beaches along the Bay's coastlines in 2013 for DO, Total Coliform, and Fecal Coliform. Four of the five stations along NCR coastlines failed to meet the DO criterion for a Class SB water body (Fig. 6) (Gorme et al. 2010; Jalilov et al. 2018). All five stations failed in the Total Coliform and Fecal Coliform criteria. Due to continuous waste dump, the riverbed has become increasingly silted with organic matter and non-biodegradable garbage. This has led to significant flooding along the river, affecting nearby communities and carrying polluted water to households close to the river (Zoleta-Nantes 2000). This highlights significant opportunities to improve Manila's sewage system.

Historical review and factor analysis of flood disaster

Beijing

Beijing has experienced floods many times in history. From 1991 to 2016, 7 floods and 13 waterlogging disasters occurred in Beijing, including "the 2004, 7 · 10 urban rainstorm," "the 2011, 6 · 23 urban rainstorm," and "the 2012, 7 · 21 heavy rainfall." In particular, the "7 · 21" rainstorm in 2012 had an average rainfall of 170 mm, with more than 100 mm of rainfall area occurring across 86% of the area, which was rare in the history of Beijing (dingning Zheng 2013). The city is under great pressure when there is heavy rain, as there is no close and large recipient outlet to be discharged to such as big river, lake, or sea. As such, a significant flood can lead to direct economic losses amounting to more than 160 000 million RMB (Chen 2012; Wei 2012).

In recent years, the frequency and extent of flooding disasters have increased due to global climate change and human activities, and global warming is considered to be the most important factor. Beijing has a temperate continental monsoon climate, with an average annual precipitation of 626 mm and an annual total precipitation of 9.996 billion m^3 (Duan et al. 2019b). In addition, global

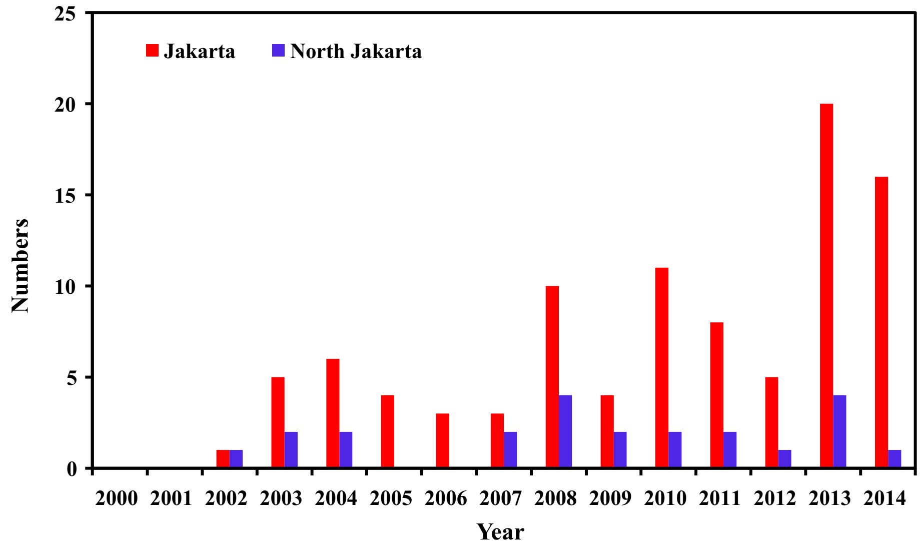

Fig. 7 Numbers of floods in Jakarta

warming is also an important reason for the increased rainfall. Therefore, flood disasters tend to occur in months with concentrated precipitation (June–August). With the rapid urbanization, many natural/suburb areas have become hard, impervious surfaces. For example, the Lian hua Bridge area was once a river network area; it has been one of the most heavily flooded spots in recent years. Urbanization also leads to the urban heat island effect, rain island effect, and air pollution, leading to an increase in rainfall (Yuping 2016).

Jakarta

Many rivers, coupled with insufficient drainage caused by rainfall and blockage in the rainy season, make Jakarta prone to floods (Fig. 7). Major floods occurred in 2007 and 2013, when 5000 hectares of land were flooded (Simarmata, 2018). Losses from state revenue and infrastructure damage reached at least 5.2 trillion rupiah and 190 000 people fell ill due to flood-borne disease. Approximately 70% of Jakarta's area was flooded with water up to four meters deep in parts of the city (Batubara et al. 2018). Jakarta has a wet season that runs approximately from October until May. Maximum rainfall amounts are generally seen in January and February due to heavy monsoon rainfall. Differences in rainfall volumes between the wet season and the dry season are significant in the northern part of the Jakarta area. In the southern part of the area, orographic effects cause relatively high rainfall amounts, even in the dry season. The rainfall is characterized by high intensity short duration storms (Chay et al. 2018). In addition, increasing population pressure and soil subsidence (10 cm/year or more) in areas that are already below mean sea level have independently increased flood risk, causing Jakarta sea defense mechanisms to sink below critical levels and significantly impacting the quality of life (Delinom, 2011). A community survey found residents are forced to throw garbage into the rivers since the slum area they are living in and inaccessible roads. The government is planning to renovate the Ciliwung riverbanks and build inexpensive flats for the community to maintain a clean riverbank environment and control the flood problem (Voorst and Roanne 2016).

Hanoi

Hanoi is a highly disaster–prone city in Vietnam due to its unique location and topography. These conditions have led to floods, typhoons, and seawater intrusion, with floods being particularly frequent and damaging (Mu 2020). A 1971 statistic indicated that there had been 7 significant floods within 70 years from the Red River, Da River, and Lo River; three particularly large floods occurred in 1971, 2008, and 2018. Between October 30 and November 1, 2018, torrential rains triggered a flooding disaster, which led to significant human casualties and economic loss (Luo 2018; Mu 2020). The flood affected Hanoi, north Vietnam, and southern parts of China and caused the death of 92 people. The average flow during the flooding months is 8000 to 10 000 m^3/s. Due to impacts of inclined geography of surrounding mountainous areas, Hanoi has a low level of vegetation coverage, a fan shaped river network structure, and heavy and prolonged rain in river basin (Luo 2018). Besides, there are high annual deforestation rates in upstream areas, especially in the central highlands. This leads to an increased vulnerability to flooding downstream and in low-lying areas (McElwee 2004). Water levels and flood flows rapidly change, sometime unexpectedly. Floods can also last a long time at about 6–7 days, with a maximum of 20 days. The flooding range can extend from 7 to over 10 m. In the midstream areas of the Red River, the flooding regime is particularly complicated, with a flow velocity as high as 3–5 m/s and a high water level at 3–7 m/day during flooding. In downstream areas, after the Da River and Lo River connect to the Red River, all the water flows to delta areas with low–lying terrain. There, the river bed narrows due to the coverage of the dyke system, resulting in large floods (Hammond et al. 2015; Scaparra et al. 2019).

Kathmandu

In Kathmandu, flooding events are particularly common in the lower region from June to August (summer monsoon months). Floods in August 2020 were among the worst in 60 years, washing away homes in the Kathmandu area and causing economic losses of more than 10 billion yuan. An extreme flooding event in Nepal in 1993 killed 1029 people, impacted 400 000 people, damaged 25 000 houses, and destroyed 40 000 ha of agricultural land (DWIDP 2005). Floods will contaminate clean water resources, usually lead to biological pollution (malaria and cholera) and impact agricultural production.

Many studies have shown that flood disasters in Kathmandu have resulted from the combination of a fast-growing, vulnerable local population and variable climatic conditions (Hu et al. 2019). River flooding is a serious problem during the main monsoon months (July to August). The highly silted river systems and the steep and highly erodible mountains are primary natural drivers for flooding. Continuously high and intense rainfall during the monsoon period, when 80% of the annual rainfall occurs, are main causes of flooding (Dhital and Kayastha 2013). Further, the Kathmandu valley urban area consists of impervious paved surfaces, such as roofs, streets, and paved zones, that allow very little infiltration (Sarah et al. 2015). The sewer system is directly connected and quickly channeled to the river, accelerating run-off. Unsustainable urban planning (construction and land plotting) throughout the valley in recent years is further contributing to increased run-off and flooding risks (Carrasco and Dangol, 2019).

