Research Paper

Assessing water service performances in rural sub-Saharan Africa environment: The case studies of two councils of the southern and eastern regions of the Republic of Cameroon (Central Africa)

Victor Dang Mvongo and Célestin Defo

ABSTRACT

This study uses multi-criteria analysis to assess water services performance provided to rural communities. The approach is based on five indicators (water availability, water quality, accessibility, affordability, and reliability) and allows the assessment of service levels. The indicators used provided a solid baseline for water services to identify a strategy for the improvement and achievement of universal access to water. We empirically applied the approach to rural water services in Cameroon and particularly in Mvangan and Mandjou Councils. A total of 77 water services has been investigated through technical inspection (water point inspection, flow measurement, and water quality analysis), semi-structured interviews with the technical services of these councils and surveys with water point committees, including 25 in Mandjou Council and 52 in Mvangan Council. The main results show that 43.40% of villages have enhanced services in Mvangan Council while only 4.76% of services are enhanced in Mandjou Council. Results also suggests that monitoring rural water services can improve the levels of services provided to populations and, hence, universal access to water. 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.

Key words | drinking water, multi-criteria analysis, rural area, water service

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HIGHLIGHTS

- The research uses multicriteria analysis to develop an approach to assess water service level received by rural community.
- The approach has been applied to the rural water service in Cameroon particularly in Mvangan and Mandjou Councils.
- This assessment suggests that monitoring water service can improve the levels of service provided to rural communities.

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INTRODUCTION

For more than three decades, significant progress has been made in improving access to safe drinking water around the world. It is estimated that approximately 50 billion USD was invested in the construction of water infrastructure between 1990 and 2008 to improve access to safe drinking water (Carter & Lockwood 2011). At the same time, the proportion of the population with access to drinking water from a water system has increased from 44 to 58% (World Bank 2017). In addition, the Millennium Development Goals (MDGs), launched in 2000 by the United Nations, ended in 2015 with significant progress in accessing safe drinking water. The MDG on drinking water was achieved in 2010, providing water from an improved water source to 91% of the world's population, up from 76% in 1990 (Mulenga *et al.* 2017; WHO & UNICEF 2017).

However, although this progress has been made, there are large disparities in access to safe drinking water between countries, within countries, and between the sexes (Osei *et al.* 2015; UNICEF 2016). The MDG assessment found that the Caucasus and Central Asia, North Africa, Oceania, and sub-Saharan Africa (SSA) have failed to meet the drinking water target (WHO & UNICEF 2017). More recently, estimates from the Joint Monitoring Program 2019 show that 435 million people used unimproved sources, and 144 million still used surface water. Eight out of ten people still lacking even basic services lived in rural areas. Nearly half lived in least developed countries (WHO & UNICEF 2019).

With the adoption of the Sustainable Development Goals (SDGs), governments have committed to ensure universal and equitable access to safe drinking water for all by 2030, reducing inequalities in access to safe drinking water, and providing high levels of water services in terms of quality, accessibility, and reliability. This involved a reorganization of the sector adapted to the new institutional situation, an urgent increase in financial resources for water, and the development of sustainable water service management models. The SDGs posed a triple challenge: improving the levels of service provided, ensuring the sustainability of services, and promoting universal access to safe drinking water.

In addition, Agenda 2030 commits UN member states to 'leave no one behind.' This involved analyzing who is excluded from the water supply and finding out why; to determine what can be done and to take steps to ensure that people who are marginalized in the past are included now and in the future. The aim was to reconcile the sustainability objectives of water services with the objectives of achieving universal access to water. Then, the purpose of this article is to use a multi-criteria approach to assess water service levels of drinking water services received by rural communities at the village level. More specifically, the multi-criteria analysis will be used to weigh the relative importance of service level indicators in order to assess water service performance.

METHODOLOGY

Study area

The area chosen to apply the methodological tool consists of Mandjou and Mvangan Councils. The Mandjou Council, situated in Lom and Djerem Division (Eastern Region of Cameroon), is located between 13°40′ and 13°84′ north latitude and 4°50′ and 4°87′ east longitude. The Mvangan Council, on the other hand, is situated in Mvila Division (Southern Region of Cameroon). It is located between 11°50′ and 12°00′ north latitude and 2°00′ and 2°65′ east longitude (Figure 1).

Biophysical environment

The Mandjou and Mvangan Councils are subject to a four-season Equatorial Guinean climate (Olivry 1986; Suchel 1988). Rainfall is abundant and varies from 1,500 to 2,000 mm per year with an average annual temperature of 25 °C and an average amplitude of 2.4 degrees. Annual relative humidity is around 82% (Mvangan Council 2014). Their geography is that of the Southern Cameroonian plateau with ferralitic soils. These councils present two phytogeographical complexes: the dense and humid forest in Mvangan and Mandjou, and the savannah in the northern part of Mandjou Council (Mandjou Council 2017). The river system is quite dense with the presence of rivers such as Kom in Mvangan and Dja in Mandjou.

