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Research Paper

Application of the Water Service Sustainability Index to water services in sub-Saharan Africa: the case studies of eight councils in the Southern region of Cameroon (Central Africa)

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ABSTRACT

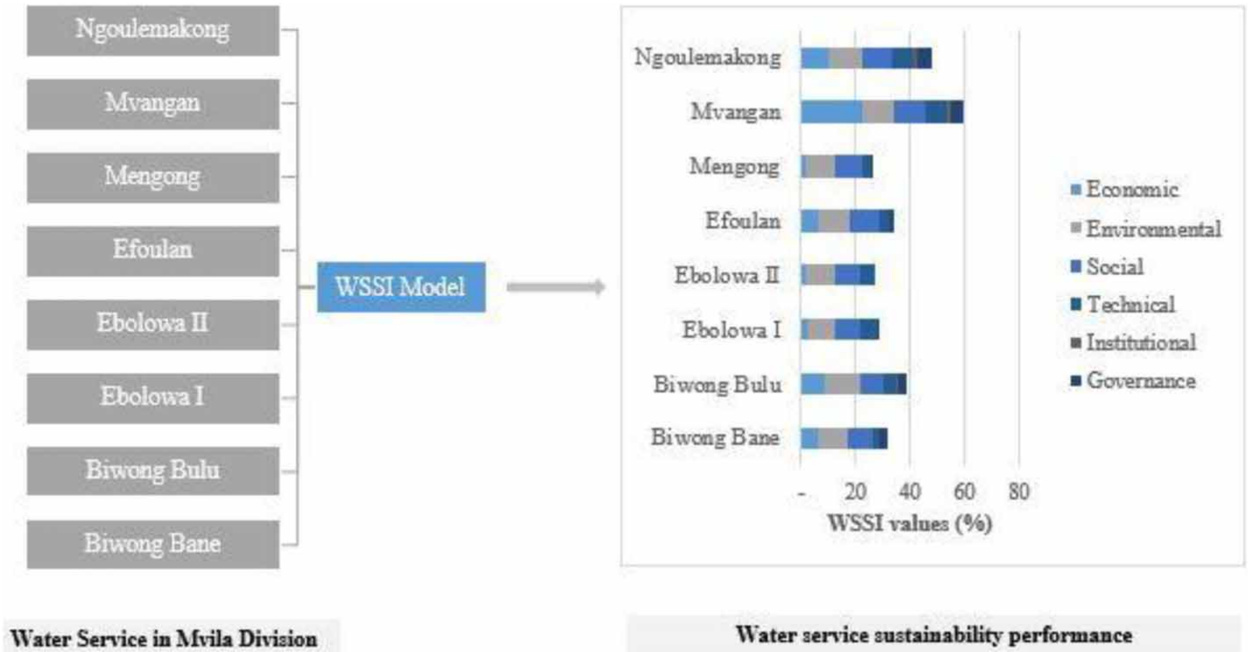
The aim of this article is to assess the sustainability of rural water service in the Mvila Division (Southern region of Cameroon) in order to constructively feed the debate on the most effective ways to improve access to rural water service in sub-Saharan Africa. The methodological approach was based on the application of the Water Service Sustainability Index (WSSI) and was implemented through technical inspection of the rural drinking water supply system (RDWSS), the semi-structured interview, and a survey of 103 service providers. Results show that the sustainability performance of rural water service in the Mvila Division is poor–medium. The highest aggregate value of the WSSI was obtained in the Mvangan council (59.54%) followed by the Ngoulemakong council (47.99%), Biwong Bulu (38.53%), Efoulan (33.99%), Biwong Bane (31.51%), Ebolowa I (28.96%), Ebolowa II (28.19%), and Mengong (26.57%). Results also show that rural water service is influenced by factors such as the low pricing of rural water service, climate risk, the poor structuring of the maintenance chain, and the weak commitment of the municipal authorities. However, this study represents only a current snapshot of rural water service delivery conditions and should be conducted at regular intervals to track changes in overall and local conditions.

Key words: index, rural water service, sub-Saharan Africa, sustainability

HIGHLIGHTS

- This study aimed to assess the sustainability of rural water service in the Mvila Division, Southern region of Cameroon.
- The methodological approach was based on the application of the Water Service Sustainability Index.
- Findings suggest that the community-based management is not an effective means of delivering rural water services.

GRAPHICAL ABSTRACT



1. INTRODUCTION

Water is essential for human health and well-being. The United Nations considers access to clean water as a basic human right and an essential step toward improving living standards worldwide. In the recent decades, significant progress has been made in improving access to drinking water around the world. In fact, from 1990 to 2015, the proportion of the world's population with access to safe drinking water has risen from 76 to 91% (United Nations 2018). This improvement has mainly occurred in rural areas where access to safe drinking water has doubled (WHO & UNICEF 2017).

However, the presence of the rural drinking water supply system (RDWSS) in a rural area does not always indicate that people living there have access to a sustainable water service. Water service in the rural area faces problems and challenges related to inadequacies in maintenance operations and financial flow management (Molinos-Senante *et al.* 2019). Therefore, it is essential to examine the performance of rural water service to help decision-makers determine how the quality of service can be improved, prioritize how and where investments should be made, and evaluate the effectiveness of existing policies. Several indices have been developed to analyze the sustainability of water service including the Index of Drinking Water Adequacy (IDWA) (Lee Kuan Yew School of Public Policy 2010), the Equity Index in Water and Sanitation (Luh *et al.* 2013), the Sustainability Index Tool (SIT) (Schweitzer *et al.* 2014), the Sustainable Water Management Index (Maiolo & Pantusa 2019), and the Index of Water Quality Service (Molinos-Senante *et al.* 2019).

The IDWA allows cross-country comparisons and helps in ascertaining which of the five components (resource, access, use, capacity, and quality) access to drinking water is weak and requires priority attention. The Equity Index in Water and Sanitation assesses progress in equity in achieving human rights to clean water and sanitation (Luh *et al.* 2013). The SIT is designed to assess the sustainability of drinking water and sanitation programs and projects (Schweitzer *et al.* 2014). The Sustainable Water Management Index measures the sustainability of water management and assesses the effects of policies taken to achieve sustainability goals. The index of water service quality is based on the analytical hierarchy process (AHP) and Monte Carlo simulations to evaluate water service quality provided by the RDWSS (Molinos-Senante *et al.* 2019).

Although there are successful experiments in the implementation of these indices, they are not fully applicable in rural areas without modification. Indeed, these indices focus on one aspect of service sustainability including water governance (IDWA and Equity Index in Water and Sanitation), water–sanitation–hygiene (SIT), water management (Sustainable Water Management Index), and the service quality (Index of Water Quality Service). Therefore, they do not provide a comprehensive assessment of the sustainability of rural water services, which could lead to poor decision-making on the part of managers. In addition, these indices are made up of indicators that are not directly applicable to rural areas in sub-Saharan Africa. Better yet, they need to be adjusted to reflect contextual parameters before being applied (Mvongo *et al.* 2021a).