Manila

Manila, surrounded by the Pacific Ocean, is a large international city at high risk for flooding disasters, with annual flooding problems in Metro Manila affecting many more people and causing more property damage than in other cities (Boquet, 2015). The first widely recorded instance of serious flooding was in 1942, when unprecedented water levels inundated the city for several days. Major floods also occurred in 1972, 1977, 1986, and 1988 as water overflowed the main rivers and canals. The flooding caused by Typhoon Miding in 1986 caused serious damage, with floodwaters extending to 103.6 square kilometers or over 16 percent of the total area of Metro Manila. Thousands of Manila residents were stranded on the streets or trapped in vehicles after heavy rains on 28 July 1995 and major flooding incidents happened again on 28 May 1996 and 18 August 1997 (Bankoff 2010; Yumul et al. 2011).

Flooding is caused by many factors during urbanization. A first major challenge of Manila is to mitigate the risk of flooding, which is expected to increase due to sea-level rises and more intense storms from global warming (Yeung 2001). In a tropical context of heavy monsoon rains and frequent typhoons, riverside slums that impede water flow increase flooding risks. Therefore, a second challenge is to develop policies that provide better living conditions for millions of people. In addition, researchers have found that land subsidence have worsened floods in recent years (Bankoff 2010). In northern Metro Manila, the area of land prone to flooding has increased, and floods have been lasting longer. There have also been increases in the frequency of low-level floods caused solely by high tides (Abad et al. 2020).

Crisis and challenge of groundwater environment

Beijing

By the end of 2018, Beijing's surface water resources were 1.431 billion m^3; its groundwater resources were 2.114 billion m^3, and its total water resources were 3.546 billion m^3. Groundwater constituted 68% of the total water resources in the area (Affairs 2018). Water demand has redoubled over a nearly half century since the rapidly increasing population and high-speed economic growth. The mean annual available water resources per capita have decreased to less than 200 m^3/y, due to decades of successive aridness and other factors (Shao et al. 2016; Zhang, 2017). Local authorities reported that at the end of May 2018, the average groundwater depth in the plain was 23.32 m, a cumulative increase of 3.16 m compared with the same period in 2015 (Wang et al. 2015a). In recent years, however, the city's groundwater resources have been effectively protected and restored. The overall groundwater level has risen significantly according to the Beijing Municipal Bureau of Water Affairs. Compared with the same period in 2015, the groundwater level of Beijing had risen 2.18 m, resulting in an overall increase in the groundwater reserves of 1.62 billion cubic meters between

2015 and 2018 (Affairs 2018). To meet the growing demand for water for living and production, groundwater use had been kept in a state of high intensity and overload. Compared with the beginning of 1980, the groundwater level had dropped by nearly 20 m and the reserves had declined by nearly 9 billion cubic meters. However, over the years, the municipal government placed protecting groundwater resources high on its agenda, and curbed the overuse of water from the south-to-north water diversion project and surrounding reservoirs to recharge the groundwater. Due to the city's efforts to restore the groundwater resources, Beijing's groundwater level stopped falling in 2016 and began to gradually recover (Long et al. 2020).

Jakarta

Since the beginning of the twentieth century, groundwater from the Jakarta Basin has been used for drinking water and other purposes. Statistics show that water demand in Jakarta has reached 413 million cubic meters a year, with more than half supplied by groundwater (Tirtomihardjo 2011). With urbanization and population growth, groundwater consumption is increasing annually and pollution from agriculture, industry and residential wastewater has led to reduced water quality. The permeable surface area has decreased to the point where there is insufficient groundwater recharge, because of the rapid urbanization during the past 30 years (Fadly et al. 2017). The groundwater is generally replenished by rainfall, rivers, and human activities, such as through artificial recharge lakes or wells. However, land conversion has resulted in a recession in the rate of groundwater recharge. This, combined with excessive extraction rates, has rapidly lowered water tables throughout the city.

As another factor, 45–90% of Jakarta's groundwater resources have been contaminated by E-coli from wastewater, because less than 2% of Jakarta's sewage is treated by centralized sewage systems (Kosasih et al. 2009; Kooy et al. 2018). In addition, high loads of industrial and household wastes and high nitrate-nitrogen concentrations have been detected in part of the region. This is due in part to the fact that there is little sanitation coverage in Jakarta; the city has only one wastewater treatment plant with a capacity of 22 million litres per day (MLD). This makes it capable of treating less than 5% of the wastewater produced by the city, contributing to significant damage to the groundwater environment (Rukmana 2015).

Hanoi

Hanoi is the economic and political center of Vietnam, and has experienced significant increases in population, agricultural, and industrial activities, placing additional stress on groundwater quality (Li et al. 2017). With population growth, the city's demand for water is projected to increase from 900 000 m^3/day in 2011 to 2 359 000 m^3/day in 2030 (JS company (VIW ASE) and Hanoi people's Committee (HPC) 2012). To meet this growing demand, a water-supply system using surface and ground water was developed in 2008, and has been gradually expanded in urban areas (full capacity, 300 000 m^3/d, as of 2010; VIW ASEHPC 2012). Excessive groundwater extraction has caused significant declines in the groundwater level in the central and southern parts of Hanoi; however, water availability is reported to remain insufficient in the city (Hanoi Water Limited Company 2016). Particularly, most of the rivers and lakes are seriously polluted due to the discharge of untreated industrial, agricultural, and domestic waste (Bui et al. 2012; Duan et al. 2019a).Groundwater pollution can devastate communities that tap their water from shallow wells. Previous studies found a serious decline in groundwater levels in this area. The rapid use of groundwater, without an appropriate management system, has been a major factor.

Kathmandu

Groundwater depletion is a serious worldwide problem where alternate water resources are lacking. Groundwater is a crucial natural water resource for Kathmandu, which has consistently faced water scarcity challenges and year-round groundwater shortages (Guragai et al. 2017). The valley consumes approximately 350 million liters per day, however, Kathmandu Upatyka Khanepani Limited Corporation has been able to provide only 90 and 105 million liters per day during the dry and wet season; as such, only about 31% (90 MLD) and 38% (105 MLD) of the needs are being met during the two seasons, respectively (Shrestha 2009). In 2011, the groundwater extraction was estimated to be approximately 40–60 MLD, meeting approximately 15–20% of demand, and approximately 50% of available water in the valley (Pathak et al. 2009; Rana 2011). The remaining water demand has been satisfied through excessive groundwater extraction. The annual groundwater recharge rate is 9.6 million m^3 per year, however, the extraction rate is continuously rising. Extraction from the deep aquifers is currently 20 times more than the recharge rate, causing the deep water table to fall at a rate of 2.5 million m^3 per year (Pant 2011).

Further, urbanization has resulted in large changes in land use patterns, also reducing groundwater recharge and significantly impacting the quality and quantity of groundwater resources (Table 3) (Pandey et al. 2010). The construction of modern infrastructure increases the impermeability of the ground, resulting in frequent flood

Table 3 Land cover change in the Kathmandu Valley

Land cover type	Area in 1984		Area in 1996		Area in 2000	
	km^2	%	km^2	%	km^2	%
Agriculture	409.5	64	333.1	52.1	275.7	41.1
Forest	194.4	30.4	209.5	32.7	206.8	31.0
Non-agriculture	35.7	5.6	97.1	15.2	184.1	27.6
Urban area	31.0	4.8	83.8	13.1	97.5	14.6
Total	639.6	100.0	639.6	100.0	666.6	100.0

disasters and reduced groundwater recharge. Sanitation coverage for Kathmandu city is 93.77%, which exceeds the national average of 43.04%, however, most of the piped sewers discharge untreated sewage directly into rivers (Shrestha et al. 2018). In addition, the storm water carries garbage from streets to the sewers which are easily blocked. This contributes to an overflow of foul sewage and storm water on the streets, and contributes to groundwater contamination.

