Applied Environmental Science and Engineering for a Sustainable Future

Nevelina Pachova
Perlie Velasco
Antonina Torrens
Veeriah Jegatheesan *Editors*

Regional Perspectives of Nature-based Solutions for Water: Benefits and Challenges

Springer

Applied Environmental Science and Engineering for a Sustainable Future

Applied Environmental Science and Engineering for a Sustainable Future (AESE) series covers a variety of environmental issues and how they could be solved through innovations in science and engineering. Our societies thrive on the advancements in science and technology which pave the way for better standard of living. The adverse effect of such improvements is the deterioration of the environment. Thus, better catchment management in order to sustainably manage all types of resources (including water, minerals and others) is of paramount importance. Water and wastewater treatment and reuse, solid and hazardous waste management, industrial waste minimisation, soil restoration and agriculture as well as a myriad of other topics need better understanding and application. This book series aims at fulfilling such a task in coming years.

Nevelina Pachova • Perlie Velasco •
Antonina Torrens • Veeriah Jegatheesan
Editors

Regional Perspectives of Nature-based Solutions for Water: Benefits and Challenges

Springer

Editors
Nevelina Pachova
RMIT Europe
Barcelona, Spain

Perlie Velasco
Department of Civil Engineering, College of Engineering and Agro-Industrial Technology
University of the Philippines Los Baños
Laguna, Philippines

Antonina Torrens
Department of Biology, Healthcare and Environment, Faculty of Pharmacy and Food Sciences
University of Barcelona
Barcelona, Spain

Veeriah Jegatheesan
School of Engineering and Water: Effective Technologies and Tools (WETT) Research Centre
RMIT University
Melbourne, VIC, Australia

ISSN 2570-2165 ISSN 2570-2173 (electronic)
Applied Environmental Science and Engineering for a Sustainable Future
ISBN 978-3-031-18411-6 ISBN 978-3-031-18412-3 (eBook)
https://doi.org/10.1007/978-3-031-18412-3

This Springer imprint is published by the registered company Springer Nature Switzerland AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

This book is dedicated to the late Professor John Argue (1933–2022), Order of Australia, who pioneered the development and establishment of Water Sensitive Urban Design (WSUD) in Australia. John was a passionate and dedicated researcher, mentor and educator, based at the University of South Australia. He developed ground-breaking concepts and practices in urban stormwater management, resulting in the redefining of stormwater from being a civil engineering problem that needed to be managed and controlled, to being a valuable water resource of significant benefit to communities. John authored seminal professional practice manuals for civil engineers on stormwater *management and WSUD. He also toured Australia extensively presenting WSUD concepts and practices through lectures, workshops, and seminars, and continued this through his retirement years. For his major contributions to stormwater management and to the development of stormwater as a valuable resource, John was awarded the "Order of Australia" in 2013. In the same year, he was inducted into Engineers Australia's Water Engineering "Hall of Fame" becoming the first South Australian to receive this recognition. In 2016, Professor John Argue was inducted into the "Hall of Fame" of Stormwater Australia and became an Honorary Fellow of Engineers Australia, which is their highest award.*

Preface

Nature-based solutions (NbS) are solutions inspired or supported by nature, including ecosystem conservation and restoration measures, as well as the creation or enhancement of natural processes in man-made ecosystems, such as cities. Examples of NbS interventions for water in urban areas include constructed wetlands, floating wetlands, maturation ponds, bioswales, green spaces, and buildings, among others. NbS vary in their location, attributes, functions, and scales and therefore in the environmental, social, and economic values that they generate. Recent interest in NbS all over the world has emphasised their importance for water management. For instance, the 2018 UN water development report explored the role of NbS for water management in detail. A recent technical report by the European Union (EU) also reviewed the results from EU-funded NbS projects with respect to water quality. Similar reports have been produced by the International Union for Conservation of Nature (IUCN), the United Nations Development Programme (UNDP), the International Water Association (IWA), or the Asian Development Bank (ADB). Evidence of the effectiveness of NbS solutions, however, particularly those implemented in urban contexts, has been dominated by experiences from the Global North. Furthermore, NbS are often documented as technical solutions disconnected from the actors that drive them and the context in which they are implemented, thus limiting the understanding of their embeddedness and how they can be replicated or scaled.

