Chapter 11
Replicability and Pathways for the Scaling of Nature-Based Solutions for Water Treatment: Examples from the Philippines, Sri Lanka, and Vietnam

Veeriah Jegatheesan, Nevelina Pachova, Perlie Velasco, Ngo Thuy Diem Trang, Vo Thi Phuong Thao, Thi-Kim-Quyen Vo, Cong-Sac Tran, Xuan-Thanh Bui, Ma. Catriona Devanedara, Darry Shel Estorba, Amy Lecciones, M. I. M. Mowjood, Sujithra Weragoda, and Shameen Jinadasa

Abstract The importance of nature-based solutions (NbS) for urban water treatment is growing due to their cost-effectiveness and the multitude of ecosystem services they offer, contingent on appropriate design and meticulous implementation. Drawing upon the experiences of a project that assessed the effectiveness of a set of NbS solutions in South and Southeast Asia, namely, constructed wetlands in the Philippines, constructed floating wetlands in Sri Lanka and Vietnam, and green roofs for water treatment in Vietnam, this chapter explores possible approaches to and pathways for the scaling of those solutions. Specifically, it discusses the results of targeted efforts aimed at supporting the replication of those technologies in different locations and contexts and other possible pathways for scaling that have emerged in the course of the implementation of the project.

Keywords Constructed wetlands · Constructed floating wetlands · Green roofs · Nature-based solutions · Scaling

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V. Jegatheesan (✉)
School of Engineering and Water: Effective Technologies and Tools (WETT) Research, Centre, RMIT University, Melbourne, VIC, Australia
e-mail: jega.jegatheesan@rmit.edu.au

N. Pachova
RMIT Europe, Barcelona, Spain

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

N. T. D. Trang · V. T. P. Thao
College of Environment and Natural Resources, Can Tho University, Can Tho City, Vietnam

Thi-Kim-Quyen Vo
Faculty of Biology and Environment, Ho Chi Minh City University of Industry and Trade (HUIT), Ho Chi Minh city, Vietnam

C.-S. Tran · X.-T. Bui
Key Laboratory of Advanced Waste Treatment Technology & Faculty of Environment and Natural Resources, Ho Chi Minh City University of Technology (HCMUT), Ho Chi Minh City, Vietnam

Vietnam National University Ho Chi Minh (VNU-HCM), Ho Chi Minh City, Vietnam

M. C. Devanedara
Department of Community and Environmental Resource Planning, College of Human, Ecology, University of the Philippines Los Baños, College, Laguna, Philippines

Society for the Conservation of the Philippine Wetlands, Pasig City, Philippines

D. S. Estorba · A. Lecciones
Society for the Conservation of the Philippine Wetlands, Pasig, Philippines

M. I. M. Mowjood
Department of Agricultural Engineering, Faculty of Agriculture, University of Peradeniya, Peradeniya, Sri Lanka

S. Weragoda
Joint Research Demonstration Centre for Water Technologies, E.O.E. Pereira Mawatha, Peradeniya, Sri Lanka

S. Jinadasa
School of Engineering and Technology, Central Queensland University, Bundaberg, Australia

11.1 Introduction

Growing populations in cities across Southeast Asia are turning water quality into a pressing challenge for human well-being and ecosystem health in the context of climate change. Increased demand for clean water for both people and nature, coupled with limited resources for the implementation of large-scale grey infrastructural interventions and increasing awareness of the multiple services offered by nature itself, has opened up spaces for experimentation with nature-based water treatment across the region over the past decade (Pachova et al. 2022). Assessments of the effectiveness and impacts of such interventions have begun to provide evidence for policymakers and practitioners interested in taking existing experiments further (Jegatheesan et al. 2023). Understanding whether and if so, how existing interventions can be replicated across different contexts and by different actors, however, remains limited. This chapter contributes to addressing this gap by sharing the experiences with the replication of a set of NbS for water treatment tested in the framework of a project on 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, funded by the Asia-Pacific Network for Climate Change Research.

11.2 Innovative Approach to Exploring Existing Practices and Scaling Opportunities

Designed as a 2-year initiative that aims to explore and learn from existing small-scale nature-based water treatment practices employed across cities in Sri Lanka, the Philippines, and Vietnam, the project employed an integrated and participatory approach consisting of three core elements: (a) an integrated assessment of existing practices, (b) stakeholder consultations and knowledge exchange, and (c) exploration of alternative pathways for scaling (see Fig. 11.1). The project was led by RMIT University in Australia and included seven partners from different research, non-government organisations (NGO) and public sector institutions in Sri Lanka, the Philippines, and Vietnam, alongside two academic partners based in Europe. The discussion in subsequent sections provides an overview of its major findings and achievements.

11.2.1 Integrated Assessment of Existing Nature-Based Water Treatment Solutions in Sri Lanka, the Philippines, and Vietnam

Nature-based solutions (NbS) are solutions that are inspired and supported by nature and are seen as cost-effective and able to simultaneously provide environmental, social, and economic benefits and help build resilience (European Commission

Fig. 11.1 Integrated and participatory approach for exploring and learning from existing nature-based water treatment practices

(n.d)). As such, they are expected to generate a range of diverse benefits and a number of methodologies for capturing those have been developed and advanced over recent years (Kooijman et al. 2021). Most methodologies, however, are generic and need to be adapted to the specific nature-based water treatment solutions and contexts in which they are to be employed. In the framework of the specific project, an integrated approach for assessing and learning from a set of selected nature-based water treatment practices employed across the countries participating in the project was developed and tested during the first year of the initiative (Jegatheesan et al. 2023).