Manila

Studies on the groundwater resources of Metro Manila started in the 1960s to determine the groundwater abstraction and recharge patterns. In 1990, there was an estimated count of 3434 private wells, of which 2216 were operational and 1218 were abandoned. The distribution of private deep well usage was as follows: 49.2% is used by public and institutional users, 8.6% is for commercial uses, and 42.2% is for industrial use (Jalilov et al. 2018). Based on the type of water source used, approximately 40% of domestic water supply came from groundwater and 60% came from Metropolitan Waterworks and Sewerage System (MWSS) surface water. For industry, only 18% had MWSS connections, and up to 82% of the water came from their own deep wells. The distribution of private water withdrawals in 1990 was as follows: 71 000 cum/day commercial, 356 000 cum/day industrial, and 414 000 cum/day for public and institutional use. The total groundwater withdrawal reached about 930 000 cum/day, of which 841 000 cum/day were pumped by private deep wells and the remainder by MWSS wells (Bierkens and Wada 2019; Zoysa et al. 2021).

As of 1995, the estimated groundwater withdrawal from the NCR aquifer system was approximately 1 million cum/day, representing an approximately fivefold increase in groundwater withdrawal since the early 1970s (Clemente et al. 2001). Increasing water demand has outpaced the capacity of the water agency or MWSS to expand supply. Since the increasing use of groundwater, especially by private and self-supplied users, four significant environmental problems and externalities have been recognized: aquifer depletion, groundwater pollution, land subsidence, and salinization (Munasinghe 1993). These problems significantly impact the groundwater environment in Metro Manila.

IMPLICATIONS AND SOLUTIONS FOR SUSTAINABLE URBAN WATER MANAGEMENT

Surface water

Surface water resources have been widely used for drinking water, irrigation, shipping, industry and hydropower, and provide the basis for human survival and development and sustain much of the socioeconomic activities of countries (Mirza et al. 2003; Babel et al. 2014). This section mainly discusses the similarities and differences in the treatment of surface water problems in different cities.

Similar solutions (Ss)

Saving water resources, as a global consensus of human beings, is the driving force to explore various water-saving schemes. Based on the awareness, Global organizations and institutions have put forward Sustainable Development Goals(SDGs), especially in SDG 6.5, which explicitly calls for the protection of the water environment through sound and robust water resource management (Nations 2018). The use of alternative sources is considered to be one of the solutions to the problem of surface water shortage, mainly including rainwater collection and wastewater recycling (Yoshino et al. 2014). The use of rainwater helps to reduce the use of treated water, thus saving the cost of the treatment system, increasing the supply of treated water and reducing the water charges of users. In addition, many experts and scholars are studying rainwater collection (Song et al. 2009; Zhang et al. 2012), and rainwater

Table 4 Water reuse

Wastewater reuse	Potential uses and benefits
Wastewater reclamation Definition: The treatment of wastewater such that it may be used for beneficial purposes	• Agricultural irrigation • Industrial uses • Aesthetic uses • Recreational uses • Construction-related uses • Increased environmental flows
Gray water reuse Definition: Waste water from bathtubs and showers; hand washing toilet; waste water not exposed to toilet waste; sink and washing machine	• Landscape irrigation • Ground water recharge • Freshwater conservation • Toilet and urinal flushing • Reduced energy consumption • Increased environmental flows

collection technology is becoming more and more mature. Therefore, not only in China, Southeast Asia, but also in the world, rainwater utilization has been integrated into people's daily life. As another solution to alleviate the scarcity of surface water, wastewater reuse is widely used in various countries and regions. Its potential uses and benefits are shown in the Table 4.

Different solutions (Ds)

Different regions have different characteristics of water environment, so different countries have unique treatment measures to alleviate surface water pressure. China is the third largest country in the world with vast territory and abundant water resources. However, the water resources in the north and the south are unevenly distributed (Chen et al. 2013). Due to the unique distribution of water resources in China, the Chinese government has constructed the South-to-North Water Diversion Project to balance the water resources of the whole country (Huang et al. 2015). As of June 3, 2020, the first phase of the middle route of the South-to-North Water Diversion Project has been delivering water safely for 2000 days, with a total of 30 billion cubic meters of water to the north, benefiting 60 million people along the route (Yang 2020). Meanwhile, as a traditional agricultural country, China is adjusting its agricultural structure and reducing the planting of high water consuming crops (CCTV 2014; Wei 2016). In coastal cities like Jakarta and Manila, seawater is a kind of rich surface water resources (Raflores and Regmi 2015). Seawater desalination has become a source of drinking water, and membrane reverse osmosis is becoming the preferred technology (Rian et al. 2018; Shokhrukh-Mirzo Jalilov 2018). Seawater can also be used to flush toilets after simple treatment, which has been widely adopted by some coastal cities (Ling 2015). Inland cities such as Hanoi and Kathmandu usually have rich water systems. However, this does not mean that urban residents have access to clean and sufficient drinking water, irrigation water and industrial water (Bajracharya et al. 2019; Pandey 2021). They mainly reduce the amount of waste water discharged into the river by closing the sewage outlets of some enterprises and eliminating outdated process equipment (Kuroda et al. 2017; Le et al. 2020). At the same time, the law strictly forbids residents to directly discharge domestic waste and untreated wastewater into rivers. Through these measures, inland cities ensure the quality of surface water and groundwater.

Flood

The rapid development of urbanization leads to the change of underlying surface and land use, and the imperfection of underground drainage network, which is considered to be the main cause of flood. Flood disaster is a kind of dangerous natural disaster, which has caused great harm and serious consequences to the society, especially to the economically underdeveloped areas. In this section, we classified and discussed the common and special flood control measures and policies in different cities.

Similar solutions (Ss)

As early as the 1970s and 1980s, people began to research early warning systems (EWS), which is developed to reduce social risk and vulnerability, but also to support sustainable development. Currently, various organizations all over the world participate in flood forecasting and early warning. To forewarn flash flood disaster, a geomorphology-based hydrological model (GBHM) is developed (Miao et al. 2016). The high resolution ensemble precipitation flood forecast and early warning system based on numerical weather forecast model is being improved (Yu et al. 2016). A flood early warning and decision-making system based on atmospheric ensemble forecast is established, which uses weather research and forecast model to forecast the heavy precipitation (Goodarzi et al. 2019). In addition, Sponge city has also been widely studied in various countries, extending its own characteristics (agenais et al. 2017; Zha et al. 2021). For example, Australia's Water Sensitive Urban Design (WSUD) (Media 2005), New Zealand's Low Impact Urban Design and Development (LIUDD) (Ignatieva et al. 2008), and the UK's Sustainable Urban Drainage System (SUDS) (Mitchell 2005), are like-minded technologies. Since the Chinese government proposed to build Sponge city in 2013, Beijing's flood management has entered a systematic management stage. The total amount of rainwater utilization in Beijing is increasing year by year, from 3.3 billion cubic meters in 2010 to 4.962 billion cubic meters in 2016, which greatly reduces the flood risk (Zhang et al. 2018). Southeast Asian cities such as Jakarta and Manila are learning from sustainable flood management measures such as biological ditches and rainwater gardens. As an alternative to a "grey" infrastructure (e.g., rainwater pipe) solution, "green" infrastructure (e.g., vegetated stormwater solutions) is becoming more and more common due to its lower construction and maintenance costs (Sarah et al. 2015).

