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WATER GOVERNANCE: URBAN WATER CONSERVATION AS A RESPONSE TO CLIMATE CHANGE

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Abstract

This study aims to formulate recommendations for water conservation strategies through solving the causes of water scarcity. Through a qualitative approach, the study was conducted through a review of secondary data sourced from institutions related to the research topic, accompanied by an analysis review of relevant literatures. Secondary data obtained shows that the majority of urban communities choose boreholes/pumps and piped water as the main SAM for purposes other than drinking, while drinking is dominated by refill water. Among the strategies identified, NbS (Nature-based Solution) based on ecosystem strengthening and economic valuation through Payment for Ecosystem Service (PES) will support sustainable natural resource planning in urban areas by considering ecological aspects and community welfare. Sustainable water management in urban areas requires a synergy of driving factors such as policy formulation based on ecological sustainability, involvement of stakeholders with effective coordination, and community involvement in planning and management. Therefore, alignment of perceptions and goals between actors is required to achieve strategic steps and sustainable natural resource governance planning as an inevitable response to climate change.

***Keywords**: Water Governance; Water Conservation; Climate Change; Urban Area; Sustainable*

Introduction

Water is a resource that significantly affects socio-economic growth [1, 2] and the protection of a healthy environment [2]. The uncertainty of future climate conditions will increase the challenges of water resources management, which is more uncertain [2], making decision-making difficult [3]. These challenges and threats demand sustainable water management for sustainable community development, such as water conservation, which can be a strategic option according to F. Meng *et al.* [4]. Water conservation needs to start from sustainable water management with an effective way to measure the demand and supply of water resources and improve the efficiency of using evenly and spatially distributed water resources [2]. Water deficit has also been known to reduce crop production, such as palm oil productivity in Indonesian peatlands [5]. Further, C. Pahl-Wostl [6] argues that hybrid governance systems with synergistic interplay between these many governing forms are necessary for coping with complicated water management concerns.

Among the challenges in sustainable planning is the unequal distribution of water resources, leading to scarcity. In times of climate change, water scarcity has become a major threat to sustainable development [7]. Scarcity causes some areas to experience a surplus and

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other areas to experience a deficit. In the model studied by Z. Huang *et al.* [7], the global total water deficit is projected to increase by 48.3% from 2186.3km^3/year in 2020 to 3241.9km^3/year in 2050. In the same study, non-agricultural water demand was also projected to increase by 82.5% or 540.6km^3/year in 2050 from 296.2km^3/year in 2020.

Urban areas are one of the most vulnerable areas. According to UNICEF [8], water shortages and scarcity are major risks in urban areas. Water scarcity is the lack of water resources available to meet the needs of a given population - whether experienced by a community, region or country - on a temporary basis - for example for a few months of the year - or over a period of time [8]. Water shortages in urban areas are an intersection of several trends including population increase [9], unsustainable water management, poor management, infrastructure degradation, inefficient water use, and increasing competition for water demand between sectors [8]. One example of a water scarcity case occurred in 2020 in the Asian region, which reached a deficit of 0.36 million km^3 [10].

The problem of water scarcity in residential areas is mainly caused by inappropriate urban planning measures [11]. The importance of integrated water planning and management in regional planning at local and regional scales [12-14] can use a watershed-based spatial planning approach [15]. Such an approach will increase competition for water use across sectors between upstream and downstream areas, which is useful for considering the development of adaptation strategies towards sustainable water management [7].

In the context of watershed as a planning unit of analysis, it is necessary to cooperate between regions [16] to synergize plans. In the research of J. Ma *et al.* [13], optimal regulatory integration proved effective in dealing with water shortages in their study site. An integrated area ensures that a region functions efficiently because it forms cohesiveness between regions and decentralization occurs [16]. Such planning integration can occur when there is coordination and cooperation between regions.

Integrated regional planning in Indonesia can be seen in the Provincial and National Spatial Plans (RTRW). However, these RTRWs have not been effective in ensuring sustainable water resources management. The integration that occurs focuses on the infrastructure of water network systems that support agricultural activities, drinking water needs, and flood control systems [15]. Meanwhile, the integration of sustainable water management should be reflected in the programs and targets at each level of the RTRW [15].

In realizing sustainable water management, it is not only enough to have an integrated plan but also needs to be supported by the availability of laws and community involvement. According to S.B. Megdal *et al.* [17], laws, regulations and institutional frameworks are important aspects in supporting or hindering the development of sustainable water governance. In addition, weak coordination and cooperation between actors between regions is another obstacle [15, 16, 18]. These obstacles are then interesting to be studied further. For this reason, this research aims to formulate a mechanism for sustainable water management cooperation through resolving the barriers that are key to completing integrated planning.

