Local Environment
The International Journal of Justice and Sustainability

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/cloe20

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To cite this article: S. P. Dewi, Rina Kurniati & Novia Sari Ristianti (2023): Revealing community capacity for applying rain water harvesting in Semarang coastal areas, Local Environment, DOI: 10.1080/13549839.2023.2221891

To link to this article: https://doi.org/10.1080/13549839.2023.2221891

Published online: 14 Jun 2023.

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LOCAL ENVIRONMENT
https://doi.org/10.1080/13549839.2023.2221891

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Revealing community capacity for applying rain water harvesting in Semarang coastal areas

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ABSTRACT

Public participation is essential in integrated water management, including in the implementation of rainwater harvesting (RWH). RWH is an alternative water supply generation method that can be implemented at the household level. Residents in drought-prone areas with a lack of water supplies system who rely on private vendors for clean water provision may utilise this method. However, it is difficult to encourage the community to apply RWH because of socio-economic constraints. Therefore, this study aims to analyse the willingness and ability of a community in the Semarang coastal areas to apply RWH. The research was done through quantitative method by distributing questionnaires to 96 respondents to determine their knowledge, ability, and willingness to implement RWH. Rainwater potential was calculated by comparing the maximum volume of rainwater that can be captured annually to the volume of water demand. The estimated results were communicated to the community members and we further explore their responses to comprehend the possibility and advantages of applying RWH. Factors that influence community capacity were also analysed through factor analysis. The community members emphasized that the high cost of adopting RWH is the main reason they object to the idea. In addition, there are also health concern that make the community refuse to use RWH. Therefore, RWH implementation requires both support from the government and collective participation of community leaders as role models.

ARTICLE HISTORY
Received 16 December 2021
Accepted 27 May 2023

KEYWORDS
Rainwater harvesting; community capacity; coastal areas

Introduction

Water is an essential issue globally and locally. It relates to access to clean water, sanitation, water-related problems, food security, and sustainable development. Ensuring the sustainability of water access and sanitation for all of the community members is one of the sustainable development goals. However, it deals with several challenges, such as sustainable water sources and water quality (https://sdgs.un.org/goals/goal6). The United Nations World Water Development Report 2020 stated that water is related to two opposing sides, the problem and the solution; it requires a comprehensive approach to formulate water-related strategies. Hence, water management must be well-delivered, especially at the community or local level. One of the water-related strategies implemented at the local level is rainwater harvesting (RWH). According to Yannopaulos et al., rain-water harvesting practices have been conducted since 6000 years ago in China, 4500 years ago in Iraq, and 4000 years ago in Thailand, and since then they have spread all over the world (Yannopou-los, Giannopoulou, and Kaiafa-saropoulou 2019). RWH is a rainfall-collection method as a way to

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store water for direct or future purposes (Yannopoulos, Giannopoulou, and Kaiafa-saropoulou 2019). Regarding the urban water cycle, RWH is useful for reducing water runoff before its discharge to the sea. Water is collected at the rooftops and further channelled into storage tanks. Such temporary rainwater storage practice encourages the evapotranspiration process, in which the rainwater can be reused (Lamera et al. 2014).

Previous studies on RWH have been carried out both technically (Alim et al. 2019; Ammar et al. 2016; Norman et al. 2019; Terêncio et al. 2017) and socially, such as those that explored community involvement in water management (Park and Kim 2014), community perceptions about RWH activities (Bunclark et al. 2018), as well as community and stakeholder capacity for water sustainability planning (Ferrero et al. 2019; Juwana, Muttil, and Perera 2012). However, RWH is done at the household scale (domestic) and it relies on the community's role and capacity to manage rainwater successfully. Community capacity is derived from the water management context, which reveals how people can manage their environment (Craig 2007). Community participation in water management is dependent on institutional support and mutual understanding among community members regarding the importance of water (Craig 2007; Landström et al. 2019).

For capacity-building purposes, it is necessary to recognise the characteristics of the community (Craig 2007). Community capacity building consists of five main elements, including knowledge building, leadership and network building, respecting the community, inviting the community to achieve goals together, and information support to access the resources (Davenport and Seekamp 2013; Franco and Tracey 2019; Jones et al. 2018). Community perception influences the readiness to implement RWH and determines the programme's success or failure (Demeke, Andualem, and Kassa 2021). Comprehending the community's willingness and ability is essential because it will determine the sustainability of the RWH praxis. The community's impression of water management is also an opportunity to overcome water-related problems and gain economic benefits (Gao et al. 2018). Hence, it is essential to understand the community's acceptance of RWH as "a new method" to fulfill their daily water needs.

In Indonesia, water is used beyond for daily purposes. For centuries, rainwater has been uses as a means of self-purification, including from evil, and glorified as a blessing. Water is used to cleanse oneself from the lust for bad qualities in humans (Fadli, Hamidi, and Harianto 2014). Whether it is sourced from water springs or directly from rainfall, water is a gift from God and its existence needs to be acknowledged. For instance, "*wayang jantur*", a traditional performance from Java, raises stories about rainwater as water from the sky (heaven) that is valuable and must be glorified (Purnomo 2020). However, such a traditional and local perspective on rainwater is fading away gradually. People are reluctant to use rainwater, especially for consumption, because it is considered dirty and unfit for the purpose. They prefer to use surface water from wells, and therefore rainwater utilisation is uncommon. A similar condition also occurs in the greater Sydney area, where people are unwilling to install an RWH system in their household due to its high cost. The local government alleviates this by providing incentives and assistance with installation costs to residents who are willing to adopt this system at home (Rahman, Keane, and Imteaz 2012). Likewise, in Indonesia, the government attempts to encourage the community to use rainwater as an alternative water source, especially in drought-prone areas, because it is easy to get and cheaper than buying water for their daily needs.