Socio-economic background

The population of Mvangan Council is estimated at 31,475 inhabitants. The Fangs and the Boulou are the two main

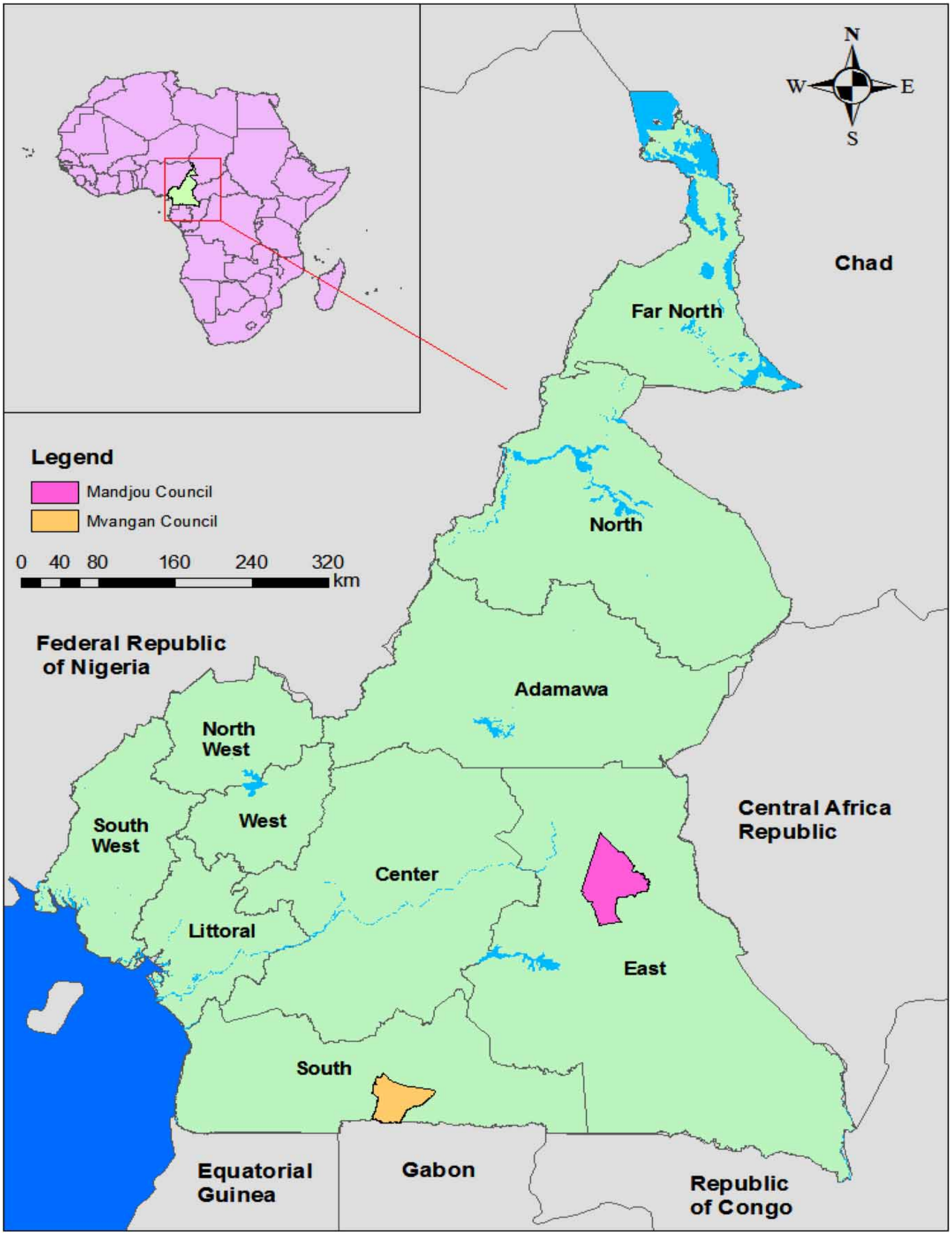

Figure 1 | Study area location.

indigenous ethnic groups. There are also a few minority groups, namely, the pygmies and three Kaka groups (Mvangan Council 2014). The Mandjou Council has about 68,182 inhabitants, including 13,479 Central African refugees (Mandjou Council 2017). The main indigenous ethnic groups are the Gbaya, Kako, and Mbororos. The main economic activities carried out in these councils are agriculture, livestock, logging, trade, hunting, and fishing.

Study population and data sampling

The study population consists of public drinking water services in all rural villages in the Mandjou and Mvangan Councils. These water services have been systematically evaluated. A total of 25 villages in Mandjou Council and 52 villages in Mvangan Council were investigated.