Accelerating the development of an integrated water resources planning and management system is an effort to meet the increasing demand for water resources [19]. Sustainable water management can be done by optimizing the use of water from several sources and minimizing the use of groundwater [20]. Proper planning and allocation of water resources is an effective way to improve the efficiency of water resource utilization by ensuring distribution and maximizing economic benefits [4]. A good understanding of the correlation between the availability and water consumption/needs of each type of activity will help policy makers to plan and allocate water resources with water allocation priority given to water-based industries, such as primary industries [21] so that the utilization of water resources must match the availability and type of use. Across the world, collaborative partnerships are being employed to address complex water challenges and incorporate multiple government and non-government views [22].

One example of the diverse utilization of available water resources in Saudi Arabia consists of ground water (GW), surface water (SW), desalinated water (DW), and treated wastewater (TWW), while the users are domestic, agricultural, and industrial sectors [20]. The solution implemented in Saudi Arabia is to ensure sustainable water supply for all consumers through the formulation of a multi-objective optimization model, which includes multi-source water allocation, multi-user satisfaction, water quality control, and cost optimization [20]. However, the availability of water resources is affected by the geographical location, management, and utilization of water in desert areas which will be different from equatorial areas even though they are connected to each other.

Water availability is integrative and is commonly referred to as virtual water. The concept of virtual water is the volume of water used along the supply chain to produce products and services [23] in one location that can then impact water resources at distant locations in the supply chain [23]. For example, water supply in Kazakhstan is affected by water conditions in China due to significant changes during the period 1931-2013 due to increased precipitation and ice melt. In addition, in 1998-2013, the country's average annual discharge also increased 26.5% above the 1931-1997 average [19].

Site-to-site linkages are crucial for sustainable water management. The importance of understanding the spatio-temporal patterns of water scarcity and future climate uncertainty can guide decision-makers to choose the best strategies to ensure integrated long-term sustainability [3]. Water scarcity and future uncertainty vary by location and need to be considered in the water resources sustainability investment process, i.e. locations with high water scarcity and low uncertainty are good candidates for high-cost, high-value investments; locations with high uncertainty scarcity can benefit most from low-cost investments to minimize the potential for assets to be impacted if water supply increases; while those with in-between conditions need more flexible planning [3].

A sustainable form of water management can use the NbS (Natural-based Solution) method, which uses ecosystems and ecosystem services as solutions to problems and challenges such as climate change, food security or other natural disasters [24]. NbS and evidence-based solutions can be used to address problems by mimicking the complexity and way nature works [25, 26]. The goal of NbS is to support the achievement of community development goals and safeguard human well-being by reflecting cultural and social values, and enhancing ecosystem resilience, renewal capacity, and service provision [24]. The application of NbS was initially only used for climate change adaptation, but later this concept developed into a natural resource management concept to deal with socio-environmental problems [27].

The definition of NbS has different interpretations. The IUCN (International Union for Conservation of Nature) emphasizes NbS on ecosystem management or restoration, while the European Commission focuses more on the application of nature as a source of inspiration and encouragement [24]. In the research of Z. Boukalová *et al.* [28] and M. Everard *et al.* [29], NbS is defined as green infrastructure because the term is juxtaposed with gray infrastructure. This is different from Woo's research [27] that NbS is a holistic approach with natural concepts and processes. The difference in terminology can be seen from the spatial hierarchy scale, namely NbS - EE (Ecological Engineering) - BGI (Blue-Green Infra) - CRT (Close-to-River Techniques) - GI (Green Infra) - LID (Low-Impact Development) [27]. Further details can be seen in the Figure 1.

It can be observed that NbS can cover five approaches [27]. Scientifically, the use of NbS has different terminologies according to the local situation and context [30]. NbS is often used as an alternative response to solve complex problems [26]. Likewise, the application of NbS in sustainable water management.

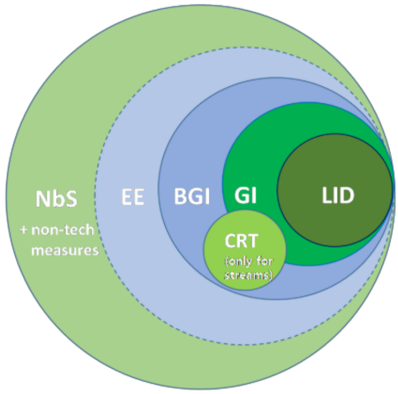


Fig. 1. Conceptual Diagram for the Hierarchy of NbS and Similar Approaches, Source: [27]

Sustainable urban water management is driven by the occurrence of crises that generally result in urgency and the need for change such as the Amsterdam cholera epidemic in 1866 which exemplifies the need for preventive action [31]. Research in the Netherlands has also shown that an increase in disease burden due to accelerated environmental pollution during periods of urban expansion requires improvements in drinking water infrastructure [31]. In addition, not only infrastructure improvements, but also better management systems need to be supported. Other research includes the case study in Australia, where the study expresed urgency on Identifying and Overcoming Barriers to Collaborative Sustainable Water Governance in Remote Indigenous Communities [32].

