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Sustainable Water Consumption Patterns and Factors: A Case Study of Income-Related Water Security

Zuraini Anang[1]*, Zulkifli Yusop[2,3], Ashok K. Sharma[4,5], Amera Otoum[1]

[1] Faculty of Business, Economics, and Social Development, UMT, Malaysia

[2] Centre for Environmental Sustainability and Water Security (IPASA), UTM, Malaysia

[3] Department of Water and Environmental Engineering, Faculty of Civil Engineering, Universiti Teknologi Malaysia, Malaysia

[4] Institute for Sustainable Industries and Liveable Cities, Victoria University, Australia

[5] College of Sport, Health and Engineering, Victoria University, Australia

***Corresponding author:** zura@umt.edu.my

Water security has become a critical issue worldwide in the 21st century due to rapid population growth, urbanization, and climate change. These factors have affected water availability, particularly for domestic consumption, leading to a potential water crisis. To better understand the factors affecting water security among various income groups and explore water consumption patterns, a study was conducted using a multiple regression model. The dependent variable was water security, and the independent variables were based on socioeconomic characteristics. A total of 571 residents from Malaysia's higher-income, middle-income, and lowest-income groups participated in the study. The study found that several factors significantly influenced water security, including race, household size, type of house, education, and income. In Johor, household size, type of house, and income explained 65% of the variance in water security for the overall income group. In Terengganu, race, type of house, education, and income explained 96% of the variance in water security for the overall income group. The variable income had a significant relationship with water security, with approximately 0.01% and 0.05% in Johor and 0.10% in Terengganu. These results indicate that socioeconomic factors play a crucial role in water security for both indoor and outdoor activities. Access to water is a basic need that affects the quality of life, especially for drinking water. Therefore, these findings are essential for water operators to manage and educate households through campaigns on sustainable water use and conservation. The lack of availability and access to basic water impedes individuals and communities from achieving a greater quality of life.

Keywords: water security, residential, water consumption, determinant, income group.

Introduction

Climate change, urbanization, and population growth have a significant impact on water security, which results in a reduction in the supply of safe and affordable drinking water for residential areas. The ultimate objective of the Global Water Partnership (2000) is to ensure clean, healthy, and sufficient water supplies while also

protecting and improving the environment. Piped-water households, as seen in a study conducted by Winter et al. (2021), reported being happier, healthier, and having more time to participate in employment within or outside the home.

One of the Sustainable Development Goals, specifically Goal 6, emphasizes the importance of access to clean drinking water for everyone, as highlighted by Akinyemi et al. (2017). Despite this, 2.2 billion people still do not have access to clean water sources, and it is expected to quadruple by 2030 (UN-Water, 2019). The global population is also expected to increase by three billion in the next fifty years, especially in developing nations (Jury and Vaux, 2005). Water scarcity can result from human actions or natural causes, but the consequences are catastrophic for the health, dignity, and prosperity of billions of people worldwide.

Moreover, there is a goal to improve water quality worldwide by 2030 by reducing pollution, eliminating dumping, and avoiding the release of dangerous chemicals and materials, halving the share of untreated wastewater, and significantly increasing recycling and safe reuse. Ambient water quality is critical for human and ecological health, and it has become a global concern in both developing and developed countries, as revealed in a study by Arora and Mishra (2022).

Household socioeconomic status may impact water security by improving access to and utilization of various water sources, such as piped-water versus open wells. Increased household resources may also be linked to improved toilet facilities and sanitation practices, according to a study by Garvey (2008).

As a result, the National Water Resource Study 2000-2050 expected that domestic water demand in Malaysia will rise in 50 years (2000-2050) to 5,904 million m^3 as opposed to the current 2,029 million m^3. Also, the overall volume is expected to increase to 17,675 million m^3 from the current 10,833 million m^3 (*Table 1*).

Table 1. *Water demand for Peninsular Malaysia (Million m^3/yr)*

Demand*	1998	2000	2010	2020	2030	2040	2050
Domestic	1,833	2,029	2,987	3,862	4,606	5,251	5,904
Industry	1,260	1,454	2,592	3,561	4,330	5,016	5,639
Both	3,093	3,483	5,578	7,423	8,936	10,267	11,543
Irrigation	7,350	7,350	6,517	6,517	6,517	6,132	6,132
Total	10,443	10,833	12,095	13,940	15,068	16,399	17,675

**Include losses*

Source: *Department of Irrigation and Drainage (DID) (2011) National Water Resource Study 2000-2050*

In the states of Johor and Terengganu, the total demand for water has increased across all economic sectors including residential consumption and industries. However, the total surface water availability has been decreasing every year due to water resources scarcity and pollution. These findings are presented in *Table 2*, which compares the total consumptive water demand against the total surface water availability for all sectors.

Numerous research studies have been conducted on the drivers of water quality and quantity, and their impact on the quality of life and health. Hamad et al. (2021) aimed to assess the susceptibility of the aquifer to contamination. In vulnerability maps, there are two classes of vulnerability - moderate and high - in the Morsott, Bakaria, and Foussana basins. The purpose of this research is to describe the physicochemical parameters and geothermal features of the El Hamma hydrothermal system in northeastern Algeria. The main thermal reservoir was discovered to be Jurassic limestone at depths of more than 2300 m, as studied by Benmarce et al. (2021). Hamad et al. (2021) explored the underlying structure of the collapsed basins of Hammamet-Tebessa and Foussana-Talah (Tunisia-Algeria). Benmarce et al. (2023) evaluated the hydrogeological properties of aquifers in the Guelma Basin.