Data collection

Secondary information on water service management was obtained from the Mvangan and Mandjou Communal Development Plans, databases of the Participatory Development Assistance Package, and activity reports from technical services. Specifically, these were data on the management of financial flows of services, the frequency of outages and maintenance operations, and data on water quality monitoring. The primary data were obtained through a technical inspection of water supply systems, semi-structured interviews, and a survey.

Technical inspection

The technical inspection of water supply systems consisted of identifying and classifying water points such as well, borehole, and spring, measuring flows and taking water samples for analysis. The identification of drinking water systems was done using an observation grid. It made it possible to make an inventory of water points present in each village visited, as well as their basic state of operation. Data on the amount of water provided to populations were collected through measurements of the flow of water points by the volumetric method. This required a container of 15 liters of volume and a KD2015 KADIO brand stopwatch, and consists of measuring the time it takes for the container of known volume (15 liters) to fill up. Equation (1) was used to calculate the flow.

$$Q = \frac{V}{T} \quad (1)$$

with Q: the flow in liter-per-second (l/s); V: the volume of water in the container in liter (L), and T: the average pumping time in seconds (s).

Water quality data were collected at 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. In the case of groundwater, there were two very different cases. When it was a borehole or a well equipped with a hand pump, the samples were taken after an uninterrupted pumping test lasting a total of 5 minutes. In the case of a collection at a fountain terminal, the maximum flow faucet was opened for 5–10 seconds and then reduced to an average flow for 2 minutes. The bottle was then put under the tap without closing it in order to take the sample. In this study, two parameters were used to measure water quality: the presence of *Escherichia coli* in water and turbidity (less than 2 NTU). Turbidity was measured *in situ* using a PCE-TUM 50-brand turbidimeter.

A total of 77 samples was 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. In principle, a volume of water (100 mL) is filtered onto a filter membrane that is deposited on an agar. This agar is then incubated for 24 hours at 35 °C. At the end of the incubation period, *E. coli* bacteria held on the membrane form colonies that appear blue in visible light. Then, the number of colonies formed of *E. coli* are expressed in UFC/100 mL.

Semi-structured interview

Semi-structured interviews were conducted to gather information on the institutional framework and regulatory framework for water services 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 monitoring of water service managers. Respondents were selected from members of the communal executives and executives of the decentralized structures of the State, including two technical chiefs and two departmental delegates.

Survey

A survey was conducted among Water Point Committees (WPCs) in all the villages in Mvangan Council (52 villages) and in all the villages in Mandjou Council (25 villages). This survey was conducted using a questionnaire administered by eight Master's students. This questionnaire was divided into four sections. The first section is intended for general information on the service and the identity of the respondent. The second section is for technical data and service reliability while the third part collects data on service accessibility. The last part is devoted to collecting information on the affordability of service. A total of 77 questionnaires was administered to the water service manager. The questionnaire was administered through semi-structured interviews with water point managers. Verbal consent was sought prior to the interview.

Data analysis and processing

Selection of indicators

Indicators were selected through a literature review on existing evaluation frameworks (Chaves & Alipaz 2007; Juwana *et al.* 2010). This review of the literature provided a panel of indicators that were then refined through discussions with the various stakeholders involved in rural water service management. The PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) approach by Moher *et al.* (2009) was used to select publications to be used to identify indicators.

Weighting indicators

After selecting water service indicators, pairwise comparisons were made between them to calculate the weight of each of these indicators in determining service levels. For this purpose, four researchers and four professionals specializing in the management of rural water services in sub-Saharan Africa expressed their preference for one indicator over the other. The indicators were therefore compared two to two to determine their priorities. The relative importance values of one indicator over the other used in this study are those proposed by Saaty (1980) and presented in Table 1. These comparisons lead to the establishment of a matrix called the judgment matrix (Equation (2)).

$$A = [a_{ij}] = \begin{bmatrix} 1 & a_{12} & \dots & a_{1n} \\ \frac{1}{a_{12}} & 1 & \dots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \frac{1}{a_{1n}} & \frac{1}{a_{2n}} & \dots & 1 \end{bmatrix} \quad (2)$$

with A the decision matrix, a_{ij} are the values of the importance of comparisons between indicators i and j for all i, $j \in \{1, 2, \dots, n\}$. From this matrix, the weight determination of the indicators was made by solving the problem of own vectors.

