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Sociodemographic determinants of water conservation behavior: A comprehensive analysis

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ABSTRACT

The manifold repercussions of climate change encompass diverse facets, encompassing the management of resources, agricultural infrastructure, production systems, and their profound implications for food security, self-sufficiency, and the overall well-being of societies. Regrettably, a significant portion of the populace remains indifferent to or uninformed about the adoption of water conservation practices. Previous scholarship has scrutinized factors influencing individual water-saving behaviors, yet these inquiries have predominantly overlooked the broader contextual elements shaping communal conduct. This study undertakes a comprehensive investigation to discern the multifaceted factors and sociodemographic variables that exert influence upon the water-saving conduct of individuals within a community. Primary data were collected through structured questionnaires administered to a sample of 633 participants. Employing rigorous factor analysis, we distilled a reduced set of factors from the multitude of variables under examination. Factor 1 exhibits a robust association with the utilization of water conservation equipment, while Factor 2 delineates patterns in water usage behavior. Furthermore, this research advances the discourse by deploying a probit model to delineate the relationship between sociodemographic characteristics, such as gender and occupation, and community engagement in water conservation in response to government incentives. Notably, the significance of these models is comparable across different sociodemographic groups, highlighting that both women and individuals with diverse occupational profiles stand to benefit from incentivized water-saving initiatives.

1. Introduction

The high population growth rate and increasing community activities will impact the provision of community needs such as clean water. The consequence is the increasing need for water to meet basic needs and other activities. On the one hand, the increasing water demand is faced with the constraint of increasingly limited water sources, one of which is due to climate change. On the other hand, climate change is a condition of several climate elements whose magnitude and intensity tend to change or deviate from the dynamics and average conditions towards a particular direction (trend) (increase or decrease). The leading cause of climate change is human activity (anthropogenic) which is related to

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increasing greenhouse gas (GHG) emissions such as CO_2, methane (CH_4), NO_2, and CFCs (chlorofluorocarbons) which are driving global warming and have been going on for almost 100 years (Kooch et al., 2022).

The effects of climate change are multi-dimensional, starting from resources, agricultural infrastructure, and production systems to aspects of food security and self-sufficiency, and general welfare. The influence is distinguished by two indicators, namely vulnerability, and impact. Vulnerability to climate change is "conditions that reduce the ability (humans, plants and livestock) to adapt or carry out physiological/biological functions, development/phenology, growth, and production and reproduction optimally (reasonably) due to stress. The impact of climate change is disorders or conditions of loss and gain, both physical and social, and economically, caused by climate change stress (Palinkas and Wong, 2020).

In terms of the impact of climate change on water resources, there have been many reports on this matter globally—Indonesia's water resources (Gany et al., 2019). Indonesia's water resources sector, especially the island of Java, has undergone many changes with environmental degradation and reduced water quality, and several studies have declared it a severe critical status (Umami et al., 2022). As a complex system, changes in the water resources sector are influenced by many factors, such as population pressure with all its activities, land use, exploitation of water resources, including groundwater, and physical infrastructure development (Priyan, 2021). The water crisis in Indonesia occurs due to the gap between population-driven water demand and the availability of water supply from the main rivers in the region.

The Regional Drinking Water Company (PDAM) is a regionally owned business unit that distributes clean water to the public. However, as time goes on and technology advances, the need for clean water increases with an increasing population. People do not realize the importance of conserving the use of clean water. The use of technology in education is often perceived to be lower than in other fields such as industry, agriculture, transportation, and communication. In fact, in this era of globalization, the development of science and technology is swift, especially in transportation, telecommunications, informatics, and so on. Making animated educational media using computerized technology makes the media more engaging and interactive to increase people's motivation to save clean water (Khan et al., 2021).