Urban Water Management is a complex and comprehensive concept. According to T.A. Larsen and W Gujer [12] urban water management involves water supply, urban drainage, wastewater management treatment, and sewage treatment. V.G. Mitchell [33] elaborates on the broader concept of Integrated Urban Water Management (IUWM), which is a comprehensive approach that considers urban water services, water supply, drainage and sanitation. Sanitation is not only limited to recognizing the physical system (natural landscape) but also the organizational framework [33]. Some even proposed the concept of 'Sponge City' as a method to manage water in urban environments [34, 35].

The challenges in developing sustainable urban water management are related to spatial and temporal resolution [12] which can be seen in figure 2.

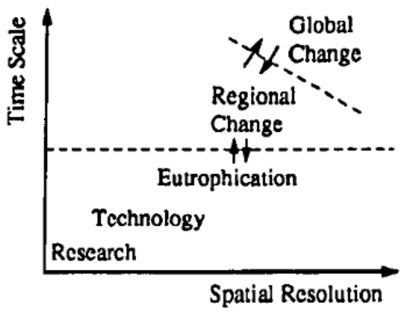


Fig. 2. Challenges for Sustainable Development of Urban Water Management Source: [12]

The determination of these two scales will affect the development plan. In the near future and small scales of coverage, technology is needed, but in larger scales of coverage, collaboration between regions is needed [12]. Integrated management can represent local distinctiveness while still considering the larger regional context so that the scale of the integrated management approach can cover both detailed and general scales.

Sustainable urban water management also requires interregional and larger-scale planning because water management is a system that cannot be solved only through local contexts. The success of IUWM will always be linked to regional and local conditions. Mitchell's [33] research explains that the key to IUWM success is planning and managing individual processes that can minimize the resulting impact and increase collective efficiency. Integrated management is a collective action that begins with individual actions that are collectively accounted for. In addition, consideration of future pressures such as climate change, sea level rise, increased global growth, and urban population are key to the success of IUWM [36].

Currently, integration between scales can be addressed through the NbS method approach, which has been commonly used at different scales and forms of application [25]. NbS cannot meet and address all challenges but its implementation requires the responsibility of different territories/scales and sectors [26]. NbS can function effectively as a downstream response to meet sustainability goals in urban areas and city regions [25]. In this study, it was mentioned that water management requires integrated treatment [26]. In addition, the success of NbS is mainly supported by accounting (interdisciplinary involvement), monitoring (integration of different scales in NbS), and communication (making NbS implicit to actors at different levels of decision-making) [26]. Therefore, integrated planning is needed from the spatial scale to cooperation between institutions and actors.

At the urban scale, NbS is a sustainable solution that contributes to the resilience of cities to deal with climate change [38]. In the context of integrated water management in urban areas, NbS can be categorized in the field of management [27]. The application of NbS in the context of urban studies is a concept developed as a form of urban adaptation strategy [39] including the development of the quality of life of urban communities, as well as being an effective solution in facing challenges [25]. In practice, according to G. Senes *et al.* [30], the application of NbS through the utilization of green infrastructure in urban and rural areas can contribute to stormwater management such as reducing flow velocity, runoff, and removing contamination from stormwater [30]. Meanwhile, water management related to soil management related to the ability of soil porosity and soil conditions will affect the ability of inflitration [38] with parameters that can be seen in the following table.

Table 1. *Selected UPIs Related to theThree Urban Challenges (UCs) (Climate, Water Management and Soil Management*), Source: Green4cities et al. (2018), in [38]

UCs	Urban Performance Indicators	
Climate adaptation	AT - Air temperature	PET – Physiologically equivalent temperature
	TLS - Thermal load score	MRT - Mean radiant temperature
	TCS - Thermal comfort score (outdoor)	PMV - Predicted mean vote
		UTCI - Universal thermal climate index
Water management and quality	**FPR - Flood peak reduction**	**WQ - Water quality**
Soil management	SBA - Soil biological activity	SAW - Soil available water for plants
	SWI - Soil water infiltration	SCF - Soil classification Factor
	SMP - Soil macro porosity	SCR - Soil Crusting
	SCT - Soil contamination	SOM - Soil Organic Matter
	CFS - Chemical fertility of soil	ECF - Ecotoxicology factor

NbS in urban water management seeks to utilize natural processes and (re)connect various flows in the urban water cycle to improve ecological sustainability [39]. The determination of the water management system is done after analyzing all components of the urban water cycle such as rainfall, runoff, groundwater, and wastewater [40]. One application of the concept can be seen in the reuse of water in the Monterey region that yields substantial economic and environmental benefits, ranging from tourism and irrigation of high-value crops, groundwater protection, and improvement of environmental flows and water quality [41]. It also does so through the integration of multiple water sources such as treated water from the reservoir at Vaigai, surface runoff generated from rainfall, groundwater recharge using artificial recharge structures, and reuse of treated wastewater to meet future demand [40]. Monterey is an example of successfully scaling up recycled water supply to indirect use systems that can delay the potential need for seawater desalination in the region by up to 30 years [41]. This provides cost and energy saving benefits, as well as providing an opportunity to resolve current planning issues [41].

