Southeast Asian Water Environment 4

Edited by Kensuke Fukushi, Futoshi Kurisu, Kumiko Oguma, Hiroaki Furumai and Psyche Fontanos

IWA Publishing

Southeast Asian Water Environment 4

Editors
Kensuke Fukushi, Futoshi Kurisu,
Kumiko Oguma, Hiroaki Furumai,
and Psyche Fontanos

IWA Publishing
London • New York

Published by **IWA Publishing**
Alliance House
12 Caxton Street
London SW1H 0QS, UK
Telephone: +44 (0)20 7654 5500
Fax: +44 (0)20 654 5555
Email: publications@iwap.co.uk
Web: www.iwapublishing.com

First published 2010

Typeset in India by OKS Prepress Services.

British Library Cataloguing in Publication Data
A CIP catalogue record for this book is available from the British Library

Library of Congress Cataloging-in-Publication Data
A catalog record for this book is available from the Library of Congress

ISBN: 184339362X
ISBN13: 9781843393627

Southeast Asian Water Environment 4

Preface
History and future vision of the International Symposium on Southeast Asian Water Environment

H. Furumai

The year 2009 was the 50th founding anniversary of the Asian Institute of Technology (AIT). We were very grateful to organize the 7th International Symposium on Southeast Asian Water Environment as one of the commemorative events of this anniversary. There have been many interesting and informative papers tackling various aspects of water environment. The papers presented at the symposia are reviewed, and selected papers are published in the "Southeast Asian Water Environment Book Series" issued by IWA Publishing, UK. Currently, there are three volumes. On the occasion of the publication of Southeast Asian Water Environment Volume 4, we would like to introduce the history of this symposium and activities of the Research Center for Water Environment (RECWET) as an organizing institute in the University of Tokyo (UT).

HISTORY OF THE INTERNATIONAL SYMPOSIUM ON SOUTHEAST ASIAN WATER ENVIRONMENT

The 1st International Symposium on Southeast Asian Water Environment was held on October 24 and 25, 2003 at AIT in Thailand. It was organized by the University of Tokyo in support with the Coordination Funds for Promoting Science and Technology, "Establishment of a Southeast Asia Water Environment Interdisciplinary Consortium", funded by the Ministry of Education, Culture, Sports, Science and Technology of Japan. The project leader was Prof. Shinichiro Ohgaki. Through the project activity, the Southeast Asian Center for Water Environment Technology (SACWET) was founded in November 2002 to promote international networking functions in collaboration with AIT. At that time, the SACWET co-director from AIT side was Prof. Polprasert Chongrak, who was the Dean of School of Environment, Resources and Development (SERD).

After the 2nd symposium in Hanoi, Vietnam, dedicated funds were not available. However, due to the numerous requests to continue this symposium series, we have made it an annual event. The following table briefly describes each year's symposium. The number of contributed papers has an increasing trend, indicating the symposium is gaining recognition. Recent symposia were held with strong assistance from several supporting Asian partners and great research projects on Asian Water issues as enumerated below.

- 21st Century COE program on Center for Sustainable Urban Regeneration (cSUR), UT
- 21st Century COE program on Integrated River Basin Management in Asian Monsoon Region, University of Yamanashi
- Alliance for Global Sustainability (AGS)
- Asian Program for Incubation of Environmental Leaders (APIEL) program, UT
- Global COE Program on Evolution of Research and Education on Integrated River Basin Management in Asian Region, University of Yamanashi
- Greater Mekong Subregion Academic and Research Network (GMSARN)
- Institute for Global Environmental Strategies (IGES)
- Integrated Research System for Sustainability Science (IR3S), UT
- Japan Society on Water Environment (JSWE)
- National Center of Excellence for Environmental and Hazardous Waste Management (NCE-EHWM), Thailand
- Research and Development of Water Reuse Technology for Tropical Regions (WaterInTro project), UT
- Research Revolution 2002, Tohoku University and Ehime University
- The Sumitomo Foundation
- United Nations University (UNU)
- West Java Environmental Protection Agency (Indonesia)
- Wisdom of Water (Suntory), Corporate Sponsored Research Program, UT

 Southeast Asian Water Environment 4. Edited by Kensuke Fukushi, Futoshi Kurisu, Kumiko Oguma, Hiroaki Furumai, and Psyche Fontanos. ISBN: 9781843393627. Published by IWA Publishing, London, UK.

Table 1. International Symposium on Southeast Asian Water Environment.

