Environment, Development and Sustainability (2020) 22:7097–7120
https://doi.org/10.1007/s10668-019-00506-1

CASE STUDY

Assessment of the sustainability of community-managed water supply services in Ghana

Emmanuel Kwame Nti[1] · Camillus Abawiera Wongnaa[1] · Nana Sampson E. Edusah[2] · John-Eudes Andivi Bakang[1]

Received: 16 October 2018 / Accepted: 18 October 2019 / Published online: 24 October 2019

Abstract
The study assessed the sustainability of community-managed water supply services drawing empirical evidence from a small town water supply system in Ghana. The study followed a fully quantitative research approach. Data were collected from 387 respondents who were almost all public standpipe users (98.45%) using a structured survey questionnaire. Descriptive statistics were reported, and MACBETH was the method of analysis. The study revealed that quality drinking water and reliability are the most important criteria in the opinion of survey respondents for small town water supply system. Building on this empirical understanding, the differences in importance that respondents attributed to each of these criteria were measured, and, for example, implementation of policies and public disclosure was their lowest priority. The results revealed that survey respondents believe that all criteria are currently within a range that indicates a sustainable water supply system. The paper recommend among other things that management of community-managed water supply system should be well positioned to ensure continuous water quality testing while designing drinking water quality improvement plans.

Keywords Multi-criteria decision analysis · Community-managed · Sustainability · Water supply system

1 Introduction

Access to water has been made a universal goal due to the role of water in supporting the achievement of sustainable development in all forms (Connor 2015), but the number of people without reliable access to quality drinking water according to WHO (2015) stands at 1.8 billion and out of that an estimated 663 million people are already not having access to improved sources of drinking water. However, in order not to continue the business as

✉ Emmanuel Kwame Nti
kwame.nti@yahoo.com

1 Department of Agricultural Economics, Agribusiness and Extension, Kwame Nkrumah University of Science and Technology, Private Mail Bag, University Post Office, Kumasi, Ghana

2 Bureau of Integrated Rural Development, Kwame Nkrumah University of Science and Technology, Private Mail Bag, University Post Office, Kumasi, Ghana

usual and to mitigate this water crisis, the UN Sustainable Development Goals built on the Millennium Development Goals sought to complete the essential full water cycle (WWAP 2016). With that, the UN Sustainable Development Goals put importance on drinking water quality, hygiene and sanitation, wastewater, efficient use of water as well as ecosystem protection; building of capacity and participation of stakeholders (WWAP 2017).

In Ghana, the community-driven approach which basically gives control of decisions and resources to community groups was adopted when it came to water supply services by the Second Community Water and Sanitation Program by the Community Water and Sanitation Agency which greatly supported Ghana's decentralization strategy through grants. Overall, nearly 800,000 people representing 6 percent of Ghana's total rural population from four regions gained access to potable water and 500 service providers received training in the Second Community Water and Sanitation Program by the Community Water and Sanitation Agency. Importantly, more than 2014 communities today are using and managing water facilities through the community-managed structure with training in various aspects of community water management (World Bank 2007, p. 5). There has been an increase in water coverage for communities over the years in Ghana. Water coverage in the year 2000 was 40% and rose significantly to 51.7% in 2004 and gradually increased to 63.41% at the end of 2012 (CWSA 2013). Again, the coverage has increased from 63.66% in 2013 to 64.00% in 2014 (CWSA 2014). Several studies have demonstrated the lack of sustainability in water supply systems at various communities in Africa and the reason comes from the difficulty in comprehending the holistic nature of sustainability issues (Ademiluyi and Odugbesan 2008; Antonio 2005). Though sustainability of community-based management is a well-researched topic that a lot of publications already cover such as Carter et al. (1999), Harvey and Reed (2006), Akbar et al. (2007), Whittington et al. (2009), Amerasinghe (2009), Schweitzer and Mihelcic (2012), there is a knowledge gap in relation to studies conducted locally (Wanjiru 2014; Whaley and Cleaver 2017) with the application of the MCDA model for a sustainability assessment of community-managed water supply services in Africa. Also, limited sources of information about sustainability hinder the provision of a clear nationwide picture of the sustainability of water projects and Macharia et al. (2015) suggested the need for more sustainability assessments of post-project implementation of community water projects. The concern of many practitioners now is whether or not community-managed water supply services in Ghana are sustainable. In view of the dimension of the problem, the study sought to answer this research question: What criteria influence the sustainability of community-managed water supply services? Following Marques et al. (2015) proposed measurement of water supply sustainability, 6 criteria were selected by the researchers as a result of their fitness and applicability in context specificity for beneficiaries to carry out pairwise comparisons through qualitative judgments of the differences in preference. This study provides a response by assessing the sustainability of Jacobu Small Town Water Supply System in the Amansie Central District of Ghana. In the framework of this study, the preferred definition of sustainability is adopted from the Brundtland report of the United Nations World Commission on Environment and Development which defines sustainability as the 'development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs' (Brundtland 1987).

Methodologically, the study adopted the multi-criteria decision analysis (MCDA) framework proposed by Marques et al. (2015). MCDA agrees in totaling the exact performance level in the entire characteristics by simply applying weighting methods that reveal the preferences of the beneficiaries. The use of MCDA model in assessing water services sustainability is evolving. The model, when employed in analyzing sustainability in the water sector, has many advantages. According to Larson et al. (2009), it is possible to use the model to determine a single dimension of sustainability as well as the global level which means that all criteria from the dimensions are taken into account. Also, the model according to da Cruz and Marques (2013) has other advantages, including flexibility for both qualitative and quantitative criteria; allowance for open and informed discussions since all the numerous objectives, criteria, scores and their weighting coefficients are transparent and not vague; the modeling procedure being participatory in nature and also very observable, which helps in communicating clear outcomes or results, auditing and reviewing the model; and finally in terms of theory, the processes to assign scores and weights are very robust in nature.

The first pioneering research in the water sector on urban water supply sustainability using the MCDA model was in the UK by Ashley et al. (1999) and subsequently in the Netherlands by Icke et al. (1999). The model has since been applied differently in other studies including Hajkowicz and Collins (2007) and equally followed by a study in the USA by Huang et al. (2011) and others dealing with issues concerning the environment in Italy by Berrittella et al. (2008) and has become very common across the globe. The lesson from the many applications of multi-criteria decision analysis model (MCDA) shows they are well suited to water resources planning as efficient tools in the decision-making process.

