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Review

Water Literacy in the Southeast Asian Context: Are We There Yet?

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Abstract: The water situation in Southeast Asia has changed from one of relative abundance to one of relative scarcity. Conventional water management that strategized around the provision of adequate water supply to users has limited sustainability. Though nations in this region have adopted the United Nations Sustainable Development Plan into their water management framework, successful outcomes are limited thus far. Water literacy has a growing importance for improving water sustainability, especially in developing countries. A literature search was employed to extract data on the different dimensions of water literacy in Southeast Asia including the sources and consumption patterns, water governance and management, and sociodemographic elements as well as the various aspects of water related challenges faced. Results from the review and analysis show that a large proportion of Southeast Asian populations are not part of a water sustainable society, and this presents a major hurdle for the countries to meet United Nations Sustainable Development Goal 6 by 2030. Therefore, active cognitive engagement through the creation of a water literate environment is critical for breaking the chain of water illiteracy and to achieve long-term water sustainability in Southeast Asia countries. Overall, this paper provides a critical analysis on lessons learnt from the region that can be mirrored in other parts of the world.

Keywords: Southeast Asia; water literacy; water management; water security; water sustainability

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1. Introduction

Water finds its application across different areas such as agriculture, industrial, domestic use, and recreation. Water literacy includes a combination of critical and active understanding of water sources, water management, and water security issues, which overall encompasses water knowledge, attitude, and behavior as shown in Figure 1 [1–4]. It has a pronounced role to play in all aspects of the health, social, management, and economic growth of a country. Conventional water conservation, which is focused around ensuring that consumers have enough water by mainly tapping into the depleting good quality freshwater sources through centralized systems, has a small role to play in long-term sustainability. As the population grows and rapid urbanization occurs, the challenges to manage water and its resources will continue to increase. Moreover, climate change is negatively disturbing water availability and quality, leading to the exacerbation of the existing anthropogenic water challenges [5]. In response to these, governments around the world are incorporating innovative water management embodiments that are more sustainable than conventional water management. Such paradigms include integrated urban water management, sustainable cities, or total water cycle management, combined with the facilitation of technologies like geo mapping and cybernetics [6,7]. Implementa-

tion of these frameworks involves many stakeholders from the federal government to the general public.

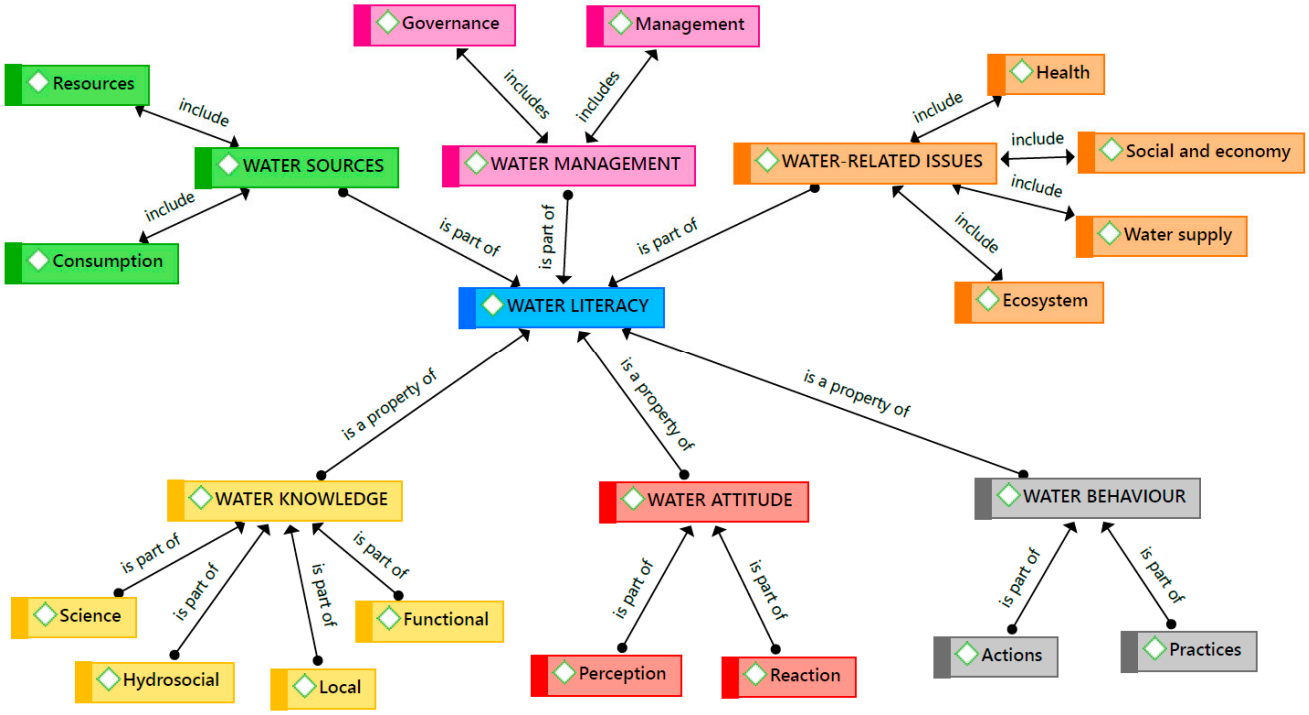

Figure 1. Different components of water literacy include water sources, water management, water related issues, water knowledge, water attitude and water behavior.

The United Nations (UN) Millennium Development Goals were established in 2000 as a 15-year framework that calls for global action in reducing inequalities to end poverty and other deprivations with eight development goals. That vision was translated into the 2030 Agenda for Sustainable Development. Since 2015, Southeast Asian countries including Malaysia, Brunei, Cambodia, East Timor, Indonesia, Laos, Myanmar, Philippines, Singapore, Thailand, and Vietnam, being part of the UN Member States, have been committed to supporting the 17 Sustainable Development Goals (SDG). The importance of water being one of the core environmental elements is reflected in UN SDG 6, which aims to "ensure availability and sustainable management of water and sanitation for all" with sub-goals addressing various water challenges [8]. Multiple international, national, and regional schemes and initiatives have been formulated in accordance with the SDG since then [8].

In fact, water related issues are not unique to the Southeast Asian region. Many developed regions including Northern Europe, Canada, and most of Latin America are currently facing low to medium water stress, whereas East Asia, the United States, much of Southern Europe and Eastern Europe have medium to high water stress [9]. Countries experiencing very high water stress include most countries in the Middle East, North Africa, and South Asia [9]. The United Nations Sustainable Development Goals report (2021) revealed that, in 2018, almost 2.3 billion people were living in high water-stressed countries [10]. The majority of countries from Sub-Saharan African, Asia, and Oceania suffer from either physical water scarcity or economical water scarcity. Water scarcity would jeopardize access to sufficient water to meet basic human and environmental needs. Continued progress in improving drinking water would yield positive results that could be leveraged to improve health, education, gender equality, and subsequently combating poverty. Data on access to clean water are more widely available in comparison to other SDG 6 indicators. Thus, it will be used as a water literacy benchmark tool.