Table 1 | Saaty numerical scale for pairwise comparisons

Intensity of importance	Description
1	Equal importance of two indicators
3	Weak preference of indicator *i* over indicator *j*
5	Strong preference of indicator *i* over indicator *j*
7	Very strong preference of indicator *i* over indicator *j*
9	Absolute preference of indicator *i* over indicator *j*
2, 4, 6, 8	Intermediate values between two judgments of indicator *i* over indicator *j*
1/3	Weak preference of indicator *j* over indicator *i*
1/5	Strong preference of indicator *j* over indicator *i*
1/7	Very strong preference of indicator *j* over indicator *i*
1/9	Absolute preference of indicator *j* over indicator *i*
1/2, 1/4, 1/6, 1/8	Intermediate values between two judgments of indicator *j* over indicator *i*

Source: Saaty (1980).

Once the weight values of each indicator were obtained, the consistency of the results was verified. For this, the Consistency Ratio (CR) was calculated. It can detect defects in calculations. The CR was calculated using Equation (3).

$$CR = \frac{CI}{RI} \tag{3}$$

with CI: Consistency Index and RI: Random Index. If $CR \leq 0.1$ the matrix is considered sufficiently consistent. Otherwise, evaluations require revision to reduce inconsistencies (Saaty 1980). Once consistency is verified, it can be used to assess the sustainability of rural water services. Random Index (RI) values are shown in Table 2.

Consistency Index is calculated using Equation (4).

$$CI = \frac{\lambda_{\max} - n}{n - 1} \tag{4}$$

with n: the number of rows or columns of the square matrix of judgment; and $\lambda_{\max}$: the principal eigenvalue. Saaty (1990) suggested that the greatest value can be obtained using Equation (5).

$$\lambda_{\max} = a_{ij} \frac{W_j}{W_i} \tag{5}$$

with a_{ij}: judgment matrix of the value of the i line element and the j column element; W_i: contribution to the selection of the best choice and each of the criteria; W_j: the contribution of specific criteria to the main objective.

Aggregation and interpretation

The aggregation method used is the arithmetic method. This method produces perfect substitutability and compensability between indicators (Nardo *et al.* 2005). The Water Service Score (WSC) was evaluated using Equation (6).

$$WSC = \sum_{i=1}^{N} W_i S_i \tag{6}$$

with WSC: Water Services Score; N: number of indicators to be aggregated; S_i: the value of the indicator i; and W_i: weight of indicator i. The interpretation of the WSC was made on the basis of the quartile scale. Performance here reflects the status of the indicator at a particular time in the evaluation and will be used as the basis for a relevant action priority to be improved (Juwana *et al.* 2012).

RESULTS AND DISCUSSION

Water service indicators

Drinking water services refers to the accessibility, availability, and quality of the main source used by households for drinking, cooking, personal hygiene, and other domestic uses. In implementing water service policy, COHRE *et al.* (2008) suggest four criteria (availability, water quality, physical accessibility, and affordability) to assess service levels, to which, reliability has been added (Table 3). These indicators were chosen for their usefulness in achieving universal access to water which can only be achieved if the quantity and quality of water is insufficient, the water point is too far away, or the system is unreliable, and the service is not affordable. In addition, these indicators are similar to those proposed by IRC International Water and Sanitation Centre as part of the WASHCost project and those used by the JMP service ladders for SDG 6 monitoring.

The following description is based on General Observation No. 15 (Right to Water) (United Nations Committee on Economic Social & Cultural Rights 2002).

Table 2 | Some Random Index values

n	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
RI	0	0	0.52	0.89	1.11	1.25	1.35	1.40	1.45	1.49	1.52	1.54	1.56	1.58	1.59

Source: Adapted from Saaty (2008).

Table 3 | Indicators involved in the assessment of rural water service

Indicators	Indicator descriptions	Units
Water availability	It is defined as the volume of water supplied to each user	Liters per capita per day (l/h/d)
Water quality	It measures the level of compliance of the physical, chemical, and biological parameters defined by the World Health Organization	
Accessibility	It refers to the degree of ease or difficulty in obtaining drinking water	Minutes per capita per day (mn/h/d)
Affordability	Affordability analyzes households' ability to pay for water services	
Reliability	Reliability is expressed as a percentage of the time the service is (or is not) fully functional	

Water availability

The water available for each person must be sufficient and constant for personal and domestic uses including consumption, individual sanitation, food preparation, and personal and domestic hygiene. The amount of water is the simplest and most used indicator for tracking and comparing services. It is measured by the number of liters per capita per day (l/h/d).

Water quality

The water required for every personal and domestic use must be safe, and therefore free of microbes, chemicals, and radiological risks that pose a threat to health. Water must have a color, smell, and taste acceptable to users. In general, the quality does not vary with the level of service.

Accessibility

Water, as well as adequate facilities and services, must be accessible safely for all segments of the population. Every human being has the right to a water service that is physically accessible either within the home, in the educational institution, in the workplace or in health facilities, or in the immediate vicinity of these places (COHRE *et al.* 2008). Accessibility therefore refers to the degree of ease or difficulty in obtaining drinking water (Moriarty *et al.* 2010). This indicator brings together other parameters such as distance to water point and waiting time. Accessibility can be measured in minutes per capita per day (mn/h/d).