A new water sustainability index, called Water Service Sustainability Index (WSSI), was recently developed using multi-criteria analysis and the AHP by Mvongo *et al.* (2021b) in order to allow an integrative, contextualized, and prospective analysis of the sustainability of water service in the rural area. This was specifically developed with the involvement of local water stakeholders and based on the Mvila Division's natural and socioeconomic characteristics. This paper discusses the application of the WSSI in eight councils in the Mvila Division (Southern region of Cameroon). The purpose of this paper is to constructively feed the debate on the most effective ways to improve access to rural water services in sub-Saharan Africa. The article also provides information on the current situation of the RDWSS in order to mobilize the national and international efforts required in the region.

2. MATERIALS AND METHODS

2.1. WSSI framework

2.1.1. Sustainability assessment criterion

Dimensions and indicators are the main constituents of the WSSI. They were selected through a literature review on existing evaluation frameworks (Mvongo *et al.* 2021b). The WSSI final framework has 21 indicators grouped into six dimensions (economic, technical, environmental, governance, social, and institutional). Table 1 presents indicators to assess water service sustainability.

2.1.2. Normalization of indicators

The normalization of indicators is done using the Min–Max method and the categorical scale method. The Min–Max method is used for the quantitative indicators. Indeed, the values of the indicators obtained with this method allow decision-makers to assess the performance of the indicator studied and to make the appropriate decisions relating to this indicator. Algebraically, the Min–Max method results in the following equation:

$$S_i = \frac{X_i - X_{\min}}{X_{\max} - X_{\min}} \times 100 \quad (1)$$

where S_i is the value of the indicator i, X_i is the current value of the indicator i, $X_{\min}$ is the minimum value of the indicator i, and $X_{\max}$ is the maximum value of the indicator i. The categorical scale method is used for qualitative indicators. Indeed, because of their nature, the Min–Max method could not be applied to them. Algebraically, the categorical scale method results in the following equation:

$$S_i = \begin{cases} Z_1 \text{ if } X_i \text{ meets criteria 1} \\ Z_2 \text{ if } X_i \text{ meets criteria 2} \\ Z_3 \text{ if } X_i \text{ meets criteria 3} \\ \vdots \\ Z_n \text{ if } X_i \text{ meets criterion } n \end{cases} \quad (2)$$

where S_i is the value of the indicator i; X_i is the current value of the indicator i; Z_j is the category for X_i which meets the criterion j; and n is the number of the category.

2.1.3. Weighting dimensions and indicators

The participatory approach was used to weighting dimensions and indicators in light of the fact that it directly involves all stakeholders involved in water service management (Mvongo *et al.* 2021b). The AHP was used because of its simplicity. It facilitates the decomposition of the problem into a hierarchical structure and ensures that the qualitative and quantitative aspects of the problem are taken into account simultaneously in the evaluation process where expert judgments are taken into account through an even comparison matrix (Saaty 1980; Siekelova *et al.* 2021). The weights of the various indicators were established by following the steps and procedures recommended by Saaty (1990), including the development of the hierarchy structure, pairwise comparisons, the establishment of the pairwise comparison matrix, the calculation of priority

Table 1 | Dimensions and indicators selected

Dimensions	Indicators	Indicators' descriptions	Weight (%)
Economic	Self-financing capacity	The self-financing capacity questions the water price policy and whether with the current price, the service can be self-financing.	17.84
	Financial autonomy	Financial autonomy analyzes the financial resources available within the management structure to determine whether they are capable of covering the current costs of the service.	11.35
	Total coast recovery	This indicator focuses on the system to collect and manage funds. In this study, coast recovery is calculated as the ratio between the total amount of contributions actually collected and the total amount of contributions to be collected.	4.85
Environmental	Water quality	Water quality measures the level of compliance of the physical, chemical, and biological parameters defined by the World Health Organization.	7.18
	Water availability	Water availability is defined as the volume of water supplied to each user.	4.57
	Climate risk	The purpose of climate risk analysis is to determine whether the service is at risk in the face of climate variability and/or change.	2.89
Social	Affordability	Affordability analyzes households' ability to pay for water services.	6.20
	Accessibility	It refers to the degree of ease or difficulty in obtaining drinking water minutes per capita per day.	3.95
	Non-discrimination and equity	This indicator will be analyzed through the existence of rules favoring access to water services to all social strata.	2.50
Technical	Quality of construction	Construction quality is assessed on the basis of the physical condition of the superstructure, given that the other parameters are difficult to assess.	2.96
	Frequency of maintenance operations	This indicator is analyzed through the frequency of maintenance operations (maintenance tours are done monthly, quarterly, semi-annually, and annually, or maintenance tours never do).	6.16
	Access to spare parts	This indicator is analyzed through the availability of spare parts at the local level. We will thus analyze the availability of spare parts at the village level and at the council level.	6.54
	Reliability of water system	Reliability is expressed as a percentage of the time the service is (or is not) fully functional.	4.29
Institutional	Post-construction support to council	This component analyses the mechanism setup by the central administration to provide technical, financial, and managerial support council.	1.63
	Post-construction support to service managers	This component analyses the mechanism setup by the council to provide technical, financial, and managerial support to service providers.	1.63
	Regulation	This indicator, therefore, analyzes the existence and implementation of service and service manager's regulatory mechanisms.	0.85
	Formalization of contract	The formalization of contracts analyses the existence of contractual documents between the council and the management structures.	0.72
	Organization of the service	The organization of the service analyzes how the service is organized and managed. It identifies the actors involved in the management of the service and looks at whether there is a clear separation of roles between the different actors.	0.80
Governance	Skills of water service managers	Skills of the management structure analyze the overall functioning of the management structure, its management capacity, and the effectiveness of its management.	2.59
	Financial flow management	Financial flow management analyzes the process of securing the savings of water sales revenue, and how expenditure commitments and disbursements are made.	4.09
	Participation	The participation of different stakeholders (including vulnerable groups) ensures better implementation and improves the efficiency and sustainability of services, providing the opportunity for social transformation.	6.42

Source: Mvongo *et al.* (2021b).

vectors, and the determination of the index and consistency ratio (Mvongo *et al.* 2021b). Table 1 summarizes the dimensions and indicators with their corresponding weights.

2.1.4. Aggregation and interpretation

The WSSI is the weighted sum of sub-index scores as shown in Equation (3). This equation obtained as a result of the pairwise comparisons shows that the determination of the WSSI is done sequentially. Indicator values are aggregated to obtain sub-index values and sub-index values are aggregated to obtain the value of the index.

$$\mathrm{WSSI} = \sum_{i=1}^{N} W_i S_i \tag{3}$$

where WSSI is the Water Service Sustainability Index; N is the number of indicators to be aggregated; S_i is the value of the indicator i or the indicator i sub-index; and W_i is the weight of the indicator i.