	Date	Venue	Number of presented papers (poster papers)	Number of attendees	Notes
1	2003/10/23–25	Asian Institute of Technology (Thailand)	65	153	Supported by the Coordination Funds
2	2004/12/1–3	Sofitel Hotel, Hanoi (Vietnam)	101 (39)	181	Supported by the Coordination Funds
3	2005/12/6–8	Asian Institute of Technology (Thailand)	67 (27)	100	
4	2006/12/6–8	Asian Institute of Technology (Thailand)	54 20)	100	Best Poster Award was established
5	2007/11/6–8	Green Lake Resort, Chiang Mai (Thailand)	73 (40)	100	
6	2008/10/29–31	Jayakarta Hotel, Bandung (Indonesia)	89 (47)	136	
7	2009/10/28–30	Asian Institute of Technology (Thailand)	68 (18)	260	Award for Asian Young Professional on Water Research was established

PROMOTION OF YOUNG PROFESSIONAL CONTRIBUTION TO WATER RESEARCH IN ASIA

The key principal founder of this symposium, Prof. Ohgaki finished his professorship at the University of Tokyo and changed his position to President of the National Institute of Environmental Studies (NIES) from April 2009. On the occasion of his professorship retirement, we established the Ohgaki Memorial Scholarship. As one of the scholarship activities, "The Award for Asian Young Professional on Water Research" was initiated. This award is given every year to distinguished young professionals who demonstrate the most outstanding and promising performance in the symposium. A specially designed medal is given to the awardees. Following the Award founder's proposal of incorporating a traditional Japanese touch on the medal, the design was inspired from a piece of work by a famous Japanese painter and lacquerer, Korin Ogata. The motif is Red and White Plum Blossoms balanced on both sides, which imply the matured senior and the developing youth, respectively.

Especially, we would like to promote the academic and practical activities of young professionals in this field. For this purpose, we aim for useful publication of collected papers contributing to better understanding of water environmental issues and water environmental research in Southeast Asia. Additionally, this serial publication encourages researchers and practitioners to submit their papers to this Symposium.

FUTURE VISION OF THE SYMPOSIUM

The International Symposium on Southeast Asian Water Environment will be extended to include a wider region of Asia. In particular, water environment research in China and India, where environmental issues are becoming apparent as their economies grow dramatically, will be included as topics in the symposia. Additionally, the symposia will be organized in collaboration with Korea, Singapore, and Taiwan, which have been conducting cutting-edge environment research. As a symposium organizing institute, the Research Center for Water Environment Technology (RECWET) should contribute to the future development of the symposium. Since the RECWET has celebrated its 10th anniversary in 2009 and will continue its center activities for six years from 2010 to 2015. Our mission is to serve as a core center for water environment both domestically and internationally. Therefore, we plan to expand activities regarding water environment issues from Southeast Asia to all of Asia.

The RECWET can effectively conduct our endeavors by strategically connecting research projects by external funds and our activities as a research center. Our new project, "Development of Harmonized Urban Water Utilization Systems adapted to Climate Changes" (FY 2009 – FY 2014), has been initiated as a Core Research of Evolutional Science & Technology (CREST) project funded by the Japan Science and Technology Agency (JST). Based on this venture, we will try to develop various research activities about water environment management. Through the research project activities, we intend to strengthen our collaborations with domestic and international research centers focused

on water environments. Furthermore, we aim to play the role of core center of water environment research in Asia by collaborating with SACWET and organizing the series of symposia and information exchange meetings.

Hiroaki Furumai
Professor
Research Center for Water Environment Technology
Graduate School of Engineering
the University of Tokyo.

Contents

 Southeast Asian Water Environment 4. Edited by Kensuke Fukushi, Futoshi Kurisu, Kumiko Oguma, Hiroaki Furumai, and Psyche Fontanos. ISBN: 9781843393627. Published by IWA Publishing, London, UK.

Introduction: Water environment in Southeast Asia: Where do we stand today?

C. Visvanathan and M. Padmasri

Environmental Engineering and Management Program, School of Environment, Resources and Development, Asian Institute of Technology, PO Box 4, Klong Luang Pathumthani, 12120, Thailand (Email: visu@ait.ac.th)

Abstract Driven by demographic change and economic growth, water resource, an essential component of the global system is experiencing severe stress. Global and regional water crisis are indicated by rapid withdrawal to meet the growing demand and scarcity. The persistent imbalance between availability and demand, and the evident degradation of ground and surface water quality are expected to elevate and further worsen the current situation. Population growth, technological development, land use changes, environmental degradation and climate change are some of the major factors influencing water demand and hence creating a water crisis in the region. This paper presents the status of water environment in Southeast Asia from four major perspectives; population growth and urbanization, agriculture, industry and climate change. Vulnerability of water resources in Southeast Asia is elaborated based on availability and demand, land degradation, water security and transboundary water issues. Few strategic approaches drawn for the overall improvement of water environment in Southeast Asia are also highlighted.