Affordability

Water services must be at a price that each person can afford without reducing their opportunities to acquire other essential goods and services such as food, housing, healthcare, and education. In the UK, the Department of Environment, Food and Rural Affairs has determined that consumers should spend no more than 3% of their income on water and sanitation, and that a rate between 1.5 and 3% of income should be considered (COHRE *et al.* 2008).

Reliability

Reliability is expressed as a percentage of the time the service is (or is not) fully functional. It indicates the extent to which the service is in line with the expected level. The concept of reliability or safety is based on the assumption that all services will eventually fail and, therefore, total safety can only be achieved if multiple water sources and/or systems are accessed (Moriarty *et al.* 2010). Reliability does not mean that a service is provided 24/7, but that it is predictable.

Analysis grid

Table 4 shows the pairwise comparison matrix of the indicators identified in the previous section. This matrix presents the relative importance of indicators on the basis of the Saaty (1980) scale. Analysis of the pairwise comparison matrix also shows that the degree of consistency of comparisons is acceptable since the CR is less than 10%.

Analysis of the pairwise comparison matrix also shows that water availabity indicators (27.87%) and water quality (27.87%) are the most important. They are followed in order by physical accessibility (18.83%), reliability (14.49%), and affordability (10.94%). Table 4 is similar to that developed by the IRC International Water and Sanitation Centre as part of the WASHCost project from 2008

Table 4 | Pairwise comparisons matrix of indicators

	Water availability	Water quality	Accessibility	Affordability	Reliability	Wi (%)
Water availability	1.0	1.0	2.0	2.0	2.0	**27.87**
Water quality	1.0	1.0	2.0	2.0	2.0	**27.87**
Accessibility	1/2	1/2	1.0	2.0	2.0	**18.83**
Affordability	1/2	1/2	1/2	1.0	1/2	**10.94**
Reliability	1/2	1/2	1/2	2.0	1.0	**14.49**
$\lambda_{max} = 5.137$ and $CR = 3.09\%$						

Wi, Weight of indicators.

to 2012 (Moriarty *et al.* 2010) and the one used by the JMP service ladders for SDG 6 monitoring. However, some differences remain. In this study, five indicators were used instead of four for the WASCost project and three for the JMP service ladders for SDG 6 monitoring. In addition, the weight of each indicator in determining service levels was assessed, which is not the case in the WASHCost service ladder and the JMP service ladders for SDG 6 monitoring.

The calculation of the weights of the above indicators resulted in the establishment of the analysis grid presented in Table 5. This grid allows evaluation of service levels on the basis of scoring. These scores vary between 0 and 2 depending on the criteria met by the service and described in Table 5.

In Table 5, 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 checked, the water is considered bad. 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. On the other hand, when there are periods of service disruption, outages and repairs that drag on, this indicator will be described as uncertain. This grid is similar to the IRC water service delivery ladder framework (Moriarty *et al.* 2011; Van Koppen *et al.* 2012) because of its simplicity and the small number of indicators used. Based on the performance obtained, the interpretation was made on the basis of the quartile scale such as presented in Table 6.

Water service level in Mandjou and Mvangan Councils

Overall, 43.4% of villages in Mvangan Council receive enhanced water services. 33.96% of villages receive basic service, 5.60% receive limited service, and 16.98% receive no services because they do not have water points and/or they have been non-functional for more than six months at the time of the assessment. In Mandjou Council, only 4.76% of villages receive enhanced water service. 33.96% of villages receive basic service, 57.49% receive limited

Table 5 | Analysis grid

		Score		
Indicators	**Weight (%)**	**0**	**1**	**2**
Water availability	27.87	Less than 5 l/d/capita	5–20 l/d/capita	Over 20 l/d/capita
Water quality	27.87	Bad	Doubtful	Good
Accessibility	18.83	More than 60 mn	10–30 mn	Less than 10 mn
Affordability	10.94	Too expensive	–	Fair
Reliability	14.49	Uncertain	Reliable	Very reliable

Table 6 | Interpretation of scores

Scores	Performance	Description	Priority of action
$0 \leq WSC < 25\%$	Non-existent service	Service that the quantity and quality of water is insufficient, the water point is too far away or the system is unreliable, and the service is not affordable	High
$25\% \leq WSC < 50\%$	Limited service	The service does not meet the basic service criteria quantity and density at the water point	High
$50\% \leq WSC < 75\%$	Basic service	Service that the quantity and quality of water is sufficient, provided collection time is not more than 30 minutes for a roundtrip including queuing, the system is reliable, and the service affordable	Medium
$75\% \leq WSC \leq 100\%$	Enhanced service	Service that the quantity and quality of water is sufficient, the water point is located on premises (less than 10 minutes), the system is very reliable, and the service affordable	Low

service, and 4.76% receive no services. Figure 2 shows the graphic synthesis of service levels per council.