The nature-based water treatment technologies selected for the study included constructed floating wetlands (CFWs), constructed wetlands (CWs), and green roofs (GRs). The technologies were selected by project partners familiar with existing practices and opportunities in the local contexts, with a view of their potential to contribute to addressing important water quality challenges in different countries. Biweekly consultations amongst the project partners at the initial stages of the project helped to agree on a set of indicators and develop methodological approaches for assessing the multi-faceted impacts of the selected technologies. Those included a range of targeted water quality but also broader environmental, social, and economic indicators that were captured through a combination of methodological approaches, including review and analysis of secondary data capturing the institutional context, history, and process for setting up and managing the selected technologies, alongside with a review of existing quantitative data, targeted surveys and consultations with relevant local stakeholders.

The findings from the study suggest that whilst relevant water quality indicators were adequately captured by existing monitoring sources in most cases, evidence of the broader environmental and social impacts was only anecdotal. Targeted surveys and stakeholder consultations employed to capture those provided an indication of their range, but further research is needed to develop and validate comparable and easily replicable tools for capturing and validating the environmental and social impacts of the examined NbS. In terms of capturing the costs and benefits of the examined projects, a simplified cost-benefit ratio assessment methodology found a positive return to investment for all of the examined nature-based water treatment solutions, even without accounting for a range of intangible benefits that were left out of the calculations (Jegatheesan et al. 2023).

With the intent of addressing prevailing limitations, the project sought to establish comprehensive guidelines for the assessed NbS, and these guidelines constitute a significant portion of this book's content. These guidelines encompass various aspects, including the mapping of current NbS in partner countries, suitability assessment, economic analysis, considerations of social acceptability, as well as detailed guides for CWs, GRs, and CFWs (both in Sri Lanka and in Vietnam), along with a guide for selecting plants suitable for CFWs.

In tandem with these chapters, this chapter is dedicated to shedding light on the pathways for upscaling and replication, drawing on the project's experiential insights. By sharing the lessons and outcomes derived from the project, this chapter seeks to enrich the understanding of how these NbS can be extended to broader contexts and effectively replicated.

11.2.2 Replicability of Examined Nature-Based Solutions (NbS)

The project then delved into the viability of replicating the aforementioned NbS, resulting in diverse approaches by project partners to identify external entities willing to undertake these replications. The guidelines developed in the project were applied and tested during the replication. The ensuing sub-sections provide detailed insights into the approaches and outcomes of these trial initiatives.

11.2.2.1 Replicability of Constructed Wetlands (CWs) in the Philippines

As part of the project, trialling the developed framework and the tools incorporated in the guide (please see Chap. 6) were considered to provide the validation and test of the replicability of CWs for wastewater treatment in the Philippines. The trial was the application of CWs in the septage treatment of a Panguil River Eco-Park in Laguna, Philippines. The eco-park highlights the Panguil River, which has an estimated length of 12.5 km and is one of the tributaries of Laguna de Bay. The Laguna Lake Development Authority (LLDA) regularly monitors the river through one of its 15 river monitoring stations. The river is used for domestic, agricultural, ecotourism, and economic purposes by the Municipality of Pangil.

The Society for the Conservation of Philippine Wetlands, Inc. (SCPW), which is one of the APN project partners, has an existing collaboration with the municipality of Pangil and the managers of the eco-park to provide a series of training on NbS and their ecological benefits, particularly CWs, to the communities (barangays) surrounding the Panguil River. The SCPW plans to build the CWs at the site to treat the septage from their septic tanks. Thus, the developed guide framework will be tested at the Panguil River Eco-Park.

The SCPW conducted a capacity-building activity focused on NbS and CWs and their role in wetland management in June 2023. It comprised lectures and learning sessions about wetlands conservation and management, NbS, and CWs framework. In addition, there was a section in the training about how to culture Effective microorganisms (Bokashi) to ensure adequate supply for the CWs and for use by local communities in their homes. Further, a survey and focus group discussions (FGD) with the local community were conducted to determine the social acceptability of CWs for septage treatment.

11.2.2.1.1 Training on NbS and CWs

This learning event was primarily conducted as a way of community preparation and promoting the social acceptability of CWs (or Green Filters) amongst the local communities to secure its successful operation at the Pangil River Eco-Park. Over a 100 participants from the eight Barangays of Pangil participated in the event, consisting of barangay officials, youth, women groups, and other local community groups. The objectives of the training are as follows: (i) to increase awareness of wetlands and the ecosystem services they provide, (ii) to understand and appreciate the importance of NbS in the treatment of wastewater, (iii) to take actions towards wetland restoration by helping to reduce water pollution in Panguil River and Laguna de Bay through local community initiatives.

During the open forum for the framework (detailed in Chap. 6), the participants were keener to learn when the CWs will be constructed and how they can be involved. They had no pressing feedback on the framework but would like to see a working system first. They emphasised that visiting an actual CWs set-up will help to appreciate more the role of CWs for their septage treatment. They also worried that CWs might not apply to them since their septic tanks already exist, and it would be hard to connect them if new CWs were built. This was then clarified to them that CWs are not necessarily connected to the septic tanks, but the septage will be desludged and directed to the CWs (location still requires further study). Overall, the participants generally accepted the framework as useful in the implementation of CWs. Finally, It was also evident that the participants showed more interest during the workshops on making Effective Microorganism (EM) solutions and bokashi balls, which means they are willing to engage with these kinds of NbS, provided with training and technical support.

11.2.2.1.2 Focus Group Discussion

Three sets of Focus Group Discussions (FGDs) were conducted with officials from different barangays in Pangil, Laguna, Philippines, including (1) Barangay San Jose and Dambo, (2) Barangay Balian, and (3) Barangay Natividad. A total of 126 participants were surveyed and interviewed. During these sessions, it became evident that the barangay officials were largely unaware of the concept and functions of CWs. They expressed that the FGDs and learning events on NbS and CWs conducted by SCPW were their initial exposure to CWs and the first time they learned about the establishment project of CWs in their municipality.