Globally, the percentage of people using safely managed drinking water services has increased from 61.7% in 2000 to 74.3% in 2020, as shown in Table 1 [10]. However, the proportion changes significantly according to regions. North America and Europe have the highest share of population with access to safely managed drinking water at 95.6%, followed by Western Asia and Northern Africa (78.7%), and Latin America and the Caribbean (75.4%) [11]. Central and Southern Asia together with Sub-Saharan Africa are lagging behind the global average with proportions of 62.4% and 30.0% [11]. The disaggregated data further showed the inequalities in terms of nation's income. The gap in access to clean water between high-income countries and low-income countries is 68.8%, reduced by only 9.9% over 20 years. Despite all the efforts and initiatives, globally, 129 out of 193 UN member states are not on track to achieve sustainable water resource management by 2030 [10]. Focusing on the Asia-Pacific region, in 2020, only seven out of 11 SDG 6 indicators had sufficient data to track the region's progress, which reflects the possibility of under-reporting and the inability to generate disaggregated data to spot vulnerable populations [12]. Therefore, a holistic approach to managing water is urgently required for accelerated progress toward achieving universal access to water.

Table 1. Share of populations with access to safely managed water services by global regions and economies. [dataset] Ritchie, H. & Roser, M. 2021. Clean Water.

Share of Populations with Access to Safely Managed Water Services			
Global regions	**Year 2000 (%)**	**Year 2020 (%)**	**Relative change (%)**
World	61.73	74.27	20
North America and Europe	90.06	95.57	6
Latin Americas and Caribbean	71.74	75.38	5
Western Asia and Northern Africa	67.91	78.69	16
Central and Southern Asia	46.06	62.36	35
Sub-Saharan Africa	17.06	30.03	76
Economies	**Year 2000 (%)**	**Year 2020 (%)**	**Relative change (%)**
High income	95.15	97.57	3
Upper-middle income	68.82	76.83	12
Lower-middle income	43.08	58.08	35
Low income	18.78	28.08	50

The key element in creating sustainable water management is the active participation of the people. Public participation in water management is an amalgamation of (i) the understanding of water science, resources and ecology environment; (ii) water attitude, which is a fusion of water appreciation, responsibility, and ethics; and last but not least, (iii) adoption of the pro-environmental behavior [2]. A hurdle that remains invisible in building an engaged community to support the water initiatives is water illiteracy. It is a general perception of the public that adequate provision of quality water is an outcome of good governance and solid management efforts by the higher authority and the water system is an isolated entity from human activities. While water is considered a renewable energy, polluted water is not suitable for potable use or even irrigation, depending on pollution level, and water treatment is a very costly, dynamic, and complex effort. The culprits responsible for polluting the water sources could be anyone from society. River pollution from the dumping of chemical waste to solid waste, point source, or nonpoint source pollution is happening on a regular basis, and consequently leads to water shortages and rationing across Southeast Asia, even amid the wreckage of COVID-19. The current scenarios in this region might create a debate that most, if not all, of the citizens are not part of a water sustainable society, which could be due to uninformed citizenry. To this end, this paper will review the current outlook on water literacy in a Southeast Asian context, and what we can learn from the situation.

Different components of water literacy will be discussed, which include water sources, consumption, governance, management, sociodemographic factors, water security obsta-

cles, and water footprint in Southeast Asia. These elements will provide a benchmark to assess whether Southeast Asian countries are on track to deliver the objectives of SGD 6. The COVID-19 pandemic might exacerbate the risk of progress setbacks and increase our vulnerability to future water security issues. Secretary-General of the UN, Antonio Guterres said, "The Sustainable Development Goals are more important now than ever. Now is the time to secure the well-being of people, economies, societies and our planet" [10]. Thus, the review presents crucial evidence for the scientific community and the stakeholders regarding water-related concerns in this part of the world. Data for different aspects of water literacy focusing on Southeast Asia were drawn from a vast literature search of both the academic and grey literature from 2000 to 2021. First, a custom Google search was carried out to identify relevant organizations, websites publishing documents, and articles on water literacy. Next, each interest organization, website, and paper were searched for potentially relevant documents by skimming and scanning of executive summaries, abstract, and/or table of contents. The screening of articles, reports, or websites was followed by a full text run for data extraction, analysis, results reporting, and discussion presented below.

2. Different Dimensions of Water Literacy in Southeast Asian Countries

2.1. Water Sources and Consumption

The world's main water sources consist of both saltwater and freshwater. Coming from the oceans, salt water contributes 97.5% of the world's water. On the other hand, freshwater is made up of groundwater and surface water, contributing to 2.5% of the world's water [13]. Home to almost 670 million people, Southeast Asia accounts for 9% of the world's population, where they rely mainly on surface water and groundwater. Rainfall is the main contributor to surface water. This is attributable to many parts of Southeast Asia receiving an average annual rainfall of more than 60 inches, which also contributes to groundwater recharge and evapotranspiration. Two dominant air currents that influence rainfall patterns are the northeast monsoon and the southwest monsoon [14]. It is estimated that 30% of the largest groundwater bodies are being depleted [15,16]. The use of the rapid provision of good quality groundwater as a potable water source is more evident in low-income regions such as developing countries or rural areas of Asia, Africa, and the Pacific [17]. Southeast Asia reported high rates of rural household groundwater consumption including Indonesia (90%), East Timor (81%), and Myanmar (78%) [17]. In countries like Malaysia, groundwater is not commonly used as the main water source. This is due to the higher cost involved in drawing groundwater, caused by its lack of accessibility, along with the easy reach of abundant surface runoff sources such as rivers. Furthermore, over-abstraction of groundwater could disturb water geology, though it is still being harnessed when there is a shortage of surface water, especially for agricultural sectors [17,18]. On the other hand, Singapore lacks natural aquifers and lakes. The four main water sources of this densely populated land are water from local catchment, imported water, desalinated water, and high-grade reclaimed wastewater. As a large part of Southeast Asian countries are located near the Equator line, the occasional prolonged dry weather with no rainfall affects the water supply in these countries. When water demand and usage exceeds the supply, water shortage occurs and puts the country under stress.