Keywords water environment, water scarcity, water conflicts, water resources, water quality, socio-economic conditions, land degradation

INTRODUCTION

Water resources, an integral part of the global system, are experiencing stress due in part to increasing water withdrawal in order to meet the demands of demographic change and economic growth. The increasing distress on both the quantity and quality of the water resources is caused by four major drivers; urbanization, intensive agriculture, industrial growth and climate change. The alteration in water demand is fundamentally driven by population growth, urbanization and industrialization.

The global use of water varies among sectors, for example, agriculture uses 70%, industry 20%, and domestic uses about 10%. Evidently, the agriculture sector is the largest consumer of freshwater resources throughout the world (Table 1). The persistent imbalance between the water availability and demand, as well as the degradation of ground and surface water quality has been debated globally. Besides population growth, technological development, land use changes, overall environmental degradation and climate change have significantly affected water sources. A change in water availability due to the changes in precipitation and temperature resulting from climate change and increase in water withdrawal due to socioeconomic changes are globally evident as well.

Southeast Asia is one of the world's fastest growing regions in terms of population and overall economic development. Stress due to severe water shortage and increase in surface and groundwater pollution is evident in the humid tropical rain belt of Southeast Asia. The change in water availability is apparent from the combined effect of increasing population, rise in per capita water consumption and climate change. The declining trend of per capita water availability as a result of these combined effects indicates the possible increment in severity of water stress in Southeast Asia.

The prevailing water environment in Southeast Asia warrants a self–sustaining water system and appropriate solutions to avoid serious water-related vulnerability in the future. The overall status of "water" in Southeast Asia has been examined in this context and towards thinking a sustainable and implementable solution for tackling water crisis in the region. Based on the overall pattern of water issues, the major pressing-factors facing the water sector and the existing water management system in Southeast Asia, an attempt has been made to present some strategic approaches towards improving the water environment.

WATER ENVIRONMENT IN SOUTHEAST ASIA

The current water environment and the major factors pressuring the water sector in Southeast Asia are presented in the following section. Figure 1 presents the major issues surrounding the water environment in Asia.

 Southeast Asian Water Environment 4. Edited by Kensuke Fukushi, Futoshi Kurisu, Kumiko Oguma, Hiroaki Furumai, and Psyche Fontanos. ISBN: 9781843393627. Published by IWA Publishing, London, UK.

Table 1. Water resource and withdrawal in Asia (Earthscan, 2007).

Region	Renewable water resource (km^3/year)	Total water withdrawal (km^3/year)	Withdrawal of renewable water resources (%)	Water withdrawal (%)		
				Agriculture	Industry	Domestic (urban)
Asia	11,594	2,378	20.5	81	11	7
World	43,659	3,829	8.8	70	20	10

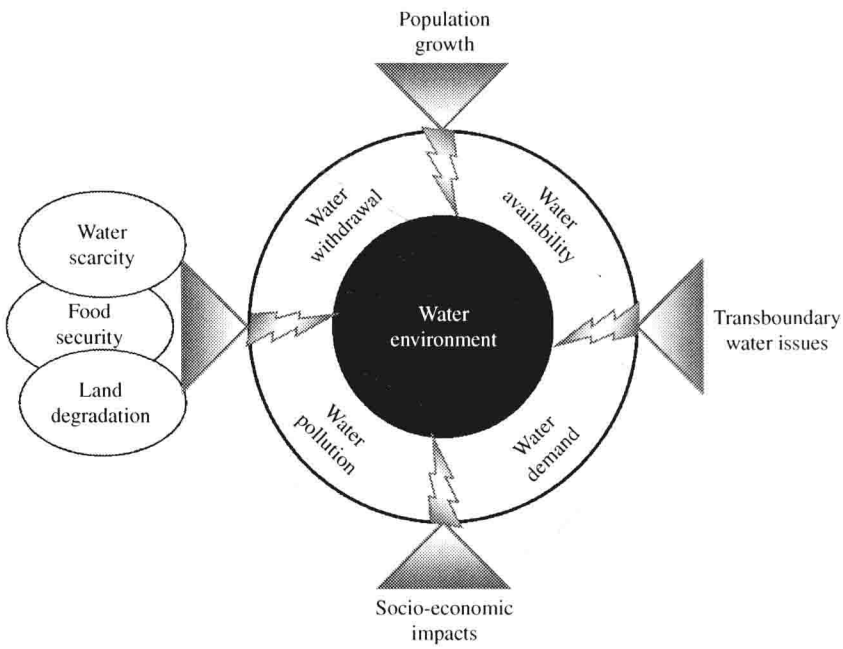

Figure 1. Issues facing the Asian water environment.