Unfortunately, many people take it for granted without trying to know or apply ways to save water. If expensive expenditures are made, the water supply might dwindle. Water is scarce in some African nations facing drought (Besada and Werner, 2015). Therefore, it is essential to implement ways to save water by maintaining its availability. The ways to save water that can be implemented include checking the faucets and water pipes to ensure there are no leaks and ensuring the faucets turn off after use (El-Nwsany et al., 2019). Then don't let the faucet run when cleaning or rinsing vegetables, fruit, and dishes (Das and Mondal, 2021). Make efforts to catch rainwater for use (Elder and Gerlak, 2019). Even using the dishwasher can significantly reduce water use (Mazzoni et al., 2023). Society must also turn off a faucet/not let the water run while brushing teeth. Finally, use a hose when washing vehicles and watering plants (Taleb and Sharples, 2011). There have been several studies in the past that focused on examining factors that impact water conservation initiatives. In previous studies, the focus was solely on the actions that may be taken to reduce water use; the factors that influence community behavior were not considered. This study aims to investigate the causes and socioeconomic classes that impact people's actions regarding supporting water-saving measures.

2. Method

The quantitative method with a descriptive and causal type of study is used in this research. This research aims to analyze the causal relationship between the independent variables into a group of causes supporting water-saving efforts. The method used in this research is a descriptive and causal type of study. Primary data, which were acquired from informants via questionnaires, made up the source of the data. There was a total of 633 participants in the sample.

The sampling technique utilized was a simple random sample, which ensures that every individual in the population has an equal chance of being chosen as a representative sample. Data collecting approaches include surveys both online and offline. The venue of the sample will take place in the Jakarta metropolitan region. Data were processed using the SPSS version 25 application to see the forming factors. The questions used a Likert scale of 1 to 5, where 1 is to disagree while 5 is to agree strongly. As mentioned in the introduction, the question indicators regarding behavior for water use in this study contained nine questions. This indicator will be reduced in factor analysis. In total, the questions used can be seen in Table 1.

Factor analysis is a technique for simultaneously analyzing the interdependence of several variables to simplify the relationship between the variables studied into fewer factors than those studied (Patnaik and Tarei, 2022). This means factor analysis can also describe the data structure of a study. In theory, factor analysis combines numerous variables with commonalities to use them as a single factor. This makes it feasible to condense several aspects that impact one variable component into several primary factors that are less in number. The construction of variance and covariance matrices, the principal component analysis (PCA) method, criteria for estimating the number of factors, and factor rotation are the phases of factor analysis.

Table 1: List of water-saving behavior questions

No.	Question	Indicator
1	I often check the tap and water pipes so that there is no leak (Tap and Pipes)	I1
2	I often make sure the tap is off after use (Tap off)	I2
3	I do not let the tap keep flowing when ignoring or rinsing vegetables, fruits, and dishes (Keep flowing)	I3
4	I often catch the rainwater (Rainwater harvesting)	I4
5	I often use a dishwasher (Dishwasher)	I5
6	I turn off the tap/not let the water flow when brushing my teeth (Torn off brushing)	I6
7	I put up a water-saving sensor for every tap at home (Sensor)	I7
8	I don't use a hose when washing the vehicle (Hose for washing vehicle)	I8
9	I don't use a hose to water the plants (Hose water the plants)	I9

In factor analysis, the goal is to reduce the total number of factors to a more manageable size than the original number of variables. The eigenvalues, % variance, and scree plots provide the foundation for the methodology applied in this research project to figure out the total number of components involved. The eigenvalues are used as the foundation for the first evaluation criterion. The variation connected to a factor may be determined by its Eigenvalue. Factors that have an eigenvalue that is either equal to or greater than one will be kept, while factors that have a value that is less than one will not be included in the model. This is because variables with less than one value are not superior to those originally used.

Cluster analysis is a multivariate technique that aims to classify objects that differ from one group to another. K-means is an unsupervised learning algorithm. K-Means has a function to group data into data clusters. This algorithm can accept data without any category labels. The Clustering Algorithm method groups some data into groups, explaining that data in one group have the same and different characteristics from data in other groups.

Lastly, we ask binary questions to respondents whether they want to make efforts to save water with incentives from the government. In this question, where the answer is yes will have a value (1) while the answer will not get a value (0). The predictor variable in this study uses community sociodemographic data from cluster analysis.