The FGD participants acknowledged that whilst they grasped the theoretical explanation of CWs, they believed that witnessing operational CWs would provide a clearer understanding. They expressed confidence in the potential benefits this approach could bring to their community, particularly if implemented across the barangays. Anticipated advantages included access to clean water, an enhanced and biodiverse wetland environment, nature conservation, improved public health, increased tourism appeal, and a potentially positive impact on long-term food security by substantially reducing water pollution. Moreover, the Barangay officials noted that implementing CWs would be especially advantageous in newly established communities, where the location and integration of CWs system within the sewerage infrastructure could be strategically planned. Some officials also suggested that CWs system could offer valuable assistance in livestock farming, notably in managing organic waste, particularly pig and poultry farming.

Whilst their response was largely positive, the officials acknowledged several potential risks. They were concerned about issues such as leaks and overflows, particularly during adverse events like storms and floods, the possibility of biological hazards from CWs, which may adversely affect community health and cause diseases, and the potential attraction of mosquitoes and flies, which CWs may bring. Furthermore, some FGD participants highlighted the importance of sustainable maintenance and operations of CWs system, expressing reservations about the government's capacity to ensure ongoing viability. They were worried that inadequate maintenance could lead to project failure.

Despite these reservations, the officials expressed overall support and acceptance for the project's pursuit and establishment within their Local Government Units (LGUs) as a pilot demonstration of the CWs technology. They believed a functional CWs example within their community would foster greater appreciation and understanding of the technology, encouraging replication in their respective barangays if resources, funding, and space permitted. They were also considering and asking for the possibility of integrating a constructed wetland with their existing waterways and rivers to reduce water pollution in the river.

To ensure successful implementation, the FGD participants emphasised key factors: raising public awareness through effective information dissemination campaigns, community involvement, unwavering commitment and support from barangay officials and the Municipal LGU, effective waste management, secure funding, robust CWs design and construction, and proper operation and maintenance protocols. Officials recommended seeking the support of the Sangguniang Bayan or Municipal Legislative Body of Pangil, Laguna, to enact an ordinance outlining the support, operation, and maintenance of CWs system, which can contribute to its sustainability. Public hearings and community participation were seen as crucial components of this process. Additionally, they mentioned that establishing a comprehensive waste management system within the municipality, including improvements to the sewerage infrastructure, should be prioritised.

When asked about their willingness to pay for ecosystem services provided by CW, all officials expressed readiness to contribute. They said the amount varied based on the extent of services and the community's financial capability. In general, officials indicated a willingness to pay an average of 20–50 Philippine pesos per month (around 1 USD per month), with a maximum limit of 300 Philippine pesos (6 USD) per month, given if CWs services could rival those of private companies in domestic wastewater management.

11.2.2.2 Replicability of Constructed Floating Wetlands (CFWs) in Vietnam

Application of CFWs for urban canal water management was conducted successfully in pilot studies at Can Tho University (CTU) and implemented in Bung Xang Canal, Can Tho City of Vietnam (10°01′37.7 "N 105°45′51.9" E) as a pioneering field-scale application in the country. The learning from the CFWs in Bung Xang

Canal was extended to the Agricultural Seed Centre in Vinh Long province (10°09′43.2 “N 106°01′10.4” E) located approximately 50 km from Can Tho City. A staff member of this centre residing alongside Bung Xang Canal has displayed a keen interest in CFWs installed at Bung Xang Canal. During a meeting at CTU, the staff inquired about the installation process for CFWs. Further, they expressed the desire to implement them for the centre’s water management and landscaping. This contributed to revising the Vietnamese version of a guide on CFWs (see Chap. 10). The confidence in comprehending the installation instructions led the staff to undertake the process independently. Upon obtaining approval from the APN project leader, the financial support was extended for the materials necessary for CFWs installation.

Additionally, the project team in Vietnam assisted the staff by preparing plants during the installation phase. Several staff members have actively engaged in all project activities within the centre. Moreover, a group of final-year agriculture students from Cuu Long University, Vinh Long province, have also played a role in installing the new CFWs.

To validate the methodology and guide produced on CFWs (Chap. 10), new trials were devised, meticulously following the guide construction steps. Notably, the dimensions of the CFWs were adjusted to accommodate the canal’s narrower width, shorter length, and shallower depth (averaging approximately 3.5 × 40 × 1.5 m). Within the 140 m^2 canal, where water drained from paddy fields flows, a total of 12 m^2 of CFWs were installed, with each CFW covering an area of 2 m^2. This installation accounted for 8.5% coverage of the canal’s top surface area. A selection of four ornamental species, including *Canna × generalis, Heliconia psittacorum, Echinodorus cordifolius*, and *Cyperus alternifolius*, were planted at a density of 9 plants/m^2 (Fig. 11.2).