The interpretation of the WSSI is made on the basis of the quartile scale (Mvongo *et al.* 2021b). This method provides for four levels of performance with a maximum value of 100 and a minimum value of 0, as shown in Table 2. Depending on the values of the WSSI, a management model will be considered not to be effective when the values of WSSI are less than 50. The management model will be considered effective otherwise.

The performance reflects the condition of the issue related to an indicator, or the overall aggregated index. The 'Priority of Action' reflects the priority of action to improve the 'performance' of indicators and would be used as the basis to improve water service sustainability.

2.2. Development of the assessment tool

The development of the assessment tool, called 'Water Service Assessment Tool' (WaSAT), was based on the WSSI framework using Microsoft Excel. Microsoft Excel was chosen for the programming of WSSI calculations because of its simplicity. The study focused on commands related to formulas and data. The main tools used to build Microsoft Excel are PRODUCT function, SUM function, SI function, conditional formatting, Radar graphics, and Hyperlinks. The PRODUCT function was used to calculate the average performance of each indicator by multiplying the evaluation made by the operator and the weight of the indicator. The SUM function made it possible to calculate the value of the WSSI as presented in Equation (3).

The SI function made it possible to display the priority level of action according to the values of the evaluation. The conditional formatting permitted us to color the cells in the action priority column according to the priority level (low, medium, and high). For this, formatting rules have been defined. The radar-type graphics were used to present the assessment results on a value scale and to highlight the factors that contributed to the achievement of the assessment result. Hypertext links were used to link the different sheets of the WaSAT. In other words, they made it possible to switch from one sheet to another by just clicking on the button containing the name of that sheet. Thus, the navigation buttons of the WaSAT are provided with hypertext links that allow navigation from one sheet to another.

2.3. Application of the tool in the sustainability assessment of rural water service in the Mvila Division

2.3.1. Study area

The Mvila Division is located in the Southern region of Cameroon. It occupies an area of approximately 8,695 km^2 which is divided into eight councils: Ebolowa I, Ebolowa II, Biwong-Bane, Biwong-Bulu, Ngoulemakong, Mvangan, Mengong, and Efoulan (Figure 1). The average rainfall over the Mvila Division is 1,800 mm/year, and the average annual temperature is

Table 2 | WSSI interpretation

WSSI value	Performance	Priority of action
$0 \leq \mathrm{WSSI} \leq 25$	Poor	High
$25 < \mathrm{WSSI} \leq 50$	Poor–medium	High
$50 < \mathrm{WSSI} \leq 75$	Medium–good	Medium
$75 < \mathrm{WSSI} \leq 100$	Good	Low

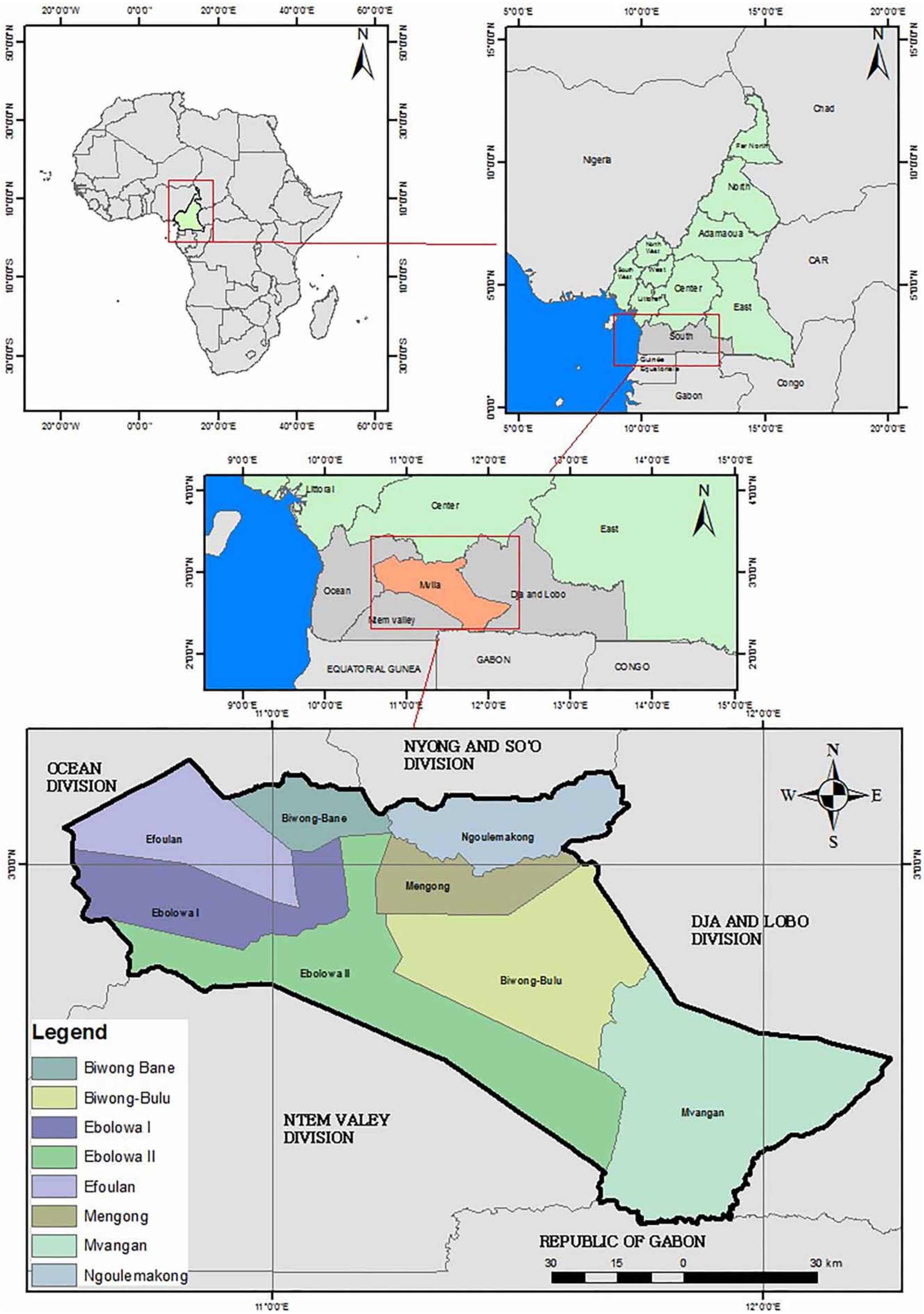


Figure 1 | Location of the Mvila Division (*Source*: Mvongo *et al.* 2021b).

24 °C (Fondjak 2006). The soils are ferralitic, and the geological context is the Precambrian complex originally covered by sediment deposits bordering the older nucleus of the Congolese craton (Olivry 1986). Plant formations belong to dense, moist forests (Letouzey 1985). The Mvila Division is watered by three watersheds: Nyong, Ntem, and Lokoundjé. In 2005, the total population within the Mvila Division was 179,429 habitants (BUCREP 2005). The indigenous people are Boulou, Ewondo, Bene, Fong, and Fang ethnic groups. The economy of the area is based mainly on agriculture with a strong practice of cocoa farming. Drinking water is supplied by the RDWSS such as wells, boreholes, and springs. A total of 736 has been identified in the area including 431 wells, 164 boreholes, 104 springs, and 37 water supply networks (Figure 2). These RDWSSs are managed by rural communities regrouped in the Water Point Committee (WPC).