This book aims to address the aforementioned gap partially by exploring various aspects of NbS for water in a systematic way. It begins with an introductory chapter with descriptions on subsequent chapters and their importance. Next chapter provides an updated overview of NbS with a European perspective and discusses about how the implementation of NbS improves living conditions. Next, the book looks at a specific NbS, constructed floating wetlands (CFW), for the treatment of surface waters and industrial wastewaters. It provides an overview of the current scientific and engineering knowledge on CFW which will be essential for the replication of CFWs. The updated definition of NbS by EU emphasises that NbS must benefit biodiversity and support the delivery of a range of ecosystem services and thus, next, the book discusses about the contributions of NbS to biodiversity net gain (BNG) in urban areas using the experiences of NbS that are implemented for water management in England. Development of BNG and habitat suitability indices (HabSI) scores for nature-based water management solutions implemented has been discussed for three key biodiversity groups active at different spatial scales. This will allow NbS to be located strategically.

Five country-wide studies have been presented next. The first study reviews the applications of NbS in urban water management in Singapore, Thailand, and Vietnam. Policies that highlight the identification of investors, educational campaigns, and sustainable joint partnerships are identified as key for the implementation of NbS in the case of Singapore; barriers found to exist in political, governance, social, and technological aspects for implementing NbS in Thailand and Vietnam. Next study provides an overview of wastewater treatment in Vietnam and the application of maturation ponds and floating wetlands as NbS to treat wastewater. The study aims to provide suggestions for future upgrades to such NbS as well as to the policy makers with recommendations for scaling up those NbS. The following study overviews the wastewater treatment in the Philippines and discusses about the utilisation of NbS in combination with grey solutions to treat domestic wastewater effectively. Next study discusses the application of floating wetlands to treat pollutants in two lakes of Sri Lanka. It discusses about assessment criteria to evaluate the performance of such NbS. The last study investigates the role of information and communication technology (ICT) in following global standard for NbS. The study considers Bangladesh and proposes an ICT framework to facilitate the implementation of NbS in Bangladesh.

How did this book proposal come about? Engagement of the editors of this book in the Horizon-2020 projects and proposals made aware that there is a wealth of information to exist in the literature some of which have been produced by numerous Horizon-2020 projects. An earnest desire to learn from a few of those project leaders led to a Global webinar on “Nature-base solutions for water in cities” in July 2021 that was organised by the Royal Melbourne Institute of Technology (RMIT) University—Europe. A call for chapters was made during the webinar to draft this book. Additionally, the editors of this book along with their international partners were awarded a grant by the Asia Pacific Network (APN) for Global Change Research in October 2021 to conduct a project on developing an “Integrated assessment of existing practices and development of pathways for the effective integration of nature-based water treatment in urban areas in Sri Lanka, the Philippines and Vietnam”. They were the catalyst to this book project.

We hope that this book provides a valuable compilation of theory and practice of some NbS for water treatment as well as case studies discussing the applications of those NbS. The information in the book will help to understand the status of NbS for water management in different parts of the world, their effectiveness and impacts as well as barriers that are to be overcome in order to replicate those NbS in a sustainable manner. We have made an effort to bring the above into one place to serve policy makers, practitioners, researchers, graduate students, and businesses in implementing NbS in an efficient and appropriate manner.

Barcelona, Spain — Nevelina Pachova
Laguna, Philippines — Perlie Velasco
Barcelona, Spain — Antonina Torrens
Melbourne, VIC, Australia — Veeriah Jegatheesan

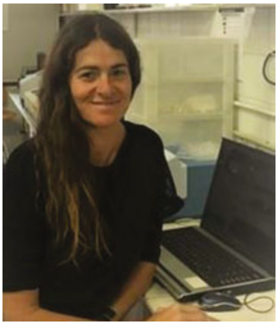
Contents

Editors and Contributors

About the Editors

Nevelina Pachova is a Research Fellow at RMIT Europe, the European hub of Australian University RMIT, where she conducts research and supports the development and implementation of research and innovation projects in the field of urban development and sustainability transitions with a focus on the integration of nature-based solutions in urban development and planning, network governance, and social inclusion. Prior to joining RMIT, Nevelina worked in the field of natural resources management and poverty reduction at different agencies of the United Nations University in Tokyo and Bonn.

Perlie Velasco is an Assistant Professor at the Department of Civil Engineering, University of the Philippines—Los Baños (DCE, UPLB). She is the lead faculty in Environmental Engineering at the department with research projects in constructed wetlands and integrated solid waste management. She got her undergraduate degree in Civil Engineering at UPLB (2005), Master's degree in Water Resources Engineering at the Katholieke Universiteit Leuven, Belgium (2010), and Ph.D. degree in Environmental Engineering at the Royal Melbourne Institute of Technology, Australia (2022). Her research works focus on membrane-based recovery of dissolved methane from wastewater effluent and constructed wetlands for wastewater treatment.



