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Research Paper

Linking poverty with water and sanitation in targeting households for achieving sustainable development

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ABSTRACT

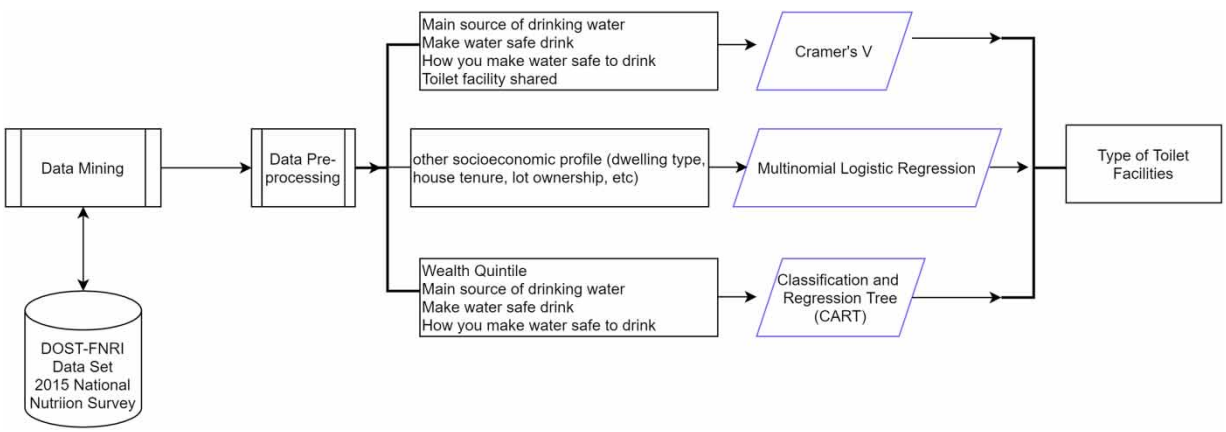
The study determined the association of access to safe water and the type of toilet facilities versus household characteristics in the Philippines. Data from the Department of Science and Technology Food and Nutrition Research Institute consisting of 39,771 respondents were included in the analysis. Cramer's V was used as a statistical tool to determine the association of toilet facility versus the access to safe water, water source, and whether the toilet is shared or not. Additionally, multinomial logistic regression was used to predict the type of toilet facility with other household characteristics. Meanwhile, a Classification and Regression Tree was used to classify the type of toilet facilities based on access to safe water, water sources and a wealth quintile. Statistically, the result showed that there is a high association among the variables mentioned. The study concludes that access to sanitation such as the type of toilet facility per household, is highly associated with water sources and access to safe water. Furthermore, there is a need to provide means of access to sanitation among the poorest households. To reduce the inequalities in these services, the decision rule presented in this study can be a guiding principle in providing such intervention.

Key words: data mining, poverty, sanitation, supervised learning, toilet facilities, water source

HIGHLIGHTS

- The poorest wealth quintile households have various sources of water which are unsafe and unprotected.
- The type of dwelling significantly predicts the type of toilet facility.
- Shared toilet facility predicts the type of toilet facility among households.
- There is a 44.8% probability of having no toilet facility if households belong to the poorest households.
- CART algorithm was used to classify toilet facilities.

GRAPHICAL ABSTRACT



INTRODUCTION

Adequate access to clean water and proper sanitation is necessary for preventing waterborne diseases, which are a leading cause of death and illness worldwide. A recent report in the literature shows that water and sanitation are predictors of neurological disorders (Sarmadi *et al.* 2021) and other waterborne diseases, such as typhoid, and *Helicobacter pylori* (Kumar *et al.* 2022). This makes water and sanitation a priority in the sustainable development goals (SDGs) because they are essential for human health and well-being.

Furthermore, water and sanitation are closely linked to other SDG indicators and goals (Dawes 2022) such as those related to food security, energy, and the environment. Thus, ensuring access to clean water and proper sanitation is crucial for achieving many SDGs and for promoting sustainable development more broadly. Prioritization among these goals is vital in achieving one goal over the other because it requires trade-offs in accomplishing some of its sub-indicators (Kroll *et al.* 2019). This can be demonstrated in a study in which SDG 1–3 are promoted with other goals (Dawes 2022). For example, reducing poverty (SDG 1) can help increase net welfare gains through improvements of related SDGs Clean Water and Sanitation and Zero Hunger (Barbier & Burgess 2017). Nevertheless, the importance of the contribution of the water and sanitation sector could not be undermined such that UN member countries adhere to achieving SDG 6 'Water and Sanitation for All,' but not there yet (Pereira & Marques 2021).