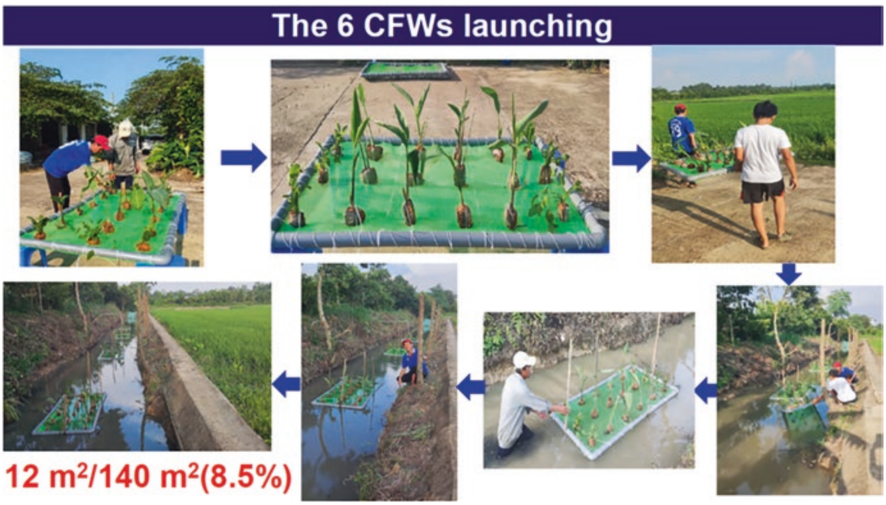

Fig. 11.2 The installation and launch of six CFWs

The installation of the six CFWs was successfully completed in June 2023. Following the construction guidelines, ongoing maintenance tasks were diligently carried out, including assessing raft materials and trimming plant biomass every 2 months. Moreover, two bachelor's students were scheduled to undertake their final BSc theses, focusing on plant growth and water quality monitoring as part of the ongoing project activities. Water quality monitoring was scheduled to be conducted monthly, whilst plant growth and biomass measurements were to be made once every 2 months. The materials used to install each CFW cost about 30 USD/2 m^2.

The Agricultural Seed Center serves as a pivotal venue for showcasing new rice varieties and restoring rice varieties, attracting numerous visitors, including farmers, local authorities from various districts and provinces, and even international visitors. This is the primary motivation behind the decision to install the CFWs, as it was recognised that the CFWs contribute to an aesthetically pleasing landscape adorned with vibrant flowers. Furthermore, the staff member anticipates that the CFWs will effectively mitigate nutrients and pollutants in the drainage water from paddy rice fields before reaching the river. Remarkably, a week after installation, the staff member personally observed and captured images of fish gathering near the CFWs during noon hours. Further, as the six newly installed CFWs have been in place for 2 weeks, the plants have exhibited robust growth. In addition to adhering to the guidance for testing the methodology and guide, alternative methods of securing plants onto the raft netting in these trials were explored. Given that hydroponic plastic cups used in the previous CFW system in the Bung Xang canal limited root growth, three different approaches were employed: (i) utilising coconut coir to secure roots and fastening them to the net with nylon string, (ii) employing coconut shells to anchor roots and attaching them to the net with nylon string, and (iii) incorporating coconut coir to stabilise roots before placing them in a rolled net structure to ensure plant stability (Fig. 11.3).

The trial in Vinh Long province remains a personalised initiative. Consequently, the replication of CFWs is considered to only occur in regions with genuine interest. The success of the practical application model of CFWs in urban water management and landscape enhancement serves as a testament to the efficacy of the guide produced (as discussed in Chap. 10). Developed through the practical implementation of CFWs in the urban Bung Xang Canal, Can Tho City, the guide has facilitated the design and installation of replicated CFWs at the Agricultural Seed Center in Vinh Long province. The design and installation of the six new CFWs closely followed the guide's materials and step-by-step instructions.

11.2.2.3 Replicability of Green Roofs (GRs) in Vietnam

Urban households are increasingly prioritising enhanced quality of life, driving them to seek green space expansion, improved air quality, and enhanced landscapes. Green roof systems emerge as potent solutions, particularly in space-constrained urban areas like Ho Chi Minh City (Vietnam). Beyond aesthetics, these systems bolster stormwater drainage infrastructure and foster healthier urban environments.

Fig. 11.3 Installation of plants into the rafts with three modified methods to hold the roots of plants

Adaptability to rapid urbanisation and the mitigation of environmental strains, especially as traditional green spaces dwindle, make green roof installations effective and pertinent (see Chap. 7 for the detailed guide to constructing and installing green roof systems).

A survey of canal-dwelling residents in Ho Chi Minh City yielded valuable life perspectives. This insight led to collaborations with specific households willing to pilot green roof installations. One such household agreed to trial a green roof system on their rooftop. Challenges arise with older buildings sporting undivided grey and black wastewater drainage systems, hampering operational efficiency. Temporary grey wastewater collection was implemented, though aesthetics suffered. New buildings require separate drainage systems during construction. Interestingly, government and public permission for green roof installations on Vietnamese building rooftops is unnecessary. As interest in green roof installations gains traction, it is foreseeable that regulations and permissions will be formulated to govern the process.

11.2.2.3.1 Description of the New Trial GRs System

The new trial system was successfully set up and operated on a household rooftop in Ho Chi Minh City, Vietnam (Fig. 11.4), in strict accordance with the comprehensive guide provided by the research team. This compact system measures 2000 × 200 × 170 mm (length × width × height) (Fig. 11.5). The media arrangement includes a coconut shell layer (1880 × 200 × 30 mm) on top, followed by a charcoal layer (1880 × 200 × 70 mm) at the bottom. Alongside, rock layers (60 × 200 × 100 mm)

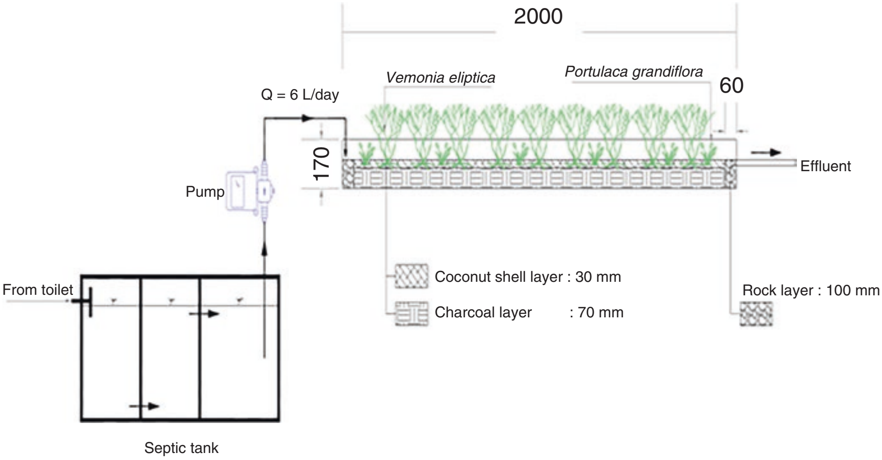

Fig. 11.4 Schematic diagram of the trial green roof

are placed on both vertical sides. Within this set-up, Vernonia elliptica and Portulaca grandiflora were planted, with densities of 40 and 20 plants/m^2 and initial heights of 30 and 5 cm, respectively. The installation involves five straightforward steps: (i) setting up the tray, pipes, and influent tank; (ii) adding charcoal to the tray; (iii) adding coconut shell to the tray; (iv) introducing rocks to the tray; and (v) planting the green roof system. The information on water quality improvement due to the implementation of GRs is summarised in Table 11.1.