Different solutions (Ds)

In terms of natural factors, the flood in inland cities is usually caused by heavy rainfall, while in coastal cities it have high flood risks because of more frequent typhoons and intense rainstorms occurring in the region. Therefore, coastal cities and inland cities have different policies and measures in dealing with floods. Jakarta, Manila and other coastal cities, to deal with the flood, have worked out the National Capital Integrated Coastal Development (NCICD) with several governments in 2014 (Zoysa 2020). The aim is to close the Gulf of Jakarta with a long offshore circular dike known as the giant seawall. Manila has increased investment in flood control projects, including an 8 km long dam, 13.1 km long river embankment, 21 large waterways and 21 pumping stations, 2.7 km long drainage channels, and a reservoir designed to cope with floods with a return period of 30 years (Abad et al. 2020; Cao et al. 2021). Delta cities are often heavily dependent on groundwater for domestic and industrial uses (due to lack of water resources), which can lead to land subsidence and thus increase the risk of coastal flooding (Kaneko and Toyota 2011; Erban et al. 2013). The government of Jakarta has adopted more strict groundwater and land use system, and recharge groundwater to fundamentally solve the problem of land subsidence, so as to alleviate the flood disaster (Chaussard et al. 2013). Some inland cities, such as Kathmandu and Hanoi, mainly adopt low impact development schemes, including paving permeable bricks, building green streets and rain gardens, to reduce the occurrence of flood disasters. Furthermore, through watershed management to increase forest area and change urban land use, the city is more flexible to adapt to environmental changes and deal with the disasters caused by rain (Sarah et al. 2015; Pour et al. 2020).

Ground water

Globally, about a quarter of water consumption depends on groundwater, which accounts for 50% of drinking water, 40% of industrial water and 20% of irrigation water (Hao et al. 2018). However, with the acceleration of industrialization and urbanization, there are more and more problems such as groundwater shortage and pollution, and ground subsidence. This section discusses the similarities and differences between Chinese and Southeast Asian cities in dealing with groundwater problems.

Similar solutions (Ss)

For all countries, groundwater quality monitoring is an important and universal measure to prevent groundwater pollution. In China, groundwater-monitoring networks have been improved and upgraded based on the State Groundwater Monitoring Project (SGMP), achieving information and automation for groundwater quantity and quality monitoring (Hao et al. 2018). Since 1990, National Groundwater Monitoring Network (NGMN) has been built in Hanoi to monitor the quality and quantity of groundwater in the study area. So far, 68 groundwater monitoring stations have been constructed (Ha et al. 2019). Meanwhile, Kathmandu, Jakarta, Manila and other cities have also established corresponding monitoring systems to protect groundwater (Pandey and Kazama 2011; Shimizu 2013). Besides, both inland and coastal cities protect surface water to prevent pollution from seeping into groundwater. According to a rough estimate, at least 4000 illegally exploited wells in Jakarta are used for living and production, accounting for 60% of the total urban water consumption (Kooy et al. 2016). Similarly, there are 386 wells in the Kathmandu valley (114 shallow, 222 deep and other wells), with the exception of shallow wells which are drilled for private purposes. However, only 249 works. More than one hundred abandoned wells can turn from shallow and deep aquifers to sources of pollution (Pandey et al. 2010a). Therefore, the Jakarta and Kathmandu government has taken measures to limit the number of drilling wells to reduce the exploitation of groundwater and make artificial recharge in areas where the surface is seriously flooded (Luo et al. 2019).

Different solutions (Ds)

Over exploitation of groundwater will lead to land subsidence, especially in coastal cities. This has led to groundwater pollution, seawater backflow and flood disasters. The water level in some parts of Kathmandu Valley drops by 2 m every year because the pumping capacity exceeds the make-up water. Currently, the annual effective recharge of groundwater in Kathmandu valley is estimated to be 8800mcm through reinjection of reclaimed water and other treated water (Shrestha et al. 2018; Adhikari et al. 2019b). In Hanoi, groundwater recharge was estimated through several techniques. The mean recharge is 340 mm/year and accounts for 20% of precipitation (Vu and Merkel 2018). In addition, coastal cities have issued policies and decrees to improve land use in order to protect groundwater. For example, Manila has implemented the 2006 comprehensive land use planning and zoning regulations/decree 8119, which combines water resources utilization policies and places more emphasis on water quality and shallow groundwater resources. In Jakarta, the Detailed Spatial Planning and Zoning Regulation are expected to be an initial tool to be used to limit infrastructure load and groundwater exploitation (Zoysa et al. 2021).

CONCLUSION

Continuous population growth, economic development, and urbanization in Southeast Asia have increased the consumption of many resources. These challenges have dramatically affected the water environment quality, resulting in frequent floods, water shortages, and deterioration of the ecosystem. For a period of time, mankind has taken a series of measures to reserve environment. However, it is impossible for mankind to completely control environmental pollution and restore it to the shape of thousands of years. What we should do is try to balance the relationship between human and nature while moving towards a brighter future. But at present, human protection of water environment is more inclined to a forced protection for their own development. What kind of attitude should mankind take towards the relationship between human and nature? This is worth pondering.

The specific conclusions are as follows:

1. With the growth of population, the water environment problems in various countries are becoming more and more serious, but the degree of pollution varies between different cities. For example, the surface water quality of Hanoi, Kathmandu and Manila is the worst, while the water quality of Beijing and Jakarta has improved. Among them, there is a high level of organic pollution in the water environment of Hanoi, and the aquatic biodiversity is reduced.
2. In this study, the causes of urban waterlogging are summarized into two kinds: natural and man-made. More specifically, the rapid growth of urban population and extreme rainfall caused by climate change. Coastal cities mainly build large-scale seawalls to prevent flood disasters caused by sea-level rise, while inland cities mainly change land use through LID measures and sponge cities to alleviate the impact of extreme rainfall on cities.
3. Through the comparison of different treatment measures, it is found that finding alternative water resources (rainwater collection and water circulation) can ensure the sustainable development of urban water resources. At the same time, building sponge city and improving urban land use are important ways to prevent floods and protect groundwater.

Further studies should focus on the details of land use changes and climate change on water environment management, and research the relationship between these factors and the water management situation. Besides, the next step is to compare the same indicators between two or three cities and conduct a deeper study on urban water environment and its management. Along with this study, a larger body of literature on this topic will further inform a rigorous assessment of the water environment in Southeast Asia.

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REFERENCES

Abad, R., T. Schwanen, and A.M. Fillone. 2020. Commuting behavior adaptation to flooding: An analysis of transit users' choices in Metro Manila. *Travel Behaviour and Society* 18: 46–57. https://doi.org/10.1016/j.tbs.2019.10.001.

Adhikari, B., S. Shrestha, and N.M. Shakya. 2019a. *Future urban water crisis in mountain regions: Example of Kathmandu valley, Nepal: Methods, approaches and practices*, 169–182. Singapore: Springer.

Adhikari, B.R., S.D. Shrestha, and N.M. Shakya. 2019b. *Future urban water crisis in mountain regions: Example of Kathmandu Valley, Nepal: Methods approaches and practices Urban drought*. Singapore: Springer.

Affairs, B.M.B.o.W. 2018. Beijing water resources bulletin. Beijing Municipal Bureau of water affairs, Beijing. (**In Chinese**)

Agenais, D.D., I. Thomas, and S. Paquette. 2017. Siting green stormwater infrastructure in a neighbourhood to maximise secondary benefits: Lessons learned from a pilot project. *Landscape Research* 42: 1–16.

Alcamo, J., M. Flörke, and M. Märker. 2007. Future long-term changes in global water resources driven by socio-economic and climatic changes. *Hydrological Sciences Journal* 52: 247–275. https://doi.org/10.1623/hysj.52.2.2470262-6667.

Amira, S., W. Astono, and D. Hendrawan. 2018. Study of pollution effect on water quality of Grogol River, DKI Jakarta. *IOP Conference Series: Earth and Environmental Science* 106: 012023. https://doi.org/10.1088/1755-1315/106/1/012023.