The government's commitment to the RWH implementation can be seen in the issuance of the Ministry of Environmental Affairs and Forestry Regulation Number 12 in 2009 about rainwater utilisation in the community. Article 1, Section 1 asserts that rainwater utilisation is an activity to collect, use, and absorb rainwater into the ground. In addition, Article 3 states that rainwater collection ponds are storage used to collect rainwater that falls on the roof of a building (house, office, or industry) and is channelled through the gutters. RWH is aimed to reuse rainwater to reduce water surface runoff. It is also considered an alternative for water storage during the dry season, particularly for households, agriculture, and other activities in drought-prone areas (Bunclark et al. 2018; Tu et al. 2018).

This study is focused on the city of Semarang, as one of the two cities that are designated for a pilot project initiated by the Asian Cities Climate Change Resilience Network (ACCCRN) and supported by the Rockefeller Foundation. ACCCRN installed RWH system at three houses and a school in Semarang in 2011. Using the Regional Revenue and Expenditure Budget (*Anggaran Pendapatan dan Belanja Daerah/*APBD), the Semarang City Environmental Agency installed RWH systems in ten sub-districts in the same year. In 2012, the APBD and Tobacco Excise Revenue Sharing Fund (*Dana Bagi Hasil Cukai Hasil Tembakau/*DBHCHT) were used to fund RWH installation at 16 sub-district offices and 23 educational facilities (elementary and high school). As of 19 November 2020, The Environmental Agency listed on its website that a RWH system has been installed in eight urban sub-district offices and 18 schools. Furthermore, the Environmental Agency of Semarang City has consistently conducted socialisation and community facilitation regarding RWH since 2020. Following that, other agencies, including the private sector, contributed more funding for RWH practices. Most RWH rooftop installations are located in public facilities such as schools, village offices, and other public facilities that require large amounts of water (Figure 1). Then, several RWH pilot projects were established in several sub-districts in Semarang. These data are evidence that the Semarang City government is committed to applying RWH to meet water demand and overcome drought, floods, and land subsidence, mainly in relevant areas impacted by these occurrences.

The justification for the RWH programme is related to the water supply. The Municipal Waterworks (*Perusahaan Daerah Air Minum/*PDAM) covers only 59% of Semarang area, whereas community-based water supply and private companies serve 10% of the total area (Table 1). The rest of the population relies on water from the river and groundwater wells for water provision, with poor water quality. In addition, the 2011–2031 Semarang City drainage master plan states that RWH is one of the methods that will be used to reduce runoff from the upstream to downstream (Semarang City Government 2014). One of the initiatives mentioned in the Semarang Resilience Strategy Document (2016) is the provision of sustainable water and energy sources, such as providing alternative water sources through RWH (Semarang City Government 2016). As previously mentioned, our ancestors have practiced traditional RWH, yet it is not institutionalised and has been discontinued currently.

RWH study in Indonesia focused on its conceptualisation, and whether RWH can be adapted in response to water-related problems (Prihanto et al. 2018). Meanwhile, research on community capacity regarding knowledge of and readiness for RWH implementation is limited (Kiviet and Edgar 2016). It is necessary to comprehend a community's knowledge of the benefit of using rainwater as an alternative water source (Demeke, Andualem, and Kassa 2021). A good understanding of rainwater management will further motivate the community to participate in its practice. Hence, this study aims to evaluate the willingness and ability to apply RWH among communities living in the coastal area of Semarang who have limited options for clean water provision as a model.

a b c

Figure 1. RWH pilot project in public facilities. RWH at Local Government Office – Rowosari subsdistrict (a and b) and at State Junior High School 42 Semarang (c). Source: dlh.semarangkota.go.id.

Table 1. Percentage of water source utilisation water source.

	Percentage
Piped network PDAM	59%
Non-PDAM	
Dug well and deep pump well	31%
Other sources	10%

Source: Semarang Resilient Document, 2020; https://www.pdamkotasmg.co.id/.

Research method

The research was conducted in Semarang, mainly in the coastal area considered vulnerable to water-related problems. This area covers 20 sub-districts spread over Tugu to Genuk District. The main focus is on Mangkang Wetan, Mangkang Kulon, and Mangunharjo sub-districts (Figure 2). As stated in the Regional Disaster Management Agency (*Badan Penanggulangan Bencana Daerah/*BPBD) website (http://bpbd.semarangkota.go.id/pages/peta-rawan-bencana-2011), these sub-districts are most vulnerable and they face several natural disaster-related problems, such as rainfall flood, tidal flood, and land subsidence. These sub-districts are also not covered by the water supply piping network from PDAM. In addition, water provision strategies such as pond buildings or RWH have not been implemented in the areas. Meanwhile, sea-water intrusion contaminates ground-water, and domestic as well as non-domestic waste pollutes the rivers and overall degrades surface water quality.

All three sub-districts are parts of the Beringin River Watershed, which is categorised as critical due to land conversion in its upstream area, sedimentation, and riverbank landslides. This leads to annual flooding and drinking water scarcity in the sub-districts. Community members that reside along the Beringin River are the respondents in this study.

Data were collected via questionnaire distribution using a simple random sampling method (Alvi 2016), and the sample size was determined based on Slovin's calculation (10% error). According to the Semarang Central Bureau of Statistics (*Badan Pusat Statistik/*BPS) data, the population size in the research areas was 2510 households. Based on Slovin formula, the sample size was then determined at 96 residents of the coastal areas spread out evenly in the three sub-districts mentioned above. The questionnaire consisted of closed questions that were designed to identify the community's preferences in implementing RWH. The questionnaire was distributed personally by visiting the respondents' houses one by one and inquiring direct responses to the questionnaire items. The following questions were included:

- Social-economic characteristic, such as livelihood, financial, and educational background
- Physical characteristics, such as the quality of housing and infrastructures, especially clean water provision facilities
- Flood characteristics, such as flood frequency and volume, and the severity of economical loss imposed on the community members due to the flood

Figure 2. The study area in Mangkang Kulon, Mangunharjo, and Mangkang Wetan Sub-districts.

In addition, an interview with two government officials, each from the Economy Department of the Planning and Development Agency and the Infrastructure and Utilities Department of the Housing and Settlement Agency of Semarang, was done to obtain information on governmental regulations and programmes regarding RWH.