Operating parameters for the green roof system were set at a flow rate of 6.0 L/d, organic loading rate of 9.0 ± 1.0 kg COD/ha/d, and nitrogen loading rate of 0.6 kg N/ha/d. The average removal efficiency of Total Suspended Solids (TSS), Chemical Oxygen Demand (COD), ammonium (NH_4^+-N), and Total Phosphorus (TP) were 66 ± 8%, 46 ± 2%, 80 ± 5%, and 50 ± 6%, respectively. The treated water from the green roof meets the discharge standard limits stipulated by the Ministry of Natural Resources and Environment (QCVN 14:2008/BTNMT, level B). The treated water was thus discharged into the urban sewerage system. On the other hand, the plant development of the GRs is summarised in Table 11.2 and Fig. 11.6. Table 11.2 shows plants are well adapted to grey wastewater in the green roof system installed at a specific household. Remarkably, the system has remained consistently functional without encountering significant issues for over 2 months.

The green roof system's construction cost comprised the material and labour expenses. The material costs comprised 30 USD for a 2000 × 200 × 170 mm chamber, 2 USD for a 0.06 m^3 plastic influent tank, 2 USD for PVC/uPVC pipes, 4 USD for 0.026 m^3 charcoal layer, 2 USD for 0.011 m^3 coconut shell layer, and 22 USD for 16 *Vernonia elliptica* and 8 *Portulaca grandiflora* plants. The total expense for a green roof module is approximately 60 USD. When the green roof systems have been well-designed and well-maintained, many benefits have been achieved, such as (i) stormwater management due to the reduction of the flow of stormwater from

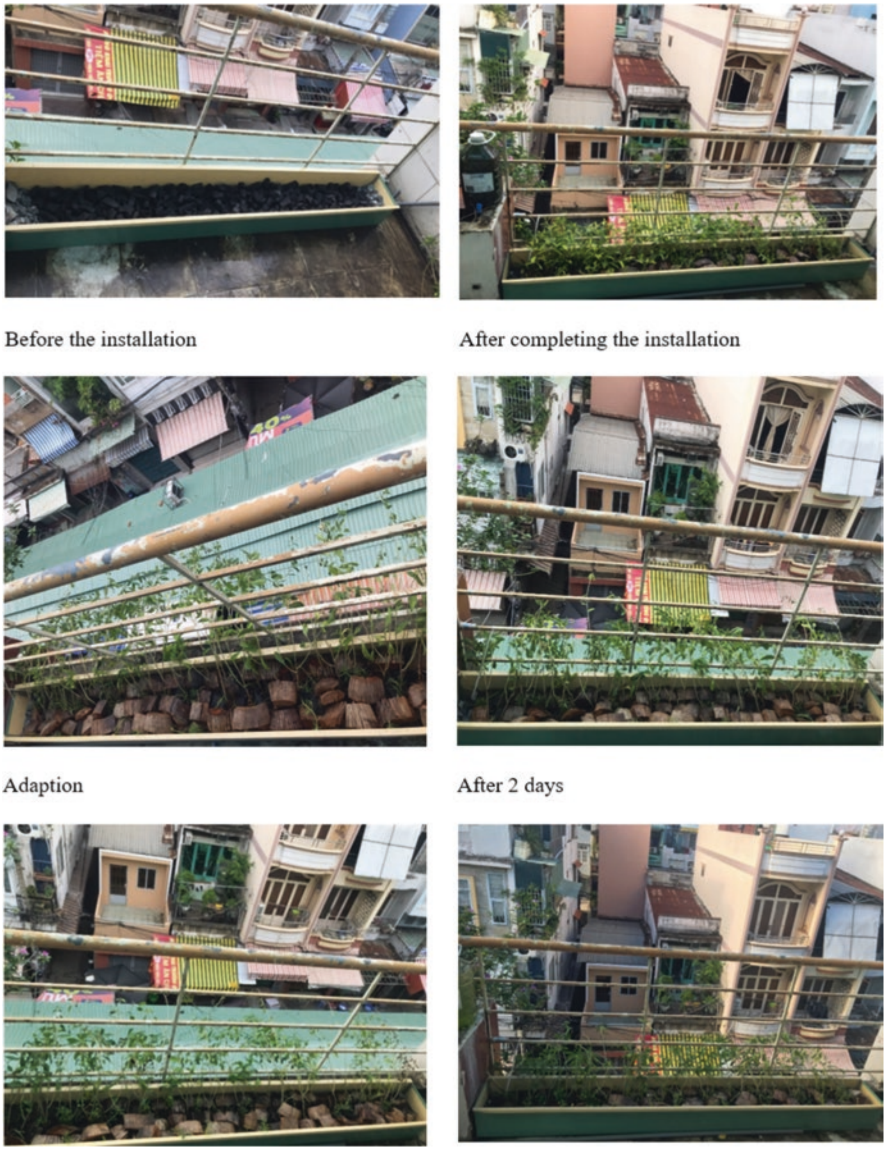

Fig. 11.5 Successful replication of a green roof in a household and the progression of plant growth for 2 months after the installation

Fig. 11.5 (continued)