2.3.2. Study population and data sampling

The study population consists of water services in the rural villages of the Mvila Division. The sampling method adopted is stratified sampling. The first step was to calculate the minimum sample size of water service to be surveyed. The following equation (Martínez-Bencardino 2012) was used to calculate the minimum sample size:

$$n = \frac{NZ^2p(1-p)}{Nd^2 + Z^2p(1-p)} \tag{4}$$

where n is the sample size, N is the total number of water services ($N = 387$ in this case study), Z is the standardized normal deviation for a particular confidence limit ($Z = 1.96$ for 95% confidence level), p is the proportion of the population estimated to maximize the sample size ($p = 0.05$), and d is the allowable error ($d = 0.05$). Based on Equation (1), a minimum of 62 villages should be surveyed. The villages were then grouped by councils (or stratum). Once the villages were grouped into a stratum, the proportions corresponding to each of the strata were calculated to represent each of them in the sample. In each of the strata, the villages that have been the subject of the study are then chosen at random. A total of 103 water services were investigated (Table 3).

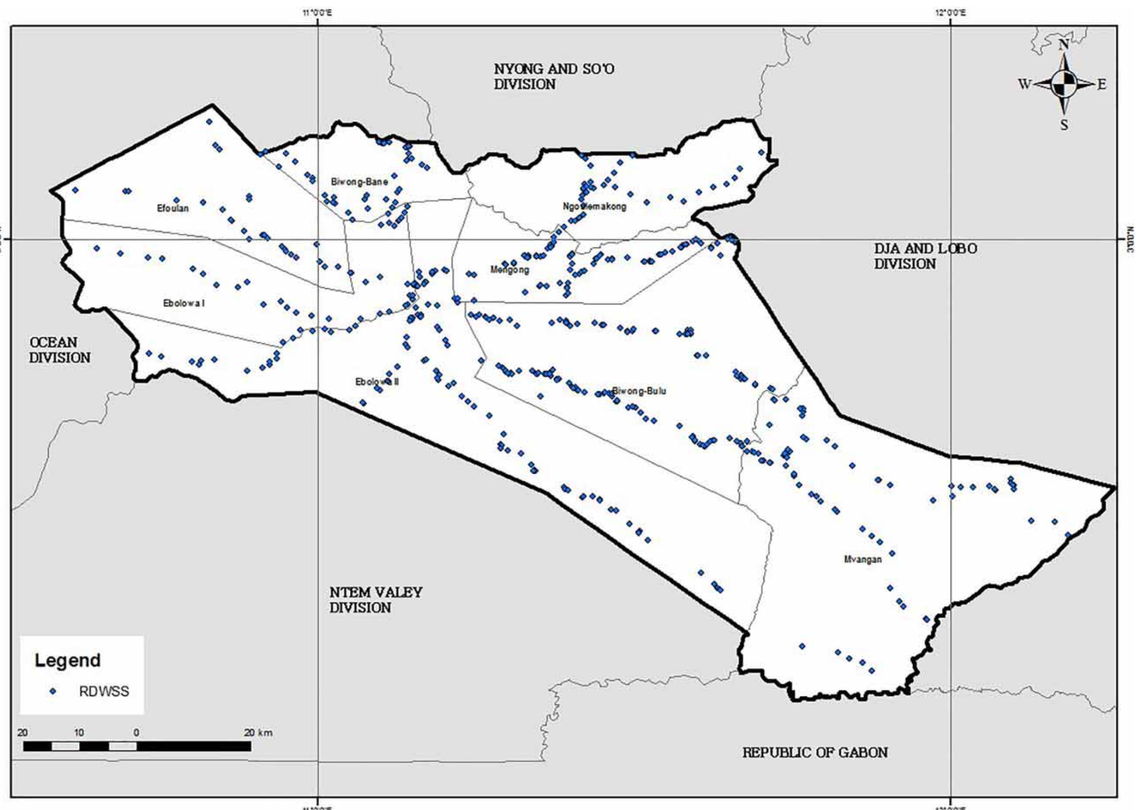


Figure 2 | Spatial distribution of the RDWSS in the Mvila Division.

Table 3 | Distribution of the sample by the council

Councils	Total population		Sample	
	Number of village	Proportion (%)	Number of village	Proportion (%)
Biwong Bane	33	8.5	9	8.7
Biwong Bulu	49	12.7	13	12.6
Ebolowa I	34	8.8	9	8.7
Ebolowa II	79	20.4	21	20.4
Efoulan	41	10.6	11	10.7
Mengong	49	12.7	13	12.6
Mvangan	53	13.7	14	13.6
Ngoulemakong	49	12.7	13	12.6
Total	387	100.0	103	100.0

2.3.3. Description of the evaluated RDWSS

A total of 103 RDWSSs have been investigated including 47 wells, 42 boreholes, 9 springs, and 5 water supply networks. The well equipped with a hand pump is a catchment structure, generally in concrete resulting from vertical earthworks, manual, or mechanized, allowing the exploitation of water from a water table. Its internal diameter generally varies from 0.8 to 1.6 m with depths between 10 and 20 m in a crystalline basement zone. The borehole equipped with a hand pump is a small-diameter (10–30 cm) collection structure intended to allow the extraction of water contained in an aquifer formation. They capture water over a great height of the aquifer. Because of the small diameter of the structure, only a pump can make the water in the structure available.

Spring is the place and the phenomenon of the natural appearance and flow of groundwater on the surface of the ground, quite well individualized, and generally at the origin of a surface watercourse. This flowing water is very often of good quality and safe to drink. However, it can be polluted when it comes out of the ground. To avoid such a danger, it must be captured. The water supply network is a distribution network that supplies standpipes and some special low-pressure connections. It consists of a production area (borehole, well, or spring), with a pumping and storage system, and a distribution network, consisting of a storage tank and delivery points (standpipes and particular connections).

2.3.4. Data collection

2.3.4.1. Secondary data. Technical data on the RDWSS were collected in the PRO-ADP databases for the Mvila Division. Data on climate risk were collected in the Report on Risk Assessment, Vulnerability, and Adaptations to Climate Change in Cameroon. Data on household income were found in the study of Folefack (2010) on poverty and income distribution in the cocoa-growing zone in Cameroon. This study shows that the average gross household income in the cocoa-growing zone in the Southern region of Cameroon is 442,480 FCFA/year or 53,504 FCFA/person.