The current statistics show that the world is not on track to achieve SDG 6.1 and 6.2 and thus requires a quadrupling of the current rates of progress (WHO/UNICEF/JMP 2020).

Moreover, poverty can have a significant impact on the delivery of SDG 6. In many parts of the world, millions of people lack access to basic water supplies. Often, the poorest communities have the least access to these essential services due to various factors such as poor water facilities (Ugwu *et al.* 2022), lack of access to improved sanitation caused by sustainable access to water (Chaudhuri & Roy 2017), low household incomes and location, especially to those informal settlers (Akawu 2020). This confirms that access to such services is a privilege among those who belong to an affluent society. As a result, the poorest communities may be more vulnerable to waterborne diseases and other health problems, which can perpetuate the cycle of poverty.

These problems can be addressed by providing aid targeting households based on their water and sanitation practices, which may help improve and accelerate the achievement of SDG 6. To meet SDG 6 by 2030 entails an associated cost (Dilekli & Cazcarro 2019) and so it is imperative that development interventions in the water and sanitation sector should be targeted.

There are several studies focusing on access to water, sanitation, and hygiene. Most of these studies are conducted in the African continent. Most notably, the authors sought to determine the factors for improved access to drinking water (Simelane *et al.* 2020) and to find the differences in households with respect to access to water and toilet facilities (Abubakar 2017). Similarly, access to improved drinking water and sanitation facilities in Ghana (Agbadi *et al.* 2019) was explored and inequalities among households were assessed using drinking water sources versus socioeconomic profile (Oskam *et al.* 2021). Broadly speaking, the studies show that socioeconomic profile is significantly associated with access to water and sanitation facilities, particularly on wealth index (a proxy for income), gender and age. However, house and lot tenure and ownership were not addressed in these studies, which could be part of the explanatory variables (Agbadi *et al.* 2019; Simelane *et al.* 2020; Oskam *et al.* 2021). These limitations are deemed important in determining access to water and sanitation (Abubakar 2017). Thus, this paper is conceived based on previous studies with the following objectives to: (1) know how access to water and other household characteristics determine the type of sanitation facility, (2) explore other socio-demographic profiles related to the type of toilet facilities, and (3) classify the type of toilet facility based on access to water and wealth for policy recommendation.

METHODS

Study area

The Philippines has a growing population with an increasing demand for safe water and basic sanitation. According to the Philippine Statistics Authority (PSA 2017), 73.6% of households had improved, unshared toilet facilities and 58% had flush to pit latrine facilities. This increased to 81.1 and 55.4%, respectively, in 2019. However, access to these services is not equal between urban and rural households, with urban areas having higher access. In 2017, 27% of families used 'safely managed drinking water' and at least 91% had 'basic drinking water services,' but access was lower in rural areas.

Basic sanitation was available to 74% of households, but 5% had unimproved sanitation. Most households (93.3%) had an improved source of water, with boiling being the most common method of treating water for drinking. The cost of achieving the Sustainable Development Goal (SDG) for water and sanitation (SDG 6) has been significant, with the local water utilities association spending 62 million in 2016 and 2021, and the metropolitan water sewerage system spending 140.9 million in 2016 and 250.8 million in 2021.

Study design and data collection

This study used secondary data through data mining as data collection method. To get representative data in Philippine households, datasets were acquired from the Department of Science and Technology – Food, Nutrition and Research Institute (DOST-FNRI) for further data analysis as it suited best for the study. According to the data source, the ethics review was conducted at the FNRI Institutional Ethics Review Committee (FNRI-IERC) for clearance and was approved on July 20, 2015. Additionally, household respondents were asked to sign for informed consent and that their responses were confidential. Moreover, before the analysis, email correspondence was sought to allow the researcher to use the data for research purposes only. The data contain the socioeconomic status and demographic profile of 41,972 household components of the 2015 National Nutrition Survey (NNS) at the household level, including the type of residence, living conditions, dwelling type, and wealth index to represent income as a proxy indicator. The unit of analysis of the data is households and covers all the 17 geographic regions of the country. The WI is determined using household assets and housing characteristics to categorize households into wealth quintiles (DOST-FNRI). Additionally, health and sanitation status were also assessed using the variables on the type and tenure of the dwelling unit, presence, and type of toilet facility in the household and garbage disposal system. Note that this is also a national updating survey, which used the 2003 Master Sample (MS) of the PSA.