Factors influencing the community's willingness to implement RWH was analysed quantitatively. There were two objectives in this step: (1) to analyse the potential financial benefits of RWH for the community by taking into account the amount of rainwater harvested annually; (2) to identify primary factors that may support community capacity to implement RWH via statistical and factor analysis. Variables included in the statistical analysis were the demographic characteristics of the community members (age, education, income, and the ability to pay), knowledge about RWH, physical characteristics of the study areas (land area and rainwater usage), and water demand.

Respondent characteristics

A majority of the questionnaire respondents (80%) are male and played a role as the head of the family. The rest of the respondents are women representing their husbands, who were not able to participate due to work. All of the respondents work in the informal sector as fishermen, construction workers, farm labourers, or small-scale traders. Most of the respondents were male because women were reluctant to share their opinion and would rather rely on their husbands to participate in the questionnaire. However, both gender represented similar perceptions of RWH implementation, which is mainly focused on its cost aspect.

All respondents live in privately owned houses, with 70% of the people living in permanent houses equipped with tile roofs and cement walls. Meanwhile, 25% of the respondents live in semi-permanent houses with a combination of cement walls and wood boards, and 5% of them occupy non-permanent houses made of wood boards with limited facilities (Figure 3). On average, the housing area is below 100 m^2 and inhabited by five family members.

Figure 3. Housing condition in study areas.

The primary factor affecting community capacity for RWH implementation is the socio-economic characteristics, such as level of education (Bunclark et al. 2018; Gao et al., 2018; Park and Kim 2014). Statistics data sourced from BPS showed that more than 50% of the community members, both men and women, have a low level of education, i.e. they are elementary school graduates (Figure 4). The questionnaire revealed that most of the male population graduated from elementary school and worked as fishermen and industrial labourers in port-industrial areas. Residents who work as fisherman followed their parents' footpath since they have been taught fishing techniques since their childhood, and therefore they have a lot of relevant experience and skills. They even used the same boat as their parents, which will be inherited for them in the future. Meanwhile, residents who work as industrial labourers are migrants who have lived in the area for more than ten years and did not come from a family of fishermen. They chose this occupation because it does not require specific skills or experience. Likewise, the industrial site are relatively close to their homes and thus there is no need to incur high transportation costs.

However, having similar characteristics in educational background, the community members in each sub-district have different occupations (Figure 5). A total of 61% of the Mangunharjo

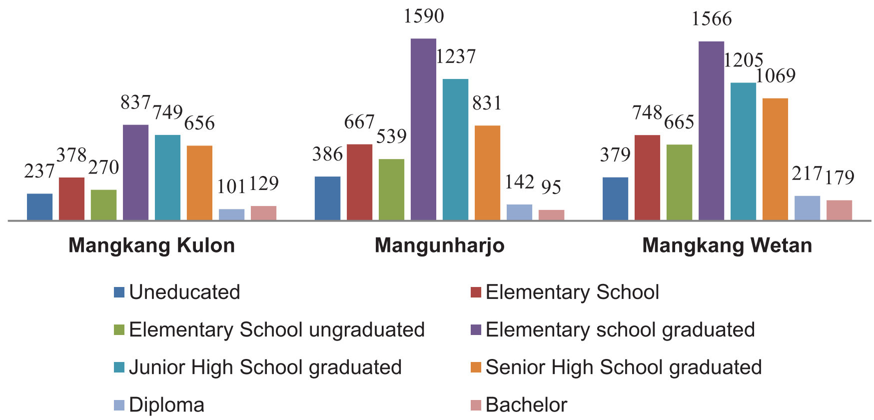

Figure 4. Distribution of education level in the study areas. (Source: processed from the questionnaire result).

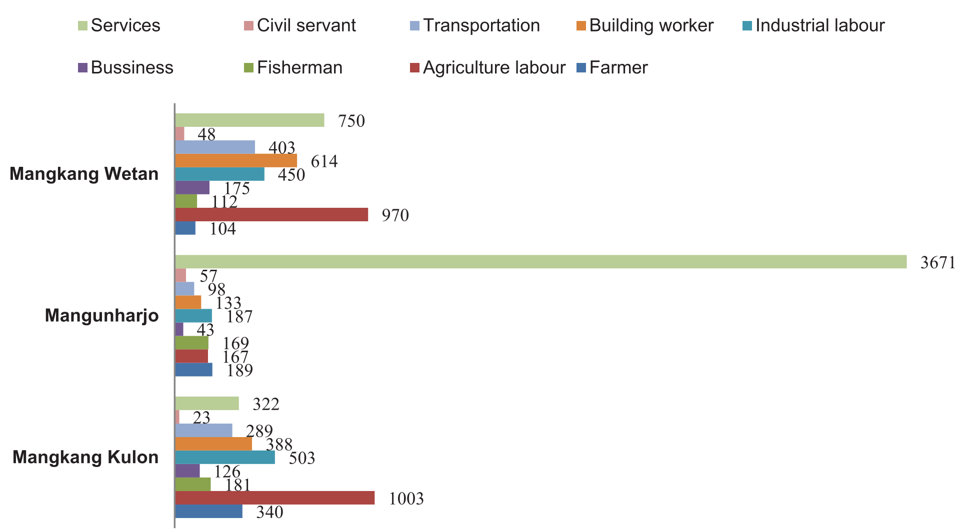

Figure 5. Occupational distribution within the study areas. (Source: processed from the questionnaire result).

community members work in the informal sector, such as street vendors and working odd jobs. Informal sector workers have no fixed source of monthly income. At IDR 2,000,000 average earnings per month, the income level is primarily categorised under the minimum wage standard of IDR 2,500,000 in Semarang (Figure 6). Meanwhile, some households that have a joint source of income, from both the husband and wife who work in the informal sector, make more than the minimum wage standard at IDR 3,000,000 per month. However, only 15% of the female residents in all sub-districts have a job. Some households consist of three generations of family, i.e. the grandparents, children, and grandchildren. This typically happens when the children are senior high school graduates who cannot afford their own house. The father and male children earn a joint income from the same job to support the whole family.