Table 2. *Total consumptive water demand against total surface water availability for all sectors*

States	Land area, km²	Rain (mm)	Total consumptive water demand (mm)					Excess/Deficit (mm) – Unregulated flows				
			2010	2020	2030	2040	2050	2010	2020	2030	2040	2050
Johor	19,210	171.0	37.2	45.8	53.8	60.6	67.7	133.8	125.2	117.2	110.4	103.3
Kedah	9,500	112.5	307.6	313.2	299.1	302.4	302.8	(195.1)	(200.7)	(186.6)	(189.9)	(190.3)
Kelantan	15,099	175.5	108.1	107.2	105.0	106.0	106.2	67.4	68.3	70.5	69.5	69.3
Melaka	1,664	85.5	194.1	219.9	225.9	245.7	263.7	(108.6)	(134.4)	(140.4)	(160.2)	(178.2)
N. Sembilan	6,686	73.5	50.9	54.0	53.6	54.7	56.0	22.6	19.5	19.9	18.8	17.5
Pahang	36,137	165.0	20.1	26.2	24.8	25.2	26.5	144.9	138.8	140.2	139.8	138.5
Perak	21,035	139.5	92.7	91.4	85.5	85.6	86.1	46.8	48.1	54.0	53.9	53.4
Perlis	821	70.5	372.1	364.2	348.1	345.7	342.8	(301.6)	(293.7)	(277.6)	(275.2)	(272.3)
P. Pinang	1,048	120.0	729.9	790.9	797.1	834.2	853.3	(609.9)	(670.9)	(677.1)	(714.2)	(733.3)
Terengganu	13,035	253.5	67.8	74.8	74.4	76.6	78.7	185.7	178.7	179.1	176.9	174.8
Selangor	8,396	114.0	266.6	296.6	306.1	328.7	114.0	(152.6)	(182.6)	(192.1)	(214.7)	(234.0)
Sabah	73,631	177.0	12.4	18.4	18.9	19.6	20.0	164.6	158.6	158.1	157.4	157.0
Sarawak	124,450	220.5	8.5	17.4	17.1	17.5	18.1	212.0	203.1	203.4	203.0	202.4
WP Labuan	91	322.5	197.7	264.3	285.0	304.0	318.0	124.8	58.2	37.5	18.5	4.5
Malaysia	**330,803**	**44.7**	**52.0**	**51.7**	**53.5**	**55.1**	**225.0**	**180.3**	**173.3**	**173.3**	**171.5**	**169.9**

Source: *Department of Irrigation and Drainage (DID) (2011), National Water Resource Strategy (NWRS)*

Ncibi et al. (2021) examined a model that was independent of weight assignment errors and utilized it to carefully improve the assessment of groundwater vulnerability. This study also analyzed the specific vulnerability index (SVI) of groundwater in Sidi Bouzid North. It had a good association with NO_3– and gave a high level of discretization of the risk to groundwater from natural and anthropogenic pollution. This worrying situation highlights the importance of implementing water-saving irrigation practices for effective water management. Brahmi et al. (2021) aimed to assess the amount of groundwater and soil pollution within and around the municipal landfill southeast of Tebessa, Algeria.

In Bensoltane et al. (2021) study, the focus was on ensuring the safety of drinking water and that it adheres to regulations. Data was collected in Souk Ahras, Algeria to observe the changes in physicochemical characteristics that occur throughout distribution. Meanwhile, Dib et al. (2022) discovered that groundwater's hydro-geochemical behavior is influenced by various natural and man-made causes, which can impact its quality and acceptability for drinking. Hamed et al. (2022) study found that 67.74% of the respondents who suffer from breast cancer are female, while prostate cancer affects approximately 17.46% of male participants, making it the second most common type of cancer in both sexes. The study also noted that the proximity of the study area to mine regions is an exacerbating factor in cancer morbidity.

Besser et al. (2021) research focused on investigating the evolution of irrigation water quality and its respective impacts on the delicate balance between ecosystem healthy functioning and sustainable services, including anthropogenic activities such as farm households and irrigation practices. The study revealed that inadequate water management amplifies the amplitude of progressive land degradation. In Mohamad et al. (2020), Mohd-Asharuddin et al. (2016), and Halizah Awang et al. (2015) studies, water quality conditions, water quality and heavy metal were examined, as well as the hydrology and water quality of the Sembrong Dam in Johor. Fathullah et al. (2018) also examined water quality data from the detention pond at UiTM Pasir Gudang Campus (UiTMCJKPG) and explored the feasibility of this potentially possible water supply source for gardening and landscaping operations on this campus.

Water quality has been studied in various river basins and lakes in Terengganu. Suratman et al. (2015) investigated the water quality of the Paka River basin, while Kamarudin et al. (2020) found that the water quality of Kenyir Lake Basin was slightly polluted but still suitable for recreational activities. Omar et al. (2022) discovered that human-caused land use changes have impacted the water quality of the Jerteh River basin during the Northeast Monsoon season. Tengku and Ahad (2021) assessed the safety of the water in the Dungun River Basin for aquatic life based on chemical characteristics. Toriman (2018) conducted a study on the water quality parameters in Kuala Nerus, Terengganu. Kasan et al. (2023) evaluated the water quality parameters and nutrient levels of Nyatuh River in Setiu Terengganu in connection to the population of freshwater prawn. Masthurah et al. (2021) conducted a spatial water quality assessment of Juru River Basin, Kuantan River Basin, and Johor River Basin. Faudzi et al. (2023) aims to investigate the pollution levels in the Perai River Basin caused by changes in rainfall throughout the year.

Pak (2020) developed a site-specific Water Quality Index (WQI) for the Johor River Basin (JRB) to investigate the impact of external factors such as land use and point sources on water quality. Camara et al. (2019) examined the correlation between land use and water quality indicators, while Abd Wahab et al. (2019) demonstrated the problem of sedimentation.

Water pollution can have a severe impact on human health, with diarrhea being the most prevalent disease transmitted by enteroviruses in the aquatic environment (Lin et al., 2022). Overall, 85 relevant studies were selected based on keywords such as water pollution, water quality, health, and cancer. The degree of impact may vary depending on regional, age, gender, and other factors.

Water scarcity and related problems are caused by various factors such as prolonged hot weather or drought, radiation, human density or population growth, and climate change. These issues can have a significant impact on economic growth, human activity, health, and water quality. In their recent study, Rashid M. F. A. B. et al. (2021) found that water supply degradation, especially during droughts, can affect families and businesses, which are increasingly interconnected. Providing reliable water service is a complex decision-making process that depends on a variety of factors such as scarce resources, hydrological conditions, supply and demand shifts, rising per capita water demand, water pollution, groundwater over-abstraction, poor distribution, and the timing and severity of accidents that can cause water disruption (Pagsuyoin and Santos, 2021; Pecharroman et al., 2021).

A study conducted by Anang et al. (2019) found that water supply disruption has become a common occurrence in Malaysia, especially in Selangor and Kuala Lumpur, due to increased demand for domestic water usage resulting from rapid population growth, urbanization, and industrialization. In many parts of the country, demand for freshwater is expected to rise further while supplies fall, leading to water supply interruption. The increasing water consumption due to population growth can put a strain on the current water infrastructure. According to a Malaysian Water Association analysis, Selangor accounted for 49.50% of all Malaysian water supply challenges, which increased to 62.40% in 2017 (Rahman, 2021).

