Assessing the performance of urban water utilities in Mozambique using a water utility performance index

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ABSTRACT

Benchmarking analysis has become a strategic tool through which water regulators around the world measure the performance of water utilities. Since 2008, the Water Regulatory Council of Mozambique has been implementing a benchmarking framework to analyse the performance of urban water utilities. This paper develops a water utility performance index (WUPI) to analyse the performance of the regulated urban water supply utilities in Mozambique during 2010 and 2012. The WUPI is based on 12 key performance indicators grouped into 3 components (economic sustainability, operational sustainability and quality of the services). The WUPI was built in 6 different ways, using 2 weighting systems (equal weights and non-equal weights), and 3 different functional forms to aggregate the indicators (additive aggregation, hybrid aggregation and TOPSIS aggregation). The results obtained show that the performance of the water supply utilities in the analysed period has evolved positively. They also indicate that the performance level between the analysed water supply utilities is heterogeneous, with water supply utilities earning both high and low scores of the WUPI. Water utilities that were working through water operator partnership mechanics obtained higher performances in terms of the WUPI. This information should enable water supply utility managers and decision makers to prioritise activities and implement working models that allow for improvement of the performance of water supply utilities.

Keywords: Benchmarking; composite indicators; performance indicators; Mozambique

INTRODUCTION

Over the past two decades, the use of performance indicators has emerged as the main tool for measuring and monitoring the performance of water utilities (Canneva and Guerin-Schneider, 2011). Benchmarking techniques have become a strategic tool for water regulators (De Witte and Marques, 2012). Benchmarking tools are used: (i) to promote and motivate competition between different water utilities in order to improve their performance, (ii) to identify the strengths and weaknesses in the performance of water utilities, (iii) to promote information sharing and improve transparency in the reporting process, (iv) to identify performance trends, and (v) to provide information regarding the performance of water utilities to water consumers (Corton, 2003; Alegre et al., 2009; Padowski, 2008).

Urban water utilities commonly operate in a monopoly environment (Alegre et al., 2009; Marques et al., 2011). Furthermore, in developing countries where major efforts have been made to improve water services consumers are paying high tariffs for those services, considering their socio-economic context (Banerjee and Morella, 2011; Hoque and Wichelns, 2013); yet these services are usually of poor quality (Mugabi et al., 2007; Padowski, 2008; WHO-UNICEF, 2013). Water regulators in both developed and developing countries have conducted performance evaluations of water utilities using benchmarking techniques (Romano and Guerrini, 2011; Marques et al., 2012). Sub-Saharan African countries are no exception. For instance, benchmarking analysis is being applied in Zambia (the National Water Supply and Sanitation Council), Tanzania (the Energy and Water Utilities Regulatory Authority), Kenya (Water Services Regulatory Board), Rwanda (Rwanda Utilities Regulatory Authority), South Africa (the Department of Water Affairs) and Mozambique (Water Regulatory Council).

Over the past 5 years, the Water Regulatory Council of Mozambique has been implementing a benchmarking framework to evaluate the performance of the main urban water supply utilities in the country. This tool is based on a set of 11 key performance indicators that are analysed separately. The evaluation is performed on a yearly basis, and the results reported to the Mozambican Council of Ministers. However, the system used does not provide an integrated evaluation of overall performance or enable comparison of the different utilities evaluated.

Therefore, the main objective of this research was to develop a water utility performance index to evaluate the performance of the urban water supply utilities in Mozambique. The use of composite indicators should enable the evaluation of performance in an integrated manner. Empirical application focused on the performances of water supply utilities in the years 2010 and 2012. The results of this study are intended to serve as a support tool for the managers and decision makers of water supply utilities to implement the most appropriate actions for improving performance.

Urban water supply utilities in Mozambique as a case study

We focused our analysis on the regulated urban water supply utilities in Mozambique. The institutional water sector framework in Mozambique is led by the National Directorate of Water within the Ministry of Public Works and Housing.