Table 11.1 Characteristics of influent and effluent grey wastewater

Parameter	Unit	Influent	Effluent	Discharge standard*
pH	–	8.1 ± 0.6	7.9 ± 0.5	6.5–7.5
TSS	mg/L	38 ± 25	13 ± 7	100
COD	mg/L	59 ± 5	32 ± 6	–
NH_4^+-N	mg/L	40.0 ± 2.4	8.1 ± 1.2	10
TP	mg/L	0.6 ± 0.5	0.3 ± 0.2	10

a The national standard for domestic wastewater (QCVN 14:2008/BTNMT—Level B)

Table 11.2 Plant development of the GRs system

Plant	*Vernonia elliptica*	*Portulaca grandiflora*
Initial average height (cm)	30 ± 2	5 ± 1
Average height after 3 months (cm)	90 ± 10	15 ± 5
Average plant growth (cm/day)	0.8 ± 0.2	0.1 ± 0.1
Average fresh weight (g/plant)	10.3 ± 0.5	1.3 ± 0.2
Density (plant/m^2)	40	20

Fig. 11.6 *Vernonia elliptica* (**a**) and *Portulaca grandiflora* (**b**)

a roof; (ii) providing new urban habitat for plants and animals, like birds and insects, thereby increasing biodiversity; (iii) reducing the effect of heat-related illness and death, and air pollution; and (iv) adding beauty and value to buildings.

11.2.2.3.2 Upscaling of GRs System

The ongoing operation of the new trial system over an extended period will determine its stability and performance, providing valuable insights for potential replication. This autonomous trial module offers a versatile approach to scalability, allowing the seamless integration of multiple units to construct larger systems. The arrangement of green roof modules can be tailored to suit the characteristics of the wastewater, available installation space, budget considerations, and other factors. This adaptable configuration can involve direct or parallel connections, offering flexibility in system design.

The trial green roof system, currently established within a specific Ho Chi Minh City household, boasts numerous benefits. These encompass efficient grey wastewater treatment, augmentation of green spaces, moderate cost (approximately 60 USD per module), ease of installation, and the added advantage of not requiring formal clearance from local authorities. Given these merits, the green roof system emerges as a highly promising solution for broader implementation across metropolitan areas.

In terms of public acceptance, many people are willing to install GRs in their houses because they recognise that these systems can improve the environmental quality and enhance the landscape. However, upscaling green roof systems depends on the installation space, cost etc. Thus, it needs more time to convince people to employ the GRs systems.

11.2.2.4 Trial of Improved Floating Wetlands in Kurunegala Lake, Sri Lanka

The CFWs implemented at Kandy and Kurunegala lakes, pivotal to the framework's development, yielded significant insights into their operational performance. The evaluation process informed an important enhancement to the design, introducing a coir pith mat with a geomembrane outer layer. This revision aimed to curb erosion of the original growth media (coir pith mat), optimising system durability. Despite the plants being in their vegetative stage, their average height ranged from 30 to 50 cm, demonstrating robust growth even in the absence of regular maintenance. These advancements were guided by design criteria drawn from the project's comprehensive guidebook (Chap. 8), and the following are some essential parameters along with their corresponding values: Seven units of CFWs, each having approximately 14 plants, were installed at a site in Kurunegala Lake in June 2023. The dimensions of a floating wetland unit were 1.98 × 0.58 (= 1.14 m^2) (Fig. 11.7), and the views of those CFWs in the lake are illustrated in Fig. 11.8.

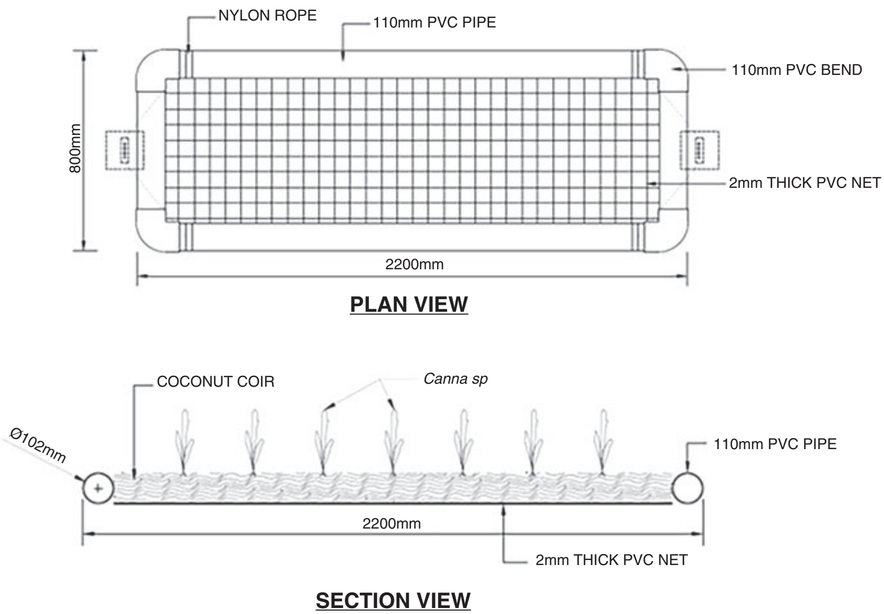

Fig. 11.7 Plan and sectional view of a constructed floating wetland

Fig. 11.8 Views of CFWs

Materials and labour costs per unit of constructed floating wetland with 220 cm × 80 cm (outer area) were LKR 8613.00 and LKR 7000.00, respectively. Fabrication and installation costs per unit were LKR 15,613.00 and LKR 10,000.00, respectively. Thus, the total cost per unit was LKR 25,613.00 or USD 79.42 (1 USD = LKR 322.55 on August 29th, 2023).

These improved CFWs are in the process of being installed at Kandy Lake. Additionally, biofilm carrier incorporation is being tested in the laboratory to evaluate their impacts on plant growth and nutrient uptake in CFWs. It will be applied in a lake situated in the eastern province of Sri Lanka through a research study to further development of pathways. Thus, the trials highlight that the design, fabrication, installation, maintenance, and performance assessment of CFWs in urban lakes for water pollution control are continuous and evolving processes that demand meticulous attention and well-informed decision-making.