Asdak, C., and S. Supian. 2018. Watershed management strategies for flood mitigation: A case study of Jakarta's flooding. *Weather & Climate Extremes*. https://doi.org/10.1016/j.wace.2018.08.002.

Babel, M.S., S.P. Bhusal, S.M. Wahid, and A. Agarwal. 2014. Climate change and water resources in the Bagmati River Basin, Nepal. *Theoretical and Applied Climatology* 115: 639–654.

Bajracharya, R.M., N. Dahal, K.R. Neupane, V. Singh, and R. Habeeb. 2019. Urban water security challenges in the Nepal and Indian Himalaya in the context of climate change. *Resources and Environment* 9: 9–18.

Bankoff, G. 2010. Constructing vulnerability: The historical, natural and social generation of flooding in metropolitan Manila. *Disasters* 27: 224–238. https://doi.org/10.1111/1467-7717.00230.

Bao, P.N., T. Aramaki, M. Otaki, and Y. Otaki. 2013. Water demand management: A strategic approach towards a sustainable urban water system in Hanoi. *Journal of Water and Environment Technology* 11: 403–418. https://doi.org/10.2965/jwet.2013.403.

Bartram, J. 2010. Regional and global costs of attaining the water supply and sanitation target (target 10) of the millenium development goals. *Bulletin of the World Health Organization* 86: 13–19.

Batubara, B., M. Kooy, and M. Zwarteveen. 2018. Uneven urbanisation: Connecting flows of water to flows of labour and capital through Jakarta's flood infrastructure. *Antipode*. https://doi.org/10.1111/anti.12401.

Bierkens, M., and Y. Wada. 2019. Non-renewable groundwater use and groundwater depletion: A review. *Environmental Research Letters*. https://doi.org/10.1088/1748-9326/ab1a5f.

Boquet, Y. 2015. *Metro Manila's challenges: Flooding, housing and mobility*. Tokyo: Springer.

Botequilha-Leito, A., and E. Díaz-Varela. 2020. Performance based planning of complex urban social-ecological systems: The quest for sustainability through the promotion of resilience. *Sustainable Cities and Society* 56: 102089. https://doi.org/10.1016/j.scs.2020.102089.

Bui, D.D., A. Kawamura, T.N. Tong, H. Amaguchi, and T.M. Trinh. 2012. Aquifer system for potential groundwater resources in Hanoi, Vietnam. *Hydrological Processes* 26 (6): 932–946. https://doi.org/10.1002/hyp.83050885-6087.

Bui, N.T., A. Kawamura, H. Amaguchi, D.D. Bui, N.T. Truong, and K. Nakagawa. 2018. Social sustainability assessment of groundwater resources: A case study of Hanoi, Vietnam. *Ecological Indicators* 93: 1034–1042. https://doi.org/10.1016/j.ecolind.2018.06.0051470-160x.

Cao, A., M. Esteban, V. Valenzuela, M. Onuki, H. Takagi, N.D. Thao, and N. Tsuchiya. 2021. Future of Asian Deltaic Megacities under sea level rise and land subsidence: Current adaptation pathways for Tokyo, Jakarta, Manila, and Ho Chi Minh City. *Current Opinion in Environmental Sustainability* 50: 87–97.

Carrasco, S., and N. Dangol. 2019. Citizen-government negotiation: Cases of in riverside informal settlements at flood risk. *International Journal of Disaster Risk Reduction* 38: 101195. https://doi.org/10.1016/j.ijdrr.2019.101195.

CBS Central Bureau of Statistics, N. 1998. A compendium on environment statistics 1998.(Government Document)

CCTV. 2014. Beijing starts agricultural structure adjustment, some areas no longer grow wheat, Contemporary animal husbandry. pp. 21–21

Chaussard, E., F. Amelung, H. Abidin, and S.H. Hong. 2013. Sinking cities in Indonesia: ALOS PALSAR detects rapid subsidence due to groundwater and gas extraction. *Remote Sensing of Environment* 128: 150–161.

Chen Yun, S.J., and Xu. Jun. 2012. Analysis and Thinking on the extreme of Beijing 721 heavy rain (I) observation analysis and thinking. *Meteorological* 10: 97–108 ((**in Chinese**)).

Chen, Z., H. Wang, and X. Qi. 2013. Pricing and water resource allocation scheme for the South-to-North water diversion project in China. *Water Resources Management* 27 (5): 1457–1472.

Chhetri, T.B., Y.P. Dhital, Y. Tandong, L.P. Devkota, and B. Dawadi. 2020. Observations of heavy rainfall and extreme flood events over Banke-Bardiya districts of Nepal in 2016–2017. *Progress in Disaster Science* 6: 100074. https://doi.org/10.1016/j.pdisas.2020.10007425900617.

Clemente, R., C. David, A. Inocencio, R. Abracosa. 2001. Groundwater supply in Metro Manila: Distribution, environmental and economic assessment. *Philippine Institute for Development Studies, Discussion Papers*. http://serp-p.pids.gov.ph/serp-p/download.php?d=172&s=3

Delinom, R.M. 2011. *The proposed groundwater management for the Greater Jakarta Area, Indonesia, groundwater and subsurface environments*, 113–125. New York: Springer.

Delinom, R.M., A. Assegaf, H.Z. Abidin, M. Taniguchi, D. Suherman, R.F. Lubis, and E. Yulianto. 2009. The contribution of human activities to subsurface environment degradation in Greater Jakarta Area, Indonesia. *Science of the Total Environment* 407: 3129–3141. https://doi.org/10.1016/j.scitotenv.2008.10.0030048-9697.

Dhital, M.R. 2015. *Geology of the Nepal Himalaya, Regional perspective of the classic collided orogene*. New York: Springer International Publishing.

Dhital, Y.P., and R.B. Kayastha. 2013. Frequency analysis, causes and impacts of flooding in the Bagmati River Basin, Nepal. *Journal of Flood Risk Management* 6: 253–260. https://doi.org/10.1111/jfr3.12013.

Dingning Zheng, W.G. 2013. Emergency management from urban waterlogging—Thinking based on Beijing 721 waterlogging. *Chinese Foreign Investment* 000: 246–246 ((**in Chinese**)).

Duan, W., Y. Chen, S. Zou, and D. Nover. 2019. Managing the water-climate-food nexus for sustainable development in Turkmenistan. *Journal of Cleaner Production* 220: 212–224. https://doi.org/10.1016/j.jclepro.2019.02.040.

Duan, W., N. Hanasaki, H. Shiogama, Y. Chen, and Y. Wang. 2019. Evaluation and future projection of Chinese precipitation extremes using large ensemble high-resolution climate simulations. *Journal of Climate*. https://doi.org/10.1175/JCLI-D-18-0465.1.

DWIDP, D.o.W.I.D.P. 2005. Preparation of water induced hazard maps of Bagmati River basin.

Elvanidi, A., N. Katsoulas, T. Bartzanas, K.P. Ferentinos, and C. Kittas. 2017. Crop water status assessment in controlled environment using crop reflectance and temperature measurements. *Precision Agriculture* 18 (3): 1–18. https://doi.org/10.1007/s11119-016-9492-3.

Erban, L.E., S.M. Gorelick, H.A. Zebker, and S. Fendorf. 2013. Release of arsenic to deep groundwater in the Mekong Delta, Vietnam, linked to pumping-induced land subsidence. *Proceedings of the National Academy of Sciences of the United States of America* 110 (34): 13751–13756.

Fadly, M., T.E. Prayogi, F. Mohamad, D.Y. Zulfaris, M.W. Memed, A. Daryanto, F. Abdillah, E.M. Nasution, et al. 2017. Groundwater quality assessment in Jakarta Capital region for the safe drinking water. *Iop Conference* 180: 012063. https://doi.org/10.1088/1757-899X/180/1/012063.