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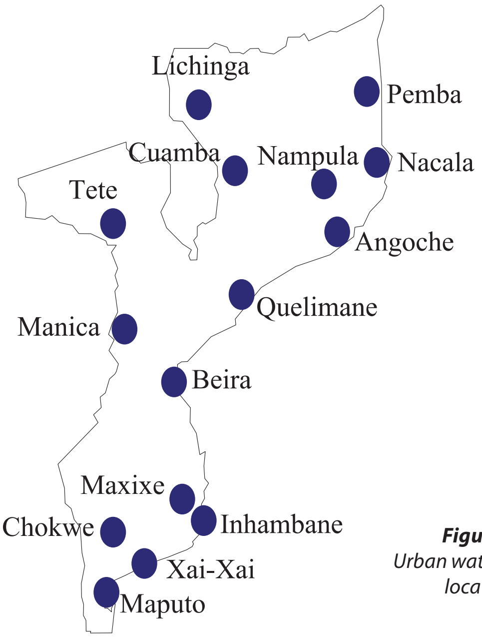

Figure 1
Urban water utilities location

Among other responsibilities, this Directorate has the mandate to secure reliable water supply services in Mozambique (Matsinhe et al., 2008). Since the approval of the 1991 Water Law and the 1995 National Water Policy, which emphasise the decentralisation of water supply services, the water sector has enacted deep reforms in pursuit of this principle. In 1998 Decree No. 72/98 established the Delegated Management Framework (DMF) for water supply in the principal cities. The DMF is rooted in 3 main principles: (i) separation of asset management and operation, (ii) inclusion of private companies in the operation of water systems, and (iii) establishment of an independent institution to regulate water tariffs and service quality and protect the interests of water consumers (IP3, 2007).

Within this context of delegated water supply services, 2 key institutions were created in 1998: the Fund for Investment and Patrimony of Water Supply (FIPAG) and the Water Regulatory Council (CRA). FIPAG was created in 1998 and is responsible for promoting and ensuring the efficiency and sustainable management of the assets of the water supply system through the delegation of its management to third parties. In contrast, CRA is in charge of the regulation of the water services in the delegated water supply systems, including economic regulation and safeguarding consumers' interests.

Nineteen urban water supply systems operate under the umbrella of this delegated management framework (PPIAF-World Bank, 2009). However, 7 of these are operated as 3 single water utilities: (i) Beira water supply utility, which comprises the water supply systems of Beira and Dondo, (ii) Tete water supply utility, which includes the supply systems of Tete and Moatize, and (iii) Manica water supply utility, which includes the Manica, Chimoio and Gondola supply systems. Thus, we analysed 15 urban water supply utilities spread throughout the country (see Fig. 1), of which 14 are operated directly by FIPAG and one (Maputo) has been operated by a private company since 1999 (Águas da Região de Maputo or AdeM). Table 1 shows the main features of the 15 regulated urban water supply utilities analysed.

METHODOLOGY

The water utility performance index

The water utility performance index (WUPI) used to assess the performance of the Mozambican water supply utilities was developed following the guidelines suggested by the OECD-JRC (2008). In summary, the OECD-JRC (2008) recommends building composite indicators following 10 steps: (i) development of a theoretical framework; (ii) selection of the basic indicators; (iii) imputation of missing data; (iv) multivariate analysis; (v) normalisation; (vi) weighting and aggregation; (vii) robustness and sensitivity; (viii) back to the details (indicators); (ix) association with other variables; and (x) dissemination. However, despite the fact that composite indicators are widely used internationally, criticisms of these tools have been voiced; Saisana and Tarantola (2002) have summarised the pros and cons of the composite indicators (see Table 2).

TABLE 1
Characteristics of the main cities

Water utility	Population to be served by the system (2012)	Start year of water regulation	Province	Water operator partnership	Province GDP (per capita USDs) (2012)	Gini (2011)	Province HDI (2011)
Maputo	1.962.765	2000	Maputo	No	2074	0.512	0.669
Xai-Xai	137.434	2004	Gaza	Yes	472	0.427	0.440
Chokwe	104.405	2004	Gaza	Yes	472	0.427	0.440
Inhambane	67.749	2004	Inhambane	Yes	723	0.383	0.505
Maxixe	92.789	2004	Inhambane	Yes	723	0.383	0.505
Beira	551.072	2000	Sofala	No	753	0.456	0.467
Manica	350.545	2009	Manica	No	296	0.345	0.423
Quelimane	211.357	2000	Zambezia	No	288	0.365	0.409
Tete	227.690	2009	Tete	No	461	0.323	0.430
Nampula	528.863	2000	Nampula	No	435	0.419	0.424
Nacala	238.171	2009	Nampula	No	435	0.419	0.424
Angoche	103.827	2009	Nampula	No	435	0.419	0.424
Lichinga	176.524	2009	Niassa	No	288	0.427	0.403
Cuamba	97.994	2009	Niassa	No	288	0.427	0.403
Pemba	154.661	2000	Cabo Delgado	No	350	0.347	0.373