Although it is clear that water security studies should consider both the quantity and quality of water from both hydrological and social perspectives, the conventional paradigm has traditionally focused on quantity alone (Vogel et al., 2015; Gain et al., 2016). This omission of water quality from discussions about water security, as well as the tendency to evaluate both quantity and quality from an engineering and hydrology perspective rather than from a more comprehensive socio-hydrological perspective, is problematic. The amount and quality of available water, as well as the social, political, and economic structures and choices that govern the quantity-quality relationship, all affect water usage. (Vogel et al., 2015). The need to evaluate water security in an integrated and interdisciplinary manner has become increasingly apparent as our understanding of the complex relationship between water quantity, water quality, and human influences on both has grown (Vogel et al., 2015; Gain et al., 2016; Tundisi et al., 2015).

This study aims to investigate the quantity and quality of clean, safe water that households receive, as water plays a vital role in our health and constitutes more than 70% of our bodies. It is important to balance the demand and supply of water to avoid exacerbating the current water crisis. Therefore, this study will focus on households' water security by examining their water consumption patterns and identifying the factors that determine their water security. The ultimate goal is to identify the most critical drivers for achieving water

security and implement a water-saving approach to tackle water scarcity in the future.

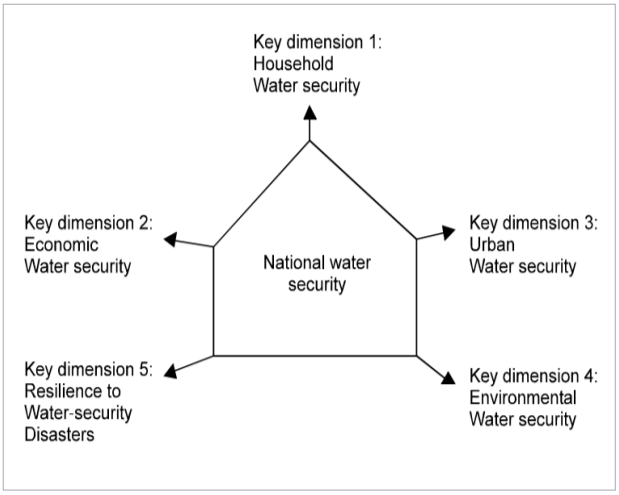
The paper's structure can be summarized as follows: the first section defines water security and its determinants, followed by the models, methods of analysis, and data sources used in the study. The last section discusses and interprets the empirical findings, drawing policy implications based on the results.

Literature Review

Definition of water security

Water security can be defined in various ways by different organizations. UNESCO-IHP (2012) describes water security as the ability to provide sustainable and adequate good-quality water for livelihood sustainability, promoting well-being and socioeconomic development, protecting against contamination and waterborne diseases, and maintaining peaceful and politically stable ecosystems. According to Water Aid (2012), water security is characterized by reliable and sufficient water sources based on quantity and quality for general, small-scale, and local ecosystem use, and it is managed under a system that effectively handles water-related disasters. The Asian Water Development Outlook (2013) identified five key dimensions that are critical to a nation's water security, which focus on people's well-being, livelihoods, reducing poverty, and governance to assess national water security. However, the Global Water Partnership (GWP) provides the most preferred definition, defining water security as ensuring that everyone has access to safe and affordable water for a productive, clean, and healthy life without compromising environmental protection and enhancement (GWP, 2000).

Fig. 1. *Dimension of water security*



Source: Adapted from AWDO (2013)

Water security, as defined by Grey and Sadoff (2007), is the reliable access to sufficient quality water, which is necessary for maintaining the well-being, livelihood, and productivity of individuals, while minimizing the risk of water-related disasters that could harm people, the environment, or the economy. Chenoweth et al. (2013) provide a simple definition of "household water security," which is ensuring that households have an adequate quantity and quality of water to maintain the health of their members. Jensen and Wu (2018) suggest that indicators for water security can be broken down into indices, including resources, access, hazards, and governance. Resource indicators include diversity (the variety of water sources), availability (the amount of resources available), and quality (raw water quality). Access indicators encompass service sustainability (the cost of water utility recovery), affordability, and capacity (supply coverage and capacity) (water tariff). Hazard indicators include floods (the frequency of flooding and flood damage) and public health threats (access, sanitation, and contamination incidents). Governance indicators include strategic planning, catastrophe management, and regulatory framework. Economic water security refers to water use for food production, manufacturing, and energy sectors to continue growing. Urban water security focuses on improving water management and services to support thriving, livable cities that are water-sensitive. Environmental water management involves monitoring the condition of rivers and aquifers and the advancement of national and local efforts to rehabilitate rivers, aquifers, and ecosystems. Finally, resilience to water-related natural disasters involves creating adaptable communities that can lessen the impact of changes.

Wutich and Ragsdale (2008) identified three aspects of water insecurity that can impact mental health: insufficient water supply, poor access to water distribution networks, and reliance on seasonal water sources. Their study focused on the quantity and quality of water available to residential properties for domestic activities like cooking, bathing, and showering. The study

found that access to water distribution systems and female gender were significantly associated with emotional distress, while water supply and dependence on seasonal water sources were not significant.

To ensure water security, societies must effectively manage their water resources and services to meet the demands of each aspect of water security, especially residential water security. This involves providing reliable and secure services to everyone for water and sanitation. Several key components are necessary to achieve and maintain water security, including ensuring access to enough drinking water at reasonable prices to meet basic needs such as hygiene, protecting livelihoods, human rights, and recreational and cultural values. It is also crucial to preserve and protect ecosystems in water allocation and management systems to ensure they can continue to provide essential ecosystem services, water resources for activities and socioeconomic development (such as energy, transportation, industry, and tourism), preserving the environment and human lives by collecting and treating wastewater. Using cooperative methods to manage transboundary water resources inside and between nations can help improve freshwater management.

An imbalance between the demand for water and the available supply can lead to water scarcity and insecurity, which can negatively impact the quality of life and cause diseases. In this study, household water security is defined as having access to a sufficient quantity of water that meets the standard quality set by the Ministry of Health (MOH), making it safe and secure for drinking. Water operators have a responsibility to manage and treat the available water resources effectively. The components of ecosystem services that contribute to water resources should be preserved and protected to ensure that residential customers have access to secure and safe water.