Goodarzi, L., M.E. Banihabib, and A. Roozbahani. 2019. A decision-making model for flood warning system based on ensemble forecasts. *Journal of Hydrology* 573: 207–219.

Gorme, J., M. Maniquiz-Redillas, P. Song, and L.-H. Kim. 2010. The water quality of the Pasig river in the City of Manila, Philippines: Current status, management and future recovery. *Environmental Engineering Research* 15: 173–179. https://doi.org/10.4491/eer.2010.15.3.173.

Guragai, B., S. Takizawa, T. Hashimoto, and K. Oguma. 2017. Effects of inequality of supply hours on consumers' coping strategies and perceptions of intermittent water supply in Kathmandu Valley, Nepal. *Science of the Total Environment* 599–600: 431–441. https://doi.org/10.1016/j.scitotenv.2017.04.1820048-9697.

Ha, Q.K., K. Kim, N.L. Phan, T.H. Phung, and N.P. Chu. 2019. A hydrogeological and geochemical review of groundwater issues in southern Vietnam. *Geosciences Journal* 23 (6): 1005–1023.

Hammond, M.J., A.S. Chen, S. Djordjevic, D. Butler, and O. Mark. 2015. Urban flood impact assessment: A state-of-the-art review. *Urban Water Journal* 12 (1–2): 14–29.

Hanoi Water Limited Company. 2016. Temporary water shut-off schedule.

Hao, Aibing, and Yilong Zhang. 2018. Review: Groundwater resources and related environmental issues in China. *Hydrogeology Journal* 26 (5): 1325–1337. https://doi.org/10.1007/s10040-018-1787-1.

Hao, A., Y. Zhang, E. Zhang, Z. Li, J. Yu, H. Wang, J. Yang, and Y. Wang. 2018. Groundwater resources and related environmental issues in China. *Hydrogeology Journal* 26 (5): 1325–1337.

Hu, M., X. Zhang, Y. Li, H. Yang, and K. Tanaka. 2019. Flood mitigation performance of low impact development technologies under different storms for retrofitting an urbanized area. *Journal of Cleaner Production* 222: 373–380. https://doi.org/10.1016/j.jclepro.2019.03.044.

Huang, X.R., J.W. Zhao, and P.P. Yang. 2015. Wet-dry runoff correlation in Western Route of South-to-North Water Diversion Project, China. *Journal of Mountain Science* 12: 592–603.

Ignatieva, M., C. Meurk, and G. Stewart. 2008. *Low impact urban design and development (LIUDD): Matching urban design and urban ecology*. Landscape Architecture Group: Lincoln University.

Iliman, V.A. 1992. Department of Environment and Natural Resources. (Government Document)

Irawan, D.E., H. Silaen, P. Sumintadireja, R. Lubis, B. Brahmantyo, and D. Puradimaja. 2015. Groundwater–surface water interactions of Ciliwung River streams, segment Bogor-Jakarta, Indonesia. *Environmental Earth Sciences* 73: 1295–1302. https://doi.org/10.1007/s12665-014-3482-41866-6299.

Jalilov, S.-M., M. Kefi, P. Kumar, Y. Masago, and B.K. Mishra. 2018. Sustainable urban water management: Application for integrated assessment in Southeast Asia. *Sustainability* 10: 122. https://doi.org/10.3390/su100101222071-1050.

Jensen, O., and A. Khalis. 2020. Urban water systems: Development of micro-level indicators to support integrated policy. *PLoS ONE* 15 (2): e0228295. https://doi.org/10.1371/journal.pone.0228295.

Jha, P.K. 1995. Pollution preventing efforts and strategies for the Kathmandu valley. *Water, Air, and Soil Pollution* 85 (4): 2643–2648. https://doi.org/10.1007/BF011862331573-2932.

Johnston, B.R. 2011. Water, cultural diversity, and global environmental change. *Water, Cultural Diversity, and Global Environmental Change*. https://doi.org/10.1007/978-94-007-1774-9.

JS company (VIW ASE) and Hanoi people's Committee (HPC), H., Vietnam. 2012. Hanoi capital urban water supply master plan to 2030 and vision to 2050, Report of Vietnam water sanitation and environment.

Kaneko, S., and T. Toyota. 2011. Long-term urbanization and land subsidence in asian megacities: An indicators system approach. Long-term urbanization and land subsidence in asian megacities: An indicators system approach

Keeler, B.L., P. Hamel, T. McPhearson, M.H. Hamann, M.L. Donahue, K.A. Meza Prado, K.K. Arkema, et al. 2019. Social–ecological and technological factors moderate the value of urban nature. *Nature Sustainability* 2: 29–38. https://doi.org/10.1038/s41893-018-0202-12398-9629.

Kooy, M., C.T. Walter, and I. Prabaharyaka. 2016. Inclusive development of urban water services in Jakarta: The role of groundwater. *Habitat International*. https://doi.org/10.1016/j.habitatint.2016.10.006.

Kooy, M., C.T. Walter, and I. Prabaharyaka. 2018. Inclusive development of urban water services in Jakarta: The role of groundwater. *Habitat International* 73: 109–118. https://doi.org/10.1016/j.habitatint.2016.10.0060197-3975.

Kosasih, B.R., S. Samsuhadi, and N.I. Astuty. 2009. Kualitas Air Tanah Di Kecamatan Tebet Jakarta Selatan Ditinjau Dari Pola Sebaran *Escherichia coli*. *Jurnal Teknologi Lingkungan Universitas Trisakti* 5 (1): 1.

Kron, W. 2015. Flood disasters—A global perspective. *Water Policy* 17 (1): 6–24. https://doi.org/10.2166/wp.2015.001.

Kumar, P., Y. Masago, B.K. Mishra, and K. Fukushi. 2018. Evaluating future stress due to combined effect of climate change and rapid urbanization for Pasig-Marikina River, Manila. *Groundwater for Sustainable Development* 6: 227–234. https://doi.org/10.1016/j.gsd.2018.01.0042352-801X.

Kundzewicz, K., H. Seneviratne, and Sherstyukov. 2014. Flood risk and climate change—Global and regional perspectives. *Hydrological Sciences Journal/journal Des Sciences Hydrologiques*. https://doi.org/10.1080/02626667.2013.857411.

Kuroda, K., T. Hayashi, A.T. Do, V.D. Canh, T. Nga, A. Funabiki, and S. Takizawa. 2017. Groundwater recharge in suburban areas of Hanoi, Vietnam: Effect of decreasing surface-water bodies and land-use change. *Hydrogeology Journal* 25 (3): 727–742. https://doi.org/10.1007/s10040-016-1528-2.

Le, D.N., H. Anh, T. Hoang, H. Nguyen, and T. Le. 2020. Antibiotic and antiparasitic residues in surface water of urban rivers in the Red River Delta (Hanoi, Vietnam): Concentrations, profiles, source estimation, and risk assessment. *Environmental Science and Pollution Research* 28: 10622–10632.

Le, V., D.N. Cao, and P.N. Xuan. 2017. The overview of water pollution in the world. *International Journal of Scientific & Technology Research* 6 (08): 2277–8616.

Li, P., R. Tian, C. Xue, and J. Wu. 2017. Progress, opportunities, and key fields for groundwater quality research under the impacts of human activities in China with a special focus on western China. *Environmental Science and Pollution Research International* 24: 13224–13234. https://doi.org/10.1007/s11356-017-8753-70944-1344.

Ling, N.T. 2015. Cost comparison of seawater for toilet flushing and wastewater recycling. *Water Policy* 17 (1): 83.

Liu, J.H., D.Y. Qin, H. Wang, and M. Wang. 2010. Dualistic water cycle pattern and its evolution in Haihe River basin. *Chinese Science Bulletin* 2010: 1688–1697. https://doi.org/10.1007/s11434-010-3043-5.