Success requires green infrastructure that can optimize the water cycle to work naturally in accordance with the NbS concept. Rainwater harvesting, infrastructure maintenance and green spaces need improvement to achieve a resilient urban water cycle [42]. In addition, according to Y. Liu *et al.* [43], effective water use can increase water reserves in urban areas along with saving capital and energy used.

The application of the NbS concept in sustainable water management can be achieved if there is integrated planning and consideration of reuse and recycling aspects through good land use planning. Urban land use planning - supported by initiatives, planned investments and good governance - can help address urban water issues through additional green space [42, 44]. It can increase the city's resilience to flooding, more frequent and intense heat waves, improve human and economic well-being [42], create recreational spaces as social capital, and can reduce heat island and water demand [44]. Meanwhile, research by Y. Wang *et al.* [45] in Suzhou, which consists of natural lakes, rivers, and canals, showed the importance of land diversification in water management in the water system in that area.

In addition to land diversification, it is also important to implement decentralized stormwater control towards a sustainable transition of future cities. Such diversification efforts can be through BAU trajectory engineering that can significantly affect ecological performance such as reducing runoff by up to 50% [46]. Currently, the majority of urban residents rely on "natural supplies" for their water supply, which are already affected by the existing infrastructure network [39]. These efforts are a form of application of the NbS concept that uses nature as an example and reference to deal with sustainable water management issues. The application of NbS in sustainable water management in urban areas, especially related to service provision and water availability, can support integrated planning in identifying and modifying service recipients and payers as well as determining land use in the planning.

Experimental part

Materials

Practice of meeting community needs, especially in urban areas in Indonesia, this study reviews data sourced from the reports of State agencies namely the Ministry of PUPR (Ministry of Public Works and Housing) of Indonesia and the Ministry of Health of Indonesia, as well as official agencies namely ADB (Asian Development Bank). Using a qualitative approach, the accumulated data obtained is then analyzed and further reviewed by mirroring the results of previous studies on the same topic.

Methods

The data search process was conducted online, while the screening process was based on the author's personal assessment of the suitability of the literature for the purpose of this study. The majority of the literature used was in the form of journals and some was in the form of books.

The secondary data was used as a basic reference for water scarcity issues due to climate crisis, while the selected literature was used for further comparison and analysis of water conservation strategies, especially in urban areas.

Results and discussion

Results

Figure 3 shows that water availability in Indonesia is uneven, where there are 4 islands that experience surplus, namely Papua, Maluku, Kalimantan, and Sumatra, while the other 3 islands namely Sulawesi, Java, and Nusa Tenggara experience water crisis/deficit. The island with the most water availability is Papua at 350,590 billion m^3/year or 50.7% of the total water availability in Indonesia. While the island of Nusa Tenggara is the island with the least percentage of water availability at 8,827 billion m^3/year (1.3%). Based on the aspect of needs, Papua as an island with the highest amount of water availability only requires 3,644 billion m^3/year of water or about 1.6% of the total water needs in Indonesia. Meanwhile, the island of Java, which only has water availability of 4.4% of Indonesia's total water availability, requires more than a third of the total national water demand, which is 35.2% or around 78,263 billion m^3/year.

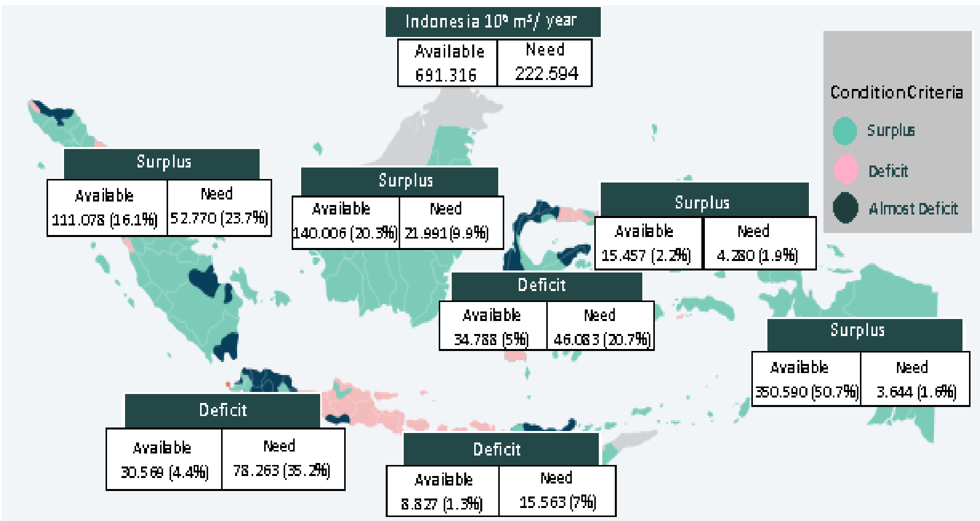


Fig. 3. Water Balance of Each Island in Indonesia in 2016, Source: [47, 48]