2.3.4.2. Primary data

(a) Technical inspection

The technical inspection of the RDWSS consisted of identifying and classifying RDWSSs, measuring flows, and taking water samples for microbiological analysis. The identification of the RDWSS was done using an observation grid. Data on the amount of water provided to populations were collected through measurements of the flow of the RDWSS by the volumetric method. This required a container of 10 l of volume and a brand stopwatch, and consists of measuring the time it takes for the container of known volume to fill up. Five measurements were taken for each measurement point in order to reduce handling errors, and the flow rate was calculated using the following equations:

$$Q_i = \frac{V}{T} \tag{5}$$

$$Q = \frac{\sum_{1}^{5} Q_i}{5} \tag{6}$$

where Q is the flow in liter per second (l/s); Q_i is the flow in l/s for measure i; V is the volume of water in the container in liter (l), and T is the average pumping time in seconds (s).

Data on water quality were collected at the source by sampling and laboratory analysis. The collection equipment consisted of plastic vials because of the facilities they present for transport. The method of sampling was made according to the origin of the water. When it was a borehole or a well, the samples were taken after an uninterrupted pumping test lasting a total of 5 min. In the case of a collection at a fountain terminal, the maximum flow faucet was opened for 10–20 s and then reduced to an average flow for 3 min. The bottle was then put under the tap without closing it in order to take the sample. Two parameters were used to measure water quality: *Escherichia coli* and turbidity. Turbidity was measured *in situ* using a turbidimeter. A total of 103 samples were taken and sent to the laboratory for microbiological analyses. The method used to detect *E. coli* is membrane filtration. This method can detect and quantify *E. coli* bacteria in water.

(b) Semi-structured interview

Semi-structured interviews (SSIs) were conducted to gather information on the institutional framework and the regulatory framework for water service management. Specifically, it was a matter of collecting information on aspects such as the organizational structure of water services, community participation, technical aspects, and post-construction support to service providers. Respondents were selected from council's technical services and decentralized structures of the state, including eight technical chiefs and one divisional delegate.

(c) Survey

A survey was conducted among WPCs in 103 villages in the Mvila Division. Each WPC surveyed completed a questionnaire administered by eight Master's students. The questionnaire (Supplementary Material, Appendix 1) was divided into seven sections. The first section presented general information on the service and the identity of the respondent. The second section concerned economic indicators, while the third section presented environmental indicators. The fourth section concerned social indicators, and the fifth section presented technical indicators. The sixth section concerned institutional indicators, while the seventh section presented governance indicators. A total of 103 questionnaires were administered to the water service manager. The questionnaire was administered through SSIs with WPCs. Verbal consent was sought prior to the SSI.

2.3.5. Data analysis and processing

Microsoft Excel was used to analyze quantitative data from the survey. Qualitative data from the technical inspection and semi-structured interviews were analyzed according to the attributes studied. Both quantitative and qualitative data provided information to assess the level of compliance with indicators. The results on the ratings of the indicators were then multiplied by the weight assigned to each indicator to obtain sub-index values using the WaSAT, and sub-index values were aggregated to obtain the value of the index. These data were synthesized using a bar chart. This chart highlight the relative performance of each dimension and indicator.

3. RESULTS AND DISCUSSION

3.1. Results

3.1.1. Assessment tool

The WaSAT (Supplementary Material, Appendix 2) is composed of seven sheets or pages (menu, welcome, description of indicators, normalization of indicators, evaluation, summary, interpretation, and contact). Some pages (welcome, description of indicators, normalization of indicators, and interpretation) present the modalities of use, while others (evaluation and summary) allow to calculate the WSSI and to present the calculations in the form of a graph.

The 'Welcome' page briefly presents the WaSAT and the context in which this tool was developed. The 'Description of indicators' page presents the dimensions and indicators used in the calculation of WSSI, while the 'Normalization of indicators' page presents the criteria for evaluating qualitative indicators. The 'Evaluation' page is used to calculate the WSSI, and the 'Summary' page presents the summary of the results and the associated graphs. The 'Interpretation' page is devoted to WSSI interpretation methods, while the 'Contact' page presents information on the authors of the WaSAT.

Table 4 presents the analysis grid used by the WaSAT. This grid allows the evaluation of sustainability levels on the basis of scoring. These scores are based on a five-point scale (fully met (score of 100%); met to a high degree (score of 75%); met acceptably (score of 50%); met to a low degree (score of 25%); and not met (score of 0%)) depending on the criteria met by the service and described in Table 4.

In Table 4, self-financing is good if the theoretical price is lower than the selling price of water. Otherwise, it is considered null or void. Water quality is considered good when it does not contain *E. coli* and turbidity is lower than 2 NTU. If one of these two parameters is not verified, the water is classified as questionable. In the event that these two parameters are not

Table 4 | Analysis grid

			Score (%)				
Dimensions	**Indicators**	**Weight (%)**	**Not met (0)**	**Met to a low degree (25)**	**Met acceptably (50)**	**Met to a high degree (75)**	**Fully met (100)**
Economic	Self-financing capacity	17.84	Bad	/	/	/	Good
	Financial autonomy	11.35	Bad	/	/	/	Good
	Total coast recovery	4.85		Between 0 and 25	Between 25 and 50	Between 50 and 75	Between 75 and 100
Environmental	Water quality	7.18	Bad	/	Doubtful	/	Good
	Water availability	4.57	0	Less than 5 l/d/capita	5–20 l/d/capita	/	Over 20 l/d/capita
	Climate risk	2.89	Category C	/	Category B	/	Category A
Social	Affordability	6.20	Too expensive	/	/	/	Fair
	Accessibility	3.95	More than 60 mn	/	10–30 mn	/	Less than 10 min
	Non-discrimination and equity	2.50	Lack of fair access rules for water services	/	/	/	Fair access rules for water services
Technical	Quality of construction	2.96	Bad	/	Average	/	Good
	Frequency of maintenance operations	6.16	Never done	Annually	Semi-annually	Quarterly	Monthly
	Access to spare parts	6.54	Lack of spare parts in the council	/	Spare parts available in the council	/	Spare parts available in the village
	Reliability of water system	4.29	Uncertain	/	Reliable	/	Very reliable
Institutional	Post-construction support to council	1.63	Lack of support to council	/	/	/	Existence of support to council
	Post-construction support to service managers	1.63	Not existent	/	Limited	Average	Good
	Regulation	0.85	Bad	/	/	/	Good
	Formalization of contract	0.72	Lack of contract between WPC and council	/	/	/	Existence of contract between WPC and council
	Organisation of the service	0.80	Bad	/	/	/	Good
Governance	Skills of water service managers	2.59	Bad	/	Average	/	Good
	Financial flow management	4.09	Bad	/	Average	/	Good
	Participation	6.42	Never	Annually	Quarterly	Monthly	Weekly

checked, the water is considered bad. Affordability is too expensive if the price of water is more than 3% of the household income. Otherwise, affordability is considered as fair. In terms of reliability, this indicator will be described as very reliable when users are sure to obtain good quality water at any time. When users have water only during the opening hours of the water point, this indicator will be classified as low.