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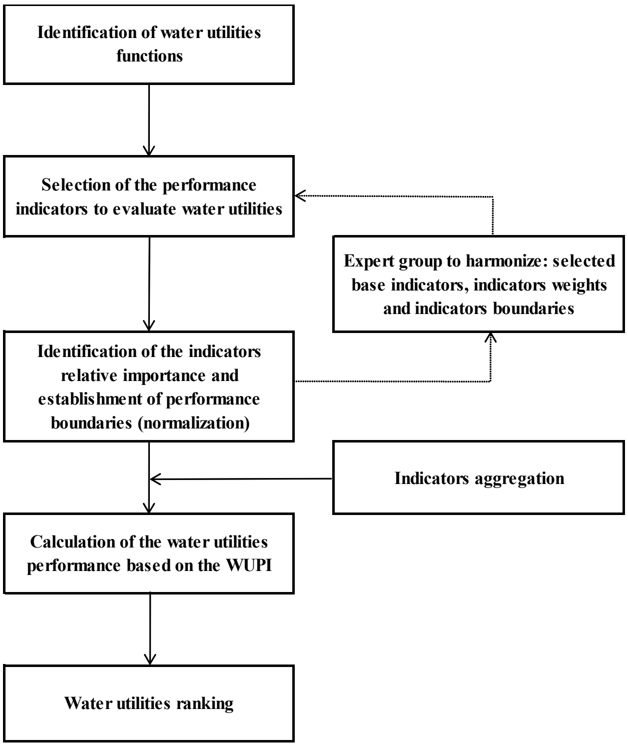

Figure 2
Methodological outline

To develop the WUPI, an expert group was selected to debate and harmonise each of the main aspects involved in the construction of the WUPI. The expert group was composed of technicians from the Water Regulatory Council of Mozambique and the main water supply institutions in Mozambique (FIPAG and AdeM). The main inputs resulting from these critical debates were used to develop a refined version of the WUPI. Figure 2 outlines the methodological approach followed to develop the WUPI. The main steps followed for the WUPI computation are described in the following sections.

Theoretical framework and selection of performance indicators

We followed the theoretical frameworks developed by Alegre et al. (2006) and Van der Berg and Danilenko (2011) to obtain a coherent structure of the WUPI that reflects the main dimensions linked to the performance of water supply utilities in Mozambique. These two approaches are based on the water utility functions that should be implemented. Alegre et al. (2006) divided the functions of water utilities into 6 different categories, while Van der Berg and Danilenko (2011) used 12 categories. Both provide a set of performance indicators. However, as stated for both approaches, the selection of categories and indicators to measure performance should be based on their relevance to the water utilities' context. It is not compulsory to implement the full spectrum of categories and indicators and these should be adapted to the local context. In our case study, we identified 3 main components to assess performance: (i) economic sustainability, (ii) operational sustainability and (iii) quality of the services. After the main WUPI components were established, an in-depth review of the indicators provided by Alegre et al. (2006) and Van der Berg and Danilenko (2011) was carried out to identify a core group of indicators that would enable measurement of water utility performance based on the country's reality. The Bell and Morse (2008) criteria for the selection of indicators to build composite indicators were also followed. The most important criteria to take into consideration for the selection of an indicator are (see Bell and Morse, 2008): measurability (the data are available and can be collected); the indicators are sensitive to spatial and temporal change; economically viable – cost effective; easy to interpret; reliable and robust; replicable; timely (show trends over time); relevant to the context; scientifically well-founded. Thus, 12 key performance indicators were selected (see Table 3). For further information about the definition and calculation of the indicators selected, interested readers may consult the works of Alegre et al. (2006) and Van der Berg and Danilenko (2011). Three roundtable meetings with an expert group, using an interactive approach, were necessary to achieve agreement on the final 'format' of the WUPI (components and indicators). During those meetings the structure of the WUPI and the base indicators to measure the performance of water utilities were identified.

Indicator normalisation

Indicator normalisation is used to transform the set of base indicators selected, which are expressed in different units of measurement, into a homogeneous set of variables expressed in the same unit, which can then be used for comparisons and arithmetic operations. There is a wide array of methods that have been developed for indicator normalisation, all of which have pros and cons (Freudenberg, 2003). For our case study, we selected the max–min technique, as this is one of the most common normalisation procedures used for the construction of composite indicators.