Water tariff and expenditure on water bill in Malaysia by States

The water tariff determines the monthly water bill, which differs throughout Malaysian states. The most expensive water rates are in Johor, and Labuan. Pulau Pinang has the cheapest water rates as reported in *Table 3*.

Table 3. *Domestic tariff ranking in 2020*

State	Last tariff review	Average water tariff (RM/m$^{3)}$					
		For first 20m^3		For first 30m^3		For first 35m^3	
		(RM/m^3)	Ranking	(RM/m^3)	Ranking	(RM/m^3)	Ranking
Pulau Pinang	2015	0.22	1	0.30	1	0.32	1
Pahang	1983	0.41	2	0.54	3	0.57	3
Terengganu	1997	0.42	3	0.50	2	0.52	2
Kelantan	2013	0.45	4	0.62	4	0.67	4
Perlis	1996	0.48	5	0.55	8	0.57	3
Kedah	2010	0.50	6	0.63	5	0.67	4
Perak	2006	0.50	6	0.67	6	0.71	6
N.Sembilan	2015	0.55	7	0.65	8	0.68	5
Selangor	2006	0.57	8	0.72	7	0.77	7
Melaka	2015	0.60	9	0.72	9	0.75	8
F.T. Labuan	2015	0.70	10	0.87	9	0.91	9
Johor	2015	0.80	11	1.20	10	1.31	10
Average		0.52		0.66		0.71	

Note: RM is Ringgit Malaysia
Sources: Malaysia Water Industry Guide 2022

Households in Malaysia spent 6% of their income on water bills, according to data from Bank Negara Malaysia (BNM) in 2019. The remaining portion of their income was spent on housing, water, electricity, gas, and fuel, as reported by the International Labour Organization (ILO) in 2010. However, the percentage spent on water bills increased to an

estimated 25.6% in 2019, according to *Table 4*. The Household Expenditure Survey (2019) reported that the highest expenditure on water bills was estimated to be RM64.92 in Labuan and RM24.66 in Kelantan, based on the composition of monthly household consumption expenditure by subgroups of expenditure, state, and strata.

Table 4. *Expenditure pattern on water bill by states in Malaysia (2019)*

States	Water bill	
	RM	%
Johor	48.53	0.97
Kedah	35.61	1.00
Kelantan	24.66	0.68
Melaka	39.39	0.79
N Sembilan	44.51	0.97
Pahang	36.39	0.92
P Pinang	32.84	0.70
Perak	42.23	1.18
Perlis	33.39	0.96
Selangor	43.97	0.75
Terengganu	34.21	0.79
Sabah	36.04	1.29
Sarawak	30.77	0.89
WP Labuan	64.92	1.58
WP Putrajaya	52.20	0.65

Source: Household Expenditure Survey Report 2019

Households spend 22.2–25.6% of their total expenditure on housing, water, electricity, gas, and other fuel, with no major differences between poor and non-poor households, as reported in *Table 5*.

Table 5. *Composition of monthly household consumption expenditure by household income group in Malaysia (2019)*

Household Income Group	Housing, water, electricity, gas and other fuel	
	(RM)	%
Top 20%	2054	22.2
Middle 40%	1036	22.8
Bottom 40%	636	25.6
Average	**1242**	**23.53**

Source: Household Expenditure Survey Report 2019

Determinants of water security

Various studies have found that a number of factors such as socioeconomic development, environmental conditions, climate change, and geography significantly affect water security around the world. According to Zawahri (2017), climate change, population growth, socioeconomic development, and poor management practices are the key factors impacting water security. The study focuses on assessing water access and availability in terms of price, quality, circulation, and usage, as demonstrated by Zerah (2000), Savenije and van der Zaag (2002), Machiwa (2003), Ribot and Peluso (2003), and UNEP (2010).

Researchers have conducted various studies on factors that influence water security in different regions. For instance, Sinyolo et al. (2014) found that socioeconomic characteristics such as farmer age, location, training, off-farm income, and association participation were important in boosting water security. However, conflict was a major factor in the decline of water security. Similarly, Sharaunga and Mudhara (2016) noted that farmer age, land access, and association membership led to a decrease in water security in South Africa's irrigation systems.

In another study, Elias Nkiaka (2022) analyzed the socioeconomics of water security in three emerging regions: Africa, the Asia-Pacific, and Latin America and the Caribbean (LAC). The study used five independent variables, namely governance, GDP per capita, urban population percentage, official development assistance for water and sanitation services (ODA-WSS), and the percentage of female primary school graduates. The study created a water security index (WSI) using two socioeconomic variables, integrated water resources management, and three biophysical variables: water accessibility, environmental conditions, and climate risk. The results indicated that water security had a significant correlation with ODA-WSS in regions with higher levels of ODA-WSS per capita than in those with lower levels.

Several studies have also been conducted to identify factors that influence water demand. Some of these factors include population (Koo et al., 2005; Rao 2005), water price (Agthe and Billings, 2002; Martinez-Espineira, 2002; Liu et al., 2003; Neto et al., 2005; Rinaudo et al., 2012; Yoo et al., 2014), dwelling or housing type (Troy and Holloway 2004; Kowalski and Marshalsa, 2005), income (Liu et al., 2003), and household size (Martinez-Espineira, 2002; Liu et al., 2003; Bradley 2004).

Several studies have suggested that achieving water security (SDG6) could make it easier to achieve other SDGs since water has the potential to facilitate the accomplishment of multiple objectives (Di Baldassarre et al., 2019; Taka et al., 2021). The failure to achieve water security could lead to significant consequences for society, such as adverse effects on human health, ecological breakdown, exacerbation of food and energy shortages, and even armed conflict in regions where there is a lack of sufficient water resources. Physical and infrastructural components such as hydrological patterns, artificial water storage, topographical features, and conveyance facilities, as well as institutional constraints like statutory laws, customary laws, and other types of inequality, are all important factors in determining water security (Sharaunga and Mudhara, 2016).

Ningi et al. (2021) examined the Hamburg and Melani coastal areas of South Africa's Eastern Cape province to identify the factors affecting water security status among rural households. They used the water poverty index (WPI) to determine the water security status between the two communities and measured the household's primary determinants of water security using the Tobit regression model. The results indicate that households face water security issues due to water scarcity and the lengthy process of obtaining water. The Tobit regression analysis showed that payment, toilet types, and the time to get water were significant factors influencing households' access to water in these locations. Therefore, securing clean and safe water is essential for human well-being.