Then in this question, a model was carried out with logit and probit regression based on the total respondents and the class formed (Suryawan et al., 2023). In binary logistic regression, the link between the response variable (y), which is dichotomous or binary, and the predictor variable (x), which is polychotomous, may be found by comparing the two sets of values. The probit model is a nonlinear model that assumes the normal distribution of the error factor I and employs binary integers (dummy variables) as the response variable. The probit model is a type of nonlinear model.

3. Results and discussion

Before entering the factor analysis stage, the first step is to make several assumptions, namely the assumption of data adequacy and correlation between variables. Next, a data adequacy test is required to ensure that the data collected and presented in the weighing report is objectively adequate. The Kaiser Mayer Olkin test (KMO) aims to determine whether all the data taken can sufficiently be factored in (Shrestha, 2021). The KMO value in this study is above 0.5, which means that factor analysis can be carried out with results that can be accounted for (Table 2).

Table 2: Calculation results of the Kaiser-Meyer-Olkin measure of sampling adequacy and Bartlett's test of Sphericity

Kaiser-Meyer-Olkin measure of sampling adequacy	0.767	
Bartlett's test of Sphericity	Approx. Chi-square	1504.843
	df	36
	Sig.	0

Table 3 shows the results of multivariate data reduction (a lot of data), which seeks to change (transform) an initial/original data matrix into a set of fewer linear combinations but absorbs most of the amount of variance from the initial data. The primary objective of this stage is to explain as much of the original data's variation with as few of the principal components, also known as factors, as feasible. The number of factors (components) that can be extracted from the original data is as many as there are variables. In addition, PCA is a statistical technique that aims to simplify the observed variables by reducing their dimensions (also known as data reduction techniques). The main principle in PCA is that there is a correlation between variables (Kherif and Latypova, 2020). If this happens, then there is the researcher's estimation that some of these variables can be reduced. The judgment that is made is based on the scree plot. A figure that compares the eigenvalues to the total number of components extracted is called a scree plot. The point at which the scree first begins to appear indicates several distinct variables, the most important of which is when the scree starts to level off. Based on Fig. 1, it is known that the scree point starts to level out at the initial variable extraction at the 7th point. It is possible to conclude, based on the combination of the three criteria, namely eigenvalues, a percentage of the total variance, and a scree plot, that the most suited factor extraction is comprised of two factors.

Examining the Component Matrix shown in Table 4 is the final stage of identifying the factors. Table 4 demonstrates a strong link between factor 1 and the variables equipment, I1, I4, I5, I7, I8, and I9. Equipment in water-saving service operators are the ones responsible for the operation of the project as well as the maintenance (Li et al., 2020). Meanwhile, factor 2 is connected to how people use water daily. I2, I3, and I6 are all indicators included in factor 2. Research shows that behavior-based treatments may help boost water conservation programs (Lede et al., 2019). For example, it was demonstrated that providing social norms information outlining the water-saving behavior undertaken by water-efficient households and providing personalized feedback led to reduced consumption in a water-scarce region in Australia (Fielding et al., 2013). Compared to a condition with information only or no treatment at all, the condition with personalized water consumption feedback and normative information about the usage of other families reduced the amount of water households use (Kurz et al., 2005).

Table 3: PCA calculation results for initial eigenvalues and extraction sums of squared loadings

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of variance	Cumulative %	Total	% of variance	Cumulative %
1	3.136	34.842	34.842	3.136	34.842	34.842
2	1.621	18.008	52.85	1.621	18.008	52.85
3	0.92	10.221	63.071			
4	0.758	8.424	71.495			
5	0.735	8.164	79.659			
6	0.704	7.826	87.485			
7	0.481	5.342	92.827			
8	0.352	3.914	96.741			
9	0.293	3.259	100			