Current worldwide water withdrawal is escalating at a rate of about 1% annually and global water demand is estimated to increase by 20–30% by 2050 [16,19]. Fresh water demand in Southeast Asia is on the rise due to contributing factors of population growth, rapid urbanization, and industrialization with increasing irrigated agriculture to meet the demand of staple food production. The water withdrawal pattern of each country in Southeast Asia is strongly dependent on its socioeconomic construction. Agriculture accounts for 69% of global water withdrawal, which in turn contributes to only an average 4% of the worldwide gross domestic product (GDP) [10]. Indonesia is the largest agricultural water consumer in Southeast Asia, at nearly 92.76 billion m^3, followed by Vietnam and the Philippines [9]. For many developing countries, agriculture contributes a smaller

share of income compared to other sectors; however, it consumes the largest quantity of water, where more than 90% water resources of developing countries are allotted to agriculture [20,21]. For industrial water, Indonesia again is the biggest consumer at nearly 24.65 billion m^3, more than three-times that of other countries in the region [9]. In terms of household water withdrawal, Indonesia, with the highest population number, dominated the chart, followed by the Philippines and Malaysia [9]. In many nations, especially in developing countries, population growth and urbanization intensify the pressure on many water resources, causing rapid depletion of supply. In the last century, water consumption has been escalating at more than twice the rate of population growth [10]. These challenges introduce further complexities in Southeast Asia's water governance and management.

2.2. Water Governance and Management

Water governance involves a set of political, social, economic, and administrative structures that are in place to establish and maintain water supplies as well as water services at different levels of society. Effective water resource management is dependent on good water governance as it lays down the principles under which water management works [22]. Proper regulation of water sources at different organizational levels in the nation and international transboundary are necessary to ensure that water is being used safely and efficiently [23]. Integrated water resources management (IWRM) is a component of water governance, defined by the Global Water Partnership as "a process which promotes the coordinated development and management of water, land and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems" [24]. It is a concept established based on the four Dublin principles introduced at The Earth Summit in 1992 [25]. IWRM provides a very feasible path forward for sustainable use and control of water, and allows for an integrated partnership system and adaptation to changing circumstances. It incorporates the three "E's", namely environmental sustainability, equity, and economic efficiency, in order to build an enabling environment in which institutions can be developed and empowered to fulfil the role of water resource management [26]. Different countries in Southeast Asia have different strategies to implement the IWRM to suit their national challenges in water resource management, where a few are discussed below.

In Malaysia, the National IWRM Strategies Implementation Road Map was developed to guide and accelerate the nation's water sector transformation to overcome the following challenges: protecting water resources, especially from pollution; need for more cost-efficient water treatment for potable use; minimization of water wastage in the distribution network; and water conservation for the short-, medium-, and long-term [26]. The National Water Services Commission's role is to regulate matters regarding the water services industry. The Malaysian Water Vision was conceptualized in 2000 in support of Vision 2020. The key principles are water for people, water for food and rural development, water for economic development, and water for the environment [24]. As the way forward to realize the national water vision, the National Water Resources Council formulated the National Water Resources Policy to refine current policies and regulations to ensure more structured water resource conservation and management [27].

In the Philippines, the National Water Resources Board is the government agency responsible for all water resources and services. The National Economic and Development Authority is responsible for policy-making and the current Water Code, Environmental Code, and Clean Water Act are part of the constitution of the Philippines [28]. The dominant water problems include an increasing number of water stressed cities, declining water quality, depleting watersheds and effects of climate change [28]. The development of the Philippine Eco-Efficient Water Infrastructure Strategic Roadmap is an instrument to execute the IWRM. The vision of this roadmap is to achieve efficient and sustainable water resource management within the next 25 years through eco-efficient approaches [28]. The green strategies emphasize (i) sustainable urban water management; (ii) alternative water source

development; (iii) agricultural water resources management; and (iv) economic zone water management [28].

Singapore, being a country with a limited natural supply of freshwater sources, has a unique IWRM work plan. Its national water authority, the Public Utilities Board, plays a role in supervising the entire water cycle comprising water services, sewerage, and drainage [29]. Three central strategies steering Singapore's approach to managing water are (i) maximizing water collection by capturing every drop of rain that falls on the land; (ii) converting seawater into drinking water; and (iii) rendering water an endlessly renewable resource through wastewater reclamation, in order to close the water loop for better sustainability [29]. Gardens by the Bay, a nature park covering 101 hectares of the Central Region of Singapore is an initiative to create a city in a garden. The Supertrees towering the garden are made up of solar photovoltaic systems and function to capture solar energy as a cooling tower and rainwater harvester, which provides alternative water sources for irrigation to support the growth of almost 162,900 plants on them [30]. Furthermore, Singapore's approach of Whole-of-Government allows collaboration with transparency between public agencies [31]. This provides opportunities to develop strategies based on ideas from multiple perspectives and allows for close monitoring of the spill-over effects of the policy actions of various agencies.

Overlaps of water management responsibilities across several organizations are commonly observed in many countries including Myanmar. To ensure long-term economic development and poverty reduction, it is important to develop an entity with capacities at all levels of water resource management. Starting from 2013, stakeholder participation in the Myanmar Water Sector has been promoted through the establishment of the National Water Resources Committee of Myanmar to provide high-level coordination of the water services industry [32].

2.3. Sociodemographic Factors

Water literacy is intertwined with sociodemographic factors, predominantly age, education level, socio-economic status, ethnicity, and gender. There are currently limited studies in Southeast Asia assessing the relationship between these factors and water illiteracy. Age is traditionally correlated with world experience, which will affect the water literacy level. Older populations are found to have higher water-related awareness due to the cumulative knowledge and experiences acquired throughout their lives [33]. On the other hand, younger groups are reported to be at the other end of the spectrum due to the lack of exposure to information and experiences in relation to the environment [33]. Afroz et al. (2015) reported that age significantly influences risk perception of water pollution [34]. Moreover, the adaptation of water sustainability is effortful and time-consuming. The current roadmap for implementation of Malaysia's IWRM Strategies Implementation Road Map itself is planned over a 15-year period, while the IWRM policy has been in place since the late 90s [26]. The same goes for behavioral change among the citizens to be more water literate—it is a long-winded commute. Thus, young people with longer future years should be the target audience in water literacy programs for better impact as they are the young advocates of tomorrow who will be in the position to devise water management policies. In Singapore, the Public Utilities Board collaborates with the Ministry of Education and schools to organize water-related programs at various levels [35]. The Myanmar National Water Policy is the country's first integrated water policy approved in 2014 and under Chapter 16—Research and Capacity Development Needs. The policy stated the need for a national campaign on water literacy that is in line with Myanmar's education sector reform, further reiterating the importance of educating the young minds about water governance regardless of a country's progress in achieving water sustainability [32].