The organization of the service is good when there is a separation of roles between service management actors. Otherwise, the organization of the service is considered as bad. Financial flow management is bad when there is lack of procedures related to managing financial flows; average when existence and non-compliance with financial flow management procedures; and good when existence and compliance with financial flow management procedures. Supplementary Material, Appendix 3 gives more detail about the scoring grid.

3.1.2. Sustainability of rural water service in the Mvila Division

The overall performance of the sustainability of rural services in the Mvila Division is poor–medium (Table 5) with a high level of priority of action. No water service achieved a 'Good' performance. Indeed, 29% of services have a 'Medium–Good' performance, 45% have a 'Poor–Medium' performance, and 26% have a 'Poor' performance. Figure 3 shows that the highest aggregate value of the WSSI was obtained in the Mvangan council (59.54%) followed by the Ngoulemakong council (47.99%), Biwong Bulu (38.53%), Efoulan (33.99%), Biwong Bane (31.51%), Ebolowa I (28.96%), Ebolowa II (28.19%), and Mengong (26.57%).

Figures 3 and 4 show that there are disparities in the levels of sustainability of services between the eight councils of the Mvila Division. These disparities are due to economic, environmental, social, technical, and institutional and governance factors that limit the sustainability of water services. These factors, often mentioned in the literature on the sustainability of water services by several authors (Katko 1991; Bendahmane 1993; Carter *et al.* 1999; Hellström *et al.* 2000; Ashley *et al.* 2003; UN 2007; Giné & Pérez-Fouguet 2008; Montgomery *et al.* 2009; Van Leeuwen *et al.* 2012; Eneas da Silva *et al.* 2013; Spaling

Table 5 | WSSI sub-index values for the Mvila Division

Indicators/sub-indicators	Actual values (%)	Weight (%)	Sub-index (%)	Performance	Priority of action
Self-financing capacity	33.01	17.84	5.89	Poor–Medium	High
Financial autonomy	11.29	11.35	1.28	Poor	High
Total coast recovery	9.37	4.85	0.45	Poor	High
Water quality	87.48	7.18	5.58	Good	Low
Water availability	77.67	4.57	4.00	Good	Low
Climate risk	64.08	2.89	1.79	Medium–Good	Medium
Affordability	78.64	6.20	4.88	Good	Low
Accessibility	67.48	3.95	2.67	Medium–Good	Medium
Non-discrimination and equity	99.03	2.50	2.48	Good	Low
Quality of construction	88.35	2.96	2.62	Good	Low
Frequency of maintenance operations	16.50	6.16	1.02	Poor	High
Access to spare parts	14.08	6.54	0.92	Poor	High
Reliability of water system	18.45	4.29	0.79	Poor	High
Post-construction support to council	0.00	1.63	0.00	Poor	High
Post-construction support to service managers	8.74	1.63	0.14	Poor	High
Regulation	19.42	0.85	0.17	Poor	High
Formalization of contract	0.00	0.72	0.14	Poor	High
Organization of the service	19.90	0.80	0.00	Poor	High
Skills of water service managers	19.90	2.59	0.52	Poor	High
Financial flow management	8.74	4.09	0.36	Poor	High
Participation	21.12	6.42	1.36	Poor	High
Final index (WSSI)			37.10	Poor–Medium	High

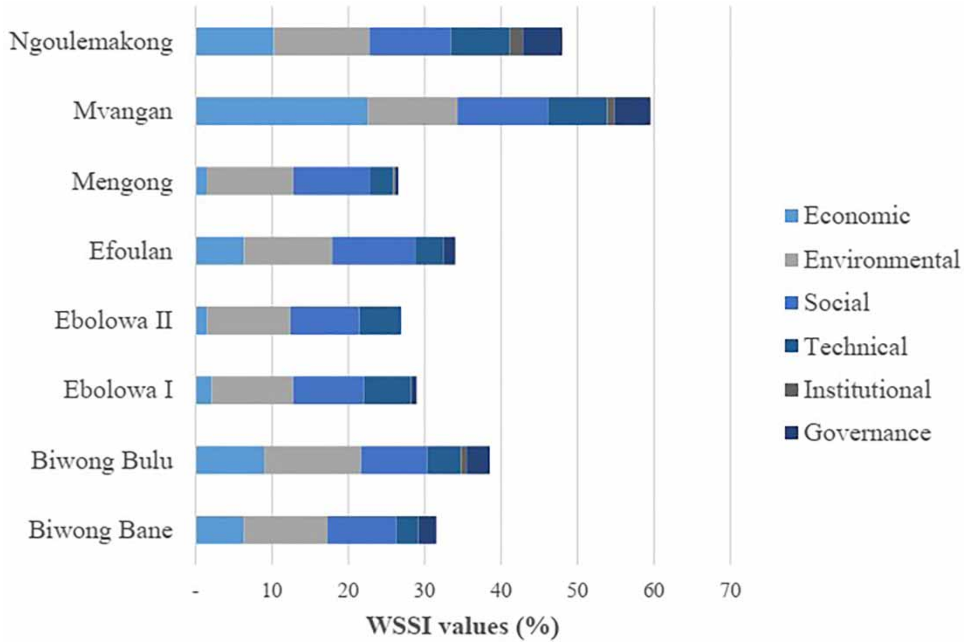


Figure 3 | WSSI values for the Mvila Division.