In Mangkang Wetan and Mangkang Kulon sub-district, 27% of the community members work as agricultural labourers. They do not own the paddy fields or ponds. They cultivate agricultural land and get paid based on the crop yield three times a year or work in fish farming ponds.

Result

Physical characteristics of study areas

According to the BPBD Semarang City, the three sub-districts included in this study are categorised as flood-prone areas, in which residents experience both pluvial and fluvial floods every year. Sedimentation in Beringin River, which flows through these sub-districts, has caused the river to get narrower downstream. Fluvial flood occurs due to high-intensity rain, during which water flow cannot be obtained within the river and ends up flowing into the surrounding areas. Likewise, flash floods are caused by landslides triggered by critical embankments and water flow to the settlement. Meanwhile, a pluvial flood happens when extreme rain in the upstream area increases water runoff beyond the river's downstream capacity.

Flood mitigation efforts from the government, private institutions, and non-governmental organisations have failed to overcome the floods significantly. The river normalisation programme planned by the Semarang government in 2020 is problematic due to land acquisition problems. This programme aims to rehabilitate the river and reduce the occurrence of flooding. Based on the Ministry of Environmental Affairs and Forestry regulation, the Beringin River border would be rehabilitated at least 50 m from the right and left side of the riverbed along the river channel (Figure 7). However, some residential areas and public facilities along the proposed area are located less than 3 m from the river. Residents belonging to this category refuse to be displaced, causing a delay in river normalisation.

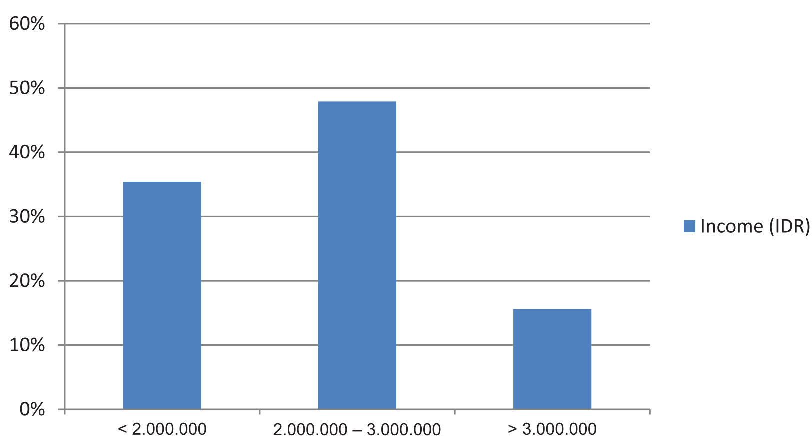

Figure 6. Income distribution within the study areas. (Source: processed from the questionnaire result).

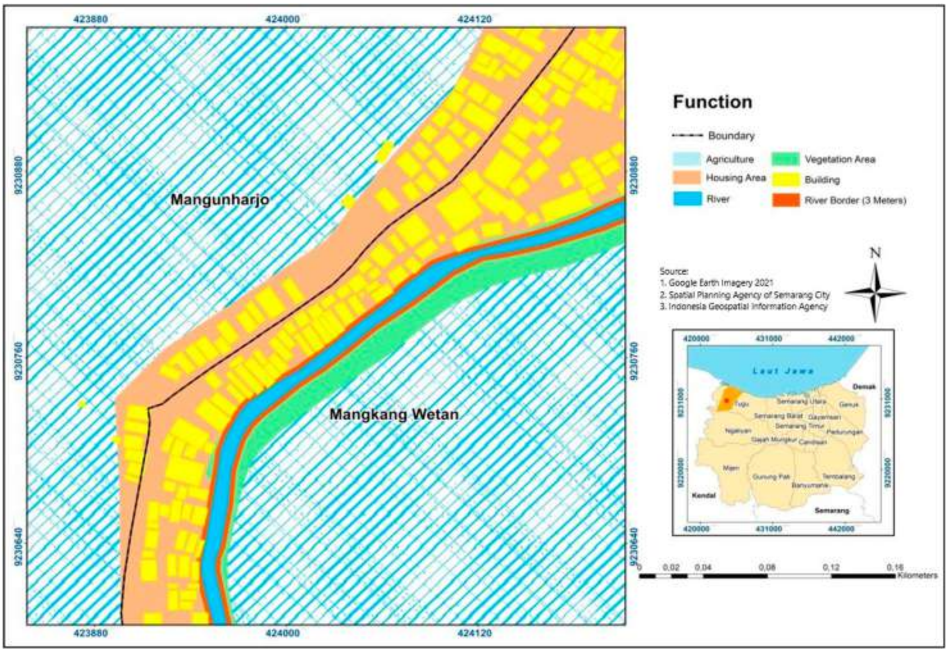

Figure 7. Settlement distribution at the riverbank area.

Floods decrease the environmental quality of the coastal area. Furthermore, the coastal area typically lacks adequate infrastructures, such as drainage, water, and sanitation networks. Settlement quality has also included poor, represented by semi-permanent houses. The community's self-improvement was difficult because of their economic limitations. Hence, the Semarang City government improved environmental quality through the Neighborhood Upgrading and Shelter Project Phase 2 (NUSP-2) of the Semarang City Non-Slum City programme. In addition, these three sub-districts were also included in the Resilient Coastal Sub-district programme by the Ministry of Maritime Affairs and Fisheries, which emphasized community empowering programmes and poverty alleviation.

Among the three sub-districts, Mangunharjo is prioritised for environmental quality improvement programmes due to recurring flooding and high abrasion risks. Moreover, some of the community settlements are adjacent to the coast, making them susceptible to significant abrasion during sea level rise. Hence, the government and the private sector (through Corporate Social Responsibility programmes) support multiple strategies to strengthen coastal barriers, i.e. through mangrove planting and coastal land conservation to reduce abrasion levels. Previous mangrove conservation attempt at Mangunharjo was unsuccessful because of the lack of community participation in maintaining mangroves. Moreover, sedimentation also contributed to this failure.