Interestingly, parents have an important role as an educator at home to impart a great deal of positive water conservation behaviors in their children. Abdullah et al. (2018) reported that parents who had higher education levels and income were likely to positively impact their children's level of environmental awareness [36]. This is because these parents

can easily obtain information about the environment, making them more reactive toward environmental concerns. Thus, parents would be able to instill the tenets of conscientious pro-environment attitudes in their children, resulting in increased water literacy. A case study in Indonesia by Febriani (2017) showed a positive correlation between education level and level of water literacy, indicating that individuals with higher education levels tend to have better water literacy [1]. However, the relationship between lack of education and poor water literacy is a difficult problem. Providing education to an individual is not a straightforward solution to water illiteracy. There is no clear cut strategy, and each water illiteracy hurdle is linked to other issues. For example, lack of education could be due to lower household income and poverty. Differences in household income could be a reflection of socioeconomic gap between rural and urban populations, where rural areas have a strong relationship with poverty [37]. In general, the dimensions of inequality in water, sanitation, and hygiene (WASH) services include socio-economic status, underreported data from very remote geographical locations, or even individual characteristics such as intra-household gender roles, which are always related to specific contexts such as indigenous communities [38].

Poverty is one of the main issues encountered by lower income countries, especially among the rural communities of Southeast Asia. Despite the UN Millennium Declaration in 2000, a report in 2020 still showed that almost 2.1 billion people, accounting for 26% of the world, still lack access to safely managed drinking water services [11]. In 2017, almost 2 billion people were living in high water stress facing countries [39]. By 2030, it is estimated that water scarcity could displace 700 million people [39]. This situation is further compounded by the huge disparity between urban and rural populations, where the gap in accessing safely managed drinking water is at about 32% in most countries across the world [38]. There are 3.4 billion people in the world who live in rural areas and three quarters of the Southeast Asian population lives in rural localities. In Southeast Asia, East Timor and Laos reported the highest percentages of extreme poverty (living on less than $1.90 per day) at 30.30% (2014) and 22.70% (2012), respectively [40]. The disparity and stability in monthly income of urban and rural households has led to the megatrend of the internal migration of rural communities to the metropolitan cities. According to UNESCO (2018), internal migration significantly outweighed the international migration, especially in low and middle income nations [41]. Worldwide, there are 763 million internal migrants, which is almost three times that of 258 million foreign migrants [41]. For example, in Indonesia and Thailand, almost 50% of the population reside in urban areas, where rural–urban migration is at the top of the chart [42]. In 2010, urban areas of the Philippines were home to almost 45% of its population and from 2010–2015, 36.2% of migration that happened in Vietnam was rural–urban [42]. In Southeast Asia, currently, there is an immense need to provide the basic amenities such as clean water for the growing number of internal migrant populations. This has led to other complications, where rapid urbanization leads to water pollution, environmental degradation, congestion, and inappropriate management of waste and sanitation services in Southeast Asia [43].

Local comprehension of water knowledge often does not intersect with the scientific understanding [3]. Indigenous people tend to exhibit a special bond with nature and practice unique knowledge and beliefs, especially in the sustainable management of environmental elements [44]. Sustainable Development Solutions Network Southeast Asia's foremost annual project, the Happiness Festival aims to encourage public engagement to learn about the social issues as well as sustainable growth and strategies that can be adopted together [45]. The Happiness Festival is rooted in a Balinese belief, Tri Hita Karana, which stresses human-to-human, human-to nature, and human-to-spiritual harmonies [45]. This traditional doctrine further highlights the importance of local knowledge in water sustainability. Given that the UN explicitly recognized rights of indigenous peoples to safe drinking water and sanitation, disproportionate access to WASH among many remote indigenous communities compared to non-indigenous population is a major contributor to the poorer quality of life and cycle of poverty [46,47]. There are ongoing health and

social challenges such as poor drinking water quality, incompetently built sanitation infrastructure, and hygiene-related disease burden faced by many indigenous communities regardless of the countries' development status globally. These include remote Torres Strait Islanders and Aboriginal people of Australia, Native American and Alaskan communities of the USA, Canada's First Nations people, or even indigenous people of Southeast Asia [47,48].

Different challenges exist among various communities. The indigenous people of Peninsular Malaysia, known as the Orang Asli, are particularly affected by unsustainable water services. A total of 38% of the Orang Asli dwellers live in remote areas, 61% in the outskirts of Malay villages, and remaining 1% in towns [49]. The Malaysian Ministry of Rural Development reported that about 82% of Orang Asli villages have access to water supply [50]. As reported by the Special Rapporteur in 2019, water services provided to these indigenous communities lack sustainability due to incompatibility with their cultural value [50]. He observed the non-functionality of the water supply facilities, thus the local communities' reliance on self-fetched surface water and self-made unsustainable gravity-fed water systems [50]. The numbers might not be statistically representative, however, from the human rights perspective, they cannot be rendered unseen [50]. In terms of disease burden, childhood diarrhea and malnutrition are often correlated with poor sanitation, poor hygiene, or unsafe drinking water [38]. Childhood malnutrition remains relatively higher in the Orang Asli population compared to other Malaysian rural communities. This is attributable to the economic inaccessibility to WASH services by the indigenous people, who are reportedly among the most socio-economically disadvantaged population groups in Malaysia [48]. The local people in East Timor are affected by the lack of impact assessment of megaproject developments. Tasi Mane is a project that is part of East Timor's Strategic Development Plan (2011–2030), which aims to build offshore and onshore oil and gas pipelines, refinery, and other development accessories including highways, ports, and airports along the south coast of East Timor. During the Special Rapporteur's visit in April 2019, the local communities expressed their dissatisfaction with their lack of involvement in decision-making and planning stages and their concerns about pollution to water and land resources, which will have a negative consequence on community health and biodiversity [51]. The Special Rapporteur urged the relevant authority be guided by the United Nations Declaration on the Rights of Indigenous Peoples [51]. These challenges are a timely reminder that working in partnership with the indigenous people who are the local stakeholders, through intercultural dialogue and adaptation of their local water literacy system, will ensure long-term water sustainability in remote areas.