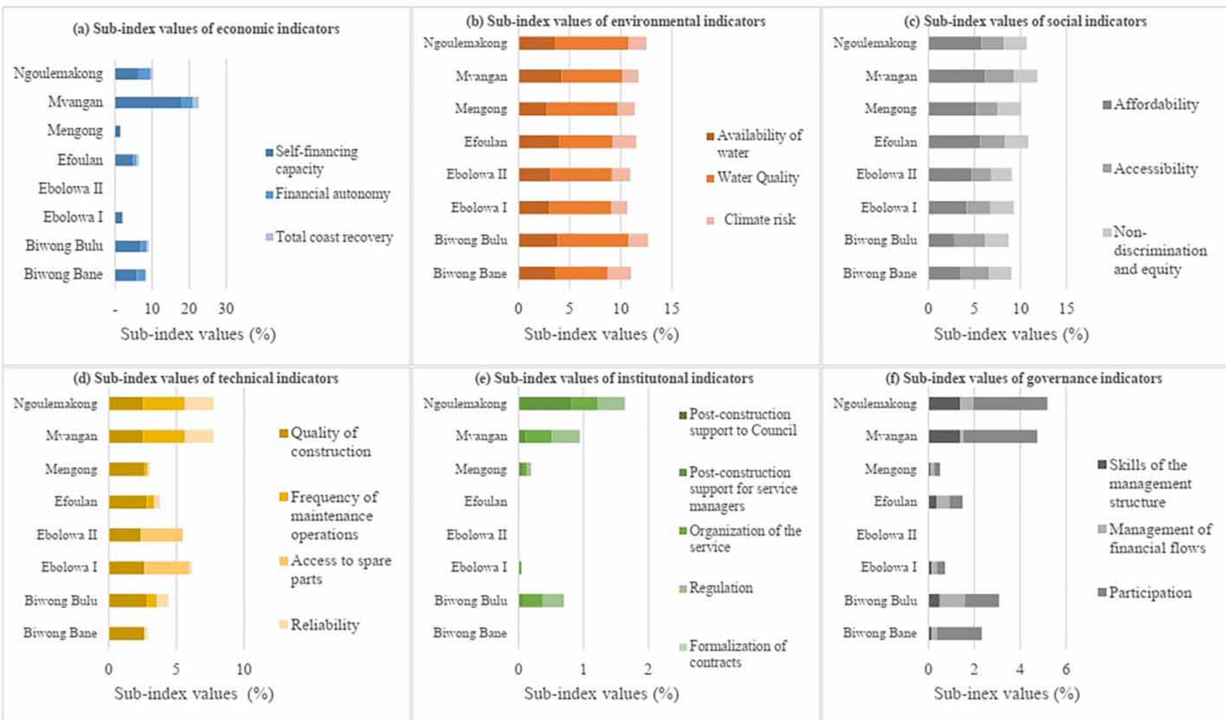


Figure 4 | Sub-index values of WSSI indicators in the Mvila Division.

et al. 2014; Marques *et al.* 2015; Behailu *et al.* 2016; Boukhari *et al.* 2018; Domínguez *et al.* 2019; Daniel *et al.* 2021), are interrelated, and none of them can be analyzed separately.

At the economic level, the financial viability of community-based management (CBM) constitutes a major barrier to operationalizing the economic sustainability of water services. It has been identified as a factor limiting the sustainability of water services by several authors (Whittington *et al.* 2008; RWSN 2010; Chowns 2014, 2015, 2017; Gbahabo 2015) in various countries of sub-Saharan Africa. In the specific case of the Mvila Division, this is due to the low pricing of the service. In fact, 67% of the services investigated have no pricing policy. In services where the pricing policy exists (33% of services investigated), the pricing of water is not based on the charges of the service. Rather, it is the result of a consensus among populations. Thus, the financial flows generated by the sale of water are very low which partly explains their vulnerability and the difficulty in supporting long-term monitoring and evaluation mechanisms. External financial contributions are therefore essential to ensure the sustainability of water services (Carter *et al.* 1999; Lockwood & Smits 2011).

At the environmental level, climate risk is the main limiting factor. Some services (70% of services investigated) risk being impacted by climate change. Indeed, wells and springs, the main RDWSS used to provide water in these services, are more vulnerable to the effects of climate change (Yopo *et al.* 2015). Currently, they are not yet subject to the effects of climate change but are likely to be impacted by the future effects of climate change as presented by Ndongo *et al.* (2012) in the coastal river basin of Cameroon to which the Mvila Division belongs. One of the consequences of climate change in this area is the modification of the monthly rains of the dry seasons which induce strong variations in the level of the water table. The impact of climate change on water services has been highlighted by Ohwo & Agusomu (2018), Yopo *et al.* (2015), and Global Public Policy Network on Water Management (2008) in sub-Saharan Africa.

At the social level, although most users have access to drinking water without discrimination, free access to water service constitutes a limiting factor. This finding has been highlighted by some authors (Bosson 2015; Koukougnon 2021). More generally, the payment for water in the Mvila Division is a subject of controversy among those who advocate free access by clinging to the universal right to drinking water and the social and cultural value of the water, and proponents of full-cost pricing. In reality, the chasm of misunderstanding between these two camps is over the elements of pricing. The price of water corresponds to the cost of the drinking water and distribution service, while the resource remains free. More generally, this debate stems from an absence of the culture of selling water favored by decades of free water supplies to populations by the state and maintained locally by certain elites who build and support repairs of some RDWSSs. This created the 'wait-and-see' attitude of rural populations toward the state.

At the technical level, the poor structuring of the maintenance chain for the RDWSS is the main limiting factor. Spare part providers and artisan repairers are almost absent. The main spare part providers are Yaoundé and Douala. This makes access to spare parts difficult. As for the repair workers, some councils (Mvangan and Ngoulemakong) have recruited technicians responsible for maintaining the RDWSS. However, insufficient financial and material resources limit their actions. This weak structure of the maintenance chain increases the cost of repairs and the duration of breakdowns. The correlation between the spare parts' supply chain, the cost of repairs, and the duration of breakdowns has been demonstrated previously by several authors (Harvey & Reed 2004; RWSN 2005; ACF 2007; Baumann & Danert 2008; Whittington *et al.* 2008; Harvey 2009; Lockwood 2019; University of Colorado Boulder 2020) in different countries of sub-Saharan Africa.

At the institutional level, common factors that influence the sustainability of rural water service delivery are the capacity, accountability, and willingness of governments and councils to provide and finance post-construction support. Indeed, as shown in Figure 4(e), the post-construction support to councils and WPCs is absent except in Mvangan and Ngoulemakong councils where post-construction support is still embryonic. This situation results not only from the insufficiency of financial, material, and technical skills at the level of these institutions but also from a weak commitment of the municipal authorities. In addition, the political context of decentralization does not yet promote better management of water services. Indeed, the state has transferred competences to the councils without, however, providing them with the material, financial, and human resources necessary to provide water service.

At the managerial level, the main factor influencing the governance of water services concerns the limited capacities of communities, councils, and decentralized state services to manage the service once the RDWSS is built. Indeed, each of the entities raised has weaknesses to varying degrees at the origin of the limited post-construction support that WPCs receive. This situation is at the origin of the low rate of functionality of the WPCs, the absence of real collection of revenue from the sale of water, the weak willingness to pay for water, and the absence of transparency in management (Githae *et al.* 2018). These challenges identified in the Mvila Division are similar to those identified in various studies (Giné & Pérez-Fouguet 2008; Lockwood & Smits 2011; WaterAid 2011; Lockwood & Le Gouais 2015; World Bank 2017) carried out in developing countries.

3.2. Discussion

3.2.1. Assessment tool

Multi-criteria analysis and especially the AHP are used to determine the most important factors in assessing the sustainability of the rural service by assigning weights to them. As a result, it allows for a more accurate assessment of the sustainability of rural water services. Indeed, in unweighted approaches (IDWA, Equity Index in Water and Sanitation, and Sustainable Water Management Index) to assessing the sustainability performance of water services, indicators are not weighted or are taken at equal weights. This tends to produce results that do not reflect reality. On the other hand, the use of the tool has better results since it takes into account the relative importance of the indicators and dimensions. The use of multi-criteria analysis and, in particular, the AHP appeals to expert judgments which are, in fact, the result of the subjective evaluation (Saaty 1980; Scholz & Tietje 2002) and which depend heavily on the expert's experience, the social, and geographical context in which the study is carried out (Mvongo *et al.* 2021b). Thus, weights are not directly transposable to other contexts because of socio-cultural variables (Charreaux 2004).