Sharma et al. (2016) explored the sustainability of current urban water systems under various challenges, such as aging infrastructure, climate change impacts, urbanization, and population growth. Their research applied Integrated Urban Water Management (IUWM) and Water-Sensitive Urban Design (WSUD) approaches.

According to Mishra et al. (2021), the demand for water resource systems has increased significantly due to global development, such as urbanization, growing population, climate change, evolving energy needs, and socioeconomic changes. Promoting sustainable development is crucial in achieving global water security. Although research on the topic is still in its early stages, comprehensive studies with evolving dimensions are necessary to understand water security, current environmental changes (such as urbanization and socioeconomic changes), and their implications. In their research, Dau and Adeloye (2021) examined the impact of socioeconomic and climatic changes on water resources in the Beas-Sutlej River basin in the Himalayas. To analyze the potential effects, they combined five climate models into multiple-model ensembles using the Shared Socioeconomic Pathway SSP 1 and the Representative Concentration Pathway (RCP) 8.5 scenario. Their study uses a narrative review approach to understand water security and proposes various environmentally friendly strategies to achieve it.

In Australia, researchers have used various methods to study water conservation behavior. For instance, Loh and Coghlan (2003) used multivariate linear regression analysis and decision trees to determine the best factor to predict self-reported water conservation behavior. Umapathi et al. (2019) conducted a monitoring-based investigation of rainwater collection systems in Adelaide, South Australia, using economic performance indicators to support water demand. Newton and Meyer (2012) also used linear modelling and multiple regression to identify factors that influence water demand and conservation behavior, such as energy, water, carbon-intensive travel, housing, and domestic appliances in Melbourne, Australia.

Water insecurity can lead to various illnesses such as diarrhea, eye and skin infections, and worm infestations. Malnutrition and stunted growth, caused by water insecurity, can reduce productivity and impair learning and brain functioning. According to UNDP (2006), water is so vital for human survival that there is no alternative to it. Deprived access to good water resources can be due to human factors such as inappropriate policies, programs, and natural forces. Both man-made and natural factors influence water security, and when these factors link, they can threaten the concerned household members' ability to access water (Buzan et al., 1998). Lack of access to clean water for consumption, cooking meals, and cleaning is an existential threat that demands prompt action from the government (Weaver et al., 1996).

Methods

The study area

This research was conducted in Johor Bharu, Johor and Kuala Terengganu, Terengganu. Johor Bharu is the capital of Johor state and is located near the southern end of Peninsular Malaysia, on the north bank of the Johor Strait, opposite the city-state of Singapore. The city

has a total area of 391.25 km^2 and a population of 858,118 people. Johor Bahru was also the second highest GDP contributor among Malaysian states. Kuala Terengganu, on the other hand, is the capital of Terengganu state, located on Peninsular Malaysia's East Coast, approximately 440 kilometers northeast of Kuala Lumpur. The city is situated on the Terengganu River's estuary and borders the South China Sea. *Fig. 2* presents the map.

Research framework

The research framework is illustrated in *Fig. 3*. It outlines the research objectives, identification of household groups, selection of various characteristics for survey development, creation and testing of the questionnaire, data collection and analysis covering water consumption patterns and socioeconomic characteristics. Lastly, the interpretation of analysis is conducted. The study makes a significant contribution to the development of water security policies, which is highlighted in the report.

Data collection and sampling

This study surveyed 571 residential participants in Malaysia, including those from the higher-income (T20), middle-income (M40), and lowest-income (B40) groups. B40 represents the Bottom 40% of income earners, M40 represents the Middle 40%, and T20 represents the Top 20% of Malaysian household incomes. The questionnaire focused on water consumption patterns, opinions toward water security, and socioeconomic variables.

To analyze the data, an econometric technique was applied to obtain estimators of the coefficients. Monthly expenditures for different groups of households on water consumption or monthly water bill were the main data needed for security analysis. Cross-sectional data was used to determine the relationship between water security and gender, number of children, house type, family members, and income. The data was collected in Johor Bharu, and Kuala Terengganu was chosen to represent both urban and rural areas in Johor and Terengganu.

Fig. 2. *Study area*

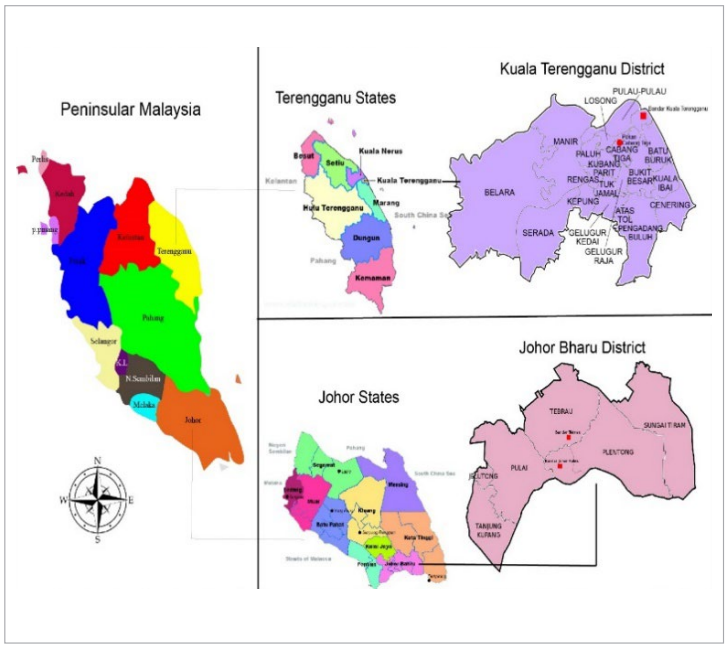
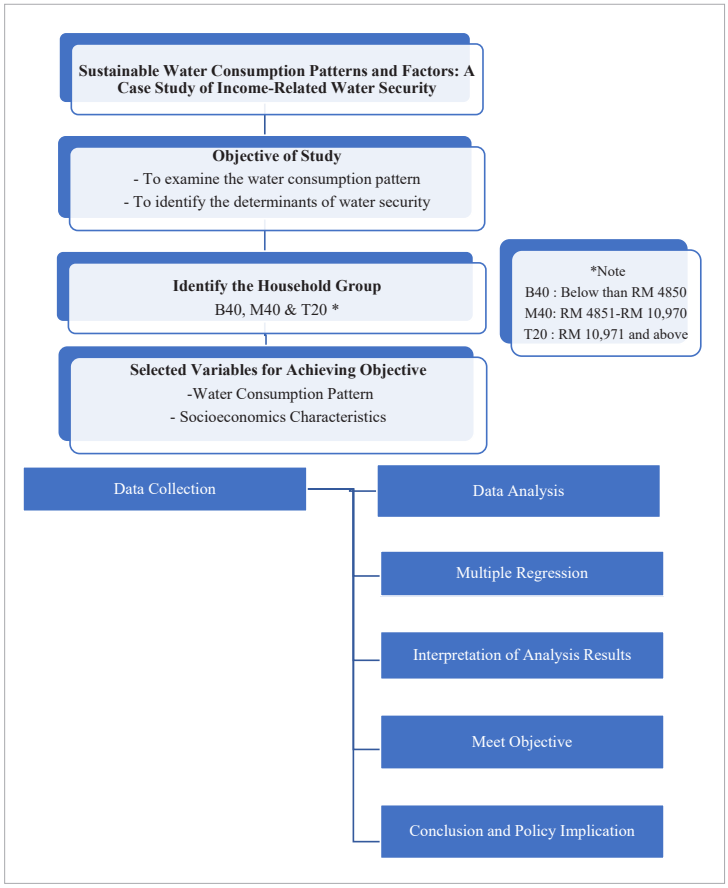