Water availability

Amidst the water resources that are widely and unevenly distributed around the world, one-third of the world's renewable water resources are concentrated in Asia. Southeast Asia with a population density 2.6 times of the world's average has an annual per capita water availability exceeding 5,800 m^3, except in Singapore (Babel and Wahid, 2009).

Figure 2 presents the per capita water availability in Asia. The average per capita availability of water in Asia is well below the world's average per capita availability. Water availability across the different Asian countries varies widely from 77,000 to less than 1,000 m^3/year per capita and the major share (72%) of water resources in Asia is located in Russia (3,107 km^3/year), China (2,700 km^3/year), Indonesia (2,530 km^3/year), and India (1,456 km^3/year) (Shiklomanov, 2001).

Water withdrawal and decline in water resources

A significant increase in water withdrawal rate could be observed throughout the world, especially in Asia. Figure 3 presents the trend of global water withdrawal from 1900–2025.

Global magnitude of water withdrawal during the last century has increased by over six times and at more than double the population growth rate. The highest water withdrawal of about 85% is observed in Central Asia, followed by South Asia 48% Mongolia and 25% northern People's Republic of China. Southeast Asia exhibits about 4.5% total water withdrawal of the available water resources.

Table 1 presents global and Asian renewable water resources and withdrawal status. Agriculture sector shows high water withdrawal followed by industry and domestic sector. Overall picture of water resources availability, magnitude of water withdrawal and the declining trend of per capita water resources clearly indicate its vulnerability in both global and Asian scale. The trend of depletion in water sector indicates the threat to water security in the region, which is the key issue for survival of the poor and water-dependent sectors.

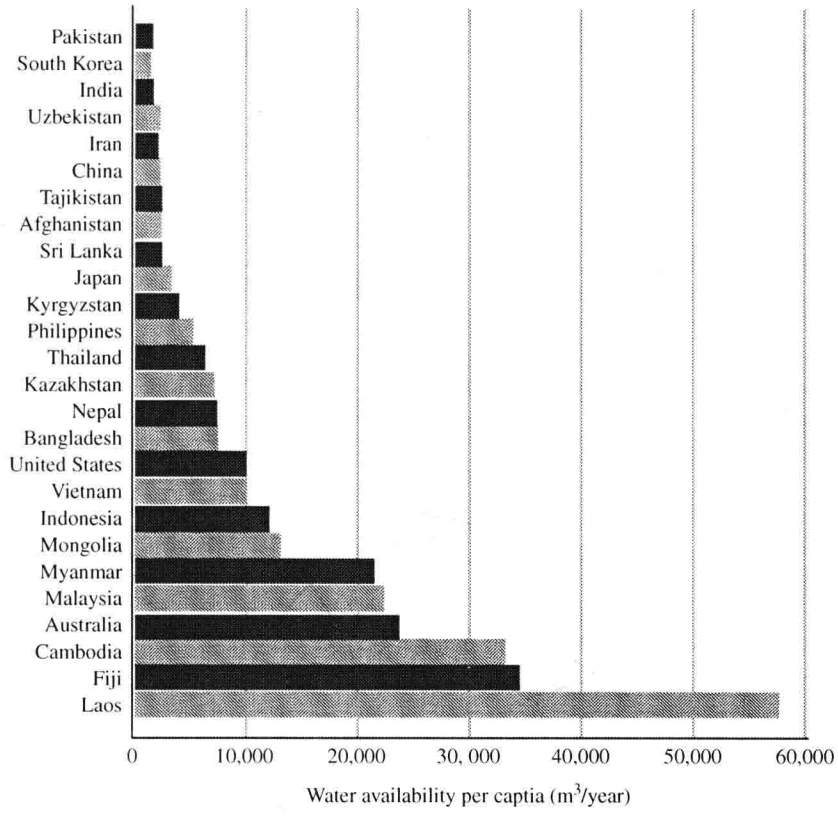

Figure 2. Total water availability per capita in Asia (Asia Society, 2009).

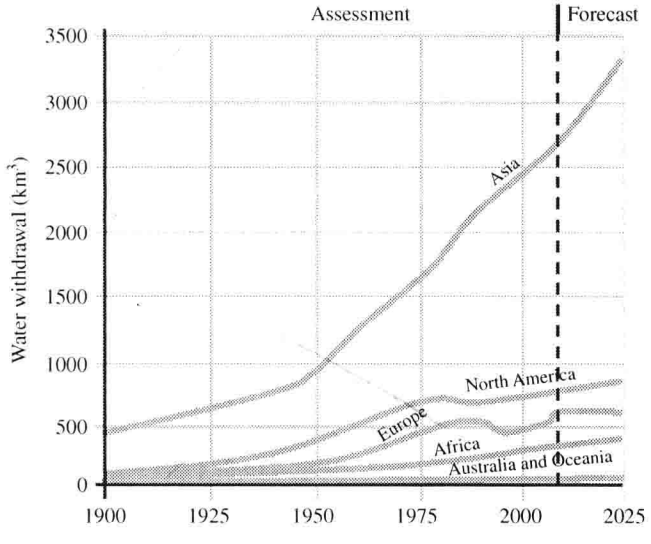

Figure 3. Global water withdrawal (Shiklomanov, 1999).