Antonina Torrens is an adjunct professor at the Department of Biology, Healthcare and Environment, Faculty of Pharmacy and Food Sciences of the University of Barcelona (UB). She is a coordinator of WASH (Water Hygiene and Sanitation) and Nature-Based Solutions (NbS) for sustainable development programmes at the Solidarity Foundation of the University of Barcelona (FSUB). She has a Ph.D. in Environmental Science and Technology for the UB. Her main research expertise is in the field of NbS for sustainable water management, water quality, and water reuse. She has been involved in numerous European research projects on water resources and international cooperation projects related to WASH and NbS for sustainable water management in Asia, Africa, and South America.

Veeriah Jegatheesan (Jega), is a Professor of Environmental Engineering and the Director of Water: Effective Technologies and Tools (WETT) Research Centre at RMIT University, Melbourne, Australia. Jega is the founder and Chairman of the international conference series on Challenges in Environmental Science & Engineering (CESE) held annually since 2008. Jega has conducted extensive research on the application of membrane bioreactors, sugarcane juice clarification, seawater desalination, and the treatment of mine tailing ponds. He has over 450 publications including more than 170 peer-reviewed journal articles and five edited books. Jega is also the managing guest editor of 40 special issues in peer-reviewed journals. In 2019, Stormwater Industry Association (Australia) has appointed him as one of the Governance Panel members for the Australian Stormwater Quality Improvement Device Evaluation Protocol (SQIDEP). Jega is the Editor-in-Chief of a book series entitled *Applied Environmental Science and Engineering (AESE) for a Sustainable Future* published by Springer and has been instrumental in publishing 12 books since 2015. Jega has been appointed as the Editor-in-Chief of Environmental Quality Management Journal (Wiley Publisher) from January 2020.

Contributors

Fahad Ahmed Water Engineering and Management, Asian Institute of Technology (AIT), Khlong Nueng, Thailand
Department of Civil Engineering, University of Sargodha, Sargodha, Pakistan

John Awad University of South Australia, Science, Technology, Engineering and Mathematics (STEM), Mawson Lakes, SA, Australia
CSIRO Land and Water, Urrbrae, SA, Australia

Jennifer Ayres University of South Australia, Science, Technology, Engineering and Mathematics (STEM), Mawson Lakes, SA, Australia

Simon Beecham University of South Australia, Science, Technology, Engineering and Mathematics (STEM), Mawson Lakes, SA, Australia

Xuan Thanh Bui Key Laboratory of Advanced Waste Treatment Technology, Ho Chi Minh City University of Technology (HCMUT), Ho Chi Minh City, Vietnam
Vietnam National University Ho Chi Minh, Ho Chi Minh City, Vietnam

Michaela Dalisay Department of Civil Engineering, College of Engineering and Agro-Industrial Technology, University of the Philippines – Los Baños, Los Baños, Laguna, Philippines

Bao-Trong Dang Faculty of Chemical Engineering, Ho Chi Minh City University of Technology (HCMUT), Ho Chi Minh City, Vietnam
Vietnam National University Ho Chi Minh, Ho Chi Minh City, Vietnam

Ma. Catriona Devanadera Department of Community and Environmental Resource Planning, College of Human College, Los Baños, Laguna, Philippines
University of the Philippines – Los Baños, Laguna, Philippines

Nguyen Thi Ngoc Dieu Department of Environmental Sciences, College of Environment and Natural Resources, Can Tho University (CTU), Can Tho City, Vietnam

Darry Shel Estorba Society for the Conservation of Philippines Wetlands, Inc., Pasig City, Philippines

José Fermoso CARTIF Foundation, Spain, Parque Tecnológico de Boecillo, Boecillo (Valladolid), Spain

Silvia Gómez CARTIF Foundation, Spain, Parque Tecnológico de Boecillo, Boecillo (Valladolid), Spain

María González CARTIF Foundation, Spain, Parque Tecnológico de Boecillo, Boecillo (Valladolid), Spain

Md Khalid Hossain Faculty of Information Technology, Department of Human Centred Computing, Monash University, Melbourne, VIC, Australia