Fig. 3. *Research framework*



Johor Bharu was chosen due to the polluted water from the river, such as the Kim Kim River, and critical water levels at the Sembrong Dam during the drought season. Customers also complained about increased water bills due to replacement of water meters, even though there was no leakage found at home. Poor quality of water in terms of taste, color, and odor during the flood and drought seasons, some staff being unfriendly, and notice of water disruption not covering the whole affected area, particularly in rural areas, were other reasons for selection. On the other hand, Kuala Terengganu was chosen due to customer complaints about water pressure, pipe burst and leakage, notice of water distribution not covering the whole affected area, particularly in rural areas, water billing, and meter.

Finally, random sampling was conducted to select the village and housing areas in the chosen areas. The model used is as follows:

$$\text{water\_sec} = \beta_0 + \beta_1 gen + \beta_2 race + \beta_3 age + \beta_4 child + \\ + \beta_5 family + \beta_6 house + \beta_7 educ + \beta_8 work + \beta_9 inc + \varepsilon \quad (1)$$

Where: water_sec is the water security (water bill monthly); *gen* is gender; *race* is race; *age* is age; *child* is the number of children; *family* is household size number; *house* is the type of house; *educ* is education; *work* is work; *inc* is income; *e* is the error term and respectively in Johor and Terengganu.

The study conducted descriptive analysis and multiple regressions to examine the factors that affect a household's water security. To analyze this, the study used linear regression with the monthly water bill as the dependent variable and socioeconomic variables such as gender, race, age, children, family size, type of house, education, work, and income as independent variables. The main goal of this research was to understand the water consumption pattern and analyze the factors that affect water security among different income groups.

Socioeconomic profile

The study involved 201 households in Johor, which has the highest GDP, and 370 households in Terengganu, which is among Malaysia's lowest GDP. Face-to-face interviews were conducted in Johor Bharu, and Kuala Terengganu district was chosen as the representatives of urban and rural areas in Johor, and Terengganu, respectively. The study analyzed the socioeconomic factors influencing the security of households with regards to housing and utilities, including water bills. The study considered various socioeconomic demographics such as gender, marital status, education sector, head of household (HoH), household size, and gross income. These factors were analyzed to determine their impact on households' security.

Table 6. *Socioeconomic characteristics profile (N= 571)*

		Johor	Terengganu
Items	Respondents	N - (%)	N - (%)
Gender (Head of Households - HoH)	Male	119 (59.2%)	173 (46.8%)
	Female	82 (40.8%)	197 (53.2%)
Race	Malay	133 (66.2%)	289 (78.1%)
	Chinese	31 (15.4%)	35 (9.5%)
	Indian	36 (17.9%)	25 (6.8%)
	Others	1 (0.5%)	21 (5.7%)
Education	Primary school	5 (2.5%)	19 (5.1%)
	Secondary school	33 (16.4%)	188 (50.8%)
	College	46 (22.9%)	51 (13.8%)
	University	117 (58.2%)	112 (30.3%)
Household Size Number	Less than 2 people	26 (12.9%)	44 (11.9%)
	3 - 5 people	101 (50.2%)	148 (40.0%)
	6 - 8 people	62 (30.8%)	105 (28.4%)
	More than 9 people	12 (6.0%)	73 (19.7%)
Type of House	Terrace	124 (61.7%)	109 (29.5%)
	Semi Detach	46 (22.9%)	70 (18.9%)
	Bungalow	20 (10.0%)	69 (18.6%)
	Others	11 (5.5%)	122 (33%)
Gross Income	Less than RM4360	63 (31.3%)	272 (73%)
	RM4361-RM9619	99 (49.3%)	74 (20.0)
	More than RM9620	39 (19.4%)	24 (6.5%)

The majority of households in Johor and Terengganu are headed by males, with 59.2% and 46.8%, respectively. Most of the survey respondents were Malay. The education levels of the respondents varied, with approximately 39% having completed the Lower Secondary Assessment/Malaysian Certificate of Education (PMR/SPM) or equivalent, 16.9% having completed a Diploma or Certificate, and 40% having a degree or higher education. In Johor, 61.7% of the households lived in terrace houses, while in Terengganu, 33% lived

in other types of housing. In terms of gross income, the majority of respondents in Johor (31.3%) and Terengganu (73.5%) earned less than RM5001.

Water consumption pattern

Table 7 displays the patterns of water demand and usage in households. The tap water is the primary source of water supply, with almost 100% usage in both Johor and Terengganu, estimated at 93.5% and 94.9% respectively. The primary water-using appliances are the shower, bathtub, and flushing toilet. The shower is mostly used for personal hygiene, with a frequency of twice a day, taking about 20 to 30 minutes per bath. The residents who prefer to take a shower are females who are young and educated and are more concerned about hygiene. The laundry is done almost every day, with one to two loads. The residents who prefer to do laundry are females who are young and educated.