Also, Marques et al. (2015) proposed measurement of water supply sustainability that covers five dimensions with 14 specific objectives. The objectives are met if various targets set for the different criteria materialize. Various case studies according to Marques et al. (2015) were selected during the conceptual development of the model, and many of such studies originated from the USA, UK, Canada, Singapore, Philippines, Israel and Portugal. However, few case studies on water supply sustainability have employed the methodology, but unfortunately most developing countries especially those in Africa were not part of the selected case studies since sustainability studies in water supply were limited (Marques et al. 2015) especially with the application of the MCDA model for a sustainability assessment of community-managed water supply services in Africa.

This study bridges the gap in terms of the use of the MCDA model by assessing sustainability of community-managed water supply services in 12 distribution zones of Jacobu small town water supply system in the Amansie Central District in Ghana. Using Marques et al. (2015) non-numerical weighting coefficient of Measuring Attractiveness by a Categorical Based Evaluation Technique (MACBETH), it is possible to determine the weights of certain reference profiles by asking the beneficiaries of the water supply system who were divided into domestic users and public standpipe users and were selected by applying the simple random sampling technique to carry out pairwise comparisons through qualitative judgments of the differences in preference.

Importantly, Ashley et al. (2004) noted that some authors interchangeably use dimensions as 'criteria' to assess factors or options that offers the ultimate impact on achieving sustainability objectives. Indeed, many are the criteria identified to achieve the sustainability of water supply services, and for example, Spangenberg and Bonniot (1998) developed sustainability indicators which focused on the economic, environmental, social, human rights and society. Also, Hiessl et al. (2001) in their studies adopted social, economic and ecologic to design and assess sustainability. Other criteria or dimensions adopted by UNCSD (2001) include the environment; social; economic; and institutional dimensions. Balkema et al. (2002) sort them out into economic, environmental, technical, social and cultural dimensions/criteria. Also, the study of GRI (2006) suggests the economic, environment, social, human rights and society as the major ones.

To assess the sustainability of urban water cycle, an indicator approach was developed which is termed as City Blueprint. The study used 24 indicators from 8 broad criteria, namely water security, water quality, drinking water, sanitation, infrastructure, climate robustness, biodiversity and attractiveness and governance as the water supply sustainability dimensions/criteria (Van Leeuwen et al. 2011). According to Marques et al. (2015) in their study, water supply sustainability encompasses five dimensions which include social, environment, economic, governance and asset. They are further divided into 14 objectives and 24 criteria, namely physical service accessibility, economic service accessibility, quality of service, drinking water quality, willingness to pay, complaining, acceptance of new sources of water, social responsibility, work conditions, efficient use of water, energy use, material use, final uses of efficiency, pollution prevention, pollution control, investment, efficiency, leverage, liquidity, participation initiatives, availability of information and documents, accessible information and written documents, public disclosure, individual mechanisms of accountability, collective mechanisms of accountability, clearness of policies defined ex-ante, change of policies, implementation of policies, corporate planning, city planning, water resources planning, failures, flexibility, adaptability and reliability. This approach has been modified and applied in the Jacobu water supply system in the Amansie Central District by means of an interactive beneficiaries approach, essentially because of its easiness to explain and be understood by the beneficiaries. The justification therefore is that beneficiaries are the major stakeholder, especially in the community management model, which places responsibility for water point functionality on users (Chowns 2014) and the application of the MCDA model is aimed to help the Water Management Team to make sustainable decisions. Also, in terms of selecting the criteria according to Marques et al. (2015), one must avoid including different criterion that ultimately will ‘measure’ the same phenomena such that the performance in one criterion must not have any influence in any other criterion to avoid redundancy and possible overvaluation. However, in this study 6 criteria which are drinking water quality, quality of service, efficient use of water, implementation of policies and public disclosure and reliability were selected from the proposed 24 criteria as a result of their fitness and applicability in context specificity and also the most appropriate and representative to illustrate the beneficiaries’ preferences, attractiveness and understanding of the social (drinking water quality and quality of service), environment (efficient use of water), economic (investment), governance (implementation of policies and public disclosure) and asset (reliability) dimensions of sustainability. To the best of our knowledge, this is the first application of Marques et al. (2015) MCDA model using the MACBETH methodology to assess sustainability of a community-managed water supply services in Africa. The research would be beneficial for policy-making aimed at improving the sustainability of community water supply services and also serve as a baseline data to obtain a clear picture for the sustainability of community management of water supply systems.

2 Materials and methods

2.1 Study area

The study was carried out at Jacobu, the district capital of Amansie Central District in the Ashanti Region of Ghana. The district has a total area of approximately 710 km^2 (275.4 miles^2). This constitutes about 2.5% of the total land area of the Ashanti region

(Amansie Central District Assembly 2006). The district is among one of the thirty (30) administrative districts in the Ashanti Region. The district was carved out of the Bekwai Municipal in 2004. Jacobu community lies in the forest dissected plateau region, which is generally having a wavy shape and with an average height between 150 and 300 meters above sea level. The population size of the Amansie Central District is 90,741, and Jacobu which is the district capital is having the highest population among all the other communities with a population of 10,725 as at 2010 (GSS 2010). There are a number of perennial and seasonal streams located in the forest and are known for important rivers such as Oda, Offin and Fena Rivers. River Offin flows along the southeastern border and also forms the boundary between the Ashanti Region and the Central Region. There are two geological formations which are the Birimian, Tarkwaian and Granitic rocks found in the district which are also rich in mineral deposits. The mineral deposit which includes abundant gold is mostly found at Aketechieso, Apitisu, Fiankoma and Jacobu. However, human activities such as dredging for gold in these water bodies have resulted in their drying-up (Ghana Statistical Service 2010). Figure 1 shows the map of the study area.

The sources of household drinking water in the district include mechanized borehole or tube well constituting 71.1%, while pipe-borne water outside the dwelling and pipe-borne water inside the dwelling constitute about 6.8% and 0.7%, respectively. However, public taps or standpipes constitute about 12.7% as well as river or stream constitutes 4.4%, and protected well constitutes about 3.8% with the minimum usage of sachet water representing 0.5%. Though majority of the households have their sources of drinking water from improved sources such as bore holes and pipes but quite a large number still depend on unprotected sources (Ghana Statistical Service 2010).