Veeriah Jegatheesan School of Engineering and Water: Effective Technologies and Tools (WETT) Research Centre, RMIT University, Melbourne, VIC, Australia

Kristhombu Baduge Shameen Nishantha Jinadasa Faculty of Engineering, University of Peradeniya, Peradeniya, Sri Lanka

Amy Lecciones Society for the Conservation of Philippines Wetlands, Inc., Pasig City, Philippines

Nguyen Sy Linh Institute of Strategy and Policy on Natural Resources and Environment (ISPONRE), Hanoi, Vietnam

Ho Huu Loc Water Engineering and Management, Asian Institute of Technology (AIT), Khlong Nueng, Thailand

Madhubhashini Makehelwala National Water Supply and Drainage Board, Peradeniya, Sri Lanka
Joint Research and Demonstration Centre, Peradeniya, Sri Lanka

Mohamed Ismail Mohammed Mowjood Faculty of Agriculture, University of Peradeniya, Peradeniya, Sri Lanka

Cloie Mueca Department of Civil Engineering, College of Engineering and Agro-Industrial Technology, University of the Philippines – Los Baños, Los Baños, Laguna, Philippines

Ngoc-Kim-Qui Nguyen Key Laboratory of Advanced Waste Treatment Technology, Ho Chi Minh City University of Technology (HCMUT), Ho Chi Minh City, Vietnam
Vietnam National University Ho Chi Minh, Ho Chi Minh City, Vietnam

Phuoc Dan Nguyen Faculty of Civil Engineering, Asian Center for Water Research (CARE), Ho Chi Minh City University of Technology (HCMUT), Ho Chi Minh City, Vietnam
Vietnam National University Ho Chi Minh, Ho Chi Minh City, Vietnam

Nevelina Pachova RMIT Europe, Barcelona, Spain

Declan Page CSIRO Land and Water, Urrbrae, SA, Australia

Esther San José CARTIF Foundation, Spain, Parque Tecnológico de Boecillo, Boecillo (Valladolid), Spain

Raúl Sánchez CARTIF Foundation, Spain, Parque Tecnológico de Boecillo, Boecillo (Valladolid), Spain

Vo Thi Phuong Thao Department of Environmental Sciences, College of Environment and Natural Resources, Can Tho University (CTU), Can Tho City, Vietnam

Antonina Torrens Department of Biology, Healthcare and Environment, Faculty of Pharmacy and Food Sciences, University of Barcelona, Barcelona, Spain

Nature Based Solutions for Sustainable Development Program, Solidarity Foundation University Barcelona, Barcelona, Spain

Cong-Sac Tran Key Laboratory of Advanced Waste Treatment Technology, Ho Chi Minh City University of Technology HCMUT, Ho Chi Minh City, Vietnam
Vietnam National University Ho Chi Minh, Ho Chi Minh City, Vietnam

Ngo Thuy Diem Trang Department of Environmental Sciences, College of Environment and Natural Resources, Can Tho University (CTU), Can Tho City, Vietnam

John van Leeuwen University of South Australia, Science, Technology, Engineering and Mathematics (STEM), Mawson Lakes, SA, Australia
Future Industries Institute, University of South Australia, Mawson Lakes, SA, Australia

Perlie Velasco Department of Civil Engineering, College of Engineering and Agro-Industrial Technology, University of the Philippines – Los Baños, Los Baños, Laguna, Philippines

Thi-Kim-Quyen Vo Faculty of Biology and Environment – Natural Resources and Climate Change, Ho Chi Minh City University of Food Industry (HUFI), Ho Chi Minh City, Vietnam

Christopher Walker University of South Australia, Science, Technology, Engineering and Mathematics (STEM), Mawson Lakes, SA, Australia
Covey Associates Pty Ltd, Maroochydore, QLD, Australia

Doug Warner Agriculture and Environment Research Unit (AERU), School of Life and Medical Sciences, University of Hertfordshire, Hatfield, Hertfordshire, UK

Sujithra Kaushaliya Weragoda National Water Supply and Drainage Board, Peradeniya, Sri Lanka
Joint Research and Demonstration Centre, Peradeniya, Sri Lanka

Thalawatthalage Ishanka Prabhath Wimalaweera National Water Supply and Drainage Board, Peradeniya, Sri Lanka
Joint Research and Demonstration Centre, Peradeniya, Sri Lanka