In reading Figure 2, there is a significant disparity in the water services received by communities in these two municipalities. These disparities are due, on the one hand, to the management system put in place in each of these municipalities and, on the other hand, to the local context. Indeed, prior to the implementation of water management policies in these two municipalities, they were facing many problems such as the irregularity of monitoring, the poor functionality of water point committees, the low structuring of the maintenance chain, the low financial flows generated by the sale of water, and the absence of the culture of water sales (Dang 2016, 2018). These deficiencies have been identified as the result of the incomplete implementation of the ongoing decentralization process in Cameroon and most countries in West and Central Africa (Dang 2018). In response to this situation, the Mvangan Council has put in place a water management system that has been implemented. The Mandjou Council set up a water point management system that never worked. In addition, the massive influx of Central African refugees has led to a rapid deterioration of water service level provided to the population. Thus, the comparative analysis of water service levels received by the populations of these two councils (Figure 2) suggests that monitoring water services can improve water service levels provided to the population.

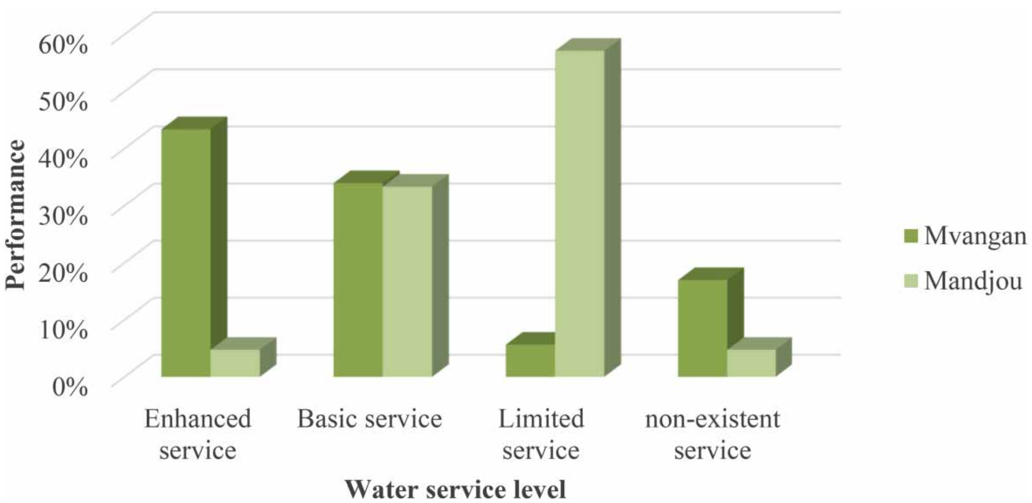

Figure 2 | Summary of service levels by council.

At the village level, Figures 3 and 4 show the levels of services received by each constituent village of these two municipalities. These levels of service are primarily determined by the quantity and quality of water provided to populations. In the specific case of Mvangan Council, affordability can be added since the municipality pays part of the costs of the service. The low water availability values are due to the low reliability of drinking water systems. It is common for households to use other water sources, such as traditional water points, when drinking water points are down or non-existent. The water quality setting from the point of view of organoleptic parameters (color, odor, and taste) was good. Only a few water points have poor quality due to the high level of turbidity. *E. coli* were absent in all water points.

In terms of accessibility, most households take between 10 and 30 minutes to collect water. They travel an average of 800 m to get drinking water. However, this parameter is difficult to measure at the local level (Flores *et al.* 2013). Economically, services are accessible throughout the Mvangan Council. Indeed, the amount allocated by households for the contribution to the maintenance fund is less than or equal to the critical threshold of 1.5% of household income. This is due to the municipality taking part of the costs of the service. In Mandjou Council, the situation is rather mixed and it depends on the level of household wealth. This distinguishes between villages that can be described as 'rich' such as Bazzama, for which the costs of service are affordable, and so-called 'poor' households for whom the costs of service are too expensive. In terms of reliability, villages close to borough chiefs are more secure than remote villages. This is due to the difficulties for the repairing craftsman to move to ensure the technical monitoring of the works because of the chronic poor condition of the roads and especially in the rainy season.