Meanwhile, figure 4 shows that the availability of surface water in Indonesia reaches 2.78 trillion m^3/year. 24.84% or 691.3 billion m^3/year can be utilized, but 468.72 billion m^3/year (67.8%) of them have not been utilized. In other words, 222.59 billion m^3/year (32.2%) has been utilized, where the most utilization is in the field of irrigation, namely 177.126 billion m^3/year (79.6%), while fishery farming is 12.533 billion m^3/year (5.6%). The remaining 14.8% or 32,935 billion m^3/year is utilized for DMI (Domestic, Municipal, Industry) where 10.7% or 23.8 billion m^3/year is for domestic-municipal needs and the remaining 41.1% or 9,135 billion m^3/year is utilized for industrial purposes.

ADB (Asian Development Bank) data [49] also shows the availability of water, especially surface water in Indonesia by island, where the island with the most water availability is in Kalimantan at 34%. Meanwhile, Java is the island with the least surface water availability at only 4% (Fig. 5a). Meanwhile, figure 5b shows a comparison of groundwater availability by region. The highest groundwater availability is in Papua, where the free aquifer is 222,524,000m^3/year, the depressed aquifer is 9,098,000m^3/year, and the safe yield is 69,487,000m^3/year. Papua's groundwater availability is more than that of Sumatra, which has a larger number of basins and a wider area.

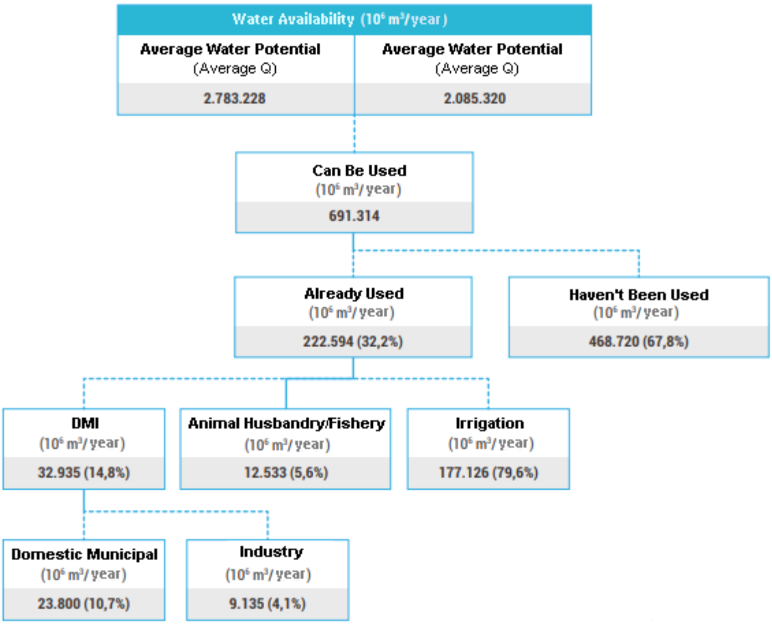
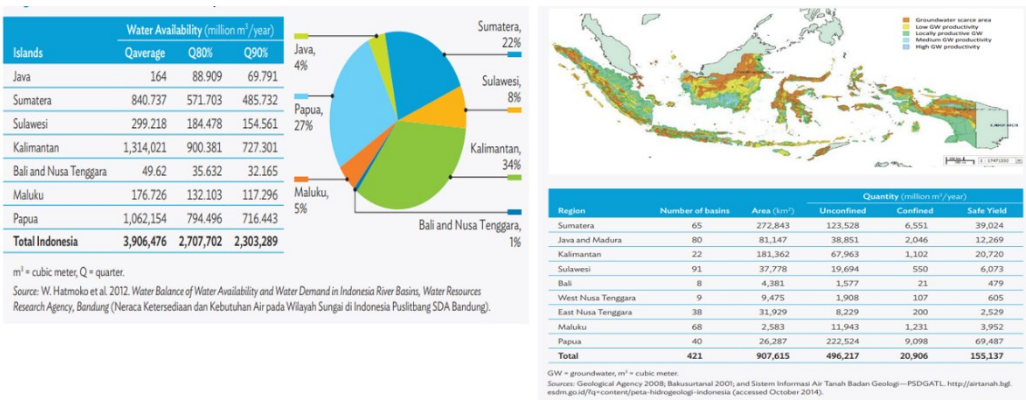


Fig. 4. Potential Surface Water Availability in Indonesia, Source: Asian Development Bank [47, 48]



Islands	Water Availability (million m^3/year) Qaverage	Q80%	Q90%
Java	164	88.909	69.791
Sumatera	840.737	571.703	485.732
Sulawesi	299.218	184.478	154.561
Kalimantan	1,314,021	900.381	727.301
Bali and Nusa Tenggara	49.62	35.632	32.165
Maluku	176.726	132.103	117.296
Papua	1,062,154	794.496	716.443
Total Indonesia	3,906,476	2,707,702	2,303,289

m^3 = cubic meter, Q = quarter.