Data pre-processing

Various python packages were used for machine learning and data processing. Data cleaning, such as selecting columns from the dataset intended for the study was done using the Pandas library. Missing values (9,999) and unavailable (NA) were removed, reducing the number of respondents to 39,771 which were used as the final dataset for analysis.

Data selection and analysis

This paper focuses on the determination of sanitary toilet facilities and their relationship to household characteristics in the Philippines. Because of the categorical nature of the data, the following statistical analysis was used. Each analysis was performed using open-source software such as JASP for Cramer's V, JAMOVI for MNL regression, and Orange software for CART analysis.

Cramer's V was used in the analysis of the association of the toilet facilities (including those with no toilet) versus Make Water Safer Drink, How You Make Water Safer Drink and Main Sources of Drinking Water, and whether toilet facility is shared or not (Table 1).

Meanwhile, multinomial logistic (MNL) regression was used to determine if the socioeconomic profile variables (shown in Supplementary Material, Table 1) predicted sanitary toilet facilities.

Furthermore, the Classification and Regression Tree (CART) algorithm was used to classify the type of toilet facility profiles among households. The CART is popular in determining and classifying binary outcomes and classifying categorical explanatory variables as used in urban planning (Antunes *et al.* 2016) and classifying therapeutic outcomes based on individual profiles (Salamate & Zahi 2022).

The target variable was the type of toilet facilities, with four categories such as water-sealed (pour with a septic tank, 1), water-sealed (flush with a septic tank, 2) and not water-sealed (3) and no toilet facility (bush) coded as zero '0' (seen in Table 1). However, wealth quintiles, main sources of drinking water, making water safer to drink, and how to make water safer to drink were explanatory variables. Wealth quintiles have 5 categories, sources of drinking water have 14, making water safer to drink has 10 variables including those with 'no treatment.' Binary variables were also included to make the water safe to drink. These variables were important in the analysis, as previously shown that various studies have determined the influence of various socioeconomic characteristics of households, including cultural aspects in the access to improved sanitation (Sinharoy *et al.* 2019). For instance, wealth or income category and location of household show a positive correlation (Akawu 2020; Iddi *et al.* 2021).

Table 1 | Household socioeconomic profile and its categories in relation to water and sanitation

Variable type	Definition	Code	Categories
Categorical	The type of toilet facility	0	No toilet facility (bush)
		1	Water-sealed (pour with septic tank)
		2	Water-sealed (flush with septic tank)
		3	Not water-sealed (pour/flush without septic tank)
Categorical	Main sources of drinking water	11	Piped into dwelling
		12	Piped to yard/plot
		13	Public tap/standpipe
		21	Tube well or borehole
		31	Protected dug well
		32	Unprotected dug well
		41	Protected spring
		42	Unprotected spring
		51	Rainwater
		61	Tanker truck
		71	Cart with a small tank
		81	Surface water (river
		91	Bottled/Mineral water
Categorical	Make water safer drinks	0	No
		1	Yes
		9	N/A (if bottled water)
Categorical	How you make water safer drink	0	No Treatment
		1	Boil
		2	Add bleach/chlorine
		3	Use a water filter (ceramic
		4	Improvised filter (cloth
		5	Solar disinfection
		6	Let it stand or settle
		9	NA (if bottled water)

The study classified the type of toilet facilities based on 'Wealth Quintile,' 'Make water safer to drink,' 'How you make water safer to drink,' and 'main source of drinking water' with six levels of depths relative to the root node. The Gini index was used to prune the attributes of the 4 explanatory variables and their 28 categories (Figure 1).