In rural parts of Southeast Asia, especially in remote areas, some females are in charge of collecting water for domestic use [50]. Spending a colossal portion of their time in fetching water could lead to females missing out opportunities, especially in education [52]. In general, females play a significant role in managing water-related activities in households such as cooking, watering the plants, and nourishing a hygienic home environment. They are the primary water decision makers at home, and manage water-related issues on a daily basis. However, their participation in the planning, decision-making, and implementation of water initiatives even at community levels is dismal, and this shows the gender gap in water-related leadership [53]. Many countries are adopting gender equity in water management bodies such as Uganda and South Africa in accordance with the UNICEF Mission Statement [54]. The World Bank reported that water projects had a 6- to 7-fold increase in efficacy when women were part of the projects [55]. However, according to the World Bank Utility Survey 2018/19, the recruitment rate of women in water utilities was as low as 20% [56]. In the Association of Southeast Asian Nations (ASEAN) Strategic Plan of Action on Water Resources Management Report 2005, the role of women in community level decision-making in water resource management had been discussed [57]. Nonetheless, the realization of equal gender representation in water governance depends heavily on the implementation of such a framework for action. The framework should not be confined to upper management levels as the scarcity of female water professionals could be easily used

as an excuse for the unbroken gender disparities [53]. Before 2009, in Laos, the average share of women in water utilities for senior staff positions and engineering graduates was around 4.2% and 13%, respectively [58]. In 2009, water supply and sanitation projects in 13 small towns of Laos were started and a gender sensitive stakeholder covenant was part of their action plans. Over a 10-year period, various technical training programs for female staff and engineering scholarships for female high school graduates have been provided [58]. By the end of 2018, the project achieved their target of a minimum 30% of female involvement in village development committees, consultations, and meetings at community levels [58]. In order to break the gender gap in water literacy, at the very early stage during schooling, gender stereotyping of specific subjects such as technology and engineering should be demolished [53]. This would help to produce a higher number of female graduates from the science, technology, engineering and mathematics fields, who will later participate in water resource management to make constructive changes.

2.4. Water Security Challenges

2.4.1. Health

The World Health Organization (WHO) has listed safe water supply, improved hygiene, sanitation, and water management as essential factors to maintain good health. Water pollution is one of the major contributors to various preventable diseases around the world. In 2017, global deaths due to poor WASH was recorded at 2.2%, which is equivalent to 1.2 million people, while low income countries reported a higher percentage of 6% [11]. Worldwide consumption of untreated and contaminated water due to unsanitary waste disposal has resulted in 1.7 billion diarrheal diseases in children under five years old and Dadonaite et al. (2019) reported that 533,768 children died from diarrheal diseases globally in 2017 [59,60]. In Southeast Asia, 59% of childhood diarrheal deaths happened in Indonesia, followed by the Philippines (21%), and Myanmar (11%) and the major contributing factors include unsafe water source, unsafe sanitation, and no access to handwashing facilities [61]. Aside from WASH-related issues, water illiterate anthropogenic activities have also impacted public health. This was seen in the incident of Malaysia's Kim Kim River pollution in 2019, where chemical waste was dumped illegally into the river [62]. The waste was later identified as marine oil waste, which radiated methane and benzene fumes, acrylonitrile, and acrolein [63]. These chemicals possess toxicity, carcinogenicity, and mutagenicity properties that can cause health problems. Benzene is classified under Schedule II (2) of the Occupational Safety and Health's Use and Standards of Exposure of Chemicals Hazardous to Health Regulations 2000, which has the potential to cause cancer depending on the exposure period [64]. The pollution had led to 6000 people with breathing difficulties as a result of inhaling toxic substances [65]. The series of unfortunate events is uncalled for, especially if proper waste disposal practice had been followed for chemical waste dumping.

2.4.2. Access to Safely Managed Water Services

Improved water sources encompass safely managed, basic, and limited drinking water services. A safely managed drinking water service is one that is located on the premises, available when needed, and free from contamination. The limited drinking water category misses an aforementioned safely managed criteria and involves over 30-min roundtrip to collect water [11]. While all the Southeast Asian countries showed either no change or increased access to improved water sources in urban and rural areas since 2000, Malaysia is the only nation with a negative growth rate in improving access to at least limited water services with −0.16% (urban) and −2.9% (rural) [11]. Lower middle income countries such as Laos, Cambodia, and Vietnam reported the highest growth rate in expanding access to improved water sources in rural localities by 120%, 72%, and 69%, respectively, over a period of 20 years [11]. Figure 2 shows the percentage of urban population with access to improved water sources versus the rural population of Southeast Asia in 2020. Thailand has reached 100% access to at least limited water services in both urban and rural

areas. However, in the majority of the countries, especially Cambodia, Laos, Myanmar, and East Timor, an urban–rural gap is still observed (Figure 2). In 2020, Cambodia and the Philippines's percentages of the population using safely managed drinking water were significantly below the global average (74.27%), which was only 27.76% and 47.46%, respectively, with Malaysia and Singapore at 93.82% and 100%, respectively [11]. Data for other countries were not available, which presumably would account for low percentages, except Brunei. Of the 24.82% of Cambodians, there is also a huge disparity between urban and rural communities, where only 55.29% of urban and 15.95% of rural populations had safely managed water services in 2015 [11]. In 2000, 5% of Malaysian rural dwellers relied on surface and unimproved water for domestic consumption compared to only 1% of urban people [11]. This inequality was further aggravated by the widened urban–rural gap from 4% in 2000 to 9% in 2017 [38]. Infrastructural complexities pose a crucial challenge in low income countries in the efforts to improve public water services to rural localities. The reasons for the lack of a public centralized water treatment facility include a (i) location that is far from major treatment centers; (ii) huge investment required for centralized systems in remote locations [66]; and (iii) lack of financial resources and funding support. In fact, some countries experience a funding gap of 61% to achieve the SDG water and sanitation targets, and only less than 15% of nations worldwide have the financial capacity to execute their water development plans [67]. According to the UN-Water Global Analysis and Assessment of Sanitation and Drinking Water 2019 Report, Indonesia, Laos, Myanmar, the Philippines, Thailand, and East Timor have less than 50% financial resources needed to implement drinking water provision plans, especially in rural areas [67].