List of Abbreviations

ABC	Active, Beautiful, and Clean
ABR	Anaerobic baffled reactor
ADB	Asian Development Bank
AFI	Artificial floating island
AOA	Ammonia-oxidising archaea
AOB	Ammonia-oxidising bacteria
APN	Asia Pacific Network
ARCOWA	ARC Of WAter
BDP2100	Bangladesh Delta Plan 2100
BNG	Biodiversity Net Gain
BNS	Basic Needs Services
BOD_5	Biochemical Oxygen Demand
BORDA	Bremen Overseas Research Development Association
BS	British Standard
CBD	Convention on Biological Diversity
Cd	Cadmium
CFW	Constructed Floating Wetlands
COD	Chemical Oxygen Demand
CPM	City Performance Monitor
Cr	Chromium
CSO	Combined sewer overflow
CSS	Combined sewage system
Cu	Copper
CW	Constructed wetland
DENR	Department of Environment and Natural Resources
DEWATS	Decentralised Wastewater Treatment Systems
DO	Dissolved Oxygen
DOC	Dissolved Organic Carbon
DOH	Department of Health
DPWH	Department of Public Works and Highways
EC	European Commission

eco-DRR	Ecosystem-based disaster risk reduction
EMB	Environmental Management Bureau
ES	Ecosystem Services
EU	European Union
EWS	Early warning system
FBA	Forced Bed Aeration
FTW	Floating treatment wetland
FWSCW	Free water surface flow constructed wetland
GIS	Geographic information system
HabSI	Habitat suitability indices
HCMC	Ho Chi Minh City
HCW	Hybrid constructed wetland
HDB	Housing and Development Board
HDPE	High-density polyethylene
HFCW	Horizontal subsurface flow constructed wetlands
HL	Hydraulic load
HLR	Hydraulic loading rate
HM	Harmonisation Middleware
HRT	Hydraulic retention time
HUC	Highly urbanised city
HUSB	Hydrolytic up-flow sludge bed
ICT	Information and Communication Technology
IoT	Internet of Things
ISA	Integrated Sanitation Approach
IUCN	International Union for Conservation of Nature
IWA	International Water Association
KPI	Key Performance Indicator
LGU	Local Government Unit
LID	Low Impact Development
LLDA	Laguna Lake Development Authority
LSSP	Local Sustainable Sanitation Plan
LWUA	Local Water Utilities Administration
MAR	Managed Aquifer Recharge
Mn	Manganese
MP	Maturation pond
MWCI	Manila Water Company, Inc.
MWSI	Maynilad Water Services, Inc.
MWSS	Metropolitan Waterworks and Sewerage System
NAP	National Academies Press
NbS	Nature-based Solutions
NbS-WT	Nature-based Solutions for Wastewater Treatment
NBWMS	Nature-Based Water Management Solutions
NCCAP	National Climate Change Adaptation Plan
NCR	National Capital Region

NEDA	National Economic and Development Authority
NERC	Natural Environment and Rural Communities
Ni	Nickel
NSSP	National Sewerage and Sanitation Program
NTU	Nanyang Technological University
NWRB	National Water Resources Board
NWSDB	National Water Supply and Drainage Board
ODA	Official development assistance
OECD	Organisation for Economic Co-operation and Development
OLR	Organic loading rate
ONIA	Open Nature Innovation Arena
Org-N	Organic Nitrogen
PAH	Polycyclic aromatic hydrocarbon
PBDE	Polybrominated diphenyl ether
PCAMRD	Philippine Council for Aquatic and Marine Research and Development
PCB	Polychlorinated biphenyl
PDP	Philippine Development Plan
PE	Person equivalent
PFAS	Per-and polyfluoroalkyl substances
PFOA	Perfluorooctanoic acid
PFOS	Perfluorooctane sulfonic acid
PPCP	Pharmaceuticals and personal care products
PSA	Philippines Statistics Authority
PUB	Public Utilities Board
PVC	Polyvinyl Chloride
RMIT	Royal Melbourne Institute of Technology
RO	Reverse osmosis
RTD	Residence time distribution
SDG	Sustainable Development Goal
SSDP	Sustainable Sanitation Development Partnership
SSFCW	Subsurface flow constructed wetlands
SSS	Separate sewerage system
SuD	Sustainable Urban Drainage
SUDS	Sustainable Urban Drainage System
TF	Translocation factors
TKN	Total Kjeldahl nitrogen
TN	Total Nitrogen
TOC	Total Organic Carbon
TP	Total phosphorous
TRM	Tidal River Management
UASB	Up-flow anaerobic sludge blanket
UNDESA	United Nations Department of Economic and Social Affairs
UNDP	United Nations Development Programme