RESULTS AND DISCUSSION

Socioeconomic profile of households in terms of sanitation facility, wealth, and access to water

In this study, the following household characteristics were used to categorize the wealth index to determine household income. By crosstabulation, it appears that many of the poorest households had no toilet facilities (Table 2). Data revealed that there are many households ($n = 2{,}419$) in the poorest wealth quintile that have no toilet facilities (bush) and are not water sealed ($n = 1{,}539$) compared with households in the rich and richest wealth quintile. However, the richest households are water-sealed (pour with septic tank) and water-sealed (flush with septic tank). Sanitary toilet facilities are important in sanitation even in septic tanks; however, as manifested in the data, these are not highly available to the poorest households in the Philippines (Table 2). Hence, sanitation among these groups should be improved and provided access to. It can also be observed that among the middle quintile household groups, many of them ($n = 7{,}513$) have water-sealed (pour with septic tank). Additionally, the data show that as income level increases, the proportion of people with access to a water-sealed toilet (flush with septic tank) increases, while the proportion of people with access to a toilet that is not water-sealed decreases. This suggests that access to a safe and hygienic toilet is more prevalent among higher income groups.

Based in Table 2, the poorest households have various water sources for drinking water compared with those in the richest quintile. Notably, many households in the poorest quintile have sourced water from a protected spring ($n = 1{,}811$) and an unprotected spring ($n = 710$). Several households ($n = 515$) have access to unprotected dug well. These findings coincide with the literature that poor households rely on open sources of rivers and streams and are less likely to use piped water

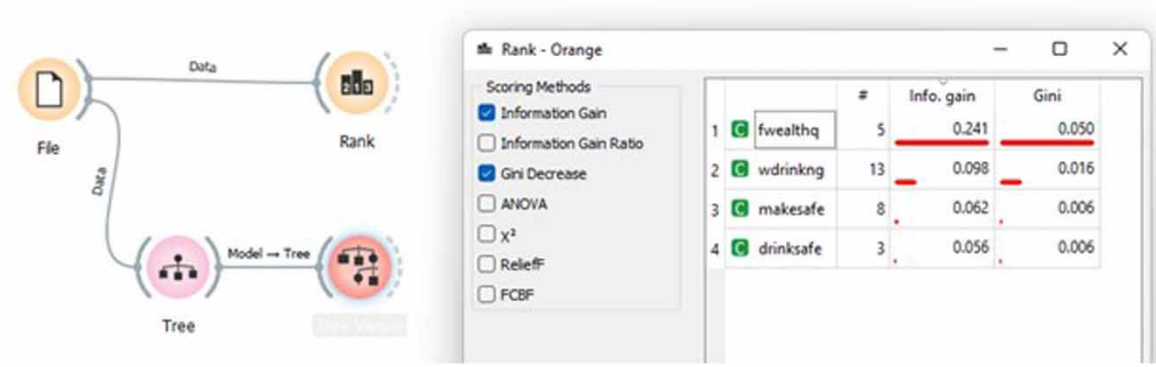


Figure 1 | CART procedure using Orange software.

Table 2 | Socioeconomic variables and its sanitation facilities and access to clean water

Variables	Categories	Poorest	Poor	Middle	Rich	Richest
Type of toilet facilities	No toilet facility (bush)	2,419	577	156	45	39
	Water-sealed (pour with septic tank)	5,368	7,803	7,513	6,698	4,555
	Water-sealed (flush with septic tank)	61	139	236	492	2,389
	Not water-sealed (pour/flush without septic tank)	1,539	459	177	88	32
Main Sources of Drinking Water	Piped into dwelling	1,257	2,325	2,524	2,221	1,478
	Piped to yard/plot	549	603	356	158	54
	Public tap/standpipe	1,211	970	557	248	77
	Tube well or borehole	1,393	1,494	1,094	554	230
	Protected dug well	1,309	987	655	357	132
	Unprotected dug well	515	150	75	19	7
	Protected spring	1,811	986	465	220	88
	Unprotected spring	710	238	110	42	9
	Rainwater	138	43	15	10	2
	Tanker truck	83	70	61	32	17
	Cart with a small tank	41	9	9	4	3
	Surface water (river	98	42	16	20	9
	Bottled/Mineral water	272	1,061	2,145	3,438	4,909
Make Water Safer Drinks	No	5,885	5,061	3,775	2,397	1,188
	Yes	3,230	2,856	2,162	1,488	918
	N/A (water bottle)	272	1,061	2,145	3,438	4,909
How You Make Water Safer Drink	No Treatment	5,885	5,061	3,775	2,397	1,188
	Boil	1,973	1,798	1,365	920	366
	Add bleach/chlorine	111	116	77	50	24
	Use a water filter (ceramic)	196	204	174	221	360
	Improvised filter (cloth)	793	595	437	219	108
	Solar disinfection	13	8	5	5	12
	Let it stand or settle	144	135	104	73	48
	NA (if bottled water)	272	1,061	2,145	3,438	4,909