Population versus water demand

Population growth and reactive factors such as irrigated agriculture, urbanization and water pollution are some of the major causes of water crisis in the region. About 60% of the present world's population lives in Asia but is benefitted only by 36% of usable freshwater available in the world. On a global scale, water for domestic use is still inadequate despite large investments in water supply systems since the 1980s. In Southeast Asia, the agricultural sector (85.5% of total water use) is the major water consumer, followed by the industrial (7.8%) and domestic sectors (6.6%) (Babel and Wahid, 2009). Population growth in the last 50 years has increased the demand for water in the region. This is evident

from the rapid rise in the domestic and industrial water demand in Asia, between 1995 and 2025 (Kataoka, 2002). Meanwhile, drop of water availability, by around 70% in South and Central Asia, 60% in Northern China, and 50% in Southeast Asia is also reported. Figure 4 presents the effect of world population on the water availability.

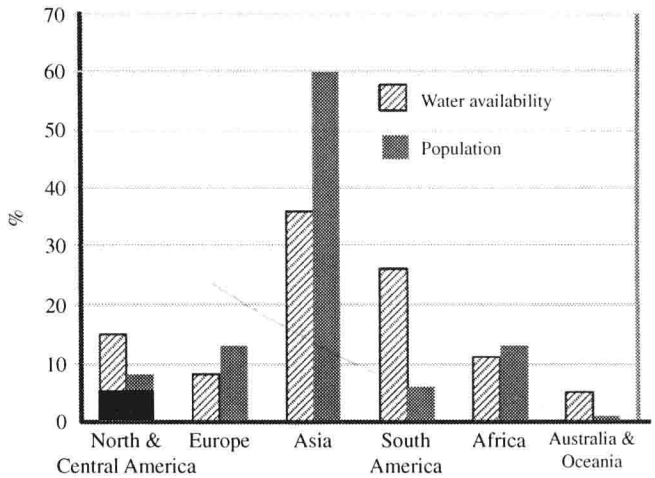

Figure 4. Population versus water availability (Environment Canada, 2004).

For example, China, one of the largest water users (in volume) is known to experience acute water challenges due to economic growth and urbanization rates which have subsequently amplified the trends of water demand and new water use patterns. This is common in other Asian countries also. In many cases, uncontrolled and inefficient use of water by the agriculture sector resulted in stress on available water. The threat of population growth on water resource can be reduced by providing demand-side and supply-side solutions.

Deterioration of water quality

Various negative impacts commonly noticed due to the deterioration of water quality are; threats to human health, reduction of the amount of good quality water available and degradation of watersheds and ecosystem. In Asia, about 750 million people in rural areas and another 100 million in urban areas do not have access to safe drinking water (ADB, 2001). However, in Southeast Asia, access to safe drinking water and improved sanitation facilities are high, compared to the world's average except for Cambodia and Lao PDR where efforts are underway.

Increasing water contamination from point and nonpoint sources because of accelerating domestic, industrial, and agricultural activities and uncontrolled dumping of municipal solid waste into water bodies are the major issues concerning many Southeast Asian countries. For example; Fecal contamination in the Saigon river and urban canals in Ho Chi Minh City due to uncontrolled discharge of fecal sludge from households into water streams without treatment in Vietnam; Arsenic contamination in drinking water; eutrophication of lakes in many Southeast Asian countries and lead contamination in surface water contributed by industrial effluents. In addition, inefficient functioning of most of the wastewater treatment plants in Asian urban centers also contributes to contamination of water bodies where, it is discharged. Water quality deterioration due to uncontrolled dumping of domestic solid waste into water bodies is critical for its degradability over time. The situation is more complex and serious for industrial wastes, which contain significant amount of toxic elements that are harmful to human beings and ecosystems.

Hence, overall control on the water system is required to prevent the deterioration of quality of water resources through proper pollution control strategies.

Groundwater resources issues

Presently, groundwater sources prone to pollution are facing severe stress. About 32% of Asia's population depends on groundwater sources for domestic purpose (as drinking water). Public trust on safety of groundwater sources compared to surface water has now changed and is diminishing because of the pollution level and irreversible damages caused by over drafting of groundwater source. For example, Kathmandu Valley of Nepal and Bangladesh which depend on groundwater to meet its drinking water needs, suffer arsenic pollution due to natural infiltration of arsenic salts from

mineral deposits. In Jakarta, unregulated extraction of water and improper management of ground water has lead to groundwater depletion inducing sea water intrusion and increased salinity in some parts of coastal northern Jakarta.