Economic benefit analysis for RWH initiatives

Not all study areas covered by the State-Water Company service. Hence, 55.03% of the total coastal area population uses groundwater generated from deep wells to fulfil their water needs. The use of surface water and rainwater to meet daily water needs is still non-existent, as opposed to other upstream communities residing in hilly areas (2.33%) that have started to implement simple water treatment methods for this purpose. Community members in the coastal area, especially those who do not have any wells at home, also rely on the community-based drinking water provision programme (*Penyediaan Air Minum dan Sanitasi Berbasis Masyarakat/*Pamsimas). However, the quality of water generated from deep wells and the *Pamsimas* programme was poor due to seawater intrusion, thereby it is unsuitable for consumption. As a result, people have to purchase commercially purified water for their daily needs. On average, people purchase 60–80 L of commercial reverse osmosis water for drinking and cooking per week, equivalent to IDR 80,000. Water generated by the *Pamsimas* programme, which is used for washing and other daily needs, cost approximately IDR 50,000 per month depending on how much water is used per household. In total, a household would have to spend IDR 370,000 per month for clean water for drinking, cooking, bathing, and other needs. On top of that, there is an additional cost for electricity to operate deep wells. The overall expenditure to provide water is up to 20% of a household's total income.

The government encourages the community to exploit alternative water sources, such as via RWH. Although this method has been known for centuries, the benefits of RWH should still be communicated to the community members. This includes the fact that RWH contributes to water-saving efforts, either related to daily consumption or agricultural use, minimises greenhouse gas emissions and pollution, and reduce water provision expenditures.

The sustainability of RWH implementation relies on rainwater debit. Semarang has low to moderate rainfall levels, about 5.64 mm on average in 2018. During the rainy season from November to April, the average rainfall rises to >300 mm (CBS 2020). The high rainwater volume generated during the rainy can potentially be used during the dry season. For instance, during the long dry season in 2019, which was extended to November, the community had to seek alternative clean water supplies.

The following analysis illustrates the potential efficiency of RWH for water provision in the study areas. This estimation refers to domestic RWH practice that utilises the roof of at building (house, office, or industry) as a rainwater collection area. Any rainwater that falls on the roof is then channelled through the gutter and stored in a tank, tub, water barrel, pond, or garden inside the house.

- The total roof area in three sub-districts is estimated at 569,652 m^2 (=56,965,200 dm^2). In 2018, the average rainfall was 5.64 mm/year (=0.0564 dm/year). Therefore, the total volume of rainwater falling on the roof of all houses in the study areas in one year is:
  $M = 56{,}965{,}200\ dm^2 \times 0.0564\ dm$
  $=3{,}076{,}120.8\ dm^3/year$
  =3,076,121 L/year
- With the assumption that only 80% of the total rainfall is harvested and the remaining 20% is lost due to evaporation or pipe leakage, the volume of water that can be harvested is:
  $=80\% \times 3{,}076{,}121$ L/year
  =2,460,896.8 L/year
  =2,460,897 L/year
- Assuming that a gallon of water costs IDR 5000 at 2,460,897 L or 649,677 gallons ($1\ L = 0.264$ gallons) of rainwater potentially harvested per year, then all households in the study areas could save up to IDR 3,248,385,000 per year.
- Given that all households in the study areas will implement RWH, then the volume of water captured through this method will be able to meet the water demand of one family for:
  $=2{,}460{,}897/(3 \times 4 \times 2510)$
  $=2{,}460{,}897/30{,}120$
  =82 days (more than two months)

The estimation above points out that water generated from RWH can meet the community's water needs for 82 days. A dry season in Semarang typically spans over six months from April to September. During a long dry season, such a period may be extended to seven or even eight months. Therefore, RWH alone is not enough to cover water demand during the entire period.

The above-estimated data were communicated to the prioritised community. Following that, we interviewed the community members to understand their perception of RWH implementation. The community members considered that the economical value of RWH was not significant because it would not cover water needs for the entire dry season. Moreover, the cost of RWH installation, such as for roof modification, tanks, and pipes, is not comparable to its benefits. The community members objected to purchasing RWH installation equipment and materials because of its high cost.

Aside from the installation cost, the community members were also unsure of the quality of rainwater for consumption. There was a common perception that rainwater contains many chemicals that are harmful to humans and other living being, including plants. In the rainwater harvesting process, microbiological contamination, such as by pathogenic bacteria, has been reported when rainwater flows through the roof (Sánchez, Cohim, and Kalid 2015; Zdeb et al. 2021). In addition, regional air quality also affects the quality of rainwater. The three sub-districts studied in this research are adjacent to an industrial area, where air pollution may contribute negatively to rainwater quality.

It's worth noting that the community members have practiced traditional water purification methods in their daily lives. Generally, people let the water settle for one night, then the next day filter it using a commercial filter or a clean cloth, then boil the water to kill pathogenic bacteria to make it fit for consumption. However, these methods have only been done for well water or water from the pipeline. In addition, there are no success stories regarding RWH practices to convince the community members to adopt this method themselves.

Despite that, 100% of the respondents are willing to apply RWH given that the government or other parties will assist in relevant equipment procurement. They only consider this method as an alternative and prioritise the use of water supply from *Pamsimas* and deep wells. They will implement RWH when the primary water sources are no longer available.

Analysis of community capacity on RWH

The capacity and willingness of a community to adopt RWH will determine the sustainability of water management. Hence, it is necessary to identify factors that will drive or hinder the community from implementing RWH. Is the cost the primary factor, or are there other factors influencing the community options? Here, we specify the principal factors related to this matter, as synthesised from the physical and socio-economic variables (Table 2). Factor analysis was done to define the key factors in RWH implementation. The first step was to determine the appropriateness of the data using KMO and Bartlett's Test (see Table 3).