(Behera *et al.* 2020). Few households in the poorest ($n = 272$) and poor ($n = 1,061$) quintile have access to bottled/mineral water. The rich and the richest households have access to bottle/mineral water, and many have piped into dwellings ($n = 1,478$). The data revealed that access to clean and safe water is a privilege for those with more financial sources compared to those with a meager income. This result is evident in Quezon City, Philippines, where those in the rich quintile have access to clean and safe water compared to those in the poor quintile, particularly in piped water (Alfonso *et al.* 2022). Although water is a basic right, this access to water should be too available to everyone despite its financial incapacity. Concerning the water treatment of households for drinking water, many of the poorest households ($n = 5,885$) do not treat water (e.g.

boiling). Many households do not treat their drinking water, and this is often because they rely on bottled water. However, some households do treat their water, commonly through boiling or using improvised filters.

Furthermore, data revealed that based on the source of drinking water, those households ($n = 5{,}884$) with water source piped into their dwellings do not make their water safe either by boiling or other kinds of treatment. It is observable from Figure 2 that those whose source of drinking water are from tube well, dug well and springs are practicing making their water safer to drink. These showed that those with piped-into dwelling water sources are confident enough that their water is safe to drink and hence do not anymore make necessary treatment. Moreover, there are still numerous households whose water sources are tube well ($n = 3{,}214$) protected dug well ($n = 2{,}157$), public tap ($n = 2{,}082$), protected springs ($n = 2{,}315$) do not make water safe. These households may not be aware of the perils of waterborne diseases. It can be inferred that tube well or borehole sources of water do not practice the necessary treatment.

Many do not treat their water whether this is from a protected dug well ($n = 2{,}157$), protected spring ($n = 2{,}315$), and unprotected spring ($n = 772$) or piped into dwellings ($n = 5{,}884$). However, for households who had some treatments, boiling and the use of water filters are widely practiced, similar to other studies in sub-Saharan countries (Geremew & Damtew 2020). But not so many households are using filters, particularly those coming from springs (protected and unprotected). Very few households however had it 'let it stand or settle' ($n = 204$) practice to make water safe. As previously discussed, simple treatment of water to make it safe should be disseminated and mainstreamed among those without access to pipes into dwellings as the main water source (Figure 3).

Meanwhile, for those with no toilet facilities, many of them also do not treat water to make it safer to drink ($n = 1{,}807$), though few also boil water ($n = 618$), use filters ($n = 51$), and some buy bottled water ($n = 235$). Although the numbers are