The above facts on deterioration of water sources, shows the need for proper management practices, maintenance and control on the withdrawal rate to reduce further deterioration of water quality and prevent irreversible damages in the region.

Socio-economic impacts

The effect of socio-economic changes on the water resources systems is evident from the vulnerability to overexploitation, pollution, ecological degradation etc. Water pollution and socio-economic status of a region are closely tied up. Often, a locality with good socio-economic status has cleaner waterways compared to one with a lower status. Socio-economic differences among and between communities is an important cause of water conflicts among users. Irreversible state of water source due to worsening water pollution has a great impact on mankind leading to isolation or abandonment of areas. The increase in migration to areas with more water security, will not only strain the existing water infrastructure, but also lead to social and political instability, and conflicts in the migrant-receiving areas.

Forecasts for the next 15–20 years show that the continued mass migration from China's rural to urban is likely to aggravate the current challenges of water quality and quantity. Water demand in China's urban areas is expected to grow more than 10% annually, and exceed 40% by 2020 (Asia Society, 2009) thus demonstrating the effect of China's economic growth on water demand. On the contrary, Malaysia, Philippines, Indonesia and Thailand which are marked as rapid industrialized and urbanized countries, have relatively higher water productivity, thus reflecting the higher value of water in the industrial sector.

The irreversible impacts from socio-economic growth in terms of pollution at present clearly indicates the possible pressure of continued urbanization and amplifying intersectoral competition for water, in future. However, approaches such as water-saving technologies, water recycling and reuse is expected to help in overcoming water demand problems associated with socio-economic growth.

Water scarcity, land degradation and food security

Water scarcity

Water scarcity occurs when the water resources are insufficient to satisfy long-term average requirements. Since water availability for agriculture is one of the most critical factors assuring food security, water scarcity is the key factor limiting food production. Increasing water scarcity, both natural and human-induced, is noted to aggravate the effects of desertification through long-term impacts on land and soil quality, accompanied by deterioration of the water quality. Water scarcity is commonly noticed in the areas where, dams and reservoirs coupled with deforestation in some watersheds and reduced stream water levels take place, lowered water tables are found, riparian wetlands are degraded and freshwater aquatic diversity are diminished and saline water intrusion into groundwater sources.

By 2025, almost half of earth's population is expected to face physical or economic water scarcity. Parts of China, India and Middle East are expected to be the major sufferers. Countries like Singapore, Islamic Republic of Iran and India are reported to run short of fresh water. Coastal cities of Bangkok, Jakarta and Manila are detected to undergo saline water intrusion as a result of soil subsidence due to excessive dependence on groundwater.

Land degradation and food security

Land degradation is one of the environmental variables that influence the water availability. It is addressed in many forms such as depletion of soil nutrients, salinization, land pollution, soil erosion and vegetative degradation.

Land and water degradation are interlinked and noted to occur in parallel. The chemical and biological degradation of land reduces water productivity at field and landscape scales, and affects water availability, quality, and storage. This is evident from reduced water productivity in Northeast Thailand in both rain-fed and irrigated systems on tropical sandy soils, (Noble *et al.*, 2004). In Southeast Asia, land degradation is reported to occur due to soil erosion, soil salinization and intensified agriculture towards exceeding food production rate due to increase in population growth with a decline in water quality. Some of the Southeast Asian countries like; Thailand, China, India, Myanmar and Nepal are expected to have dramatic effect on the water productivity due to land degradation, in future.

Land degradation being the source of negative implications on water productivity and food security, appropriate land management can be a solution for resolving the water crisis and water productivity reduction in the region. Since,

water scarcity, land degradation and food security are interrelated, an integrated land and water resource management policy can protect the water environment and bring global environmental and socio-economic benefits to rural and urban populations.

Water conflicts – transboundary water issues

Water conflicts occur within local communities and between countries when water stress rises due to the inability in addressing the demand and difficulty by sharing of very limited transboundary water resources. Nearly 40% of the world's population lives in more than 200 river basins that are shared by more than two countries. Twenty-two countries around the world, to a great extent, are dependent on other nation's water source. Southeast Asia has more than 15 transboundary river basins of various scales in terms of drainage area and water resources. Table 2 outlines the transboundary water resources in Southeast Asia and the dependency ratio of countries on the external water resources. Bangladesh shows highest dependency ratio of about 91% among the other Asian countries. In contrary, Kyrgyzstan with zero dependency ratios indicates its capacity to meet its demand with its own water sources within its borders. Mekong River Basin in Southeast Asia is one of the noted examples for water conflicts due to transboundary water issues.