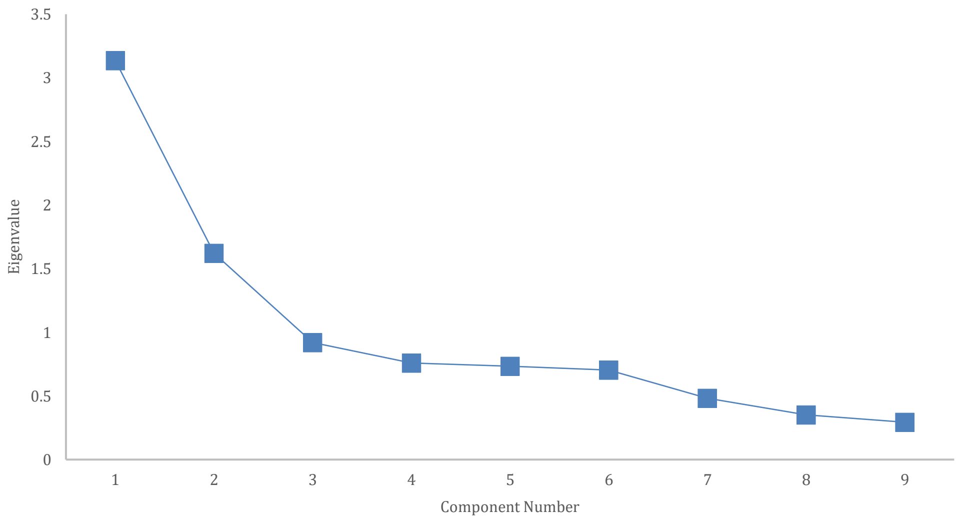

Fig. 1: Scree plots

Table 4: Component matrix

Component Matrix	Factor	
	Equipment	Human Behavior
I1	**0.483**	0.466
I2	-0.096	**0.685**
I3	0.382	**0.51**
I4	**0.514**	-0.389
I5	**0.755**	-0.322
I6	0.211	**0.641**
I7	**0.802**	-0.06
I8	**0.8**	-0.042
I9	**0.765**	0.046

K-means clustering is a popular unsupervised data mining and machine learning technique. The main objective of K-means clustering is to partition a given set of data points into k clusters, where each data point belongs to the cluster with the nearest mean. In this process, the algorithm tries to minimize the sum of the squared distances between the data points and their corresponding cluster centers. This sum of squared distances is known as the objective or distortion function. To achieve this, the K-means algorithm randomly initializes k cluster centers, then iteratively assigns each data point to the nearest cluster center and updates the cluster centers' positions. This process continues until the cluster assignments no longer change significantly or a maximum number of iterations is reached.

Table 5 displays the K-means clustering results with two significant clusters. Cluster 1 has a high level of human behavior, while Cluster 2 has behavior at the level of equipment used in making efforts to save water. This means that the algorithm has grouped the data points into two clusters based on their similarities and differences regarding their level of human behavior and equipment usage. In general, K-means clustering aims to minimize the objective function by maximizing each cluster's similarity and the dissimilarity between different clusters. This is achieved by adjusting the cluster centers' positions to represent the best data points within each cluster. Table 6 presents the sociodemographic characteristics of the community, organized according to the class groupings that have emerged. Based on the analysis, there are significant gender disparities in how men and women engage in actions aimed at conserving water, as the p-value is greater than 0.05. Specifically, most individuals in class 2 are female, indicating they are more likely to reduce their water use through devices. The analysis also shows no statistically significant relationship between the education level and class grouping (p-value less than 0.05), meaning that grades 1 and 2 have the same educational personality, and no one stands out as dominant.

Table 5: Results of cluster formation and ANOVA on cluster forming factors

Factor	Cluster		F	Sig.
	1 (n=269)	2 (n364)		
F1: Equipment	-0.45541	**0.33656**	114.435	0.00
F2: Human behavior	**0.85103**	-0.62892	729.155	0.00

On the other hand, there is a statistically significant relationship between age group and class grouping (p-value greater than 0.05), with a higher proportion of individuals between the ages of 30 and 39 belonging to class 2. This suggests that they are more likely to reduce water usage through technology rather than behavior change. Similarly, the analysis indicates that married individuals within the same age range are more likely to use equipment to conserve water. Moreover, the analysis suggests that residents who work formally and informally tend to conserve water using equipment. In contrast, those living in flats and other housing types tend to conserve water through various equipment. Lastly, residents who still board their animals tend to conserve water due to their conduct, and they live in boarding houses. These findings suggest that there are different patterns of water-saving behaviors across different sociodemographic groups in the community. These patterns are influenced by gender, age, marital status, work status, housing type, and animal-boarding practices.