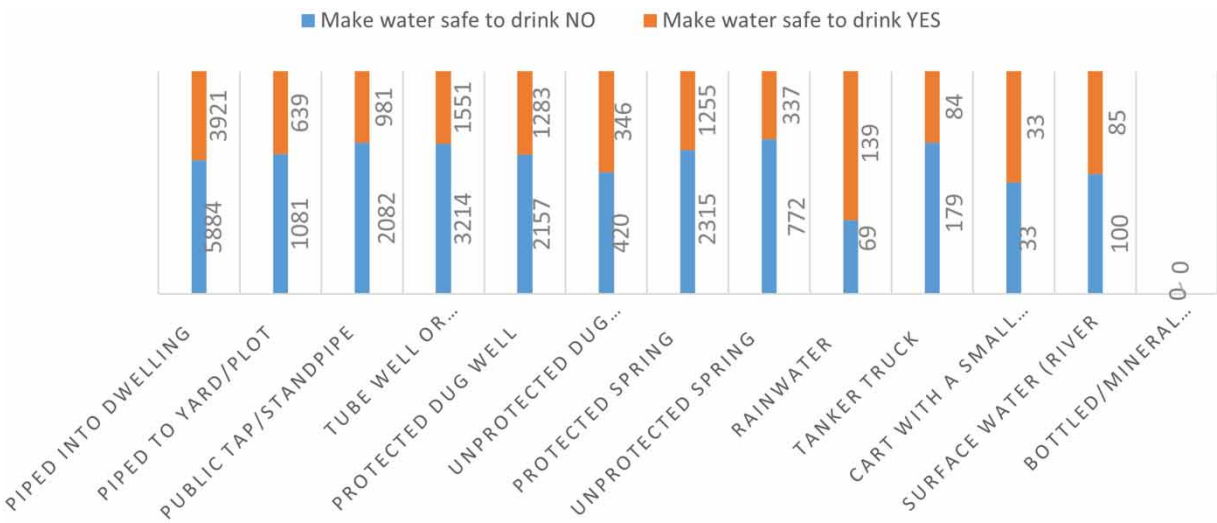


Figure 2 | Make water safe to drink by main source of drinking water.

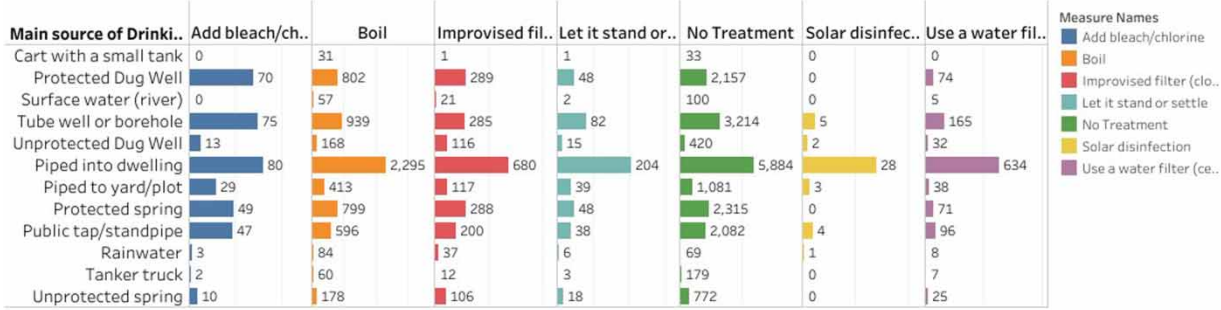


Figure 3 | How to make water safe to drink by main source of drinking water.

quite lower compared to those households with water-sealed toilet facilities that do not treat their water ($n = 14{,}120$) (Supplementary Material, Table 2). This practice is quite alarming since the water source is directly affected with the type of sanitation facilities such that poor water facilities indicate unsafe sanitation (Ugwu *et al.* 2022).

Association of household characteristics to access to water and type of toilet facilities

Table 3 shows that Make Water Safer to Drink, How You Make Water Safer Drink, Main Source of Drinking Water, and shared toilet facilities have a compelling association with the following type of toilet facilities. These findings showed that these household characteristics are highly associated with having access to the type of sanitation toilet facilities. More significantly, shared toilet facilities are compellingly associated with the type of toilet facilities. This implies that there may be a need to address the specific household characteristics that are associated with a lack of access to safe and hygienic toilet facilities, to increase access to toilets among households.

For other socioeconomic profiles, dwelling type, household tenure, lot tenure, the type of the main source of fuel, access to electricity, and floor type have a significant effect in having the type of sanitary toilet facility among households (Table 4). The model fit is significant, which indicates that the model predicts significantly better ($\chi^2 = 29{,}041$, $p < 0.001$).

The study found that the type of dwelling, house tenure, and main source of fuel for cooking were significant predictors of water-sealed toilet facilities with a septic tank. The type of flooring in the household was also found to be a significant predictor. For households with water-sealed toilet facilities without a septic tank, the type of dwelling and the main source of fuel for cooking were significant predictors. The type of flooring was also a significant predictor, but only for certain types of materials. The study found that house tenure and lot tenure were not significant predictors of toilet facilities in any category (see Supplementary Material, Table 3).