An expected value of above 0.5 indicates that all data can be analysed further. The second step was to measure data adequacy for each variable and calculate the correlation between independent variables based on the Measure of Sampling Adequacy (MSA) value (Table 4). Table 5 showed that all independent variables had a value >0.5, which implied that all variables had adequate data to be analysed in the next step. The third step was to group the variables into three main factors based on their similarity (see Table 6). The fourth step is to assess each group to identify principal variables using Total Variance Explained analysis (see Table 7).

According to the percentage of variance, the most representative component was the Socio-Economic Factor, such as age, education, and income. The community prioritised the socio-economic benefits that they may get from RWH. Indeed, residents of the three sub-districts belong to the low-income group with limited financial power. The primary consideration for the community is more on how to fund RWH installation because it is relatively expensive (IDR 9,000,000 for a 1000-L capacity system). Meanwhile, they do not consider RWH as something urgently needed. They instead would rather fulfil their daily needs than spend money on something considered less crucial and with uncertain benefits.

This implies that the community members are more focused on short-term issues, particularly the money they have to spend for RWH installation. The long-term outcome or benefit, i.e. fulfilling water demand during the dry season, was not considered. Indeed, the community has economised the expenditure previously spent on buying water from water sales points. However, according to the government officials interviewed in this study, some RWH pilot projects in Semarang have failed in the

Table 2. The community capacity indicators.

No	Variable	Indicators
1	Age	Age > 64 = "1" Age 15–64 = "2"
2	Education	Unschooled = "0" Elementary School = "1" Junior High School = "2" Senior High School = "3" Diploma/Bachelor = "4"
3	Income	Less than IDR 2,000,000 = "1" IDR 2,000,000 – IDR 3,000,000 = "2" More than IDR 3,000,000 = "3"
4	Land Area	Less than 50 m^2 = "1" 50–100 m^2 = "2" More than 100 m^2 = "3"
5	Rain-Water Usage	No = "0" Yes = "1"
6	Knowledge	No = "0" Yes = "1"
7	Water Demand	Not yet fulfilled = "0" Fulfilled = "1"
8	Ability to pay	No = "0" Yes = "1"
9	Interest	No = "0" Yes = "1"
10	Willingness to participate	No = "0" Yes = "1"

Table 3. Summary KMO and Bartlett's test results.

Kaiser-Meyer-Olkin measure of sampling adequacy		.597
Bartlett's test of sphericity	Approx. Chi-Square	169.601
	df	45
	Sig.	.000

past due to a lack of public understanding of its importance. Even though the government and private sectors have provided full financial and technical support for RWH installations, the community members did not use them and abandoned them. This is related to how the community views the urgency of RWH; they did not see the benefits of implementing RWH, and they find the practice of RWH difficult because they do not understand how it works. Therefore, below are some recommendations enhance the community's understanding and participation in RWH implementation.

Building knowledge

A total of 90% of respondents did not understand what RWH, its purpose, or its mechanism is. Respondents who are elementary school graduates or below stated that they believed that the utilisation of rainwater for daily needs was not good because it would increase their tooth porosity rapidly. Porous teeth formation is caused by fluoride deficiency. Rainwater does not contain fluoride, but it is the high acid content that may cause tooth damage. It is also worth noting that chloride (Cl) concentration in groundwater has been increasing steadily for the past 20 years. The chloride content in clean water must not exceed 250 mg/L; levels higher than that indicate poor water quality. The underground water in Semarang coastal area has exceeded the maximum chloride level permissible in clean water (Semarang City Government 2016). Waterborne disease, such as diarrhoea, were recorded as top-ten diseases reported among people treated at the local Community Health Center (*Puskesmas*) in 2021 (Figure 8).

In addition, there are concerns that still water stored in the tank will become a breeding ground for mosquitoes, which can potentially aid the spread of dengue fever. As a result, the community

Table 4. Anti image matrices of factor analysis.

		Zscore: Age	*Zscore*: Education	*Zscore*: Income	*Zscore*: Land Area	*Zscore*: Rain-Water Usage	*Zscore*: Knowledge	*Zscore*: Water Demand	*Zscore*: Ability to pay	*Zscore*: Interest	*Zscore*: Willingness to participate
Anti-image Covariance	*Zscore*: Age	.835	−.145	−.068	−.044	−.045	.112	−.006	.080	−.009	.042
	Zscore: Education	−.145	.572	−.266	.078	−.044	.028	−.073	.061	.004	.026
	Zscore: Income	−.068	−.266	.442	−.175	.011	−.027	−.010	−.259	−.047	−.021
	Zscore: Land Area	−.044	.078	−.175	.838	−.065	−.067	.106	.023	.041	−.050
	Zscore: Rain−Water Usage	−.045	−.044	.011	−.065	.896	−.091	−.024	−.082	−.115	−.072
	Zscore: Knowledge	.112	.028	−.027	−.067	−.091	.735	.310	−.002	−.060	−.034
	Zscore: Water Demand	−.006	−.073	−.010	.106	−.024	.310	.713	−.070	−.119	.008
	Zscore: Ability to pay	.080	.061	−.259	.023	−.082	−.002	−.070	.693	.037	.098
	Zscore: Interest	−.009	.004	−.047	.041	−.115	−.060	−.119	.037	.701	−.329
	Zscore: Willingness to participate	.042	.026	−.021	−.050	−.072	−.034	.008	.098	−.329	.720
Anti-image Correlation	*Zscore*: Age	.734[a]	−.210	−.111	−.052	−.052	.143	−.007	.105	−.011	.055
	Zscore: Education	−.210	.635[a]	−.528	.112	−.061	.042	−.114	.096	.006	.040
	Zscore: Income	−.111	−.528	.578[a]	−.288	.018	−.047	−.017	−.468	−.085	−.037
	Zscore: Land Area	−.052	.112	−.288	.578[a]	−.075	−.086	.138	.031	.054	−.064
	Zscore: Rain−Water Usage	−.052	−.061	.018	−.075	.716[a]	−.112	−.029	−.104	−.146	−.090
	Zscore: Knowledge	.143	.042	−.047	−.086	−.112	.578[a]	.428	−.002	−.084	−.047
	Zscore: Water Demand	−.007	−.114	−.017	.138	−.029	.428	.593[a]	−.099	−.168	.011
	Zscore: Ability to pay	.105	.096	−.468	.031	−.104	−.002	−.099	.576[a]	.054	.138
	Zscore: Interest	−.011	.006	−.085	.054	−.146	−.084	−.168	.054	.547[a]	−.463
	Zscore: Willingness to participate	.055	.040	−.037	−.064	−.090	−.047	.011	.138	−.463	.557[a]

[a]Measures of sampling adequacy (MSA).