UNESCO	United Nations Educational, Scientific and Cultural Organization
UNFCCC	United Nations Framework Convention on Climate Change
UVA_{254}	UV Absorbance @ 254 nm
VFCW	Vertical flow constructed wetlands
WCC	World Conservation Congress
WHO	World Health Organization
WSP	Waste stabilisation pond
WSUD	Water Sensitive Urban Designs
WUC	Water Urban Challenges
WWTP	Wastewater treatment plant
Zn	Zinc

Chapter 1
Nature-Based Solutions for Urban Water Management: Challenges and Opportunities in the Context of Asia

Nevelina Pachova, Perlie Velasco, Antonina Torrens, and Veeriah Jegatheesan

Abstract Nature-based solutions (NbS) are increasingly recognized as important tools for moving towards a more holistic approach to using and managing water. Integrating NbS in existing water management practices, however, is an ongoing process. The book provides a state-of-the-art overview of technologies and approaches for integrating NbS in water management based on experiences from across the world and a diverse range of in-depth case studies of NbS applications to urban water management in Asia. This chapter introduces and brings together the different contributions to the book, highlighting emerging challenges and opportunities for harnessing the potential of NbS in the region. Emerging experiences considered in the book suggest the need for better integration of different technologies and approaches, given the diversity of urban water challenges and the complementary benefits of different NbS. Closely related to this is also the need for integrated approaches to monitoring and assessing the impacts of existing practices as a basis for enhancing their technical performance, sustainability and co-benefits. Recent methodological advances in the design, implementation and assessment of NbS from Europe and outside could also inform the development of more effective approaches to stakeholder engagement, biodiversity generation, financing and learning from NbS.

N. Pachova (✉)
RMIT Europe, Barcelona, Spain
e-mail: nevelina.pachova@rmit.edu.au

P. Velasco
Department of Civil Engineering, College of Engineering and Agro-Industrial Technology, University of the Philippines – Los Baños, Los Baños, Laguna, Philippines

A. Torrens
Department of Biology, Healthcare and Environment, Faculty of Pharmacy and Food Sciences, University of Barcelona, Barcelona, Spain

V. Jegatheesan
School of Engineering and Water: Effective Technologies and Tools (WETT) Research Centre, RMIT University, Melbourne, VIC, Australia

N. Pachova et al. (eds.), *Regional Perspectives of Nature-based Solutions for Water: Benefits and Challenges*, Applied Environmental Science and Engineering for a Sustainable Future, https://doi.org/10.1007/978-3-031-18412-3_1

Keywords Nature-based solutions · Water management · Cities · Asia

Water is essential for life (WWAP 2003) and human existence has been an ongoing journey of learning how to use and manage it wisely. Marked by a growing understanding that water is a shared and finite resource, at a given time and place, the past decades have brought about important advances in working together with both people and nature in ensuring access to water for all.

Driven by the goal of providing equitable development opportunities for people across the world embedded in the Millennium Development Goals, the United Nations (UN) Decade for Action "Water for Life" (2005–2015) gave significant impetus to initiatives and investments that brought about important improvements in access to safe drinking water and sanitation, recognized the importance of a human-rights based approach to both and advanced the adoption of integrated approaches to water management (UN 2010; UNCSD 2012; UNEP 2012; UNW-DPC 2015). Despite notable achievements, however, billions of people remained without access to safe water and sanitation at the end of the UN-water decade (UNW-DPC 2015). Furthermore, although the value provided by water-related ecosystems had begun to be recognized, water for the environment was seen as one of a range of different water needs to be met and ca. 50% of the countries worldwide ranked it as an issue of medium to low priority in 2012 (UNEP 2012).

The UN Agenda 2030 for transforming our world agreed upon by international leaders in 2015 has attempted to bring about a shift in the dominant human-centred perspectives on development by giving environmental concerns, including with respect to water, a prominent place in the Sustainable Development Goals (SDGs) (UN 2015). Unlike earlier formulations of the challenge of access to clean water and sanitation, for example, SDG six, which focuses on it, highlights ecosystem degradation as an integral part of the problem and calls for reducing pollution and protecting and restoring water-related ecosystems as essential aspects of the solution (UN 2015). In 2016, the UN General Assembly also agreed upon a new Decade for Action on "Water for Sustainable Development" (2018–2028) with the aim to energize implementation of existing projects and programmes and mobilize water-related action to contribute to sustainable development and achievement of the SDGs (UN 2016).