Long, D., W. Yang, B.R. Scanlon, J. Zhao, D. Liu, P. Burek, Y. Pan, L. You, et al. 2020. South-to-North Water diversion stabilizing Beijing's groundwater levels. *Nature Communications* 11: 3665. https://doi.org/10.1038/s41467-020-17428-62041-1723.

Luo, A.S.S.P. 2015. Overview of Jakarta water-related environmental challenges.

Luo, P., S. Kang, Z. Apip, and D. Nover. 2019. Water quality trend assessment in Jakarta: A rapidly growing Asian megacity. *PLoS*

ONE 14 (7): e0219009. https://doi.org/10.1371/journal.pone.0219009.
Luo, P., D. Mu, H. Xue, and T. Ngo-Duc. 2018. Flood inundation assessment for the Hanoi Central Area, Vietnam under historical and extreme rainfall conditions. *Scientific Reports*. https://doi.org/10.1038/s41598-018-30024-5.
Lyu, J., P. Luo, S. Mo, M. Zhou, B. Shen, L. Fan, and D. Nover. 2019. Towards sustainable water regulation based on a distributed hydrological model for a heavily polluted urban river, northwest China. *Hydrology Research*. https://doi.org/10.2166/nh.2019.005.
March. 2009. Bagmati action plan (2009–2014) DRAFT REPORT. (Report)
Mateo-Sagasta, J., S.M. Zadeh, H. Turral, and J. Burke. 2017. Water pollution from agriculture: A global review. Executive summary. FAO and IWMI.
McElwee, P. 2004. You say illegal, i say legal. *Journal of Sustainable Forestry* 19: 97–135. https://doi.org/10.1300/J091v19n01_061054-9811.
Media, E. 2005. Australian runoff quality: A guide to water sensitive urban design.
Miao, Q., D. Yang, H. Yang, and Z. Li. 2016. Establishing a rainfall threshold for flash flood warnings in China's mountainous areas based on a distributed hydrological model. *Journal of Hydrology* 541: 371–386.
Mirza, M., R.A. Warrick, and N.J. Ericksen. 2003. The implications of climate change on floods of the Ganges, Brahmaputra and Meghna Rivers in Bangladesh. *Climatic Change* 57: 287–318.
Mitchell, G. 2005. Mapping hazard from urban non-point pollution: A screening model to support sustainable urban drainage planning. *Journal of Environmental Management* 74 (1): 1–9.
Mu, D., P. Luo, J. Lyu, M. Zhou, A. Huo, W. Duan, D. Nover, B. He, et al. 2020. Impact of temporal rainfall patterns on flash floods in Hue City, Vietnam. *Journal of Flood Risk Management*. https://doi.org/10.1111/jfr3.12668.
Munasinghe, M. 1993. Water supply and environmental management.
Nagabhatla, N., P. Pouramin, R. Brahmbhatt, C. Fioret, and V. Smakhtin. 2020. Water and migration: A global overview, UNU-INWEH. Institute for Water environment and healthy. http://inweh.unu.edu/publications/
Noviandi, T.U.Z., R.L. Kaswanto, and H.S. Arifin. 2017. Riparian landscape management in the midstream of Ciliwung River as supporting Water Sensitive Cities program with priority of productive landscape. *IOP Conference* 91: 012033. https://doi.org/10.1088/1755-1315/91/1/012033.
Pandey, C.L. 2021. Managing urban water security: Challenges and prospects in Nepal. *Environment, Development and Sustainability: A Multidisciplinary Approach to the Theory and Practice of Sustainable Development* 23: 241–257.
Pandey, V.P., S.K. Chapagain, and F. Kazama. 2010. Evaluation of groundwater environment of Kathmandu Valley. *Environmental Earth Ences* 60: 1329–1342.
Pandey, V.P., S.K. Chapagain, and F. Kazama. 2010. Evaluation of groundwater environment of Kathmandu Valley. *Environmental Earth Sciences* 60: 1329–1342. https://doi.org/10.1007/s12665-009-0263-61866-6299.
Pandey, V.P., and F. Kazama. 2011. Hydrogeologic characteristics of groundwater aquifers in Kathmandu Valley, Nepal. *Environmental Earth Sciences* 62: 1723–1732.
Pant, B.R. 2011. Ground water quality in the Kathmandu valley of Nepal. *Environmental Monitoring & Assessment* 178: 477–485. https://doi.org/10.1007/s10661-010-1706-y.
Parmeshwar, U., I. Hiroshi, T. Bhesh, and S. Narendra. 2016. The status of domestic water demand: Supply deficit in the Kathmandu Valley, Nepal. *Water* 8: 196–196. https://doi.org/10.3390/w8050196.
Pathak, D.R., A. Hiratsuka, I. Awata, and L. Chen. 2009. Groundwater vulnerability assessment in shallow aquifer of Kathmandu Valley using GIS-based DRASTIC model. *Environmental Geology* 57: 1569–1578. https://doi.org/10.1007/s00254-008-1432-81432-0495.
Pham Ngoc Bao, T.A., and O.T.A.K.I. Masahiro. 2013. Water demand management: A strategic approach towards a sustainable urban water system in Hanoi. *Journal of Water and Environment Technology* 11: 5. https://doi.org/10.2965/jwet.2013.403.
Philippine Atmospheric, G.a.A.S.A.P. 2011. Scientific normals: Rainfall normal values. (Government Document)
Pour, S.H., A.K.A. Wahab, S. Shahid, M. Asaduzzaman, and A. Dewan. 2020. Low impact development techniques to mitigate the impacts of climate-change-induced urban floods: Current trends, issues and challenges. *Sustainable Cities and Society* 62: 102373. https://doi.org/10.1016/j.scs.2020.102373.
Programme, U.N.E. 2016. Global Material Flows and Resource Productivity: Assessment Report for the UNEP International ResourcePanel.
Raflores, L.S., and R.K. Regmi. 2015. Understanding the water and urban environment of a megacity: The case of Metro Manila, Philippines.
Rana, K. 2011. Uses of ground water in Nepal.
Rian, M.S.P., A. Auzan, N. Farika, E.W.T. Nonik, P. Ca hyo Nugroho, R. Apriatresnayanto, D. Roosmini, K. Pribadi, et al. 2018. Value engineering application for conceptual design of seawater desalination plant in Jakarta. *MATEC Web of Conferences* 147: 06005.
Rukmana, D. 2015. The change and transformation of Indonesian spatial planning after Suharto's New Order Regime: The case of the Jakarta Metropolitan Area. *International Planning Studies* 20: 350–370.
Sarah, P., and Church. 2015. Exploring Green Streets and rain gardens as instances of small scale nature and environmental learning tools. *Landscape and Urban Planning*. https://doi.org/10.1016/j.landurbplan.2014.10.021.
Scaparra, M.P., N.C. Chinh, T. Dang, and T.H. Tran. 2019. Community perceptions of social, economic and environmental impacts of flooding in central districts of Hanoi, Vietnam. *Proceedings of the British Academy*. https://doi.org/10.5871/jba/007s2.137.
Shao, J., J. Liu, Q. Zhang, R. Wang, Z. Li, L. Wang, and Q. Yang. 2016. Chapter 16 - Groundwater environment in Beijing, China. In *Groundwater environment in asian cities*, ed. S. Shrestha, V.P. Pandey, B.R. Shivakoti, and S. Thatikonda, 345–381. Oxford: Butterworth-Heinemann.
Shimizu, S.J.H.S. 2013. An overview of the effects of urbanization on the quantity and quality of groundwater in South Asian megacities. *Limnology* 14 (2): 135–145.
Shrestha, R.R. 2009. Rainwater harvesting and groundwater recharge for water storage in the Kathmandu Valley. *Sustainable Mountain Development*. http://www.icimod.org
Shrestha, S.R., G.N. Tripathi, and D. Laudari. 2018. Groundwater resources of Nepal: An overview. *Groundwater of South Asia*. https://doi.org/10.1007/978-981-10-3889-1_11.
Simarmata, H.A. 2018. Planning institutions of adaptation to flood in Jakarta, Phenomenology in adaptation planning: An empirical study of flood-affected people in Kampung Muara Baru Jakarta. Springer, Singapore, pp. 39–64.
Song, J., M. Han, T.I. Kim, and J.E. Song. 2009. Rainwater harvesting as a sustainable water supply option in Banda Aceh. *Desalination* 248: 233–240.
Sood, A., V. Smakhtin, N. Eriyagama, K. G. Villholth and C. Dickens, 2017. Global environmental flow information for the sustainable development goals. *International Water Management Institute*

Sun, Z. 2013. Situation and countermeasures of water resources in Beijing. *Beijing Water*. https://doi.org/10.3969/j.issn.1673-4637.2013.04.003.