DISCUSSION

Multi-criteria analysis is used to assess indicators and determine the most important factors in assessing service levels by assigning weights to them. As a result, it allows for a more accurate assessment of the performance of water services. Indeed, in unweighted approaches to

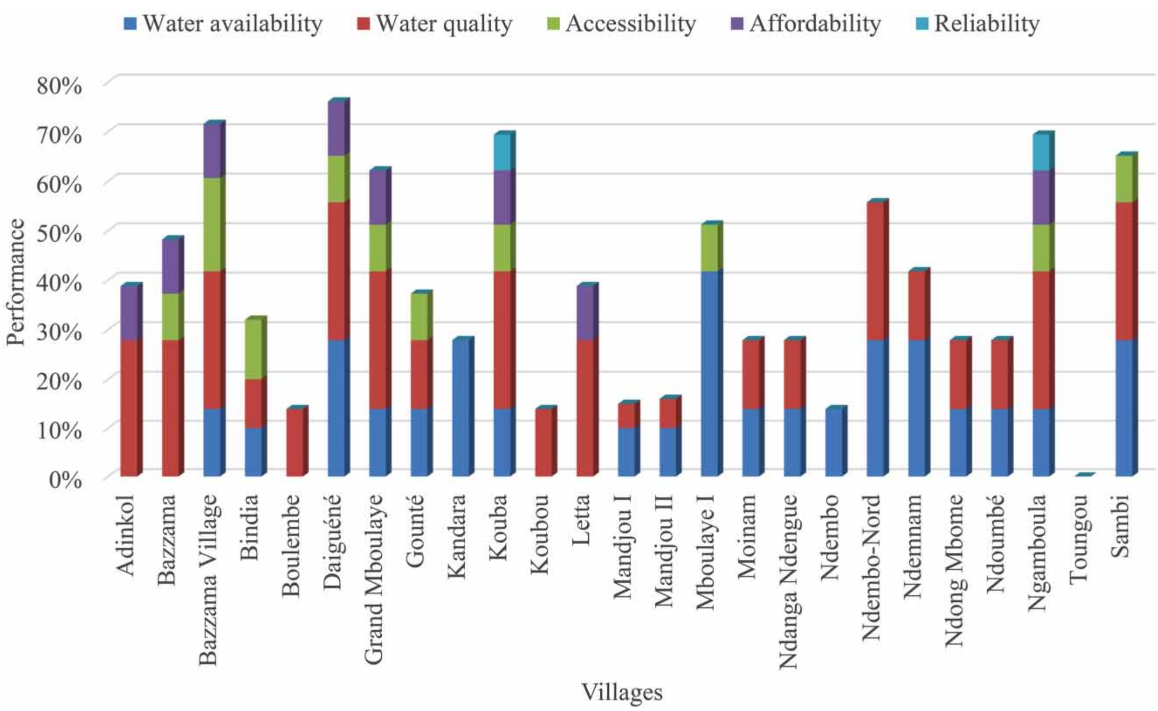

Figure 3 | Water service level in Mandjou Council.