11.2.2.5 Lessons Learnt from the Replicability Studies

From the replicability of the examined solutions, it can be said that they are potentially justifiable from a long-term investment perspective, but set-up costs and availability of resources (human, financial, institutional etc.) arguably play a stronger role in determining decisions on establishing small-scale trials. The following findings were made from the study: (i) The set-up of such small-scale initiatives and trials is usually not based on formal cost-benefit analysis but is driven by intrinsic interests, professional motivations, relevant supporting networks, an enabling context and appropriate windows of opportunities; (ii) formal analysis of the costs and benefits, however, could be important to convince potential donors for investing in the scaling of good practices; and (iii) there are different types of scaling, and again, arguably, many of those could be seen as somewhat bigger trials themselves and thus are driven by and require a wide range of different resources and creative approaches for exploring and mobilising them.

11.2.3 Approaches to Scaling

Scaling is often oversimplified, with a common belief that producing evidence for policymakers constitutes the extent of researchers' contributions. However, scaling is a complex endeavour. Even with adequate funding, the intricate interplay of contextual variations can determine the triumph or failure of endeavours. In light of these challenges, a more nuanced approach emerges, which can be termed as action research. This approach seeks to engage stakeholders in the research process and implementation of the interventions. By adopting a bottom-up perspective, action research delves into the intricacies of scaling pathways, acknowledging the vital role of grassroots efforts in driving meaningful expansion. Further, such research should emphasise scaling pathways for impact to provide larger-scale changes (Moore and Riddell 2015). Some known scaling pathways are scaling up, scaling deep, scaling across, and scaling out or wide (Westley et al. 2014; Moore and Riddell 2015; Nardini et al. 2022). In the case of the APN project presented here in the book, several types of scaling pathways of NbS can be identified, which are described below:

- Scaling deep: Scaling deep can be defined as enhancing the performance and impacts of existing measures by deepening the understanding and relations with the broader socio-ecological ecosystem. Improvements of existing demonstration projects through closer engagement of local stakeholders and searching for additional partners and resources, as were the case in the trials of CFWs and GRs and large-scale application of CWs, are types of scaling deep. Further, community engagement activities, such as NbS-CW training, done at the Pangil, Laguna, establish and will eventually deepen the relationships with the stakeholders (Nardini et al. 2022).

- Scaling up: Scaling up can be considered as integrating relevant concepts, guidelines, and tools in governance and planning to improve the enabling environment for both sustaining existing interventions and supporting the establishment of new ones. Examples of scaling up of this project are (i) the commitment to establishing a regular stakeholder consultation group by the Sri Lankan project partners and forming lake management committees, fostering stakeholder exchanges in Sri Lanka and (ii) the co-development of guidelines for the establishment of nature-based water treatment solutions by the Philippines project partners with local policymakers, for use by local authorities, as transpired during the national consultative meeting in 2022.
- Scaling out or wide: Scaling wide is the replication of existing good practices and examples in different geographic locations and socio-economic contexts. Examples are the integration of guidelines in planning and potential up-taking by other cities in the Philippines and the development of the local network of NbS in Sri Lanka. In Vietnam, one of the staff at the Agricultural Seed Centre in Vinh Long province adopted the CFWs to manage the canal adjacent to the centre, whilst the GR is being implemented at one household in Ho Chi Minh City.
- Scaling across: Scaling across entails the expansion of prevailing methods and strategies into different realms. This involves adapting and redefining existing interventions or incorporating components of those interventions into various sectors, as in the case of transitioning from maturation ponds as NbS due to their large size and limited control to more manageable and replicable GR trials in urban settings. Meanwhile, in Sri Lanka, the impact of constructed floating wetland trials extended to educational settings, as seen in integrating these trials into a school environment alongside the formation of a youth researchers exchange group—both instances exemplifying scaling across. Notably, an unconventional form of scaling across emerged from addressing water pollution caused by bird droppings in Sri Lanka's lakes, a pertinent concern under the project's objectives. On the other hand, including biofilm carrier trials and plant tests in CFWs in Sri Lanka, as well as green roof substrate improvements and Bokashi cultivation in the Philippines, can be considered as scaling across.

11.3 Conclusions

The efficacy of the framework devised to assess the effectiveness and impacts of nature-based solutions (NbS) for urban water treatment was validated through trials involving constructed floating wetlands and green roofs. This validation aimed to ensure the framework's robustness. Furthermore, the socio-economic facet of the framework was put to the test during a planned CWs trial. These experimental endeavours provided valuable insights into the applicability of different facets of the framework when considering the scaling of NbS. The project partners' guidelines played a pivotal role in enabling the replication of NbS, such as constructed floating wetlands and green roofs at various stakeholder locations in Vietnam, illustrating wide-scale implementation or scaling out. Scaling deep manifested in the enhancement of existing NbS through trials and community engagements. Scaling up was evidenced by the adoption of wetland construction guidelines by the local government in the Philippines and the formation of lake management committees in Sri Lanka. Scaling across is exemplified by studying water pollution caused by bird droppings, biofilm carrier trials, and plant experimentation in Sri Lanka, as well as improvements to green roof substrates and the cultivation of Bokashi in the Philippines.

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Veeriah Jegatheesan (Jega) is a Professor of Environmental Engineering and former 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, sugar cane juice clarification, seawater desalination, and the treatment of mine tailing ponds. He has over 500 publications including more than 195 peer-reviewed journal articles and 14 edited books. Jega is also the managing guest editor of 60 special issues in peer-reviewed journals. In 2019, Stormwater Industry Association (Australia) 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 16 books since 2015. Jega has been appointed as the Editor-in-Chief of *Environmental Quality Management Journal* (Wiley Publisher) since January 2020.