Takagi, H., M. Esteban, T. Mikami, and D. Fujii. 2016. Projection of coastal floods in 2050 Jakarta. *Urban Climate* 17: 135–145. https://doi.org/10.1016/j.uclim.2016.05.003.

Tbca, B., D. Ypdc, T.A. Yao, B. Lpd, and E. Bdb. 2020. Observations of heavy rainfall and extreme flood events over Banke-Bardiya districts of Nepal in 2016–2017. *Progress in Disaster Science*. https://doi.org/10.1016/j.pdisas.2020.100074.

Tirtomihardjo, H. 2011. Groundwater Resource Potential in Indonesia and their Management. Asia Pacific Water Forum (APWF) Regional Water, Asia Pacific Water Forum (APWF) Regional Water.

Tran, T., and K.G. Nguyen. 2018. Metal and metalloid concentrations in soil, surface water, and vegetables and the potential ecological and human health risks in the northeastern area of Hanoi, Vietnam. *Environmental Monitoring and Assessment* 190: 624. https://doi.org/10.1007/s10661-018-6994-7.

United Nations. 2018. SDG 6 synthesis report 2018 on water and sanitation. United Nations. https://doi.org/10.18356/e8fc060b-en

Uprety, A., A. Ozaki, Y. Senoo, I. Yoshida, C. Leppold, A. Higuchi, and T. Tanimoto. 2017. Flood damage in Nepal exacerbated by underlying conflict with India. *The Lancet Planetary Health* 1: e351–e352. https://doi.org/10.1016/S2542-5196(17)30159-62542-5196.

Voorst, V., and Roanne. 2016. Formal and informal flood governance in Jakarta, Indonesia. *Habitat International*. https://doi.org/10.1016/j.habitatint.2015.08.023.

Vu, V.H., and B.J. Merkel. 2018. Estimating groundwater recharge for Hanoi, Vietnam. *Science of the Total Environment* 651: 1.

Wang, J., Y. Shang, H. Wang, Y. Zhao, and Y. Yin. 2015a. Beijing's water resources: Challenges and solutions. *Jawra Journal of the American Water Resources Association* 51: 614–623. https://doi.org/10.1111/1752-1688.12315.

Wang, J., Y. Shang, H. Wang, Y. Zhao, and Y. Yin. 2015b. Beijing's water resources: Challenges and solutions. *JAWRA Journal of the American Water Resources Association* 51: 614–623. https://doi.org/10.1111/1752-1688.12315.

Wei, S. 2012. Reflections on the "721" heavy rain in Beijing. *Civil Aviation of China* 000: 46–48.

Wei, W. 2016. Several relationships need to be dealt with in the construction of water saving agriculture in Beijing. *Economic Research Guide* 14: 39–41.

Yang, S.J. 2020. The middle route of the South-to-North Water Diversion Project has delivered 30 billion cubic meters of water to the north, benefiting 60 million people. http://news.cctv.com/2020/06/03/ARTIeM75r6xhvG5YZKLLgTbT200603.shtml. accessed June 3 2020.

Yeung, Y. 2001. Coastal mega-cities in Asia: Transformation, sustainability and management. *Ocean & Coastal Management* 44: 319–333. https://doi.org/10.1016/S0964-5691(01)00053-9.

Yoshino, G.H., L.L. Fernandes, J.H. Ishihara, and A. Silva. 2014. Use of rainwater for non-potable purposes in the Amazon. *Environment Development & Sustainability* 16 (2): 431–442.

Yu, W., E. Nakakita, and K. Jung. 2016. Flood forecast and early warning with high-resolution ensemble rainfall from numerical weather prediction model. *Procedia Engineering* 154: 498–503.

Yumul, G.P., Jr., N.A. Cruz, N.T. Servando, and C.B. Dimalanta. 2011. Extreme weather events and related disasters in the Philippines, 2004–08: A sign of what climate change will mean? *Disasters* 35: 362–382. https://doi.org/10.1111/j.1467-7717.2010.01216.x0361-3666.

Yuping, X. 2016. Current situation and challenges of urban traffic flood control management in Beijing. *Beijing Water* 000: 39–44. https://doi.org/10.3969/j.issn.1673-4637.2016.04.010.

Zha, X., P. Luo, W. Zhu, S. Wang, J. Lyu, M. Zhou, A. Huo, and Z. Wang. 2021. A bibliometric analysis of the research on sponge city: Current situation and future development direction. *Ecohydrology*. https://doi.org/10.1002/eco.2328.

Zhang, L., C. Cong, H. Pan, Z. Cai, V. Cvetkovic, and B. Deal. 2021. Socioecological informed comparative modeling to promote sustainable urban policy transitions: Case study in Chicago and Stockholm. *Journal of Cleaner Production* 281: 125050.

Zhang, L., C. Cong, H. Pan, Z. Cai, and B. Deal. 2020a. Socioecological informed comparative modeling to promote sustainable urban policy transitions: Case study in Chicago and Stockholm. *Journal of Cleaner Production*. https://doi.org/10.1016/j.jclepro.2020.125050.

Zhang, S., Y. Li, M. Ma, T. Song, and R. Song. 2018. Storm water management and flood control in sponge city construction of Beijing. *Water* 10 (8): 1.

Zhang, X., M. Hu, C. Gang, and Y. Xu. 2012. Urban rainwater utilization and its role in mitigating urban waterlogging problems-A case study in Nanjing, China. *Water Resources Management* 26: 3757–3766.

Zhang, Y.M. 2017. Current situation and sustainable development countermeasures of water resources utilization in Shunyi District, Beijing. *Beijing Water* 000: 5–9. https://doi.org/10.19671/j.1673-4637.2017.05.002.

Zhang, Y., P. Luo, S. Zhao, S. Kang, and J. Lyu. 2020b. Control and remediation methods for eutrophic lakes in recent 30 years. *Water Science & Technology*. https://doi.org/10.2166/wst.2020.218.

Zhongshan Yang, Y.D., and Z. Wang. 2010. Cause analysis and Countermeasures of serious decline of groundwater level in Beijing. *China Water Conservancy* 19: 60–62. https://doi.org/10.3969/j.issn.1000-1123.2010.19.019.

Zhu, Y.L., F. Su, S. Zhang, and B. Sun. 2020. Spatiotemporal analysis of hydrological variations and their impacts on vegetation in semiarid areas from multiple satellite data. *Remote Sensing* 12: 4177. https://doi.org/10.3390/rs12244177.

Zoleta-Nantes, D.B. 2000. Flood hazards in metro Manila: Recognizing commonalities, differences, and courses of action. *Social Science Diliman*. https://doi.org/10.5194/nhess-13-653-2013.

Zoysa, S.D. 2020. Beyond the wall: Dyking as an object of everyday governance in the Bay of Manila, Philippines. *Marine Policy* 112: 10366.

Zoysa, S.D., T. Schne, J. Herbeck, J. Illigner, and A.K. Hornidge. 2021. The "wickedness" of governing land subsidence: Policy perspectives from urban Southeast Asia. *PLoS ONE* 16 (6): e0250208. https://doi.org/10.1371/journal.pone.0250208.

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