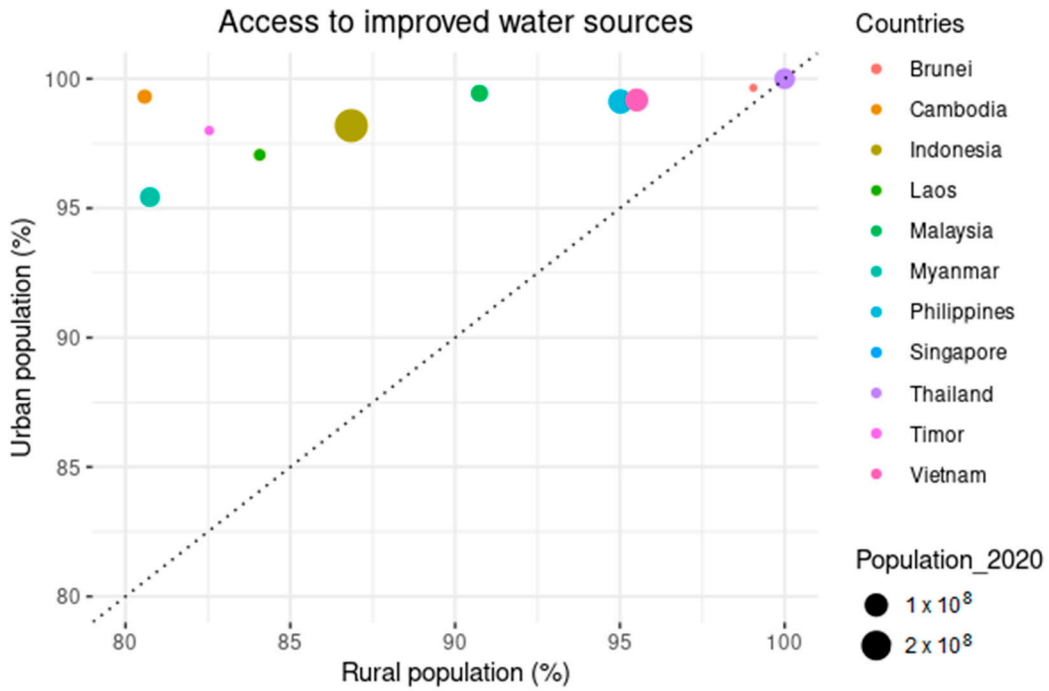

Figure 2. Percentage of Southeast Asian urban and rural populations with access to improved water sources in 2020 (excluding Singapore as it has zero rural population). [dataset] WHO/UNICEF Joint Monitoring Program (JMP). 2021. Data: Households.

Meeting growing demand by developing new water supplies only has limited potential and focus is increasingly being placed on exploring non-conventional water sources. Currently, the abundantly available annual precipitation is not being tapped effectively for good use. As discussed by the UN World Water Development Report (2021), one of the adaptation strategies to tackle water scarcity is to enhance water supply through improving the efficiency of water use such as natural infrastructure for water management—rainwater harvesting and water recycling and reuse [16]. In this regard, Singapore has shown great

success where, given its lack of fresh water source, it is the only nation in Southeast Asia with more than half of the country's water supply coming from reclaimed rain and wastewater and desalinated water. Currently, the high-grade reclaimed water called NEWater, which is generated from wastewater, contributes to 40% of the nation's water needs [29]. On the other hand, half of the nation's water needs are fulfilled by imported water from the Johor State of Malaysia. However, this international transboundary is constantly challenged by water pollution and climate change. In 2016, the water level of Linggiu Reservoir in Johor River fell to a worrying level of 20% after almost 20 years [68]. Recently, in 2021, though the water level has risen back to a healthy level of 80%, it was reported to be due to monsoon surge [68]. The dependency on weather changes puts the reservoir at risk of drying out in the current volatile weather patterns, and will affect both Johor and Singapore's water supply, which could result in political conflict.

3. Water Footprint—A Foreign or an Ignored Concept among Southeast Asians?

Carbon footprint is a commonly discussed topic, but not many are aware of yet another concerning concept—water footprint. Water footprint measures the amount of water required to produce all the goods and services consumed by an individual, community, nation, or the world [69]. This includes direct use such as for drinking and cleaning as well as indirect use, which is the water required to produce goods and services. It consists of three components: green, blue, and grey, as illustrated in Figure 3. The green water footprint is the amount of rainwater evaporated or consumed that is usually used in the production of agricultural products. The blue water footprint is the amount of surface water and groundwater that is generally used for domestic purposes, while the grey water footprint is the amount of freshwater used to assimilate wastewater according to fixed water quality standards [69,70]. Water footprint can be further divided into internal and external water footprints, where the internal water footprint is the amount of water that is used to make local products or provide services within the country, and the external water footprint is the amount of water used by another country to make a product or service that is imported [71].

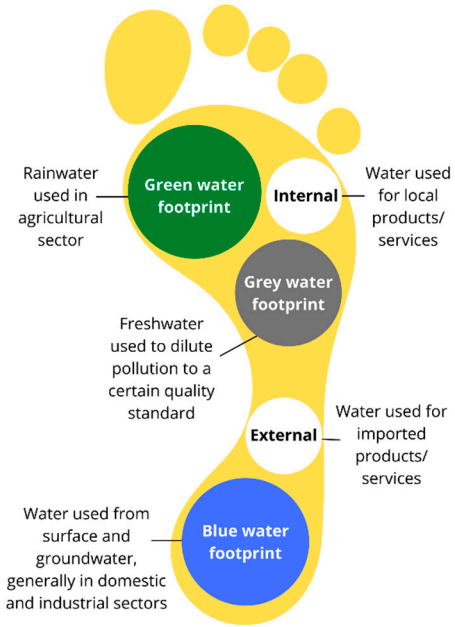

Figure 3. Different components of water footprint including green water footprint, blue water footprint, grey water footprint, internal water footprint, and external water footprint.

The three main sectors contributing to water footprint include the agricultural, industrial, and domestic sectors and the total water footprint in each country takes into account

the green, grey, and blue water footprints. Similar to water withdrawal, the total water footprint of each country is heavily dependent on its economic structure. Between 1996 and 2005, Indonesia had the highest total water footprint, which was 332,156 Mm^3/year, followed by Thailand (144,746 Mm^3/year), the Philippines (129,199 Mm^3/year), and Vietnam (109,493 Mm^3/year) [72]. This is not unexpected as the pattern corresponds to the total population of Southeast Asia, where Indonesia has the largest population size followed by the Philippines, Vietnam, and Thailand. Singapore recorded the smallest total water footprint of 20 Mm^3/year, accompanied by Brunei at 163 Mm^3/year [72]. For most Southeast Asian countries, water withdrawal is concentrated on the agricultural sector with the average agricultural water footprint for these countries at 95%, except for Singapore (37%) [72]. The agrarian economy acts as a significant GDP contributor in some Southeast Asian countries such as Myanmar (26.18%—2017), Cambodia (23.38%—2017), Indonesia (19.93%—2019), Vietnam (16.63%—2019) and Laos (16.20%—2017) [42,73,74]. Singapore, as a developed and high income country, the industrial sector forms a bigger share of total GDP and provides a larger allotment of employment, and thus explains the smallest water footprint for agricultural activities.