Source: W. Hatmoko et al. 2012. *Water Balance of Water Availability and Water Demand in Indonesia River Basins, Water Resources Research Agency, Bandung* (Neraca Ketersediaan dan Kebutuhan Air pada Wilayah Sungai di Indonesia Puslitbang SDA Bandung).

Region	Number of basins	Area (km^2)	Quantity (million m^3/year) Unconfined	Confined	Safe Yield
Sumatera	65	272,843	123,528	6,551	39,024
Java and Madura	80	81,147	38,851	2,046	12,269
Kalimantan	22	181,362	67,963	1,102	20,720
Sulawesi	91	37,778	19,694	550	6,073
Bali	8	4,381	1,577	21	479
West Nusa Tenggara	9	9,475	1,908	107	605
East Nusa Tenggara	38	31,929	8,229	200	2,529
Maluku	68	2,583	11,943	1,231	3,952
Papua	40	26,287	222,524	9,098	69,487
Total	421	907,615	496,217	20,906	155,137

GW = groundwater, m^3 = cubic meter.

Sources: Geological Agency 2008; Bakusurtanal 2001; and Sistem Informasi Air Tanah Badan Geologi—PSDGATL. http://airtanah.bgl.esdm.go.id/?q=content/peta-hidrogeologi-indonesia (accessed October 2014).

(a) (b)

Fig. 5. (a) Surface Water Balance of Every Island in Indonesia; (b) Groundwater Availability of Each Island in Indonesia, Source: Asian Development Bank [49]

ADB [49] data also explains that urban water demand on each island continues to increase. Java continues to increase and is the island with the most urban domestic demand, while Maluku-Papua is the island with the least urban water demand (Fig. 6). This is inversely proportional to the amount of water availability in Java which is the lowest compared to other regions, while Papua and Maluku have the highest amount of groundwater availability but not accompanied by domestic demand as large as the demand in Java.

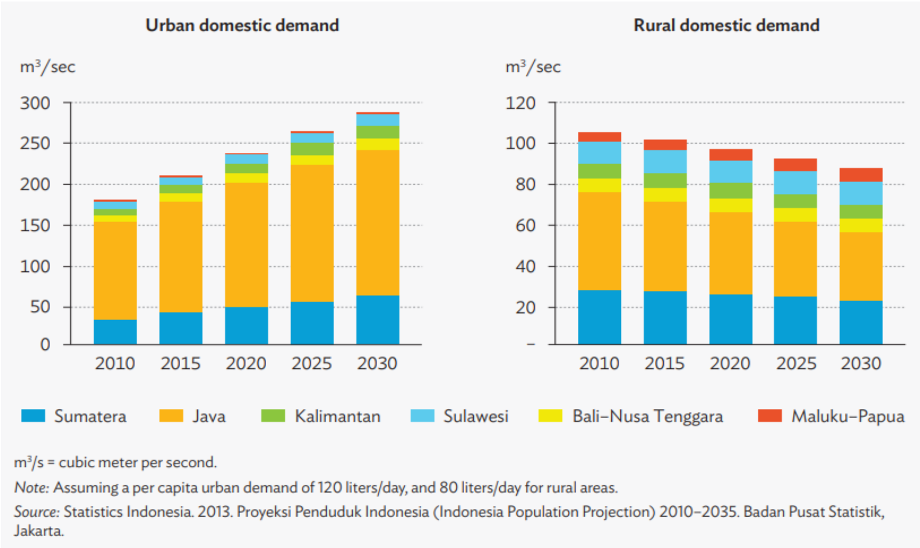


Fig. 6. Urban and Rural Water Demand, Source: Asian Development Bank [49]

Table 2 describes the proportion of households by Main Water Supply System (SAM) for drinking and non-drinking purposes. For drinking purposes, most households in urban areas use refillable water SAM at 36.5%. The main SAMs with a percentage of >10% are bottled water (16%), piped water (14.4%), borehole/pump (13.4%), and protected dug well (13%). Meanwhile, unprotected dug wells, protected and unprotected springs, rainwater harvesting, surface water, water terminals, and purchased retail water each had a percentage of <5%.