One implication of these results is that the type of dwelling, house tenure, and main source of fuel for cooking may be useful predictors of the type of toilet facilities in households. This information could be useful for policymakers or organizations working to improve access to sanitation in different communities. For example, targeting efforts toward households in commercial/industrial/agricultural dwellings or those using natural gas or biomass for cooking may be more effective at

Table 3 | Association of access to water and type of toilet facilities

	Type of toilet facilities			
Household characteristics	χ^2	**df**	***p***	**V**
Main source of drinking water (wdrinking)	5,737	36	<.001	0.219
Make water safer drink (drinksafe)	2,958	6	<.001	0.193
How you make water safer drink (makesafe)	3,247	21	<.001	0.165
Shared toilet facilities (shareit)	40,089	9	<.001	0.58

Legend: Cramer's V – Interpretation (Akoglu 2018); >0.25 – Compelling; >0.15 – Strong; >0.10 – Moderate; >0.05 – Weak; >0 – No or feeble.

Table 4 | Omnibus likelihood ratio tests

Predictor	χ^2	**df**	***p***
Dweltype	44.8	15	<0.001
Tenurhws	16.8	9	0.053
Tenurlot	101.7	9	<0.001
Fuelmain	978	21	<0.001
Electret	597.4	15	<0.001
Shareit	17,547.8	9	<0.001
Floor	1,924.3	21	<0.001

AIC: 31,094; χ^2: 29,041; R^2_{McF}: 0.485; df: 99; p: < 0.001.

improving sanitation. Similarly, targeting efforts toward households with certain types of flooring may also be effective. Understanding these predictors may help to more efficiently allocate resources and focus efforts on the households that are most in need of improved sanitation. Moreover, this result provides solid evidence to improve and provide sanitary toilet facilities to reduce the proportion of domestic wastewater flows safely treated (SDG 6.3.1).

Classification of toilet facilities based on wealth quintile and access to water

Classifying toilet facilities based on wealth quintile and access to water can help policymakers and organizations understand and address disparities in access to adequate sanitation. To facilitate the classification, CART algorithm was used. Accordingly, the CART showed 527 nodes and 264 leaves. However, Gini Index shows that 'fwealthq' and 'wdrinkng' were pruned having a higher index compared to 'drinksafe' and 'makesafe' (Figure 4).

The results allow us to describe the profiles of households according to the type of toilet facility using the features presented below. The decision tree is presented and analyzed as predictive rules in the following way.

Rule 1: if households belong to the poorest wealth quintile, 57.2% will have a probability of having Water-sealed (pour with septic tank).

Rule 2: if households belong to the poorest wealth quintile, and the main sources of drinking water are Protected Dug Well, Unprotected Dug Well, Unprotected spring, Rainwater, tanker truck, Cart with a small tank, Surface water (river), then 41.2% will have a probability of having Water-sealed (pour with septic tank).

Rule 3: if households belong to the poorest wealth quintile, and the main sources of drinking water are Unprotected Dug Well, Rainwater, Cart with a small tank, and Surface water (river), 44.8% will have a probability of having no toilet facility.

Rule 4: if households belong to the poorest wealth quintile, and their main sources of drinking water are Unprotected Dug Well, Cart with a small tank, and Surface water (river), 46.9% will have a probability of having no toilet facility.

Rule 5: if households belong to the poorest wealth quintile, and their main sources of drinking water are Protected Dug Wells, unprotected springs, or tanker trucks, then 45.7% will have a probability of having Water-sealed (pour with septic tank).

As presented above, it appears that there is less than 50% probability of households being classified as having Water-sealed (pour with septic tank) in rule 5, similar to rule 3, having no toilet facilities with a probability of 44.8% as influenced by the wealth quintile or those belonging to the poorest households.