Awareness of Water Footprint

The water footprint is considered to be a valuable technique for analyzing and enforcing new strategies in the face of water shortages. It is evident from the water footprint data that the agricultural sector is one of the biggest contributors of Southeast Asian countries' water consumption. Agriculture and water shortages are in a closed loop where agriculture is both a cause of water shortages and a victim of it. The Water Footprint Assessment that was discussed in the United Nations Economic and Social Commission for Asia and the Pacific Task Force on Innovation and Competitiveness in 2015 is increasingly being adopted to find innovative solutions to reduce inefficient local water use [75]. However, translation of the research findings into language that shows their relevance to create policies for virtual water trade, adaptation of agriculture to changing climate, and hotspot identification for quantitative target framing still require optimization, especially for lower income countries. Awareness of water footprint is critical for one to be more conscious of water usage and wastage. In few Southeast Asian countries including Malaysia, Indonesia, and Singapore, water footprint reduction initiatives are incorporated into industry production, government policy, and consumer products. The Water Efficient Product Labelling Scheme (WEPLS) is an initiative to educate the public about the level of water-efficiency of certain products such as water taps, flush toilets, urinal equipment, showerheads, and washing machines [76,77]. Products are rated according to the level of water-efficiency with one star being the least efficient and three stars being the most efficient. Although it is not compulsory for companies to comply with this policy, consumers and suppliers of water efficient products are encouraged to adhere to this policy because these products can reduce the water footprint in the long run [76]. Singapore has also implemented several programs to further support water stewardship in the industrial sector such as the Mandatory Water Efficiency Management Plan, Water Efficiency Awards, and Water Efficiency Fund [78]. There are currently no published studies conducted to determine water footprint awareness among Southeast Asians on an individual level. This does not rule out the possibilities of some local small-scale surveys that have not been published or made accessible. Thus, it is difficult to gauge the level of water footprint awareness among people from this region, which could act as a barrier for future water literacy campaigns.

4. Are Southeast Asians on the Right Track to Meet Their National SDG 6 Targets?

United Nations Water defined water security as "the capacity of a population to safeguard sustainable access to adequate quantities of acceptable quality water for sustaining livelihoods, human well-being, and socio-economic development, for ensuring protection against water-borne pollution and water-related disasters, and for preserving ecosystems in a climate of peace and political stability" [79]. This should be the starting point for a

discussion on whether the current IWRM in Southeast Asia is actually achieving the desired outcomes. In all Southeast Asian countries, the governments support policies for WASH service delivery under the SDG, where formally approved National WASH policies for drinking water are in place, except for Laos (undergoing revision) and East Timor (under development) at the time of writing [67]. However, in most lower income countries, the plans are either partially implemented, not implemented, or still under development in both urban and rural areas [67].

Based on the Southeast Asian countries that took part in the 2019 UN-Water Global Analysis and Assessment of Sanitation and Drinking Water, 60% of the countries conducted a human resource assessment to carry out the implementation plans for urban areas, and the value was reduced to 29% for rural localities (Figure 4). The implication of this poor practice is that only 40% and 29% of countries have at least 50% of human resources needed to execute the WASH plans in urban and rural areas, respectively. A similar pattern was observed with insufficient financial resources (Figure 4). Lack of financial and human resources affects the progress toward national WASH targets. An example is the reduced frequency of surveillance in practice compared to the requirement that affects the progress monitoring (Figure 4). While most countries have regulatory authorities in place, only a small percentage of Southeast Asian countries' authorities have fully published publicly accessible reports on drinking-water quality and the quality of service delivery in urban areas, with 13% recorded for urban areas, and almost 0% for rural areas (Figure 4). While community participation procedures are defined in law or policy of almost all Southeast Asian countries, lack of readily available information might hinder public participation in water sustainability practice.

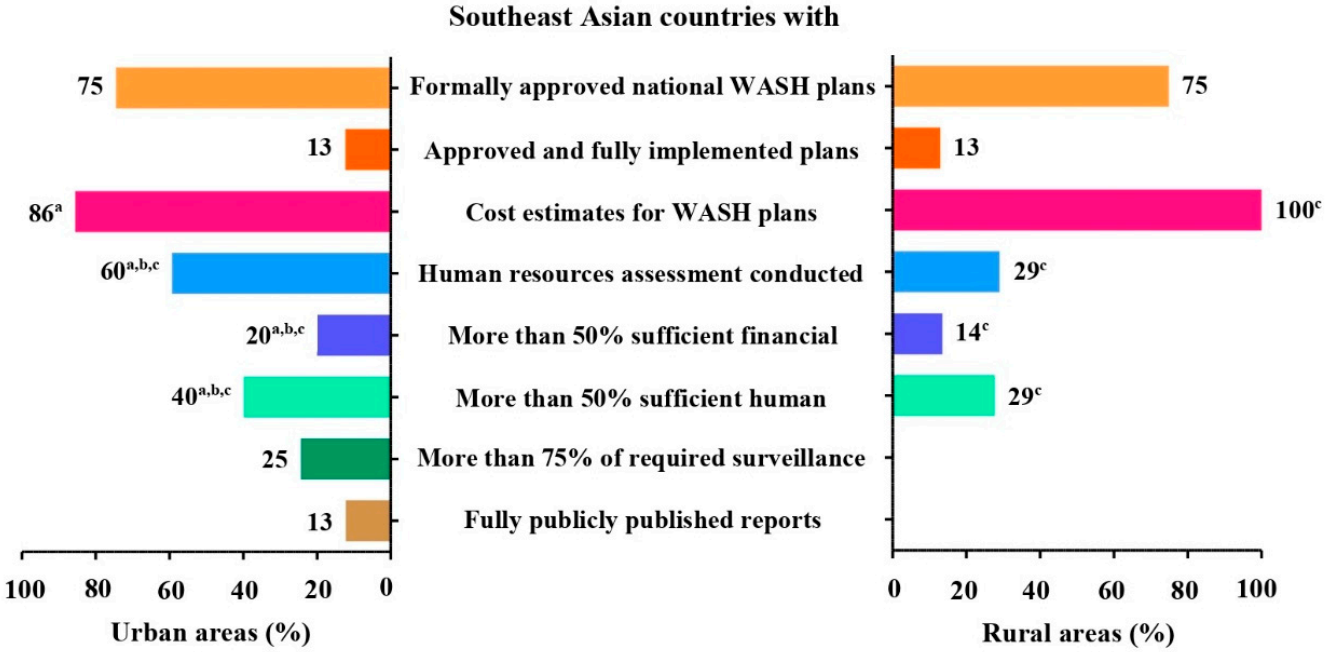

Figure 4. Percentage of Southeast Asian countries (excluding Brunei, Malaysia, and Singapore) with approved and implemented WASH plans, cost estimates, and human resource assessment conducted for those plans, more than 50% sufficient financial and human resources, more than 75% required frequency of surveillance in practice compared to the requirements and regulatory authorities publish publicly accessible reports on drinking water quality. a—without data from Cambodia; b—without data from Myanmar; c—without data from Vietnam. [dataset] WHO. 2019. UN-Water global analysis and assessment of sanitation and drinking-water (GLAAS) 2019 report.