Table 2. Water resources and dependency (Asia Society, 2009).

Country	Total internal renewable water resources (km^3)	Total external renewable water resources (km^3)	Dependency ratio (%)
Afghanistan	55	10	15
Bangladesh	105	1,106	91
Cambodia	121	356	75
China	2,812	17	1
India	1,261	636	34
Indonesia	2,838	0	0
Iran	128	9	7
Japan	430	0	0
Kazakhstan	75	34	31
Kyrgyzstan	46	−26	0
Laos	190	143	43
Malaysia	580	0	0
Myanmar	881	165	16
Nepal	198	12	6
Pakistan	55	170	77
Philippines	479	0	0
South Korea	65	5	7
Sri Lanka	50	0	0
Thailand	210	200	49
Uzbekistan	16	34	77
Vietnam	366	525	59

Mekong river transboundary issues

The Mekong River, the 10th largest river in the world in terms of volume of water, runs for approximately 4,180 km from its origin at Qinghai Province, China and flows through five countries, Myanmar, Laos, Thailand, Cambodia and Vietnam. It is the largest transboundary river in Southeast Asia shared by six countries for agriculture, fishing and for hydro power projects. Over 80 million people depend on this river for their livelihoods and for hydropower development (Goh, 2007). Water from the Mekong River accounts for about 94% of the total water withdrawals in Cambodia, followed by Thailand (91%), Vietnam (86%) and Lao PDR (81%) thus illustrating the magnitude of reliance on the river. Thailand and Laos depend on Mekong for hydro-electric power while Cambodia and Vietnam for its fishing industry. Development of large-scale hydropower projects are the major cause for the water conflicts in the region.

Some of the water conflicts faced by the Mekong River are: Difficulties faced by Cambodian communities by unexpected release of large flows from a reservoir in Vietnam due to hydropower projects in the transnational Se San/Sre Pok basin; Socio-ecological problems in the river's Delta, Vietnam; Conflicts between subsistence fishing

families and large fishing lot operations in Cambodia's Tonle Sap region; Localized conflicts on the Rasi Salai irrigation weir in the northeast over massive Khong-Chi-Mun interbasin transfer scheme, and Struggles over the likely socio-ecological impacts of the World Bank-supported Nam Theun 2 hydroelectric dam in Lao PDR (Sneddon and Fox, 2005). However, from the estimated vulnerability index (0.31) based on the water resources stresses, development pressures, ecological insecurities and management challenges faced by the Mekong river basin, this river is reported to have moderate vulnerability to water stress (Babel and Wahid, 2009). Although, the river basin does not experience water shortage or any other serious open conflicts, the basin could face threats from development pressures and transboundary issues in future without proper management, protection and monitoring.

Given the scope of threats that could be posed on the river basin by development pressure and transboundary issues, it is vital to avoid water conflicts in the region. The capacity development to monitor and predict transboundary water conflicts could promote human and environmental security in the river basin. Proper water resource management, protection and maintenance and by control on any of the projects dependency on the common water resources in the region, could control the water conflicts in future.

IMPROVEMENT OF WATER ENVIRONMENT

The current water environment in Southeast Asia presents a dire need for appropriate and implementable solutions to arrest the continued trend of diminishing freshwater resources and its consequences. Strategic approaches are essential to improve water by focusing on aspects such as water security provider of the region, water users; industry, domestic and agriculture, water demand and simple technology. Figure 5 outlines the water environment and the strategic approaches drawn.

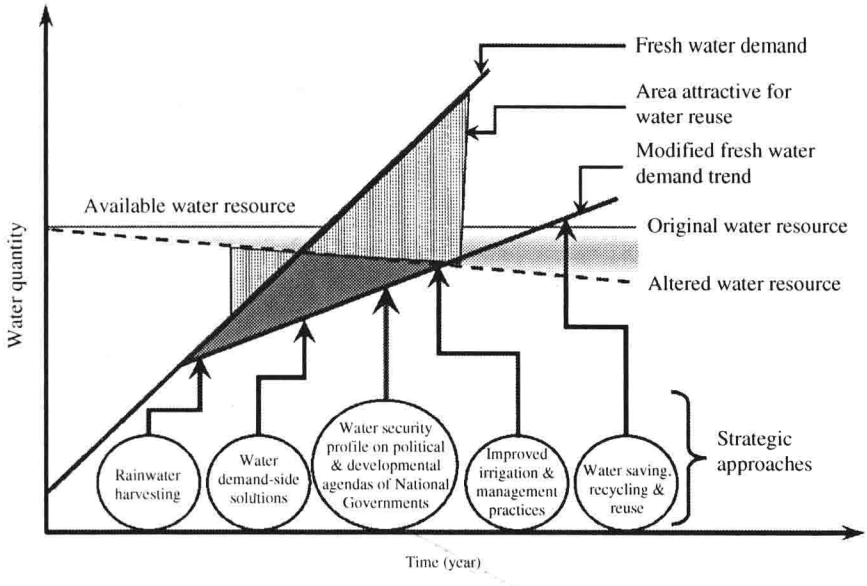

Figure 5. Strategic approaches for improving water environment.