TABLE 2
Pros and cons of composite indicators (From: Saisana and Tarantola, 2002)

Pros	Cons
• Can be used to summarise complex or multi-dimensional issues, in view of supporting decision-makers. • Provide the 'big picture'. They can be easier to interpret than trying to find a trend in many separate indicators. • Can help attract public interest by providing a summary figure with which to compare the performance across countries and their progress over time. • Could help to reduce the size of a list of indicators or to include more information within the existing size limit.	• May send misleading, non-robust policy messages if they are poorly constructed or misinterpreted. • The simple 'big picture' results which composite indicators show may invite politicians to draw simplistic policy conclusions. • The construction of composite indicators involves stages where judgement has to be made: the selection of sub-indicators, choice of model, weighting indicators and treatment of missing values, etc. • The selection of indicators and weights could be the subject of political challenge.

TABLE 3
Water Utility Performance Index structure

Component	Sub-component	Performance indicator	Measure unit	Indicator polarity
Economic sustainability		1. Collection ratio (COLLECT)	%	+
		2. Operating cost coverage (OPCO)	Ratio	+
Operational sustainability		3. Number of employees per 1000 water connections (EMPLOY)	Dimensionless	–
		4. Non-revenue water (NRW)	%	–
Quality of the service	Service to the consumers	5. Total water coverage (COVER)	%	+
		6. Percentage of sold water that is metered (SOLWA)	%	+
		7. Continuity of the water service (HOUR)	h/day	+
	Water quality	8. Percentage of monitored water quality parameters (PARAM)	%	+
		9. Percentage of conformed samples analysed (SAMPLE)	%	+
	Consumers attendance	10. Days to reply to consumers complaints (DAYCOM)	Day	–
		11. Total number of complaints for connections (TOTCOM)	No. complaints/ connections	–
		12. Percentage of complaints replied (COMRE)	%	+

** Indicators with polarity: + more is better; – less is better*

The max–min technique uses the minimum and maximum values of a given sample (in our case, the selected base indicators for the 15 water supply utilities considered) to re-scale the base indicators; the base indicators are then measured on a scale that ranges from 0 (the worst possible performance) to 1 (the best possible performance). We pre-established the minimum and maximum threshold values for each indicator, and then established the admissible range of performance, i.e., the minimum admissible performance and the best performance value for each indicator. To fix the indicators' boundaries, we used the same expert panel that was used to select the set of indicators that define the WUPI. Van der Berg and Danilenko (2011) also used the establishment of performance boundaries to evaluate the performance of water utilities in order to calculate the APGAR: water utility status index. The mathematical formulation of the max–min technique is as follows, depending on whether the indicator has a positive (more is better) or negative (less is better) polarity (see Table 3):

$$I_k = \frac{x_k - \min(x_k)}{\max(x_k) - \min(x_k)} \quad \text{'more is better'} \qquad (1)$$

$$I_k = \frac{\max(x_k) - x_k}{\max(x_k) - \min(x_k)} \quad \text{'less is better'} \qquad (2)$$

where:

I_k refers to the normalised value of the indicator k
x_k is the value of indicator k without being normalised
$max(x_k)$ is the maximum value of k without being normalised
$min(x_k)$ is the minimum value of k before the normalisation

Indicator weighting

The indicator weighting step aims to identify the relative importance of the base indicators selected to build the WUPI. Several techniques can be used to obtain the indicators' weights; the base indicators can be obtained using positive or normative techniques (OECD-JRC, 2008). Positive approaches use statistical techniques to identify the weights of the base indicators, using the information provided by the performance indicators sample. Normative approaches use participatory methods that integrate expert opinions to obtain the relative importance of the base indicators. Given that we aimed to establish specific weights relevant to the local context, we opted to use a weighting system that reflects the opinions of Mozambican experts, and thus selected the normative approach. The weights obtained may vary depending on the technique used to identify the importance of each indicator, and can thus affect the results and conclusions derived from the WUPI. To overcome this limitation, we opted to obtain the weights of the base indicator using 2 different weighting systems.

Firstly, we used the Analytic Hierarchy Process (AHP) as a normative technique. The AHP is a multi-criteria decision-making tool developed by Saaty (1980) to obtain the relative importance of the criteria under analysis (in our case, the performance indicators) based on expert opinions using a pair-wise comparison system. The AHP technique has previously been used in Mozambique for the construction of other composite indicators in the water sector, by Gallego-Ayala and Juizo (2012). The main characteristics and the mathematical formulations of the AHP for the identification of the relative importance of the indicator weights can be found in Saaty (1980). To derive the indicators' weights using the AHP, a sample of 45 technicians from the Water Regulatory Council of Mozambique and the main water supply institutions in Mozambique was used.