Lastly, we modeled the class formed by doing a model with a probit equation to see the desire of community participation to save water if they get incentives from the government. This incentive is one of the efforts to reduce the carbon footprint of water use sources. The carbon tax is a tax on carbon emissions that harm the environment. So, imposing a reward tax for the community with this carbon tax scheme will certainly reduce environmental impacts and incentivize the community. Thus, we try to use binary for people who want incentives from saving water (1) or not (0).

Table 6: Socio-demography of respondents based on cluster groups formed

Variable		Component	Cluster 1	Cluster 2	Total
Gender	Male	Count	100	168	268
	Female	Count	169	196	365
		χ^2 = 5.109, df=1, p=0.024			
Education	Postgraduate	Count	16	29	45
	Bachelor	Count	155	218	373
	High school below	Count	98	117	215
		χ^2 = 1.860, df=2, p=0.392			
Age	20-29	Count	203	207	410
	30-39	Count	55	135	190
	>40	Count	11	22	33
		χ^2 = 23.665, df=2, p=0.000			
Marital Status	Married	Count	45	135	180
	Single	Count	224	229	453
		χ^2 = 31.507, df=1, p=0.000			
Occupancy	Formal	Count	104	205	309
	Non-Formal	Count	42	76	118
	No work	Count	123	83	206
		χ^2 = 37.156, df=2, p=0.000			
Settlement	Apartment	Count	27	63	90
	Slum area	Count	64	49	113
	Boarding house	Count	55	46	101
	Housing	Count	123	206	329
		χ^2 = 24.425, df=3, p=0.000			

The utilized model considers the community's sociodemographic characteristics, including gender, age, marital status, occupancy, and settlement (Nguyen et al., 2021; Phan et al., 2022; Sutrisno et al., 2023). Both Table 7 have visual representations of the models. Both models exhibit relevance for the two sociodemographic categories of society, namely gender and occupancy, comparably.

Gender is contemplating that gender-based taxation can be used for an incentive-based water-saving program. In addition to the topic of whether or not there is a gender component in the capacity of informal enterprises to contribute to tax revenues, a more specific question that has been posed is whether or not tax rates and female gender ownership influence informality (Tahir et al., 2021). The tax system can give affirmation or assistance to women who must already pay for delivery. Personal habits and the external environment are also among the elements that influence water-saving behaviors. Adopting technology that saves water and enhancing a building's overall water efficiency are both aspects of water conservation. Both the frequency with which males and females consume water throughout this process and the primary water sources that families of farmers utilize are distinct. Therefore, farmers of different genders and with varying home water sources have varying perspectives on water conservation (Su et al., 2021).

Table 7: Logit model of community willingness to take part in water-saving incentive programs

Variable Names	Logit Model					
	All		Cluster 1		Cluster 2	
	Coeff.	Std. error	Coeff.	Std. error	Coeff.	Std. error
Constant	4.04264***	0.82708	1.8412	2.08023	4.13095***	0.95665
Gender (1 represents male, otherwise is 0)	-1.36882***	0.43122	-0.09021	0.94742	-1.71668***	0.53237
Age (1 means 20-29, >29 is 0)	-0.34827	0.64552	-0.57407	2.05999	-0.15435	0.66784
Marital status (1 means single, otherwise is married)	-0.68498	0.67934	1.25927	2.05823	-1.09394	0.74431
Occupancy (1 means working, otherwise is 0)	1.17289**	0.51942	1.91481	1.35267	1.44283**	0.56614
Settlement (1 represents apartment and housing, otherwise is 0)	-0.31366	0.4357	1.49373	1.19201	-0.57475	0.53671
−2Log likelihood	-114.68283		-24.87961		-85.77572	
Chi square value	$\chi 2$ (0.01, 5) = 11.070					