Table 7. *Residential water demand and use patterns of the household*

Items	Johor N - (%)	Terengganu N - (%)
What is the major source of household water supply?		
Indoor tap water	188 (93.5%)	351 (94.9%)
Shared tap	7 (3.5%)	15 (4.1%)
Well	4 (2.0%)	2 (0.5%)
Others	2 (1.0%)	2 (0.5%)
What is the major water-using appliances and their number?		
Shower	72 (35.8%)	99 (26.7%)
Flushing toilet	27 (13.4%)	87 (23.5%)
Hand basin	29 (14.4%)	50 (13.5%)
Washing machine	50 (24.8%)	94 (25.4%)
Dishwasher	10 (5.0%)	30 (8.1%)
Others	13 (6.5%)	10 (2.7%)
For personal hygiene, which of the following do household members use?		
Shower	171(85.1%)	325 (87.8%)
Tub bathing	21(10.4%)	17 (4.6%)
Others	9 (4.5%)	13 (3.5%)
What is the bathing frequency?		
Once a day	12 (6.0%)	11 (3.0%)
Twice a day	121 (60.2%)	132 (35.7%)
Three times a day	65 (32.3%)	126 (34.15)
One a week	3 (1.5%)	-
How long does each shower last?		
Less than 10 min.	32 (15.9%)	81 (21.9%)
20 min. to 30 min.	100 (49.8%)	167 (45.1%)
30 min. to 40 min.	54 (26.9%)	23 (6.2%)
40 min. to 60 min.	15 (7.5%)	3 (0.8%)
Others	-	2 (0.5%)
Who most frequently takes a shower among the HH members?		
By sex:		
1=male	26 (12.9%)	98 (26.5%)
2=female	173 (86.1%)	224 (60.5%)
By age:		
1=young	187 (93.0%)	271 (73.2%)
2=elderly	13 (16.5%)	94 (25.4%)
By educational status:		
1=more educated	175 (87.5%)	310 (83.8%)
2=less educated	26 (12.9%)	60 (16.2%)
In a typical week, what is the frequency of household go laundry?		
Everyday	97 (48.3%)	241 (61.9%)
Once three days	65 (32.3%)	101 (31.9%)
Once a week	37 (18.4%)	22 (5.4%)
Others	2 (1.0%)	6 (0.8%)
How many loads of laundry do you usually do?		
One load	80 (39.8%)	229 (61.9%)
Two loads	71 (35.3%)	118 (31.9%)
Three loads	41 (20.4%)	20 (5.4%)
Others	9 (4.5%)	3 (0.8%)
Whose clothes are most frequently washed among the HH members?		
by sex:		
1=male	25 (12.4%)	107 (29.0%)
2=female	175 (87.1%)	263 (71.0%)
by age:		
1=young	187 (93.0%)	250 (67.6%)
2=elderly	14 (7.0%)	15 (4.1%)
by educational status:		
1=more educated	174 (86.6%)	295 (79.7%)
2=less educated	26 (12.9%)	75 (20.0%)

Empirical analysis and discussion

A multiple regression analysis has been conducted to determine the socioeconomic factors affecting water security in each state, based on income groups. Residential customers were divided into three groups based on income, and the most important variable leading to water security in the future was identified to prevent water crisis and shortage of water for domestic water consumption. The significant variables have been explained in detail.

Table 8 illustrates the factors influencing water security by income groups B40, M40, and T20 in Johor and Terengganu. In Johor, three socioeconomic variables significantly influenced water security for the overall income group, namely household size, type of house, and income. The result showed that all the independent variables explained 65%, and the model was a good fit with a p-value of 0.001. Additionally, income was significant at 1%, while household size and type of house were significant at 5%. In the B40 group, the significant variables were household size, type of house, and income, all significant at 5%. In the M40 group, only household size was significant at 5%, while type of house and education were significant at 1%. In the T20 group, household size and education were significant at 5%, while type of house and income were significant at 1%.

Table 8. *Estimating factors affecting water security for B40, M40 and T20*

Income Group	Johor State			Terengganu State		
Overall	coefficients	standard error	P-value	coefficients	standard error	P-value
(Constant)	21.002	8.997	.020	30.893	10.283	.003
Gender	-.399	2.469	.872	2.339	2.858	.414
Race	-2.169	1.508	.151	-5.332	1.859	**.004*** **
Age	1.333	1.579	.399	2.126	1.786	.235
Number of Children	-1.241	1.627	.446	1.144	1.730	.509
Household size number	3.444	1.507	**.023****	-1.352	1.541	.381
Type of House	-2.515	1.027	**.015****	-2.597	1.141	**.024****
Education	2.266	1.431	.114	3.543	1.606	**.028****
Work	1.038	1.653	.530	-2.385	1.874	.204
Income	6.011	1.884	**.002*****	6.022	2.428	**.014****
B40	coefficients	standard error	P-value	coefficients	standard error	P-value
(Constant)	31.224	9.133	<.001	41.547	10.652	<.001
Gender	-.212	2.485	.932	2.490	2.869	.386
Race	-2.039	1.515	.179	-4.974	1.858	**.008*** **
Age	1.610	1.580	.309	2.205	1.794	.220
Number of Children	-1.201	1.634	.463	1.064	1.742	.542
Household size number	3.422	1.514	**.024****	-1.470	1.548	.343
Type of House	-2.493	1.036	**.016****	-2.622	1.147	**.023****
Education	2.706	1.425	**.058****	3.804	1.607	**.019****
Work	1.177	1.667	.480	-2.056	1.885	.276
Income	-6.511	2.668	**.015****	-6.153	3.293	**.063****

Income Group	Johor State			Terengganu State		
M40	coefficients	standard error	P-value	coefficients	standard error	P-value
(Constant)	25.475	9.083	.005	35.099	10.263	<.001
Gender	-.549	2.506	.827	2.643	2.884	.360
Race	-2.042	1.525	.181	-4.761	1.871	**.011****
Age	1.960	1.583	.216	2.405	1.801	.183
Number of Children	-.976	1.643	.553	1.219	1.757	.488
Household size number	3.209	1.522	**.035****	-1.740	1.551	.263
Type of House	-2.780	1.042	**.008*****	-2.769	1.153	**.017****
Education	3.671	1.382	**.008*****	4.331	1.595	**.007*****
Work	.835	1.683	.620	-2.116	1.918	.271
Income	1.111	2.741	.685	1.611	3.650	.659
T20	coefficients	standard error	P-value	coefficients	standard error	P-value
(Constant)	30.311	8.976	<.001	39.308	10.205	<.001
Gender	-.944	2.473	.703	2.259	2.856	.430
Race	-2.315	1.512	.127	-5.713	1.878	**.003****
Age	1.383	1.581	.382	2.238	1.781	.210
Number of Children	-1.057	1.627	.516	1.486	1.729	.391
Household size number	3.254	1.507	**.031****	-1.482	1.534	.335
Type of House	-2.829	1.023	**.006*****	-2.738	1.137	**.017****
Education	2.759	1.395	**.049****	3.739	1.587	**.019****
Work	.538	1.654	.745	-3.060	1.897	.108
Income	11.491	3.864	**.003****	14.929	5.761	**.010****

Note: ** Significant at 0.10% ** Significant at 0.05% ***Significant at 0.01%*

In Terengganu, four socioeconomic variables significantly influenced water security for the overall income group, namely race, type of house, education, and income. The result showed that all the independent variables explained 96%, and the model was a good fit with a p-value of 0.001. Race, type of house, education, and income were all significant variables.