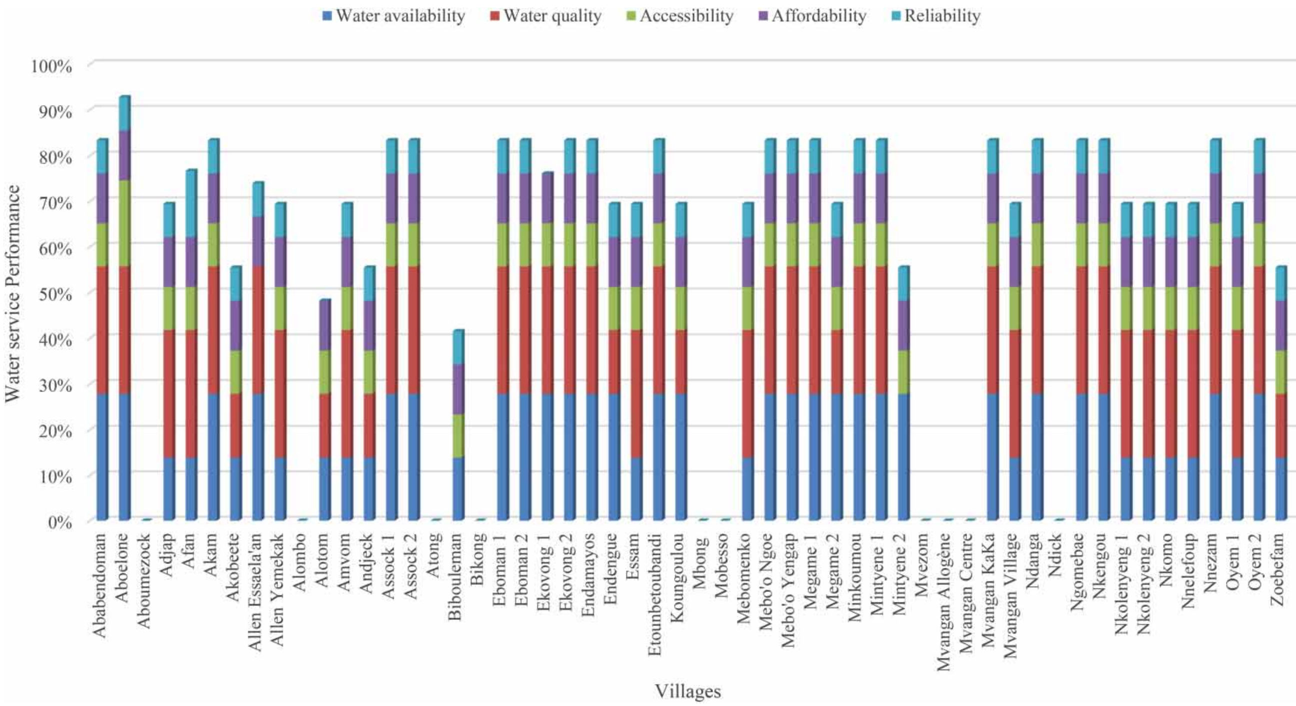

Figure 4 | Water service level in Mvangan Council.

assessing the performance of water services such as WASHCost service ladder and JMP service ladder, 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 conducted analysis has better results since it takes into account the relative importance of the indicators. However, the use of multi-criteria analysis and, in particular, the analytical hierarchy process appeals to expert judgments which are, in fact, the result of subjective evaluation (Scholz & Tietje 2002) and which depends heavily on the expert's experience, the social and geographical context in which the study is carried out. Thus, weights are not directly transposable to other contexts because of socio-cultural variables (Charreaux 2004).

Comparative analysis of service levels in Mandjou and Mvangan Councils suggests that monitoring rural water services can improves water service levels provided to populations and, hence, universal access to water. This observation has been made by several authors (Carter *et al.* 1999; Colin 1999; Harvey & Reed 2004; SKAT-RWSN 2007; Whittington *et al.* 2008; Montgomery *et al.* 2009; Skinner 2009; Lockwood & Smits 2011) which suggest that post-construction technical factors such as the frequency of maintenance operations, access to spare parts, availability of repair craftsmen, and technical support to service managers are essential to achieving universal access to safe drinking water.

The results also suggest that the approach proposed for assessing service levels has similarities to the work of Moriarty *et al.* (2010) as part of the WASCost, Flores *et al.* (2013), and Baquero *et al.* (2015). The indicators used are the result of merging the parameters proposed in these various works. Despite these similarities, there are some differences. The weight of indicators in determining service levels differs from those proposed in the literature. This is due to the fact that weightings are subjective evaluation results (Scholz & Tietje 2002) and are also influenced by contextual factors. However, the approach could be improved by establishing thresholds or benchmarks for indicators. In addition, members of rural communities could place weight on indicators, which could improve the appropriation of results and the mobilization of activities that generate positive changes in the services assessed.

However, the issue of post-construction monitoring remains financial resources. In other words, how can we finance the post-construction support of rural water services in a context marked by the sector's unsealed profitability? For wealthy councils such as Mvangan, the problem is not acute as in the case of Mandjou Council. For example, states are required to intervene through subsidies to monitor rural water services management post-construction (Hutton *et al.* 2019). The human right to drinking water, therefore, imposes on states various types of obligations, including monitoring the extent of the realization, or non-fulfillment, of the right to water. Thus, the indicators used should address the different components of achieving the human right to drinking water.

CONCLUSION

Despite decades of research on rural drinking water services, maintaining reliable water supplies remains a development challenge in rural, remote, and marginalized communities in developing countries. Most studies evaluating rural water services use a small number of indicators, presumably for pragmatism, the costs associated with data collection, or the use of indicators that are considered agents to assess service levels. The indicators selected for the assessment approach were essential for measuring water service level for decision-making. The use of multi-criteria analysis is used to assess indicators and determine the most important factors in assessing service levels by assigning weights to them. As a result, it allows for a more accurate assessment of the performance of water services comparatively to unweighted approaches.

The approach provides a holistic way to assess drinking water service levels in a local context. In analyzing water service levels, the scale of services and the empirical results of the assessment, when shared with community members, proved to be a communication tool for improving rural water services. In addition, the approach can be used to monitor the state of the right to water and as a reference point for decisions. The approach can also be used in similar contexts, providing a baseline for holistically assessing service levels, designing improvements, and monitoring behavior over time. The approach can help community managers prioritize their actions and investments, and self-mobilize for improvements for external support.

Politically and managerially, the results show the importance of post-construction monitoring of drinking water systems and community structure managers and the need for governments to provide grants to local governments to ensure that this monitoring is effective. The assessments provided represent only a current snapshot of potable water delivery system conditions. Therefore, a time interval for conducting such assessments to track changes in overall and local conditions should be considered. The approach developed could be improved by establishing thresholds or benchmarks for indicators. In addition, community members could assign weights to attributes, which can appropriate results and mobilize for actions that generate positive changes in the evaluated system.

DATA AVAILABILITY STATEMENT

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

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