*** and ** denote the significance level at 1% and 5%, respectively

Different demographic groups have distinct water consumption patterns and needs. Factors such as household size, income levels, and cultural practices influence water usage. Understanding these variations helps in designing targeted interventions and educational campaigns that address specific needs and promote water-saving behaviors (Kurz et al., 2005; Addo et al., 2018). Sociodemographic characteristics influence individuals' attitudes, beliefs, and behaviors toward water conservation (Wolters, 2014), also supported by this research finding. By considering sociodemographic factors, programs can be tailored to address specific barriers and motivations, increasing the effectiveness of water initiatives (Liu et al., 2015). Water scarcity and access to clean water are global challenges, but they affect different population groups unequally. Sociodemographic factors such as income, ethnicity, and geographical location can determine access to water resources and infrastructure. Understanding these disparities helps in designing inclusive policies and programs that ensure equitable access to water-saving practices (Cairns, 2018). Sociodemographic factors provide insights into the social and cultural contexts that shape individuals' behaviors. Tailoring water-saving interventions to specific demographic groups helps in leveraging social norms, values, and peer influence to encourage behavior change. This approach increases the likelihood of sustained water-saving practices. Sociodemographic data assists policymakers in identifying areas or population groups that require targeted water conservation efforts.

Based on the findings presented in the study, several policy recommendations can be made to encourage community participation in water conservation efforts. First, incentivizing conservation efforts through reward taxes and other policy measures can encourage individuals and households to adopt water-saving technologies and behaviors. Second, policymakers should consider developing targeted strategies that address the unique needs and preferences of different population segments, considering sociodemographic factors such as gender and occupancy. Third, awareness-raising campaigns can increase public understanding of the importance of water conservation and individuals' role in reducing their carbon footprint. Fourth, developing collaborative approaches involving community members, local organizations, and government agencies in designing and implementing conservation programs can build trust and foster a sense of ownership and accountability among stakeholders. By implementing these policy recommendations, governments and organizations can promote more sustainable water use practices and reduce the carbon footprint of water use sources.

This study has several implications for supporting the Sustainable Development Goal (SDG) 6, which aims to ensure the availability and sustainable management of water and sanitation for all. First, we highlight the importance of community participation in water conservation efforts. By involving communities in the design and implementation of conservation programs, policymakers can promote more sustainable water use practices and increase public awareness of the importance of water conservation. The study suggests that targeted strategies that address different population segments' unique needs and preferences can effectively promote behavior change. By considering sociodemographic factors such as gender and occupancy, policymakers can develop more effective water conservation programs tailored to different groups' specific needs. We also suggest incentivizing conservation efforts through reward taxes and other policy measures can encourage individuals and households to adopt water-saving technologies and behaviors. This can help reduce the carbon footprint of water sources and promote more sustainable water use practices.

4. Conclusion

This research carries profound implications for the advancement of sustainable development objectives pertinent to water resource management. In its primary dimension, the discernment of pivotal determinants influencing water conservation behavior lends strategic insights to policymakers, facilitating the formulation of precisely targeted initiatives aimed at fostering the widespread adoption of sustainable practices. For instance, the study underscores the conspicuous correlation between the utilization of machinery and equipment and water conservation, while concurrently highlighting the significance of behaviors relating to water consumption. Policy architects, therefore, possess the capacity to fashion bespoke programs attuned to these specific drivers, thereby amplifying the potency of behavioral change initiatives and augmenting public consciousness regarding the imperative nature of water conservation.

In a complementary vein, this study accentuates the indispensability of integrating sociodemographic variables into the blueprint of water conservation programs. Notably, gender and occupational status emerge as salient factors warranting meticulous consideration. By tailoring conservation endeavors to accommodate the distinctive requisites and proclivities of diverse societal cohorts, policymakers can conceive strategies more attuned to achieving their objectives and mobilizing broader societal participation in the stewardship of sustainable water resources.

Lastly, this research posits a prescriptive stance advocating the earnest consideration of energy and water-related concerns. It posits the proposition of levying taxes upon the water industry as a mechanism to curtail demand and galvanize the espousal of sustainable practices. By instituting fiscal incentives for individuals and corporate entities to engage in prudent water usage, policymakers can inculcate a heightened adherence to sustainable practices and expedite the transition towards a more sustainable and equitable societal paradigm.

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Compliance with ethical standards

Conflict of interest

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