In line with the above, the concept of nature-based solutions (NbS), i.e. solutions inspired or supported by nature, has emerged and gained significant traction in Europe and outside over the past decade (EC 2015). Defined by IUCN as "actions to protect, sustainably manage, and restore natural or modified ecosystems, that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits" (Cohen-Shacham et al. 2016), NbS are increasingly seen as an important tool for shifting towards a more holistic approach to water management and one that could contribute to other aspects of the sustainable development goals, such as food security, reduced disaster risk in urban settlements and decent work (UN-Water 2018).

The 2018 UN Water Report, which reviewed the state-of-the-art of knowledge and applications of NbS, however, notes that NbS are not a panacea and although the concept of NbS is increasingly included in Integrated Water Resources Management (IWRM) principles and discourses, in practice this is not often the case. In this regard, testing NbS in different hydrological, environmental, socio-economic and management conditions, advancing understanding of their potential and limitations and sharing knowledge were noted as essential for enhancing capacities for their implementation and upscaling (UN-Water 2018).

This collection of studies aims to contribute to addressing this gap with a focus on Asia, one of the most rapidly growing regions worldwide and one where the role of NbS for water has received only limited and piecemeal attention to date. Unlike recent reviews of the potential of NbS for water in Europe (EC 2020; Oral et al. 2020), Latin America and the Caribbean (Ozment et al. 2021) and Africa (Acreman et al. 2021), NbS for water in Asia have been discussed with respect to specific technologies (Liu et al. 2009) or approaches (Morita 2021), societal challenges (GEF 2020; Furmage 2022) or countries (Liu et al. 2009; ADB 2019; GEF 2020).

This book attempts to provide a more integrated perspective of the potential, limitations and opportunities for advancing the uptake and upscaling of NbS for water in Asia by bringing together a series of case studies from cities across the region. With more than half of the population in Asia living in cities and rapidly growing urbanization (UNDESA 2018), the book takes a special look at NbS for water in urban contexts with the aim of bringing a forward look into opportunities for the future that draw upon traditional nature-based water treatment systems and solution from Asia but go beyond by complementing them with knowledge and experiences from NbS employed in urban contexts in Europe, Australia and outside. With this in mind, the region-specific case studies are preceded by several methodological chapters that review the range of technologies and approaches that the concept of NbS for water entail, suggest possible frameworks for selecting appropriate NbS, and highlight challenges and opportunities with the implementation of some of the most prominent types of nature-based solutions for water of relevance to cities in Asia.

The book opens with a typology of NbS developed in the framework of an EU-funded project on urban greening that Sánchez et al. (2022) employ to discuss and demonstrate how different types of NbS can be selected, implemented and assessed with view of a range of urban water challenges across different scales. The authors argue for a consideration of the physical, biotic, social and economic context of the location, as a basis for determining the suitability of a given NbS and suggest that impacts can be captured with a focus on the ecosystem services that are likely to be impacted under different scenarios. They also demonstrate the capacity of floating gardens and urban forest catchments, two types of NbS developed and tested in selected cities in Europe, to contribute to addressing context-specific urban water challenges through the generation of a range of valuable ecosystem services.

Chapter 3 provides detailed overview of one of the prominent types of NbS for water treatment with relevance to the context in Asia, namely constructed floating wetlands. In the chapter, Ayres et al. (2022) review the latest evidence on the effectiveness of constructed floating wetlands (CFW) for the treatment of surface waters and industrial wastewaters. The study highlights critical attributes that need to be taken into account in the design of CFW, including structural design and buoyancy, plant selection, plant anchoring and harvesting, and how they affect water treatment effectiveness as reflected in different rates of removal of nutrients, heavy metals and organic compounds. The authors also discuss the effect of hydrodynamics on pollutant removal and suggest possibilities for improving the design of CFW installations with view of enhancing performance and other possible benefits and draw attention to measures for validating treatment effectiveness and setting up an operational monitoring system. The authors argue that a mass balance approach could take operational monitoring a step further and enable an evaluation of the significance of the CFW treatment. They also note the absence of published economic information for CFWs and suggest that an accepted validation framework coupled with hydraulic modelling, as well as research into the costs and benefits of CFWs, are required for improved confidence and greater adoption of full-scale CFWs technologies.