However, while analytical hierarchical processes are desirable for the fact that it directly involves all stakeholders involved in water service management, they may not result in sustainable outcomes if some stakeholders can dominate the process but have insufficient information or technical knowledge to make an appropriate judgment. For illustration, one of the issues discussed in this paper is the fact that tariffs are self-regulating and not enough to cover maintenance. In the development of the WSSI, the regulation and organization of the service indicators under the institutional dimension is given a low weight and self-financing capacity a high weight. Therefore, the weighting on the institutional dimension is so low if it actually influences the economic dimension. Thus, for future use of the WSSI, the weighting of indicators and dimensions should be reconsidered.

The WaSAT provides a solid baseline on the sustainability of water services at the village level in the rural area and identifies priority actions to be taken to move services toward sustainability. The tool focuses on rural water services in sub-Saharan Africa in a tropical climate context. The data used by this tool are collected at the level at which the services are provided (household or community level). The proposed tool enriches the range of tools developed in the literature to improve access to drinking water and sanitation. However, given that the WaSAT is still in the early stages of its development, there is a need to systematically validate its future results. This is necessary to ensure that the tool is linked to the actual durability of the service. However, such an analysis is beyond the scope of this study and would require the collection of data on the water services actually provided in rural areas. Although this is an expensive process, it would increase confidence in the use of the WaSAT. In addition, the tool should be more flexible and appropriate for use in urban and peri-urban areas – not limited to rural interventions – and incorporate data from different levels, for example, going beyond the single level of direct intervention to include higher-level enabling environment considerations.

3.2.2. Sustainability of water service

The results of the sustainability assessment of water services in the Mvila Division suggest that the CBM is not an effective means of delivering rural water services in Cameroon. This analysis joins those of several authors (RWSN 2010; Chowns 2014, 2015, 2017; Gbahabo 2015). However, all the failures observed in rural water service management are not attributable to the WPC. In fact, it is estimated that 70% of manual pumps managed by the WPC in sub-Saharan environment are functional (Naughton 2017). There are many constraints in water service management in rural areas which cannot be attributed to community management. These constraints are, among other things, the geological context of the water point installation site (Harvey & Reed 2004; Harvey 2009; Foster *et al.* 2018), the type of technology used (Bhandari & Grant 2007), the quality of constructions (Naughton 2017), climate change (Harvey & Reed 2004; Baumann & Danert 2008), the availability of water resources and the management land (Flowers 2009), the institutional framework (Harvey & Reed 2004; Harvey 2009), and the legislative, regulatory, and political framework put in place for water service management (Harvey & Reed 2004; ACF 2007). In addition, Kativhu *et al.* (2018) showed that the poor implementation of the CBM by the authorities is a constraint to the sustainability of water services that cannot be attributed to the WPC.

Based on the many success stories reported over the past 30 years with the community management model, some authors (Carter & Rwamwanja 2006; Harvey & Reed 2006; Schouten & Moriarty 2008; Moriarty *et al.* 2013; Mvongo *et al.* 2019; Mvongo & Defo 2021) have shown that the community management model is sustainable if we add a 'plus' that includes long-term external support to the WPC including financial support, technical advice, and managerial advice. Lockwood & Smits (2011) show that the post-construction monitoring of water point committees is an integral part of community management. However, some authors (Carter *et al.* 2011; Chowns 2015; Lockwood & Le Gouais 2015; World Bank 2017) suggest that the CBM is only really viable for relatively simple technologies like wells, boreholes, and springs.

Table 6 | Final index values based on the combination of different weighting schemes

Combination	Arithmetic aggregation	Geometric aggregation	*Changes*
Non-equal weights	37.1	20.9	**16.2**
Equal weights	36.3	21.1	**15.2**
Changes	**0.8**	**0.2**	

3.2.3. Policy implication

Two particular challenges stand out in this study. The first concerns the limited capacities of communities, local governments, and other entities to manage water services once the infrastructure is built. The second challenge is related to the limited financial income to maintain water services. The financial flows generated by the sale of drinking water are very low, which partly explains their vulnerability and the difficulty in supporting sustainable monitoring and evaluation mechanisms. So, where will the long-term subsidies come from to support the services?

The pooling of water services at the scale of the Mvila Division appears to be an avenue to be explored to improve the sustainability of water services in the Mvila Division. This option allows the costs of managing the service to be pooled by creating an inter-municipal structure in charge of maintaining the RDWSS. A study conducted by the World Bank (2017) identifies this model as relevant for water services in developing countries. The pooling of services is being tested with the first promising results in the Center Region of Cameroon where the Councils of the Mbam and Inoubou Division and those of Lekié Division have, respectively, set up the SYCOMI (*Syndicat des Communes du Mbam et Inoubou*) and SYNCOLEK (*Syndicat des Communes de la Lekié*). This action can be extended to all Divisions of Cameroon or even West and Central Africa.

3.2.4. Sensitivity analysis of the WSSI

The sensitivity analysis aims to answer the question regarding which of the weighting schemes and aggregation methods was the most important in determining the final index value. Therefore, different combinations of weighting schemes and aggregation methods were considered:

- Non-equal weighting – arithmetic aggregation.
- Equal weighting – arithmetic aggregation.
- Non-equal weighting – geometric aggregation.
- Equal weighting – geometric aggregation.

The final index values obtained from these computations are presented in Table 6.

Table 6 shows that a change from equal to non-equal weights resulted in a change in the final index value of 0.8 and 0.2 for arithmetic and geometric aggregation methods, respectively. On the contrary, a change from arithmetic to geometric aggregation methods resulted in a change in the final index value of 15.2 and 16.2 for equal and non-equal weighting schemes, respectively. Therefore, either an equal or non-equal weighting scheme can be used, as it will not have a significant impact on the final index. Based on these results, it can be concluded that the final index value of the WSSI is more sensitive to changes in the aggregation method, rather than to the changes in the weighting scheme. This stands in line with the results of Juwana *et al.*'s (2016) sensitivity analysis of the West Java Water Sustainability Index. Hence, for future uses of the WSSI, either an equal or non-equal weighting scheme can be used, as it will not have a significant impact on the final index.

4. CONCLUSION

The aim of this study was to assess the sustainability of rural water service in the Mvila Division (Southern region of Cameroon) in order to constructively feed the debate on the most effective ways to improve access to rural water service in sub-Saharan Africa. Findings suggest that the CBM of the RDWSS is not an effective means of delivering rural water services in sub-Saharan Africa in general and in the Mvila Division (Cameroon) in particular. Results also show that rural water service delivery is influenced by key factors, such as the low pricing of rural water service, climate risk, the poor structuring of the maintenance chain, and the weak commitment of the municipal authorities, which are not attributable to the WPC. These assessments represent only a current snapshot of potable water delivery system conditions and should be conducted at regular intervals to track changes in overall and local conditions.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

All relevant data are included in the paper or its Supplementary Information.

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