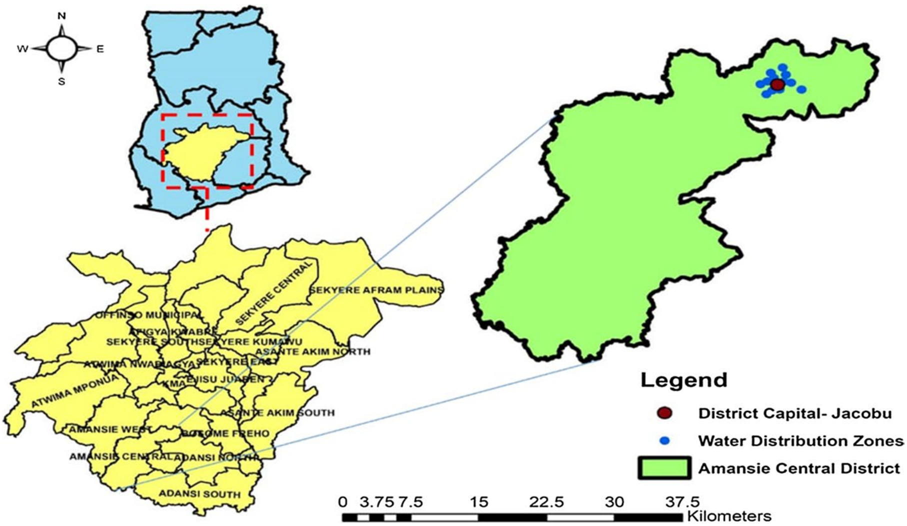

Fig. 1 Map of Amansie Central District chosen for the study. *Source*: Department of Civil Engineering, KNUST

2.2 Data collection

Primary data were mainly used in the study. The geometric method of population projection was employed from a base population (P_O) of 10,725 as at 2010 to a projected population (P_t) of 13,190 as at 2017. The sample size was calculated to be 387. The mathematical approach by Yamane (1973) which is non-proportional was established in formula (1) and gave a sample size of 387 for the study.

$$n = \frac{N}{1 + N(\alpha)^2} \tag{1}$$

where n the sample size; N the sample frame for the study, and α the confidence interval.

The data were obtained through a survey respondents from 12 identified water distribution zones in the community which were Aboabo Road, Ebenezer, Esereso, Habitat, Krofrom, Monsie, Nteduom, Odumase, Pataabo, Tunsuom, Wawase and Hwentemase. Stratified sampling technique was employed by dividing the population into two (2) main groups: those with pipe-borne water inside the dwelling and public standpipe users. The formula used in drawing a representative sample for each stratified group was given as;

$$n_1 = \frac{N_1 \times S}{N} \tag{2}$$

where n_1 the sample drawn; N_1 total number of members in the stratified group; N the total population under study; S sample size for the study.

Only 198 houses were connected as private users with pipe-borne water inside their dwelling, and using the formula, six (6) domestic/private users were selected. The public standpipes by the time of conducting this study were 23 in number used by the majority of the population which are spread across all the identified 12 distribution zones. Using the formula, 381 members were selected. Then, the simple random sampling technique was applied to each stratum to draw the sample. However, for the purpose of the study, all our findings are thus about public standpipe users since no meaningful statements can be derived from a quantitative analysis of 6 cases of the domestic/private users.

2.3 Analytical framework

The study employed descriptive statistics in analyzing the socioeconomic characteristics of respondents. However, the MCDA methodology proposed by Marques et al. (2015) to measure sustainability in the water sector and applied by Ashley et al. (1999), Icke et al. (1999), Hajkowicz and Collins (2007) as well as Huang et al. (2011) that involves different dimensions of water sustainability was employed to assess the sustainability of Jacobu Community-Managed Water Supply Services in the Amansie Central District of Ghana. A different tool employed in assessing sustainability is the sustainability scorecards which were continuously used in many countries in rural and urban water system with few examples, and a pioneering example is the Australian utilities where the Sydney Water Company uses the 'sustainability scorecard' which includes social, economic and environmental concerns and also encompasses summary statements and progress ratings based on management evaluation of performance against sustainability indicators (Marques et al. 2015). The Triple Bottom Line (TBL) framework was also employed in assessing sustainability from social, environmental and economic dimensions (Thornton et al. 2007) which according to Marques et al. (2015) seems not to deliver the appropriate framework in assessing the sustainability of the water system with many assuming that the TBL is a skeleton of water system sustainability since it fails to consider common areas like 'assets' and 'governance' dimensions which make the TBL purposes and dimensions failing to materialize effectively. The fundamental question that could be raised is to ask whether the TBL approach is the most suitable tool in assessing the sustainability of water systems. The study of ASCE and UNESCO (1998) noted that the TBL approach is not sufficient in that regard and suggests the socioeconomic, environmental, public health and management dimensions as the major ones in assessing sustainability. Also, other studies have disagreed with the TBL approach and proposed different dimensions. For example, Ashley et al. (2004) upon disagreeing with the TBL approach propose the technical, economic, environmental and social dimensions of which Murray et al. (2009) suggest the economic, ecological, social, technical and human health dimensions. In another study of sustainability dimensions, Sahely et al. (2005) sort them out into environment, economic, engineering and social dimensions. In this study of community-managed water supply services, sustainability encompasses 5 dimensions that are further modified into 5 objectives and 6 criteria as shown in Table 1.

In terms of selecting the criteria, for at least not including the many other criteria but selecting the six (6) criteria is such that it must be preferentially independent according to Marques et al. (2015), and the performance in one criterion must not have any influence in any other criterion. Furthermore, the criteria must be technically reasonable and acceptable to beneficiaries where the local contexts are taken into account to reflect the preferences of beneficiaries to avoid redundancy and possible overvaluation. For measuring the overall sustainability, the appropriate decision-makers who happened to be the beneficiaries were asked to offer judgments concerning the comparative contribution of scoring each criterion, in contrast with most approaches where the appropriate decision-makers could be those who installs and maintains public standpipes. This is so because integrated water management is a central pillar of sustainability where water users or beneficiaries are involved (Mitchell 2006), and in this study the preference of beneficiaries' for a long-term sustainability decisions through a clear participatory procedure of offering judgment is equally meant to increase the legitimacy of the model as another important decision stakeholder with responsibilities in the water sector. This is an innovative element of the study, as the preferences of beneficiaries toward sustainability are retrieved. In computing the sustainability score, the simple additive aggregation model was employed to compute the sustainability score. However, the model adopts a linear relationship between the criteria performance and score in the following simplified formula.