Table 5. Rotated component matrix.

	Component		
	1	2	3
*Z*score: Age	.478	.019	−.242
*Z*score: Education	.747	.085	−.195
*Z*score: Income	.870	.111	.090
*Z*score: Land area	.364	.089	.552
*Z*score: Rain-water usage	.228	.492	.171
*Z*score: Knowledge	−.122	.162	.775
*Z*score: Water demand	.245	.139	−.756
*Z*score: Ability to pay	.647	−.111	.086
*Z*score: Interest	.010	.838	−.108
*Z*score: Willingness to participate	−.140	.813	.050

Extraction method: principal component analysis.
Rotation method: varimax with Kaiser normalisation.
Rotation converged in 5 iterations.

Table 6. Total variance explained.

No	Factor	Variables
1	Socio-Economic	• Age • Education • Income • Ability to pay
2	Participation	• Rain-Water Usage • Interest • Community's Willingness
3	Resources	• Land Area • Knowledge • Water Demand

Table 7. Total variance explained.

	Initial eigenvalues			Extraction sums of squared loadings			Rotation sums of squared loadings		
Component	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	2312	23,122	23,122	2312	23,122	23,122	2240	22,398	22,398
2	1748	17,475	40,598	1748	17,475	40,598	1690	16,899	39,297
3	1503	15,029	55,627	1503	15,029	55,627	1633	16,330	55,627
4	984	9841	65,467						
5	836	8356	73,823						
6	776	7762	81,585						
7	591	5912	87,497						
8	514	5139	92,636						
9	452	4520	97,155						
10	284	2845	100,000						

Extraction method: principal component analysis.

members prefer to use existing water sources, including deep wells and *Pamsimas*. Dengue fever is a significant public health problem and the number of dengue fever cases increases every year. It is included in the ten priority disease list by the government. Semarang is an endemic area for dengue fever (Semarang City Health Office 2021). Therefore, water storage and water storage operations in RWH should be monitored and controlled to prevent the spread of this disease.

Responses from the questionnaire and interviews revealed that after the RWH facilities were installed, the community members attended a socialisation event, but the information they received is limited to the technical aspect of RWH facility usage and its benefits. They did not get anymore

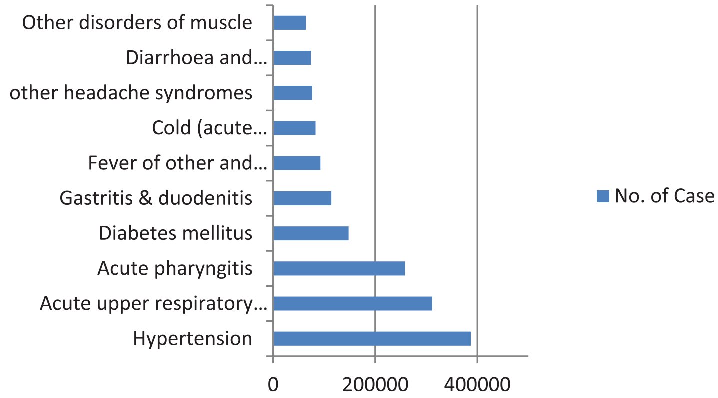

Figure 8. Top-ten disease reported at local Community Health Service Centers (Puskesmas) in Semarang 2021. Source: (Semarang City Health Office 2021).

assistance and education on RWH afterwards. Consequently, the community will go back to their understanding and perspective on the best way to water consumption.

Leadership and network building

RWH was initiated in Semarang by many parties, including the Environment Agency, Development Planning Agency (*Badan Perencanaan dan Pembangunan Daerah/*Bappeda), Public Works Agency *(Dinas Pekerjaan Umum/*DPU), university researchers, and international institutions such as ACCCRN. Moreover, as part of the 100 Resilient Cities network, Semarang has funding opportunities from national and international parties to establish clean water provision projects for vulnerable communities.

The challenge is operationalising the concept and method of water management at the local level so that community members can contribute actively. Community leaders should be involved in such water management programmes because they are role models and representatives of the community. Existing water management pilot projects, including those related to RWH, have always involved community leaders, such as the head of *Rukun Tetangga*/RT (the lowest division of government administration), *Rukun Warga*/RW (a government agency consisting of several RTs in a village), and the village community empowerment institutions (*Lembaga Pemberdayaan Masyarakat Kelurahan*/LPMK). For instance, in an RWH pilot project, the RWH facilities were first installed at the house of the head of RT or RW to encourage other community members to follow in their footsteps and participate in RWH as well. Likewise, good communication practices and active involvement from the community leaders are essential parts of RWH implementation.

Respect and comprehend the local values of the community

RWH is considered an appropriate method for water management at the community level because it gives equal opportunities to participate for all community members. With a model where the RWH facilities are set up on the rooftop of each home, community involvement is a significant factor (Jones et al. 2018). Community involvement can be encouraged through simultaneous approaches, such as having monthly meetings to sustain communication and discussion about RWH practices among community members. Such an informal setting will mediate a smooth communication process. Differences in socio-economic characteristics reflect the high heterogeneity of society, and therefore an appropriate approach is needed to ensure good communication.