In Chap. 4, Warner (2022) goes beyond the water quality and quantity impacts of NbS. The author argues that if appropriately designed and located, NbS employed to address urban water challenges, could make significant contributions to enhancing urban biodiversity as well. After a review of NbS types used for urban water management in the UK and outside, such as bus-shelters, green roofs and walls, wetland creation, bioswales and street trees, he proposes two measures for assessing and enhancing the biodiversity benefits of NbS, namely Biodiversity Net Gain (BNG), a measure designed to capture changes in individual habitat types based on a consideration of their relative distinctiveness and quality, and habitat suitability indices (HabSI), an index that predicts the likelihood of important species being present in a given habitat. To demonstrate their use, Warner employs them to assess NbS BNG and habitat suitability for three key biodiversity groups active at different spatial scales in the UK, namely, pollinators, amphibians and bats and discusses the implications of the choice, structure and location of the examined interventions.

In Chap. 5 Linh et al. (2022) present and discuss several examples of NbS employed for urban water management in Singapore, Thailand and Vietnam. Those include the Active, Beautiful and Clean (ABC) Waters Programme in Singapore, a number of urban parks employed for storm water management in Thailand, and several NbS projects for urban water management in a planning stage in Ho Chi Minh City and the ancient capital of Hue in Vietnam. While drawing upon examples from different contexts and at different stages of implementation, the chapter draws attention to the important role played by government agencies and large institutional actors in the establishment of NbS for urban water management in the three countries. Reflecting on the benefits but also limitations of such large-scale infrastructural interventions, the chapter suggests the need for a better integration across stakeholders, sectors and scales as the way forward in the design and implementation of more multi-functional, resilient and sustainable NbS for cities in the region.

In Chap. 6, Dang et al. (2022) take a closer look at two types of NbS employed for urban water management and wastewater treatment across cities in Vietnam.

Specifically, they examine existing applications of waste stabilization ponds (WSPs) employed in centralized wastewater treatment systems in the country, and floating treatment wetlands (FTWs), which are increasingly used as a form of decentralized treatment of water in the urban canals across Vietnam. The authors discuss the pros and cons of the two different types of NbS, their performance, as well as challenges and opportunities for enhancing it. They note that, while WSPs, such as maturation ponds, have been primarily employed for wastewater treatment, they could provide a number of other benefits, such as urban green space, biodiversity, flood control, urban heat control, and fish farming opportunities, if appropriately designed. A review of FTWs pilot and demo sites across the country also finds that FWTs can provide a range of complementary benefits, such as improved aesthetic value, job opportunities and possibilities for awareness raising and stakeholder engagement in environmental conservation work. The authors suggest that a combination of the two types of NbS can optimize their value for wastewater treatment in cities in Vietnam but note that better monitoring and appropriate field tests and simulation studies are needed for gaining a deeper understanding of and quantifying the expected multi-functional impacts of both.

In Chap. 7, Velasco et al. (2022) review existing nature-based solutions for domestic wastewater treatment in the Philippines. They note the growing pressures for improved wastewater treatment in the country and the limited centralized funding for this. In this context they consider the potential of NbS as low-cost decentralized water treatment solutions and discuss in more detail existing applications of Decentralized Wastewater Treatment Systems (DEWATS) and constructed wetlands in the country. Existing evidence of the effectiveness of those measures, however, is limited and the authors suggest a possible framework for assessing their effectiveness as a basis for demonstrating the value of NbS.

In Chap. 8, Weragoda et al. (2022) touch upon the long history of NbS in Sri Lanka that comprises both traditional and more modern hybrid applications. With respect to urban contexts, they note the relevance and potential of floating wetlands (FW) more concretely and examine the effectiveness of FWs established over the recent years in two of the major urban lakes in the country. The effectiveness of floating wetlands is discussed with reference to a range of different aspects, including technical design and operation, social and economic impacts, enabling environment and embeddedness in the local policy and governance system. While recognizing the importance of an integrated approach to assessing the impacts of the examined interventions, however, the authors note that existing data, particularly on the economic, social and governance aspects and impacts of the interventions are limited and suggest that those gaps need to be taken into account in the design of future monitoring systems since a deeper understanding of the multi-functional benefits of existing NbS would be beneficial for the maintenance, upscaling and replication of nature-based solutions throughout the country.

In the final chapter, Hossain (2002) explores the role of Information and Communication Technology (ICT) in following the Global Standard for NbS from a Bangladesh perspective. Based on a review of both NbS research in Bangladesh and international examples of ICT applications for NbS, the author argues that ICT can