$$\left|S(u_i)\right. = \sum_{j=1}^{n} C_j \times S_j(u_j) \text{ with } C_j > 0 \text{ and } \sum_j C_j = 1 \text{ and} \begin{cases} S_j\left('\text{most attractive criteria}'_j\right) = 100 \\ S_j\left('\text{least attractive criteria}'_j\right) = 0 \end{cases} \tag{3}$$

where $S(u_i)$ is the global sustainability score of community water services u_i, c_j is the weighting coefficient of criterion j, $S_j(u_i)$ is the local score of CWS Sustainability u_i considering criterion j, and $'\text{most attractive criteria}'_j$ and $'\text{least attractive criteria}'_j$ are the

Table 1 Dimensions, objectives and criteria of water supply services sustainability. Adapted and modified from Brattebø et al. (2013) as cited in Marques et al. (2015)

Code	Dimension	Objectives	Criteria
A1	Social	(a) Effectively satisfy the beneficiary needs and expectations	(a1) Drinking water quality
A2			(a2) Quality of service
B1	Environment	(b) Optimize the use of water	(b1) Efficient use of water
C1	Economic	(c) Ensure economic sustainability of the community water supply services	(c1) Investment
D1	Governance	(d) Measurement of water management policies, accountability and transparency	(d1) Implementation of policies and public disclosure
E1	Asset	(e) Performance and strength	(e1) Reliability

reference levels of performance on criterion j, thus agreeing to what is considered by the decision-maker or beneficiaries as being most attractive criteria and acceptable when it comes to sustainability issues.

To also calculate the weights in a participatory manner, two weighting methods were used: first, the MACBETH methodology by Banae Costa et al. (2003) which is a non-numerical technique and second the mean method where all the numerical scores for each criterion were divided by the sample size. This was done to determine the weights of the criteria and that is a pairwise comparison of qualitative judgments used to compare criteria to know the differences in preference or attractiveness by the beneficiaries. These were a tool developed in the software 'M-MACBETH current scale' and 'M-MACBETH basic difference.' The M-MACBETH assisted the modeling process and run the weights that were logical with the judgments of the beneficiaries automatically through the M-MACBETH linear programming algorithm.

Again, the MACBETH question–answer protocol was numbered in decreasing order of comparative attractiveness, that is, C_x is more attractive than C_y if and only if $x > y$. To also come out with their differences in attractiveness between C_x and C_y, the following MACBETH categories or definition of preferences which are a six-level scale was adopted namely: 'very weak,' 'weak,' 'moderate,' 'strong,' 'very strong' or 'extreme.' The MACBETH categories were used in judging for each sustainability dimension/criterion where numerical values were rather substituted for the qualitative ratings of the weights. The justification is to avoid potential difficulties that may arise from when beneficiaries are asked to produce direct numerical estimations of values and weights as required by numerical methods such as the Simple Multi-Attribute Rating Technique (Edwards and Barron, 1994). However, because of the additive evaluation model to help in the performance for each criterion, the beneficiaries ultimately define the ('most attractive criteria') and ('least attractive criteria') reference levels.

The term 'most attractive criteria' explains the level which is sustainability best practices and the term 'least attractive criteria' explains the level which is perceived to be not sufficient. The explanation of the levels of reference in each criterion gives a global meaning, and one is directly able to classify the community-managed water supply services as follows:

(1) *Highly sustainable water supply system* having a score above 100 (thus, more sustainable than a water supply services that has a performance equal to the 'most attractive criteria' level in all criteria).
(2) *Sustainable water supply system* having a score between 0 and 100.
(3) *Unsustainable water supply system* having a score below 0 (thus, less sustainable than a water supply services that has a performance equal to the 'least attractive criteria' level in all criteria).

3 Results and discussion

3.1 Descriptive analysis

Table 2 presents the descriptive statistics of community members/beneficiaries interviewed for the study. With the connection type, the result shows that 98.45% of community members/beneficiaries use the public standpipe while 1.55% uses the private household

Table 2 Distribution zones and characteristics of respondents (community members/beneficiaries) interviewed. *Source*: Field Survey, 2018

Variable	Pooled sample		Aboabo R		Ebenezer		Esereso		Habitat		Krofrom		Monsie	
	Freq	%	Freq	%	Freq	%	Freq	%	Freq	%	Freq	%	Freq	%
Connection type														
Domestic/household type	6	1.55	1	3.03	0	0.00	1	3.03	0	0.00	1	3.03	0	0.00
Public standpipe	381	98.45	32	96.97	32	100.0	32	96.97	32	100.0	32	96.97	32	100.0
Total	387	100.0	33	100.0	32	100.0	33	100.0	32	100.0	33	100.0	32	100.0
Gender of beneficiaries														
Male	170	43.93	12	36.36	9	28.12	15	45.45	12	37.5	22	66.67	9	28.12
Female	215	56.07	21	63.64	23	71.88	18	54.55	20	62.5	11	33.33	23	71.88
Total	387	100.0	33	100.0	32	100.0	33	100.0	32	100.0	33	100.0	32	100.0
Age group of beneficiaries														
18–45	316	81.65	23	69.70	28	87.5	31	93.94	23	71.87	28	84.85	28	87.50
46–60	56	14.47	9	27.27	3	9.37	2	6.06	5	15.63	4	12.12	4	12.5
60 and above	15	3.88	1	3.03	1	3.13	0	0.0	4	12.5	1	3.03	0	0.00
Total	387	100	33	100.0	32	100.0	33	100.0	32	100.0	33	100.0	32	100.0
Marital status														
Single	131	33.85	9	27.27	11	34.37	17	51.52	3	9.38	16	48.48	13	40.62
Married	233	60.21	23	69.70	20	62.5	16	48.48	26	81.25	16	48.48	18	56.25
Divorced	8	2.07	1	3.03	0	0.00	0	0.00	2	6.25	0	0.00	1	3.13
Widowed	15	3.88	0	0.00	1	3.13	0	0.00	1	3.12	1	3.03	0	0.00
Total	387	100.0	33	100.0	32	100.0	33	100.0	32	100.0	33	100.0	32	100.0
Educational level														
No formal education	14	3.63	2	6.06	0	0.00	0	0.00	4	12.90	0	0.00	0	0.00
Primary school	14	3.63	1	3.03	0	0.00	2	6.06	2	6.45	1	3.03	2	6.24
Middle school/JHS/JSS	135	34.97	12	36.36	15	46.87	3	9.09	21	67.74	10	30.30	13	40.63
SSS/SHS	119	30.83	10	30.30	11	34.37	16	48.48	3	9.68	6	18.18	13	40.63

Table 2 (continued)