In Terengganu, the income group, race, and income are significant at 1%. The types of houses and education are significant at 5%. In the B40 group, the variable race remains significant at 1%, while the type of house, education, and income are significant at 5%. For the M40 group, education is significant at 1%, while race and type of house are significant at 5%. In the T20 group, race is significant at 1%, and the type of house, education, and income are significant at 5%.

The type of house also affects water security on the demand side. This is because a larger house has more rooms, is bigger, and has fewer toilets than a smaller house. Additionally, the level of education is a driver of water security. More educated residential customers tend to consume water in a sustainable manner because they are aware of the value of water as a precious resource.

Gender also plays a role in water consumption, with females consuming more water compared to males. This is because they are usually home managers and use washing machines and dishwashers for laundry and washing dishes. Age is also a factor in water

security since young residential customers tend to use more water than older people in their daily activities.

The variables of education and race are similar to those identified by Zawahri (2017) as drivers of water security. In terms of race, the majority of survey respondents were Malay, suggesting that they consume more water for daily activities. This behavior is influenced by factors such as a high frequency of indoor and outdoor activities, low awareness of water-saving measures, and low water tariffs (Muhammad N.S. et al., 2021). Additionally, age and income (Liu et al., 2003) are also factors that impact water security, as highlighted by Sinyolo et al. (2014) and Alkire (2003), respectively. Furthermore, Mishra et al. (2021) and Dau and Adeloye (2021) also identify socioeconomic factors as contributing to water security.

According to Rockowitz et al. (2018), income is an important factor in determining the affordability of monthly water bills for households. They found that low-income individuals in each county reported paying an average of 10% of their monthly household income for water services, which is more than twice the reasonable rate of 4.5% suggested by the US EPA. However, households value the availability of water and are willing to pay what they can. In fact, less than 2% of respondents anticipated receiving free water services.

Hailu et al. (2020) and Bacon et al. (2021) found that variable income is a crucial determinant of household water security. Their research discovered that having a higher income in rural areas significantly protects water quality (OR 7.35), while an increase in household size is associated with a decrease in water availability (OR 0.44).

Moreover, the overall group's income, specifically the B40 and T20 groups, are significant at 1% and 5%, respectively.

The results of the study show that income group, type of house, and household size number have a similar influence on water consumption as found in previous studies (Buzan et al., 1998; Martinez-Espineira, 2002; Liu et al., 2003; Bradley, 2004). The study also revealed that households consider water as an essential component of daily life, required for tasks such as drinking, cooking, washing, and gardening.

The study highlights the pattern of residential water consumption in daily activities and its linkage with socioeconomic conditions. To ensure water security, water companies must develop a water management strategy by reviewing the water tariff and setting a standard price for water. This new price should encourage residential customers to value water highly and apply conservation strategies to save on water bills as well as utility expenses. The water companies can also run programs and campaigns to educate residential customers on sustainable water usage.

These findings are crucial for researchers to identify the significant drivers of water security, particularly in areas with large populations and developing regions. Researchers can compare developed and developing states, and examine water security from different perspectives, including geographical, behavioral, climate change, and determinants or drivers of water security. They can also use other methods of economic valuation, such as Choice Modeling.

The findings have significant implications for policy development. By focusing on the socioeconomic characteristics of residential customers, policymakers can strengthen current policies to promote sustainable water consumption. This is particularly important during times of drought, when water is scarce. Although water is relatively cheap compared to other utilities like electricity and telecommunications, it's essential to use it wisely. Therefore, the government should implement policies to ensure sustainable water management and encourage wise water usage.

Conclusions and Policy Implications

This study focused on water security and the socioeconomic factors affecting it in Malaysia. Water security is crucial for sustainable economic and human growth. The study revealed the pattern of water consumption among households, identified the factors leading to water scarcity, and determined the most significant socioeconomic variables affecting water security, such as race, type of house, education, household size, and income.

The findings of this study are useful for water operators to manage and educate households on the importance of using water sustainably and conserving it. Lack of access to basic water supply can negatively impact people's quality of life. Policymakers can use the findings to develop effective policies for managing water security sustainably. The government can raise awareness about the value of water through social

media campaigns targeting people of all ages, from kindergarten students to higher education students.

Understanding water security is vital for developing sustainable water management practices that balance demand and supply. Households can practice water-saving techniques in their daily activities, such as using water-saving appliances and recycling water for gardening.

At the policy and governance level, an integrated approach to water security is essential. Stakeholders should be involved in setting priorities and making decisions, and water governance should be improved to achieve sustainable water management. This new paradigm for achieving water security should provide enough water for domestic, industrial, and commercial activities, clean drinking water, proper sanitation, and wastewater treatment to reduce water pollution.

Future Research

This research study is focused on identifying the factors that affect water security in Malaysia. The study uses linear multiple regression to analyze the relationship between various socioeconomic variables and water security. The respondents are divided into three income groups. The study found that income is the most important factor affecting water security, particularly in achieving sustainable water consumption.

In Malaysia, residents are required to pay a monthly bill based on the amount of water used, which varies depending on the state. This water tariff can influence the pattern of domestic water consumption and water security in the future. With an increasing population and urbanization, the demand for water consumption keeps rising. However, the supply of fresh water is experiencing a decline due to pollution and climate change, especially during the dry season.

This leads to a critical shortage of water in the reservoir, which affects the supply of treated water to residential customers. Therefore, it is important to conduct research that focuses on the determinants of residential behavior toward water security. Economic valuation methods such as Choice Modeling and SEM AMOS can be used to identify the most effective policies to achieve sustainable water management. The findings of this research can be compared to determine the best course of action for policymakers.

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