Water security issues faced by most Southeast Asian countries are multifactorial and can be categorized into three overlapping segments, namely environment, economic, and social factors (Figure 5). Freshwater scarcity, water withdrawal exceeding water supply, poor implementation of IWRM policies, funding gap, widening urban–rural gap, poverty,

lack of inclusivity of vulnerable population, water pollution, and climate change further perplexed the problem. These can impede a country's progress toward achieving SDG 6 In this regard, each country has to focus on their capacity building in terms of acquiring and improving the necessary skills, knowledge, tools, equipment, and other resources to achieve water sustainability. While the time required to reach potential capacity to self-sustain IWRM might vary between countries, there is a need to adopt organizational hybridity to ensure access to safely managed water services in recognition of human rights to clean water and to leave no one behind.

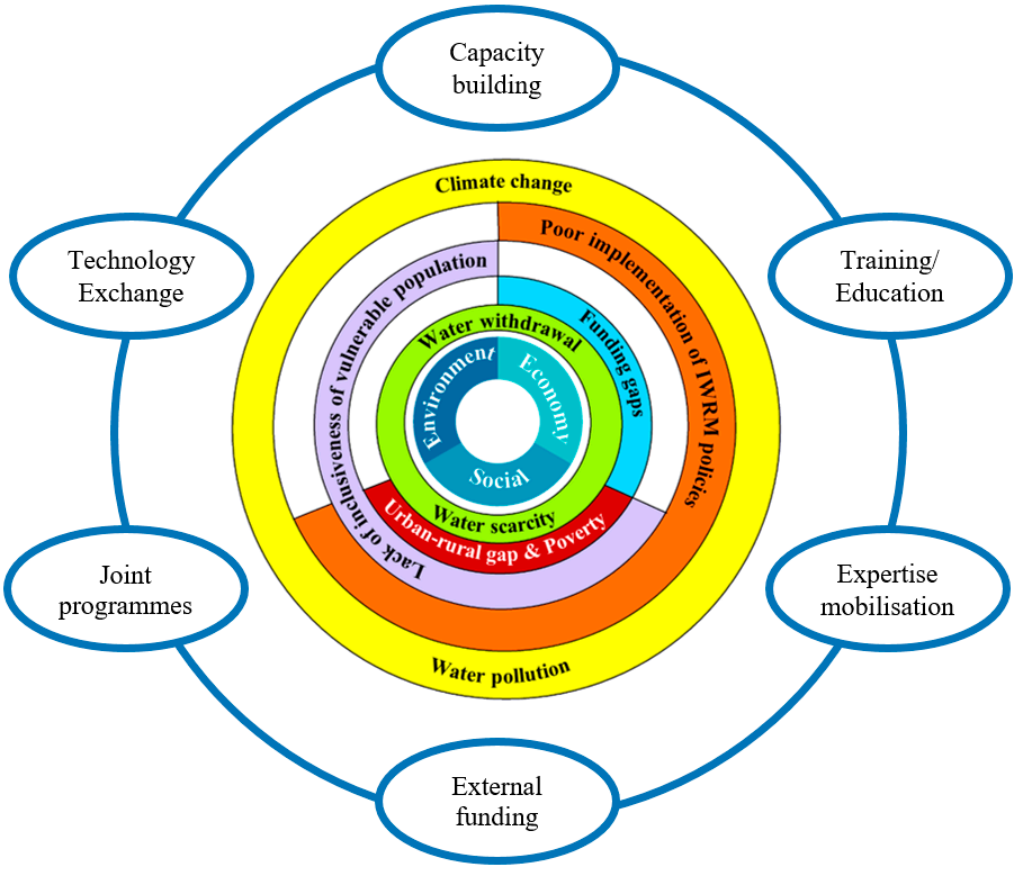

Figure 5. Water security challenges faced by Southeast Asian countries and possible strategies to mitigate them.

Organizational hybridity can take different forms including technology exchange expertise mobilization, joint programs, or even joint sourcing for external funding. The Southeast Asian countries have formed the ASEAN with the motto of "one vision, one identity, one community" for collaborative development of the countries. In facing and responding to water security issues, the ASEAN is committed to further promoting information sharing on the latest technology and local wisdom by adopting the ASEAN Socio-Cultural Community Blueprint 2025. The blueprint functions as a supervising commission of the ASEAN Working Group on Water Resources Management, which advocates for water sustainability among its members [80]. Following the Thailand flood disaster in 2011, the ASEAN Hydroinformatics Data Center (AHC) was established under the support of the ASEAN Committee on Science, Technology, and Innovation in 2017 [81]. AHC functions to create a centralized database with input on the hydroclimate from ASEAN countries for better water management, especially water-related disaster risk reduction [81]. The successful implementation of the AHC is a role model of joint efforts between neighboring countries to address the mutual problems faced. This framework can be replicated in other parts of the world, where countries in close vicinity can form an alliance to better manage water related issues in that region for the benefit of parallel progress and develop-

ment. The partnership should not be limited to inter-governments, but across all levels including private companies, NGOs, and educational institutions to deliver greater impact.

5. Conclusions

Southeast Asia is undergoing rapid development, urbanization, and population growth. The high water demand has exceeded the water supply, resulting in water stress in many parts of the region. Depleting freshwater sources and non-productive high water withdrawal in agriculture producing countries further perpetuate the situation. While each country has their IWRM policies in place, implementation of the proposed plans is still far behind in the majority of countries, mainly due to a funding inadequacy. On the other hand, poor water management, a widening urban–rural gap, and water poverty are adversely affecting the vulnerable populations in their access to clean water. High water footprint, climate change, along with anthropogenic activities that are causing water pollution, further impede Southeast Asian countries' progress toward achieving SDG 6.

Water security is a global concern and a difficult problem to solve. Southeast Asian nations will be trapped in this ongoing battle in years to come, unless drastic measures are in place. The important role of water literacy in producing responsible water users cannot be overlooked. Therefore, active cognitive engagement is critical for breaking the chain of water illiteracy. Literate environments are necessary in the pursuit of water management sustainability and should start as early as possible. Holistic water management can be achieved through continuous interactive water education to encourage public participation in supporting the government's water sustainability efforts reflected in the annual reduction in water consumption per capita per day. In addition to that, extensive and in-depth research and development is important to upscale technologies to help a country overcome water security challenges. NEWater, the high-grade reclaimed water, is one of the prominent technologies that helped Singapore advance to achieve their vision of closing the urban water loop. Good transparency and accountability in the government's policy and planning implementation as well as data availability to the public all play important roles in producing a water literate society in Southeast Asia and globally. A water literate society will provide citizens with a voice and role in decision-making. A participatory approach is necessary to conserve water and its resources sustainably. In this regard, everyone is a stakeholder including the public. At an individual level, water can be managed efficiently by either reducing, reusing, or recycling water, and by taking part in water resource preservation and conservation initiatives. In short, one needs to be a water literate citizen to make progress every day toward achieving SDG 6—clean water and sanitation for all.

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