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 Associate 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 PhD 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.

Ngo Thuy Diem Trang received her doctoral degree from the University of Aarhus, Denmark. She is a permanent senior lecturer at the Department of Environmental Sciences, the College of Environment and Natural Resources Management (CENREs), Can Tho University (CTU). She got a number of international grants and also national grants to conduct research in the Mekong Delta of Vietnam with a focus on ecophysiology of aquatic and terrestrial plants in relation to growth conditions. She has more than 19 years of experience in nature-based solutions, particularly in constructed wetland projects. She has published over 90 papers in peer-reviewed national and international journals.

Vo Thi Phuong Thao is currently a master student at the Department of Environmental Sciences, College of Environment and Natural Resources Management (CENREs), Can Tho University (CTU). She has experience involved in the operation, and evaluation of the constructed wetlands, particularly in floating wetlands. She has published three papers in peer-reviewed national journals.

Thi-Kim-Quyen Vo obtained Bachelor's and Master's degrees in the field of Environmental engineering at Ho Chi Minh City University of Technology—Vietnam National University Ho Chi Minh (VNU-HCM). Then, she got PhD degree in the field of Environmental Engineering and Energy at Myongji University (Republic of Korea). Her research focuses on the fields of biological wastewater treatment (sulphur-based autotrophic denitrification and algae-based treatment process) and membrane technology. She has 23 publications (including 12 ISI, 9 international non-ISI, 2 national papers). She has played the role of project investigator/ key member for five projects funded by international/national organisations.

Cong-Sac Tran is currently a student and a research assistant in the field of Environmental Engineering at Ho Chi Minh City University of Technology-Vietnam National University Ho Chi Minh (VNU-HCM). His research focuses on water and waste treatment technologies. He has 10 publications (including five ISI, three international non-ISI, two national papers). He has experience in green roofs and floating wetland projects for water pollution control.

Xuan-Thanh Bui received his PhD degree in environmental engineering at the Asian Institute of Technology, Thailand. His research focuses on membrane separation processes, water and waste treatment technologies, biological treatment processes, algae processes, green technologies, and environmental materials. He has published 235 SCIE journal papers, 30 book chapters, and 4 patents. He has played a role of project investigator of more than 60 international/national research projects in the field and organised three international conferences. Since 2017, he has become a member of the scientific committee of the National Foundation and for Science and Technology Development, Ministry of Science and Technology.

Ma. Catriona E. Devanadera is an Associate Professor at the Department of Community and Environmental Resource Planning, College of Human, Ecology, University of the Philippines Los Baños. She took her BS Metallurgical Engineering, MS Environmental Engineering, and a PhD in Environmental Engineering from the University of the Philippines Diliman. Dr. Devanadera has research related to wetlands conservation and management, circular economy in wetlands management, nature-based solutions such as constructed wetland systems, and has conducted several climate and disaster risk assessments for municipalities in the Philippines.

Ms. Darry Shel M. Estorba completed her Master of Community Development degree at the University of the Philippines (UP) Diliman and her Bachelor of Science degree in Human Ecology, Major in Social Technology (Cum Laude) at UP Los Baños. Her experience in the field of community development, youth and governance, and environmental conservation, particularly on wetlands, water, and sanitation through Communication, Capacity Building, Education, Participation, and Awareness (CEPA) strategies spans more than 8 years. She is well-experienced in crafting environment and community plans, facilitating capacity-building activities, developing communication and educational materials, managing and implementing Programmes, Projects, and Activities (PPAs), as evident in her 9 years of involvement with the SCPW as Project Officer for conservation and wise use of wetlands.

Ms Amy Lecciones is one of the officers of the Society for the Conservation of the Philippine Wetlands (SCPW). She works in the areas of environmental planning, policy, capacity development, project management, monitoring, and evaluation, as well as knowledge management and communication helped shape the national agenda for sustainable development in the Philippines. She has a wide appreciation, and understanding in the field of project planning, administration, and management. She has extensive experience in wetland conservation and management particularly in wetland biodiversity assessment and monitoring including ecological profiling, ecosystem services assessment, and ecosystem restoration employing NbS.

M. I. M. Mowjood is a Chair Professor of Agricultural Engineering at the Department of Agricultural Engineering, Faculty of Agriculture, University of Peradeniya, Sri Lanka. He has obtained his Master's degree from Yamagata University and PhD from Iwate University, Japan. He has gathered over 25 years of research and teaching experiences for undergraduate and postgraduate programmes in wastewater engineering, water pollution control through bioremediation, constructed wetlands, environmental hydrology, and integrated water resources management. He has authored several book chapters on water management, has contributed to knowledge management and delivery to water professionals through national and global training. He has more than 100 journal publications.

Dr S K Weragoda has specialised in water treatment. He is currently serving as the Project Director of the China Sri Lanka Research Grant Project attached to the Ministry of Water Supply, Sri Lanka. He has been recognised as an expert on the application of WSPs and an auditor by the WHO. He obtained a PhD degree from Saitama University, Japan in the Year 2009. He is a charted engineer and a member of IWA. He has been involved in water treatment plant design, construction, and operation for 20 years. He has already contributed to over 60 research publications.

K.B. Shameen N. Jinadasa is an Associate Professor at Central Queensland University and a former Professor at the Department of Civil Engineering, Faculty of Engineering, University of Peradeniya. His research greatly involves the development of sustainable water and wastewater management technologies, biological wastewater treatment methods for industrial wastewaters, and innovative methodologies in environmental protection, and constructed wetlands for water quality management in tropical regions. He is a member of the Sri Lanka Association for The Advancement of Science. He has established various international research collaborations with China, Norway, the Netherlands, Singapore, Japan, and Australia. He is also actively involved with the process, environmental, and design advisory in water and wastewater treatment plants.