Variable	Pooled sample		Aboabo R		Ebenezer		Esereso		Habitat		Krofrom		Monsie	
	Freq	%	Freq	%	Freq	%	Freq	%	Freq	%	Freq	%	Freq	%
Training college/tertiary	104	26.94	8	24.24	6	18.75	12	36.36	1	3.23	16	48.48	4	12.5
Total	387	100.0	33	100.0	32	100.0	33	100.0	31	100.0	33	100.0	32	100.0
Variable	Pooled sample		Nteduom		Odumase		Pataabo		Tunsuom		Wawase		Hwentemase	
	Freq	%	Freq	%	Freq	%	Freq	%	Freq	%	Freq	%	Freq	%
Connection type														
Domestic/household type	6	1.55	1	3.03	1	3.03	0	0.0	0	0.0	0	0.0	1	3.03
Public standpipe	381	98.45	32	96.96	32	96.96	32	100.0	30	100.0	32	100.0	32	96.96
Total	387	100.0	33	100.0	33	100.0	32	100.0	30	100.0	32	100.0	33	100.0
Gender of beneficiaries														
Male	170	43.93	11	33.33	15	46.88	12	37.5	15	50.0	20	62.5	18	54.54
Female	215	56.07	22	66.66	17	53.12	20	62.5	15	50.0	12	37.5	15	45.45
Total	387	100.0	33	100.0	32	100.0	32	100.0	30	100.0	32	100.0	33	100.0
Age group of beneficiaries														
18–45	316	81.65	30	90.90	28	87.5	29	90.63	25	83.33	14	43.75	29	87.87
46–60	56	14.47	3	9.09	3	9.38	3	9.37	4	13.33	12	37.5	4	12.12
60 and above	15	3.88	0	0.00	1	3.12	0	0.0	1	3.33	6	18.75	0	0.0
Total	387	100.0	33	100.0	32	100.0	32	100.0	30	100.0	32	100.0	33	100.0
Marital status														
Single	131	33.85	9	27.27	8	25.0	10	31.25	14	46.66	7	21.87	14	42.42
Married	233	60.21	24	72.72	23	71.87	21	65.62	12	40.00	16	50.0	18	54.54
Divorced	8	2.07	0	0.00	0	0.0	1	3.13	0	0.00	3	9.37	0	0.0
Widowed	15	3.88	0	0.00	1	3.13	0	0.0	4	13.33	6	18.75	1	3.03
Total	387	100.0	33	100.0	32	100.0	32	100.0	30	100.0	32	100.0	33	100.0

Table 2 (continued)

Variable	Pooled sample		Nteduom		Odumase		Pataabo		Tunsuom		Wawase		Hwentemase	
	Freq	%	Freq	%	Freq	%	Freq	%	Freq	%	Freq	%	Freq	%
Educational level														
No formal education	14	3.63	3	9.09	1	3.13	1	3.13	2	6.66	0	0.00	1	3.03
Primary school	14	3.63	2	6.06	12	37.5	1	3.13	9	30.0	3	9.37	0	0.00
Middle school/JHS/JSS	135	34.97	8	24.24	0	0.0	8	25.0	0	0.00	17	53.12	7	21.21
SSS/SHS	119	30.83	12	36.36	9	28.12	10	31.2	9	30.0	9	28.12	11	33.33
Training college/tertiary	104	26.94	8	24.24	10	31.25	12	37.5	10	33.33	3	9.37	14	42.42
Total	387	100.0	33	100.0	32	100.0	32	100.0	30	100.0	32	100.0	33	100.0

type, an indication that Small Town Water Supply Systems facilitated by the Community Water and Sanitation Agency are mostly planned to be used as public standpipes than private household connection type. This also confirms Adank and Tuffour (2013) statement that the utility-managed model in small towns is different from urban water supply as it focuses on the provision of a basic level of water services through public standpipes, rather than through household connections. The pooled result for the gender distribution of the respondents revealed that 56.07% of the respondents in the study were females, while 43.93% were males. Similar results were recorded in the 12 distribution zones in the study. For instance, in the Aboabo zone, 63.64% of the respondents were females, while 36.36% were males. Ebenezer zone recorded 71.88% females and 28.12% males, while Esereso zone also recorded 54.55% females and 45.45% males. Similar results were found in the Habitat zone, Monsie Zone, Nteduom zone, Odumasi zone and Pataabo zone with the exception of Tunsuom zone with 50% each for both males and females, and the other zones including Krofrom zone, Wawase zone and Hwentemase zone had more male respondents than females. This shows that majority of the respondents were females but with active male involvement. The reason could be attributed to the fact that water is continuously and consistently used for domestic chores like cooking, washing, etc., which generally describe females as main users, providers, guardians and managers of water in the various household and hence their active involvement. Probably, it could also be that the over-representation of females in the study is due to the time of the survey because most women could be at home on normal working days preparing meals or attending to other businesses when researchers visit households to conduct interviews and the men could not be at home and could possibly be working on their farms or other paid or unpaid work sites outside of the home and hence males' low representation accounting for more women being captured even though it was a random survey.

From the pooled sample in Table 2, the ages of the respondents ranged from 18 to 75 years with a mean age of 36.65 years. Table 2 also shows that majority of the respondents (81.65%) are within the age bracket of 18–45 years, while 14.47% are within the age bracket of 46–60 years and 3.88% are for the age bracket above 60 years. However, the results from the pooled sample almost follow the same trend as far as the 12 distribution zones are concerned. Table 2 again shows that 60.21% of the respondents were married and 33.85% have not married. Also, 2.07% of the respondents were divorced, while 3.88% were widowed. This indication suggests that married respondents will have more need for water than single respondents.

Results from Table 2 depict that majority of the respondents (34.97%) had formal education up to Middle/JHS/SSS level, while 30.83% had up to secondary level. However, about 26.94% had tertiary education, while 3.63% had only primary education, and the remaining 3.63% had no formal education. The table also shows that on average, the number of educational/schools years of the community members/beneficiaries was 14 years of formal education.