This study is nevertheless a valuable contribution to the field as it suggests targeted intervention to communities who have no access to clean water and sanitation, particularly in the depressed areas in the Philippines. The findings confirm that

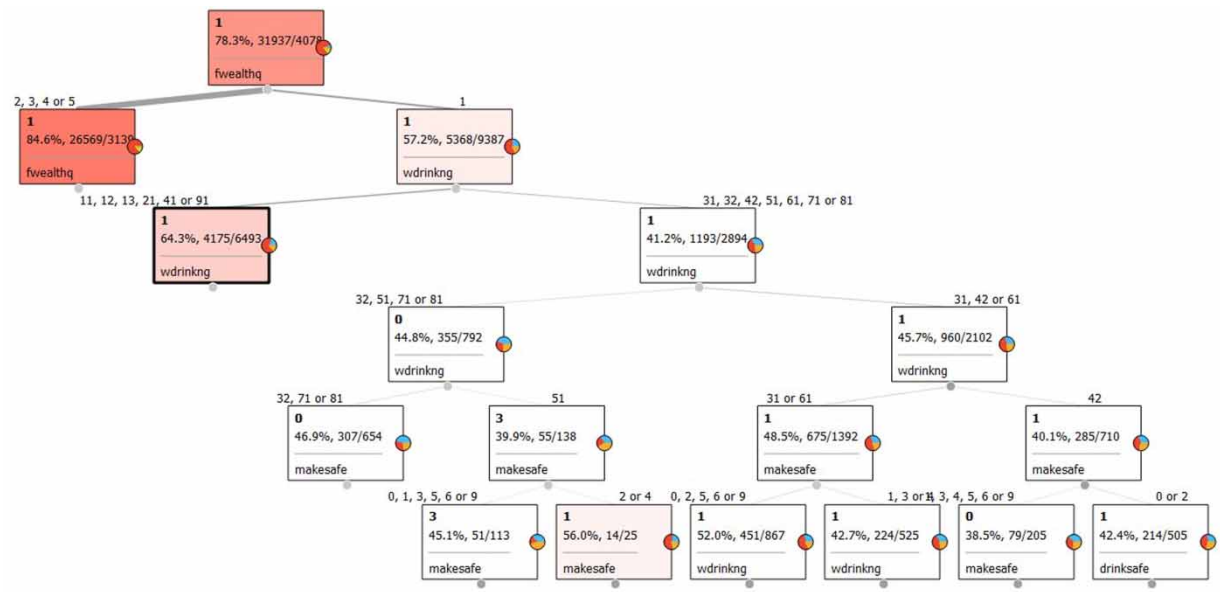


Figure 4 | CART.

households belonging to the poorest wealth quintile and having no access to potable clean water had a probability of having no toilet facility. Thus, interventions should address rules 3 and 4 and should be applied if there are interventions on providing free toilet facilities from the government. This is because aside from having no access to clean sanitation and no toilet facilities and being in the poorest wealth quintile, these households also had no access to safe and clean water. This result will provide policy makers informed data to back up policy and enforce the poorly implemented acts such as the Clean Water Act (RA 9275), and other social and environmental-related policies. Additionally, this can help provide strategic directives to translate the Philippine Development Plan (PDP) and SDG targets and commitments to locally viable programs and projects. Moreover, this can help policymakers to create policies and procedures for participating local communities in water and sanitation management (SDG 6.b.1). Likewise, this result can minimize, if not eradicate, the tendency of making water a political commodity serving only the interest of the few.

CONCLUSIONS

The study demonstrated that access to clean water and sanitation is determined by the income of households. This implies that those with sufficient incomes belonging to the rich and richest quintile have more access to clean water and sanitation facilities (e.g. toilet facility). Moreover, the rules presented in this study will guide policymakers and development workers as to who will be the direct beneficiaries of any intervention related to this matter. In particular, policy makers may consider providing aid such as free sanitary toilets to those who are in the poorest quintile and whose main sources of drinking water are unprotected dug well, rainwater, cart with small tanks, and surface water. Evidently, these households in the poorest quintile do not have access to clean safe water, which the government should also provide. Therefore, providing aid to these households may be an effective means of addressing the SDG of ensuring access to clean water and sanitation for all, and may help improve the overall health and well-being of these communities. Any intervention related to this matter should be carefully planned and implemented to ensure that it is effective and sustainable in the long term. This result can further be used by other national agency to craft adequate policies in the water supply and sanitation sector (WSS) since data and information used in planning are limited at present. Furthermore, future research should be conducted in the field of sanitation practices among households and how they cope with the problem.

ACKNOWLEDGMENT

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DATA AVAILABILITY STATEMENT

Data cannot be made publicly available; readers should contact the corresponding author for details.

CONFLICT OF INTEREST

The authors declare there is no conflict.

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