Raise the focus of water security on the political and development agendas of national governments in Southeast Asia

This is drawn from viewing the profound impact of water scarcity on the water security throughout the region and considering the national governments as the essential drivers in preventing water scarcity in the region. The approach essentially focuses on capacity strengthening, through preventive measures on water by setting water related policies; making investments to support infrastructure for water conservation and management by integrating, sustainable development strategies. Increasing focus on the water security through capacity strengthening and policy tools could ensure reduction in water scarcity in Southeast Asian countries.

Industrial and domestic water use efficiency through recycling and reuse

Introduction of water-saving technologies, recycling techniques and water reuse can substantially meet the water demand in the industrial sector as well as reduce the wastewater discharge and pollution of water resources. However, the choice of appropriate technologies varies with the industries depending on the water quality and quantity requirement for the process. In addition, wastewater reuse techniques in industry and urban sectors including groundwater recharge is proposed to provide good solution for the water crisis.

A classical example is the city-state of Singapore, which for long, relied on Malaysia to meet the water needs has now established a program to improve self-sufficiency called the NEWater project for producing high-grade water from treated wastewater by advanced water purification and membrane technologies. In addition, the Jurong and Tuas industrial estates in Singapore reuse water by treating sewage for non-domestic purposes. Though recycling technologies are efficient and acceptable, it is not economically feasible in some domestic sectors. Hence the, choice of appropriate and feasible technologies should be made carefully. For the successful implementation of these strategies for water recycling and wastewater reuse, the region needs to have capacity building, policy and institutional strengthening, financial mechanisms, and awareness rising and stakeholder participation.

Improved irrigation and management practices

Improved irrigation technologies and management practices is one of the sustainable options to enhance water use efficiency in the region. Number of programs on improved use of irrigation water has already been carried out in many Asian countries. For example, in Korea fertigation is practiced as a method for enhancing efficiency of water and fertilizer use, by simultaneous application of fertilizer along with the irrigation water. Through water reuse and recycling practices, Japan taps its biggest river in Kyushu Island, the Chikugo River, for irrigating diversified cropping systems. Philippines is noted for its common practice in the pressurized irrigation system, which uses drip and sprinkler systems. More than 21,600 hectares is now irrigated adopting this system, mainly in Mindanao, for producing high-value crops such as banana and mango (FFTC, 2004). This indicates the potential for reduction in water stress through improved irrigation and management practices in the region.

Encouraging water demand-side solutions

Demand-side and supply-side solutions could help bridging the widening gap between water demand and supply in future. Emerging water shortages in many parts of the world has lead to find solutions by choosing between supply-side and demand-side solutions. Supply-side solutions generally deal with more large dams and large water transfer projects, which are often associated with ecological and social damage. Economic analyses on the demand-side solutions such as industrial and domestic water-saving devices such as low-flush lavatories; water saving and cost effective measures like lining irrigation canals and drip-feed irrigation at lower cost compared to dams and other supply schemes have proved to be attractive. In addition, decentralized water management is also one of the important demand-side solutions, which promotes water conservation.

Water conservation, in Beijing in both domestic and industrial sectors has contributed to savings of up to 30% in overall consumption. Various water demand-side management programs implemented by Metropolitan Waterworks Authority (MWA) of Thailand are evident from programs that have been implemented; residential and commercial water audits, flush toilet replacement, labeling of washing machines, rebates for water efficient devices, public education, revised pricing system, etc. (UN, 1998). The cost effective and positive impact of the demand-side solutions is expected to provide better solution for the elevating water stress in the region.

Rainwater harvesting

Rainwater harvesting is one of the potential approaches by many, including the environment protection agencies in the region, in providing a partial solution to the problems posed by water scarcity and water stress especially to domestic and agriculture sector. This is popular for its simplicity in installation, operation and for the quality of water obtained for domestic purposes. It is accepted as a promising option for supplying freshwater and groundwater recharging by the domestic and agriculture sector in Southeast Asia.

Southeast Asia already has the history of rainwater harvesting especially in Thailand and China. About 750 private and public buildings in Tokyo have rainwater collection systems. Almost 86% of Singapore's population that lives in high-rise buildings has rainwater harvesting system and the collected roof water is kept for non-potable uses (UNEP, 2002). In Thailand and the Philippines, both governmental and household-based initiatives play a key role in