3.2 Scores of sustainability criteria

The pairwise comparison of the sustainability criteria assessed showed that drinking water quality when compared to quality of service, efficient use of water, investment, implementation of policies and public disclosure and reliability had the highest score as shown in Table 3. Thus, for example, the sustainability criteria for the drinking water quality were: 272 > 115 quality of service, 249 > 138 efficient use of water, 308 > 79 investment, 295 > 92

Table 3 Pairwise comparisons of qualitative judgment for the sustainability criteria assessed in this study. *Source*: Field Survey, 2018

Sustainability criteria	Drinking water quality	Quality of service	Efficient use of water	Investment	Implementation of policies and public disclosure	Reliability	Numerical scores
Drinking water quality		272	249	308	295	245	1369
Quality of service	115		293	341	315	174	1238
Efficient use of water	138	94		262	336	129	959
Investment	79	46	125		257	156	663
Implementation of policies and public disclosure	92	72	51	130		173	518
Reliability	142	213	257	231	214		1057

implementation of policies and public disclosure and 245 > 141 reliability and that is, 275 + 249 + 308 + 295 + 245 = 1369. Thus, 1369 times drinking water quality was considered as more important than other criterion in the table. This implies that drinking water quality is the highest preference among all sustainability criteria in community-managed water supply services. This is consistent with Chown's (2014) findings that drinking water quality is a significant factor influencing the realization of sustainability and as a general benefit for community water supply.

Quality of service was followed in that order, by quality drinking water, efficient use of water, investment, implementation of policies and public disclosure and reliability (115, 293, 341, 315 and 174).

Reliability as the third highest criteria ranked was scored (1057) when compared to drinking water quality (141), quality of service (213), efficient use of water (256), investment (231), implementation of policies and public disclosure (214) as shown in Table 3.

The table also shows that about 959 preferences were made for efficient use of water when compared to drinking water quality (138), quality of service (94), investment (263), implementation of policies and public disclosure (336) and reliability (129). Also, respondents scored (663) for investment against drinking water quality (79), quality of service (46), efficient use of water (125), implementation of policies and public disclosure (257) and reliability (156).

Finally, implementation of policies and public disclosure scored the lowest of (518) among all the sustainability criteria assessed when compared with drinking water quality (92), quality of service (72), efficient use of water (51), investment (130) and reliability (173). The implication is that implementation of policies and public disclosure as sustainability criteria for water supply systems is the least priority of community members/beneficiaries of the system. However, all the aforementioned criteria including drinking water quality, quality of service and efficient use of water and reliability were found to be among the attractive criteria toward the sustainability of community-managed water supply system. Also, implementation of policies and public disclosure had the least attractive criteria and hence quite insignificant in the community-managed water supply system as far as sustainability is concerned.

3.3 Determining weights of criteria assessed

Even though M-MACBETH was the same fundamental approach as the mean method (Table 4), there were differences in the way that the weight and attribute values were calculated (Fig. 2). The MACBETH methodology was used to show the differences of attractiveness for the sustainability criteria assessed. Drinking water quality as a sustainability criterion scored by the survey respondents had a preference of 4.97% for very weak, 7.67% for weak, 29.44% for moderate, 30.90% for strong, 22.57% for very strong and 4.46% for extreme as shown in Table 4. This implies that majority of the respondents/beneficiaries (30.90%) prefer better drinking water quality. Using the mean method, a score of 3.5 was attained for drinking water quality which confirms the community preference for better drinking water quality. A mean score of 3.5 when the MACBETH methodology was considered means that drinking water quality as a sustainability criterion lies between moderate and strong. This confirms Connor's (2015) statement that the safeguarding of drinking water quality is recognized as a pre-requisite for sustainable development.

With the quality of service, a preference of 0.81% for very weak was attained, 3.80% preference for weak, 35.06% preference for moderate, 34.57% preference for strong,

Table 4 Differences of attractiveness for the sustainability criteria using the MACBETH methodology. *Sources*: Field survey, 2018

	1 Very weak	%	2 Weak	%	3 Moderate	%	4 Strong	%	5 Very strong	%	6 Extreme	%	Total	Mean scores T (categ) Ss (387)
Drinking water quality														
Quality of service	14	5.15	25	9.19	81	29.78	99	36.40	46	16.91	7	2.57	272	3.5
Efficient use of water	6	2.41	26	10.44	76	30.52	65	26.10	70	28.11	6	2.41	249	
Investment	9	2.92	22	7.14	96	31.17	82	26.62	77	25.00	22	7.14	308	
Implementation	23	7.80	13	4.41	82	27.80	87	29.49	72	24.41	18	6.10	295	
Reliability	16	6.53	19	7.76	68	27.76	90	36.73	44	17.96	8	3.27	245	
Total	68	4.97	105	7.67	403	29.44	423	30.90	309	22.57	61	4.46	1369	
Quality of service														
Drinking water quality	5	4.35	12	10.43	33	28.70	39	33.91	19	16.52	7	6.09	115	3.2
Efficient use of water	1	0.34	9	3.07	97	33.11	122	41.64	58	19.80	6	2.05	293	
Investment	3	0.88	8	2.35	138	40.47	106	31.09	75	21.99	11	3.23	341	
Implementation	0	0.00	11	3.49	120	38.10	99	31.43	76	24.13	9	2.86	315	
Reliability	1	0.57	7	4.02	46	26.44	62	35.63	48	27.59	10	5.75	174	
Total	10	0.81	47	3.80	434	35.06	428	34.57	276	22.29	43	3.47	1238	
Reliability														
Drinking water quality	12	8.51	26	18.44	41	29.08	29	20.57	25	17.73	8	5.67	141	2.7
Quality of service	2	0.94	6	2.82	46	21.60	71	33.33	68	31.92	20	9.39	213	
Efficient use of water	8	3.10	11	4.26	81	31.40	63	24.42	75	29.07	20	7.75	258	
Investment	5	2.16	8	3.46	66	28.57	65	28.14	71	30.74	16	6.93	231	
Implementation	4	1.87	7	3.27	59	27.57	51	23.83	60	28.04	33	15.42	214	
Total	31	2.93	58	5.49	293	27.72	279	26.40	299	28.29	97	9.18	1057	
Efficient use of water														
Drinking water quality	2	1.45	7	5.07	48	34.78	45	32.61	29	21.01	7	5.07	138	2.5
Quality of service	0	0.00	4	4.26	29	30.85	29	30.85	30	31.91	2	2.13	94	

Table 4 (continued)