Information support

Generally, RWH practices in Indonesia are done through a top-down approach, from its initiation to implementation. The community tends to be the object of a project, wherein their house RWH facilities are installed. However, the socialisation, assistance, and monitoring process have less been highlighted. The government, as the initiator, expects the active role of community leaders who have obtained the information from initial socialisation activities. However, this strategy did not run smoothly because the achievements of such projects are generally measured based on how many RWH facilities have been installed rather than the sustainability of the projects. This situation has occurred in several locations of RWH pilot projects, including in Semarang. The community members ended up leaving the RWH facilities unused.

Discussion

The success of RWH implementation in Semarang depends on the government as the initiator and community members as the beneficiaries. People prefer to purchase water for their daily needs. Even though they have to spend more money for this purpose, it is considered more practical than using RWH. The community members also perceived that RWH has no clear financial benefits. This shows that they act based on subjective knowledge and do not fully understand what RWH is and how it may benefit them (Liu et al. 2022). In addition, there are no examples or success stories from other regions where the community members use RWH daily, which also influences the subjective knowledge of the communities in our study areas. In the end, subjective knowledge tends to negatively affect intention to use, perceived usefulness, and people's attitudes (Figure 9).

Building community understanding of RWH is essential for programme success. A good understanding allows the community to properly operate and maintain RWH facilities (Bouabid and Louis 2015). However, developing community comprehension takes time and is not easy, it requires assistance from relevant stakeholders. The government and related stakeholders can start by establishing regulations that organise RWH implementation. Then, in the implementation phase, there needs to be assistance to apply the method and to facilitate subsidies and/ or incentives for the community (de Sá Silva et al. 2022; Yusop and Syafiuddin 2018). Top-down regulations allow for faster RWH implementation as financial support from the government and all parties involved in the programme have been pre-determined before the initiation of the programme. However, if RWH is initiated by the community members, it will be influenced by the community perception of the technology and its benefits. Subsidies are expected to reduce the need for personal contribution from the community members, thereby motivating them to implement and develop RWH. Increasing community capacity is coherent with poverty alleviation because it mediates community empowerment and better quality of life (Imbaya et al. 2019; Wignaraja and Yocarini 2008). Hence, it is essential to build a network with similar communities that practice RWH to transfer information and knowledge.

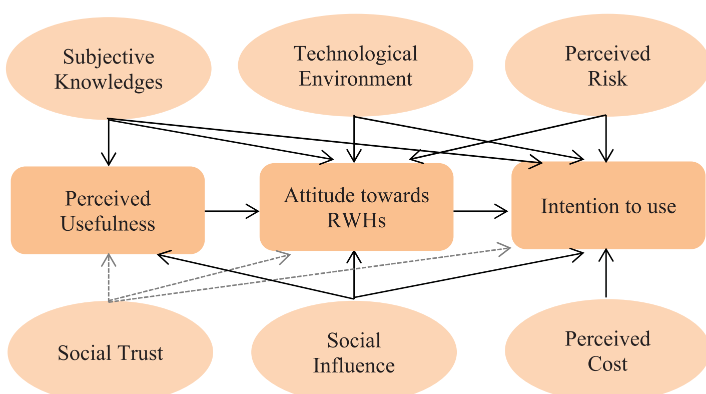

Figure 9. The theoretical framework of the RWH acceptance model. Source: (Liu et al. 2022).

On the other hand, there are no social issues related to the implementation of RWH. This can be seen from RWH pilot projects in other locations, where the community members were open to the programme and allowed their yards to be installed with RWH facilities. As long as the community members do not have to incur costs, they do not mind being subjected to a pilot project. However, such positive social trust is not necessarily correlated to the intention to use and attitude towards RWH.

Subjective knowledge is more dominant in determining community participation in RWH, including that related to the technological environment aspect. The problem is not the lack of trust in RWH technology, but people merely refuse to practice RWH even though the facilities have been installed because they do not understand the benefits to the environment, such as reducing runoff, deep water extraction, and land subsidence. The absence of outreach efforts and assistance for the community members after the RWH facility installation makes subjective knowledge unchanged.

Another aspect related to subjective knowledge is perceived risk, where people do not want to use RWH because they think rainwater is unsuitable for consumption and has a negative impact on health, such as the potential to increase tooth porosity and to become a breeding ground for dengue fever-transmitting mosquitoes.

One possible effort to increase public understanding is by cooperating with a third party as a bridge between the government as the initiator and the community members as beneficiaries. Such facilitation can be done by community leaders, village disaster preparedness groups, or NGOs. Their role is to alter the subjectivity of the community towards RWH. In addition, installation costs may be born through governmental subsidies. The government also needs to select an appropriate technology that minimises installation costs, for example by adapting the RWH facility design to the characteristics of the target area. Last but not least, it is necessary to expand the RWH location, which so far has been mostly applied to public facilities, to residential areas using either individual or communal set-ups.

Conclusion

RWH implementation in Semarang is intended to address the clean water shortage and reduce surface run-off. It is also expected to minimise groundwater exploitation and restrain land subsidence levels. RWH was initiated at the stakeholder in 2011, but the implementation is still at a pilot project scale. Furthermore, some RWH pilot projects failed because the community refused to participate. They emphasized that the instalment cost was not comparable to the benefits, and there are indications that they do not understand the paramount urgency of RWH. The community's understanding of the urgency of RWH from the environmental point of view and government assistance are the main factors that will drive successful RWH implementation. Assistance from the government or other parties only has a temporary effect because the most important thing is that the community members are willing and committed to implementing RWH. Support from the government and private sector is emphasized more on the technical aspect, i.e. RWH system installation for each household. Meanwhile, there is a lack of assistance to help the community understand the short-and long-term socio-economical and environmental benefits of RWH. Such understanding can bring a sense of belonging within the community so that they are willing to maintain RWH facilities. Despite that it is reasonable for a community to consider economic values as the main drive to implement RWH, this alone is not sufficient to sustain RWH practices. Therefore, it is also necessary to involve role models such as community leaders to enhance community awareness and encourage them to participate in environmental issues mitigation, including by adopting RWH.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

This study is part of the Research of International Publication (RPI) programme supported by the 2020 non-State Budget funds (non-APBN) Universitas Diponegoro [grant number 75000000].

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