Table 2. Proportion of Households by Main SAM for Drinking and Non-Drinking Purposes by Area Characteristics, Source: [47]

Need Type	Packaged Water		Refillable Water		Tap water/Piping		Bore Well/pump		Protected Dug Well		Unprotected Dug Well		Protected Springs	
	%	95% CI	%	95% CI	%	95% CI	%	95% CI	%	95% CI	%	95% CI	%	95%CI
Drinking	16,0	4,3-17,8	36,5	34,4-38,7	14,4	12,6-16,4	13,4	11,8-15,2	13,0	11,2-15,1	1,7	1,3-2,3	1,5	1,0-2,4
Other than Drinking	-	-	0,1	0,1-0,3	33,0	30,0-36,1	35,9	32,8-39,0	23,4	20,9-26,1	3,6	2,9-4,4	1,6	1,0-2,6

Need Type	Unprotected Springs		Rainwater Collection		Surface Water		Water Terminal		Retail Water Purchased		N Weighted
	%	95% CI	%	95% CI	%	95% CI	%	95% CI	%	95% CI	
Drinking	0,7	0,4-1,2	1,1	0,7-1,7	0,0	0,0-0,1	0,2	0,1-0,6	1,5	1,0-2,3	9.212
Other than Drinking	0,9	0,5-1,6	0,3	0,2-0,6	0,6	0,4-0,9	0,1	0,0-0,4	0,4	0,2-0,7	9.212
Indonesia	2,5	2,0-3,2	2,3	1,8-2,9	0,6	0,4-0,9	0,3	0,2-0,5	1,4	1,0-2,0	21.83

Meanwhile, for purposes other than drinking, the main type of SAM used in urban areas is dominated by boreholes/pumps at 35.9%. This is followed by piped water at 33%, protected dug wells at 23.4%, unprotected dug wells at 3.6%, protected springs at 1.6%, and refilled water, unprotected springs, rainwater harvesting, surface water, water terminals, and purchased retail water at <1% each.

Discussion

Urban water management cannot be separated from the context of water management policy. Practitioners and policy makers must ensure proper stormwater management is in place due to increased runoff from impervious surfaces. It is also necessary to plan infrastructure and urban form to minimize the heat island associated with increased demand [44]. Urban governance is an internal dynamic mechanism that becomes a recessive factor that cannot be directly seen in material space, affecting the generation, prosperity and development of cities [45]. Urban morphology is the embodiment of urban planning at the material level, while urban planning is the internal motive mechanism of urban morphology [50], which is determined by three elements: actors, factors, and institutions involved in the process of urban evolution and the initial characteristics of the city [45]. Institutions and policy-making processes are one of the three factors that influence urban morphology.

One of the efforts made to manage sustainable water is to establish a new legal framework [19, 51] that can be implemented together in an integrated manner [19]. In natural resource management systems, power is an important factor because it can determine who does and does not have access to shared resources [52]. According to V.G. Mitchell [33], the principles of sustainable integrated water management consist of considering all parts of the water cycle, who and what needs water, the local context, involving stakeholders in planning and decision-making, and balancing the social and economic environment. The involvement of these stakeholders can control and determine access for all.

There are 3 main issues regarding water governance, namely stakeholder engagement as an important tool in developing a common understanding of the context required for decision making [17], community involvement [17, 52] and the existence of qualified water governance capacity [17]. In the study by H.B. Tantoh *et al.* [52], active community involvement in sustainable water planning and management through strong traditional leadership, decisive change, and active participation of rural communities will result in community-centered and community-based development that promotes the success of sustainable water management.

In addition to stakeholder and community involvement, there is also a need to limit and control power. Difficulties in limiting vertical government control from the central government [52], passive participation [17, 52], insufficient technical knowledge, and financing mechanisms will hinder the smooth operation of integrated rural water systems [52]. Monitoring project evaluation, and improved cross-stakeholder learning through, for example, workshops involving different levels of management are needed to enhance continuous learning and make water governance more effective [42].

Stakeholder engagement also needs to diffuse and remove administrative barriers to form effective cooperation and coordination. Problematic frictions between dynamic peri-urban spaces, dichotomous static policies along the urban-rural divide, and siloed roles between government agencies need to merge in a one-size-fits-all manner [53]. Policy processes in the broader sense - policies made and transformed by a range of governmental, non-governmental, citizen actors [41, 53], scientists and others - need to critically appreciate, confront, remake and especially refocus government policies towards peri-urban and urgent water insecurity issues [53].

Decision-making in scaling up sustainable infrastructure needs to consider how to limit the impact of infrastructure inequalities on vulnerable populations and provide low-cost innovations that aim to protect and stabilize non-network ecological services for millions of urban residents who already depend on unsustainable ecological services [39]. NbS designs have proven effective in Asian cities by not exacerbating existing water vulnerabilities, but also need to be adapted to address the implications of the "gray gap" for urban residents who are most vulnerable to water quality and quantity degradation due to broader urban water management practices [39]. Sustainable urban water management solutions seek to create equity and justice that has previously been poorly achieved [39].

Sustainable urban water management must not only be integrated but also well distributed to create community resilience. Community resilience risks overlooking important insights into how peri-urban water insecurity problems are experienced by peri-urban populations and produced or reproduced in specific socioeconomic, political and policy contexts [45, 53]. The approach that needs to be used in implementing NbS needs to recognize urban politics by asking who benefits, who is harmed, and who will create externalities from NbS. This is done in order to fulfill the win win solution [39]. The existence of a policy in the form of a legal framework that includes regulating the involvement of stakeholders and the community is an important element in integrated planning because the system created cannot run if there are no rules / legal certainty and involvement between interested subjects.