	1 Very weak	%	2 Weak	%	3 Moderate	%	4 Strong	%	5 Very strong	%	6 Extreme	%	Total	Mean scores *T* (categ) Ss (387)
Investment	3	1.15	8	3.05	85	32.44	96	36.64	63	24.05	7	2.67	262	
Implementation	2	0.60	9	2.68	108	32.14	122	36.31	86	25.60	9	2.68	336	
Reliability	4	3.10	7	5.43	49	37.98	40	31.01	24	18.60	5	3.88	129	
Total	11	1.15	35	3.65	319	33.26	332	34.62	232	24.19	30	3.13	959	
Investment														
Drinking water quality	11	13.92	31	39.24	11	13.92	18	22.78	4	5.06	4	5.06	79	1.7
Quality of service	5	10.87	2	4.35	8	17.39	10	21.74	16	34.78	5	10.87	46	
Efficient use of water	3	2.40	4	3.20	54	43.20	26	20.80	28	22.40	10	8.00	125	
Implementation	17	6.61	13	5.06	82	31.91	94	36.58	48	18.68	3	1.17	257	
Reliability	8	5.13	4	2.56	41	26.28	66	42.31	32	20.51	5	3.21	156	
Total	44	6.64	54	8.14	196	29.56	214	32.28	128	19.31	27	4.07	663	
Implementation of policies and public disclosure														
Drinking water quality	7	7.61	9	9.78	32	34.78	21	22.83	21	22.83	2	2.17	92	1.3
Quality of service	4	5.56	2	2.78	25	34.72	19	26.39	15	20.83	7	9.72	72	
Efficient use of water	1	1.96	4	7.84	20	39.22	13	25.49	8	15.69	5	9.80	51	
Investment	2	1.54	8	6.15	44	33.85	25	19.23	45	34.62	6	4.62	130	
Reliability	2	1.16	5	2.89	60	34.68	63	36.42	39	22.54	4	2.31	173	
Total	16	3.09	28	5.41	181	34.94	141	27.22	128	24.71	24	4.63	518	

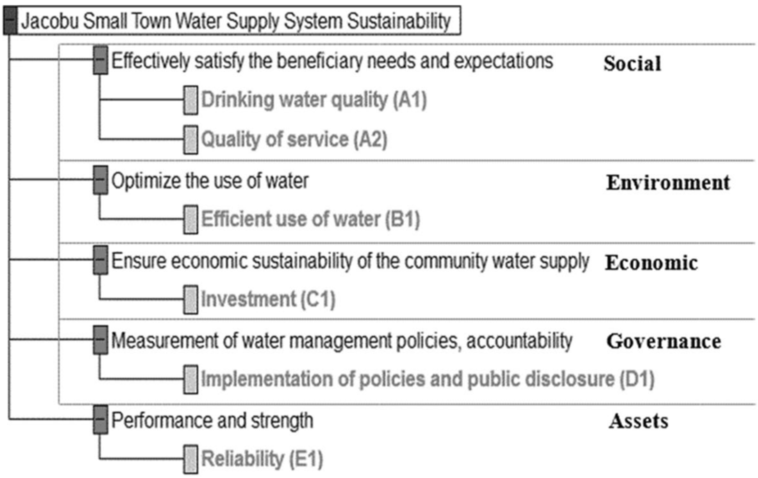

Fig. 2 Value tree showing the logical framework of the dimensions, objectives and criteria of the water supply system sustainability (M-MACBETH Software)

22.29% preference for very strong and 3.47% preference for the extreme. This indicates that 35.06% of the respondents which is the majority preference for quality of service is moderate. Using the mean method, a score of 3.2 was also attained for quality of service. However, the mean score shows that achieving sustainability of community-managed water supply services when considering quality of service lies between moderate and strong. It can be inferred that quality of service is likewise a preference for the sustainability of water supply system through the expansion of water coverage to have a positive contribution. Improved quality of service while minimizing shortage can directly and indirectly increase time available for work, reducing morbidity, mortality and school absenteeism among students as emphasized by Hantke-Domas and Jouravlev (2011) cited in WWAP (2016).

Also, reliability recorded a preference of 2.93%, 5.49%, 27.72%, 26.40%, 28.29% and 9.18% as very weak, weak, moderate, strong, very strong and extreme, respectively, as shown in Table 4. This shows that majority of the respondents/beneficiaries (28.29%) preference for reliability is very strong with a mean score of 2.7 which lies between weak and moderate. This equally means that reliability is a priority option for the beneficiaries of the system as far as sustainability is concern but strongly tilted toward moderation. According to WWAP (2016), failure to secure a reliable water supply to sustain users who depend heavily on it results in the disappearance of sustainable water management that creates an enabling environment across economic sectors.

Again, efficient use of water recorded 1.15% weak, 3.65% for very weak, 33.26% for moderate, 34.62% for strong, 24.19% for very strong and 3.13% for extreme. This also shows that 34.62% which is the majority of the beneficiaries' attractiveness is strong efficient use of water with a mean score of 2.5 which lies between weak and moderate. Efficient use of water receiving a mean score of 2.5 could be attributed to the low price charge for the pay-as-you-fetch from the standpipes by the beneficiaries to use water judiciously. The attractiveness of efficient use of water as weak and moderate is the foundation for using water judiciously and will decrease water losses and unaccounted-for water. Practically, it can help in times of making a substantial contribution to many of the sustainable development purposes, especially during water shortage without reducing the consumption of customers to affect revenue. This is in line with WSDH (2017) report that implementing a water use efficiency as a sustainability criteria without reducing the consumption of customers has the possibility to maintain financial viability.

Investment as a sustainability criterion also recorded 6.64% as very weak, 8.14% as weak, 29.56% as moderate, 32.28% as strong, 19.31% as very strong and 4.07% as extreme. This, nonetheless, indicates that majority of the respondents'/beneficiaries' (32.28%) attractiveness as far as investment is concerned is strong with a mean score of 1.7 which lies between very weak and weak as shown in Table 4. This means that investment is a weak preference as far as the management of the water supply system is concerned. The implication therefore is that mobilizing supplementary funds from different sources to support the systems management is a weak priority for the beneficiaries which will negatively affect its future financial sustainability. This could be as a result of poverty and poses a serious risk to the long-term sustainability of community water systems. As confirmed by Connor (2015), investment can be affected by poverty rendering existing investments in water less efficient simply because both households and communities find it extremely difficult to finance, operate as well as maintain infrastructure and even sustainability remains a challenge in a situation where investments are made due to weak governance associated with service cost and low income.

Finally, when it comes to implementation of policies and public disclosure, 3.09% preference was very weak, 5.41% preference was weak, 34.94% preference was moderate, 27.22% preference was strong, 24.71% was very strong, and 4.63% was extreme. Majority of the respondents'/beneficiaries' (34.94%) attractiveness was moderate. Implementation of policies and public disclosure recorded a mean score of 1.3 which lies between very weak and weak. This means that implementation of policies and public disclosure is a weak preference and is confirmed by the fact that majority of the community members do not attend community forums organized by the management team to disclose the financial position and to discuss matters affecting the smooth running of the system.