Payment for Ecosystem Service (PES)

The Payment for Ecosystem Service program is a program used to achieve the goals of ecosystem services and human well-being [54]. The economic value of water is paid less than the cost of repairing the damage caused [55]. PES is a voluntary and negotiated framework, not a command or order [56]. According to J. Sheng and M. Webber [57], PES is an incentive scheme that shares political and economic roots with environmental neoliberalism. This is in line with O. Pradit and J. Kitchaicharoen's [55] opinion that PES is a market-based instrument to support natural resources and environmental management.

There are five characteristics of PES, namely transactions are voluntary, the ES (Ecosystem Service) traded is measurable, at least one buyer buys it, at least one provider, and the transaction is carried out if and only if the provider maintains the ES [56]. This is different from J. Sheng and M. Webber [57] opinion that the purpose of such incentives is none other than to provide command and control over society. Despite these two differences, PES is a symbiotic mutualism that can create an action-reaction relationship between beneficiaries and resource custodians.

PES is a middle way to achieve sustainable development by taking into account ecological and economic impacts [58]. One of them is applied in the Ecological Planting Mode (EPM) program. The application of EPM can improve ecological quality but reduce farmers' income so that the application of PES can incentivize farmers through compensation, subsidies, and pricing for tourism activities without reducing ecological quality [58]. Economic value can be used to present the benefits of ecosystem services to all stakeholders to raise their awareness about conserving natural resources and the environment in the area [55].

The mechanism for providing incentives can be arranged and coordinated between the central government as the main goal setter and the local government as the implementation regulator [57]. Regarding limited funds, payments can be obtained from higher levels of government on the premise that ecological problems cover a wide scale [58] or obtained from compensation derived from tourism activities as service users (buyers) [59].

PES will be more effective in economically less prosperous regions [54]. In addition, community involvement can enhance and sustain the objectives of PES [54, 57] rather than relying on top-down incentives through government [57]. The scaling of recipients and payers is also key to the success of PES. According to K. Brownson *et al.* [54], local PES is more effective than national PES in preventing people from converting forest land. The determination of the upper and lower limits of ES payments should also be relevant and not extreme (lower/upper) as it will lead to ineffective participation [60].

Water resources management can also apply PES concepts. Integrative water resources require the incorporation of large investments in water resources through infrastructure investments, water regulation, or payments for ecosystem services [3, 4] that can increase water availability [3]. Meanwhile, according to L. Jin-yan *et al.* [61], the strategy carried out in achieving sustainable water fulfillment through three things, namely pumping, piloting, and storage. This is in line with the concept of virtual water, which can be the basis for implementing city-rural PES across different administrations. According to Lowe *et al.* [23], the calculation of ecosystem services can be assessed through the calculation of water footprint. However, their research also mentions that what is considered economically sustainable in the supply chain is not necessarily sustainable and does not represent the optimal allocation. To date, environmental valuation has not been used in planning for efficient water use and allocation at different locations in global supply chains [23]. However, economic valuation can at least increase public awareness and participation in protecting water resources.

Community involvement in the program will determine the PES scheme which according to X. Wang and E.A. Nuppenau [59] to be one of the PES frameworks. Research by [59] mentioned that the PES framework used consists of 5 layers, namely spatial design to determine the physical characteristics of the area, water use analysis to determine the water demand for each land use, mathematical modeling to apply the model with intervention and without intervention, water flow simulation to model seasonal variations in water flow, and determination of the PES scheme. In integrated watershed management, payments for ecosystem services can encourage forest conservation [59] by increasing community involvement and desire to protect nature through emphasizing the relationship between providers and beneficiaries through incentives.

Conclusions

The study found that there is a gap between the demand/need and availability of water. Islands with a low percentage of water availability have a high percentage of water demand, such as the densely populated island of Java. Regarding SAM, the main uses for non-drinking purposes in urban areas are using boreholes/pumps and piped water, while drinking is dominated by refill water. The findings of the state of natural resources and the practice of meeting the water needs of urban communities indicate the need to identify inhibiting factors and sustainable water management strategies that will provide understanding and help in the formulation of water sustainability governance planning which is one of the problems arising from climate change and driven by the demand for water needs, especially in densely populated cities. Regarding the concept, this research reviews NbS as one of the appropriate concepts in sustainable water management in urban areas by harmonizing aspects of community development and ecological sustainability. As for the practice of water sustainability governance, this research highlights PES that can mediate between ecological impacts, economic aspects, and community needs.

In perpetuating the implementation of both, stakeholders and communities need to synergize in integrated planning and management, both regarding objectives, implementation arrangements, obstacles and challenges for each actor, as well as related funding. However, the whole process requires a legal framework that serves as the basis for the rules and legality of the current system, which must then be formulated and discussed with all actors involved. This is important to harmonize perceptions and ensure the sustainability of the concepts and programs that are running for the management of water sustainability in urban areas and preparation for the future climate crisis.

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