3.4 Overall sustainability level

With reference to the definition of sustainability as development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs, the overall sustainability level of Jacobu Small Town Water Supply System as well as how the system is faring in each of the dimensions of sustainability and its

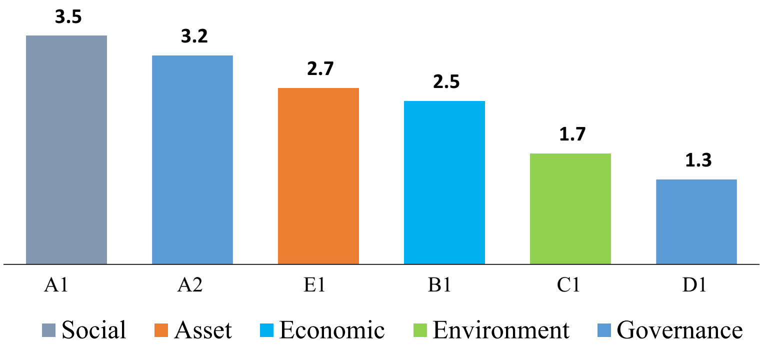

Fig. 3 Weights/mean scores of the sustainability criteria

corresponding criteria considered for the study are shown in Fig. 3. This study revealed that drinking water quality offers the greatest contribution in achieving the sustainability of community-managed water supply services. This is in line with Kulinkina et al. (2016) finding from a qualitative data which suggest that consumer demand for water supply in their various study towns in Ghana appear to be driven more by drinking water quality. The various weights for the criteria showed that social sustainability (drinking water quality and quality of service) had a mean score or weight of 3.5 and 3.2, respectively. This is followed by asset sustainability (reliability) with the weight of 2.7 and economic sustainability (investment) with the weight of 2.5. Other sustainability dimensions as far as water supply is concerned have to do with its environment (efficient use of water) with a weight of 1.7 as well as governance (implementation of policies and public disclosure) with a weight of 1.3 (Fig. 3). However, the sustainability score for each of the dimensions and the criteria are between 0 and 100 (Table 5). The implication therefore is that Jacobu Small Town Water Supply System is a sustainable community-managed water supply system but lies between very weak and moderate sustainability level, indicating that the sustainability level of Jacobu Small Town Water Supply System is not strong enough.

3.5 Comparison of the results

The ranking of the criteria varied according to the weighting method that was used. In the order of the MACBETH results of the criteria, the mean method also ranked in the same order as shown in Table 5, regardless of the numerical scale used. Thus, in both tools, the high ranking sustainability criterion tended to be drinking water quality, reliability and efficient use of water while investment and implementation of policies and public disclosure ranked the lowest. In other words, drinking water quality is the most attractive criterion to both the MACBETH Current Scale/Basic difference and the Mean Method. In terms of the order of the ranking, there was no sustainability criterion that was notably different in the order of the two methods (MACBETH Current scale/Basic difference and the Mean Method) applied and as such both ranked consistently the same (Tables 4, 5).

3.6 Conclusion and recommendation

The contribution of sustainable water supply can be seen significantly in areas like social, economic, environmental, governance, assets and as such assessing the sustainability of a specific case study to address practical problems is worth studying to benefit government and people in the study area. Among others, Ghana still faces challenges of advancing rural development, especially in terms of water supply services.

The results of the multi-criteria decision analysis (MCDA) model using the MACBETH approach allows this study to conclude that quality drinking water and reliability offers the greatest contribution to achieving the sustainability of community-managed water supply services and particularly the Jacobu Small Town Water Supply System. Our findings show that the sustainability score for each of the dimensions and its accompanying criteria ranges from 3.5, 3.2, 2.7, 2.5, 1.7 and 1.3, respectively, indicating that the Jacobu Small Town Water System sustainability lies between weak and moderate sustainability levels.

For the sustainability of community-managed water supply services to be improved, it is recommended that management of the water supply system should continuously facilitate the re-sampling of water to consistently and frequently confirm water quality testing on groundwater. Also, management should engage Ghana Water Company or other accredited

Table 5 Matrix of judgments for the sustainability criteria (M-MACBETH software and M-MACBETH basic difference)

	Drinking water quality	Reliability	Efficient use of water	Investment	Implementation of policies and public disclosure	All lower	Current scale
Weighting (JTWSS Sustainability)							
(a)							
Drinking water quality	No	Moderate	Moderate	Strong	Strong	Strong	100.00
Reliability		No	Moderate	Strong	Strong	Strong	86.96
Efficient use of water			No	Strong	Strong	Strong	73.91
Investment				No	Strong	Strong	43.48
Implementation of policies and public disclosure					No	Moderate	13.04
All lower						No	0.00
(b)							
Drinking water Quality	No 0	Moderate 3	Moderate 6	Strong 13	Strong 20	Strong 23	23
Reliability		No 0	Moderate 3	Strong 10	Strong 17	Strong 20	20
Efficient use of water			No 0	Strong 7	Strong 14	Strong 17	17
Investment				No 0	Strong 7	Strong 10	10
Implementation of policies and public disclosure					No 0	Moderate 3	3
All lower						No 0	0.00

water laboratories to undertake water quality tests in accordance with the Ghana Standards Board Standard/Water Safety Framework to ensure that the water they supply is of high quality that meets national standards and any regulatory requirements or agreed levels of service to achieve the needed sustainability of community-managed water supply services.

It is also logical to infer that the national drinking water quality management framework should be strengthened in community-managed water supply systems to guide water management teams on effective drinking water quality management and public health protection. This is to confirm the adequacy of existing water supply systems or the need for improvement to protect and improve drinking water quality and consequently to protect human health.

Moreover, the quality of water can be affected at any points either through distribution, handling or storage at the household level but the general believe is that the water supplier's ultimate responsibility is to only deliver water to the consumers or beneficiaries since it is not possible to control consumers' actions at any level. However, integrated management is essential such that water management teams should consider how drinking water quality may be affected during handling and storage at the household's level and provide appropriate information to beneficiaries to maintain water safety and also protect their health due to its interrelated nature.

Furthermore, management teams should design drinking water quality improvement plans to include both short-term and long-term programs such as enhanced mains flushing programs as well as the development of community awareness programs are ultimately adhered to. Improvement plans should include the objectives as well as actions to be taken and accountability. Finally, the study used one particular case study and did not consider other community-managed water supply systems. Therefore, the current study suggests that future research could undertake a comparative study on assessing the sustainability of community-managed water supply systems.

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