Secondly, we used an equal weighting (EW) system, which is the most common approach used to weight composite indicators (OECD-JRC, 2008). This approach assumes that all of the base indicators have equal weights, i.e., the same relative importance. In the water sector, the EW approach has been applied to construct composite indicators by Sullivan (2002) and Gine-Garriga and Perez-Foguet (2010), among others. The weights used to construct the WUPI through the AHP and EW approaches are given in Table 4.

Aggregation of the indicators

The final step in constructing the WUPI is the aggregation of all of the normalised indicators into a single indicator. As for previous steps, there is a wide variety of methods available. In

TABLE 4
Base indicator weights

Indicators	**Weights AHP**	**Weights EW**
1. Collection ratio (COLLECT)	7.50%	8.33%
2. Operating cost coverage (OPCO)	12.47%	8.33%
3. Employs per 1 000 water connections (EMPLOY)	4.44%	8.33%
4. Non-revenue water (NRW)	23.97%	8.33%
5. Total water coverage (COVER)	5.13%	8.33%
6. Percentage of sold water that is metered (SOLWA)	4.45%	8.33%
7. Continuity of the water service (HOUR)	5.42%	8.33%
8. Percentage of monitored water quality parameters (PARAM)	8.12%	8.33%
9. Percentage of conformed samples analysed (SAMPLE)	22.78%	8.33%
10. Days to reply to consumers complaints (DAYCOM)	1.85%	8.33%
11. Total number of complaints for connections (TOTCOM)	1.26%	8.33%
12. Percentage of complaints replied (COMRE)	2.62%	8.33%

fact, the selection of the functional forms for aggregation is one of the most controversial aspects of the construction of composite indicators (Morse et al., 2001; Böhringer and Jochem, 2007), because, depending on the algebraic alternative, we assume different degrees of compensation among the indicators (Munda, 2008, 2012). Thus, the results and conclusions derived from the composite indicator could be affected by the aggregation method selected during the construction of the composite indicator (Gomez-Limon and Riesgo, 2009; Gallego-Ayala et al., 2011). In spite of this limitation, and with the aim of obtaining more consistent results and conclusions, we aggregated the indicators considered using 3 different aggregation forms to allow various compensation degrees among the indicators:

Alternative 1: Weighted sum of indicators

The weighted sum of indicators is a representative functional form of additive mathematical formulations, which assumes total compensation among the indicators. This linear aggregation of the indicators is calculated using the following formula:

$$WUPI_{additive\,,\;i} = \sum_{k=1}^{k=12} w^*{}_k \cdot I_{k,\;i} \qquad (3)$$

where:
i refers to the specific water utility under analysis
w^*_k is the relative importance of indicator *k*
$I_{k,i}$ is the normalised value of the indicator *k* for water utility *i*

Alternative 2: Hybrid aggregation of the indicators

The application of hybrid aggregation rules implies the integration of different aggregation forms for the construction of the composite indicator. In our case study, we constructed the WUPI by integrating additive and multiplicative functions at 2 different levels of aggregation.

In the first step, we used an additive aggregation function to aggregate the indicators within the three components (economic sustainability, operational sustainability and quality of the services) that compose the structure of the WUPI. We thus obtained 3 independent composite indicators that measure the performance of the water utility within each of the WUPI components using the following mathematical expression:

$$WUPI_{eco\,,\;i} = \frac{\sum_{k=1}^{k2} w^*{}_k \cdot I_{k,\;i}}{\sum_{k=1}^{k2} w^*{}_k} \qquad (4)$$

$$WUPI_{op,\;i} = \frac{\sum_{k=3}^{k=4} w^*{}_k \cdot I_{k\;i}}{\sum_{k=3}^{k=4} w^*{}_k} \qquad (5)$$

$$WUPI_{qual\,,\;i} = \frac{\sum_{k=5}^{k=12} w^*{}_k \cdot I_{k,\;i}}{\sum_{k=5}^{k=12} w^*{}_k} \qquad (6)$$

For the second step, we used a multiplicative aggregation function to combine the three components obtained in the previous step to obtain the single WUPI through the following formula:

$$WUPI_{hybrid\;,i} = \prod_{j=1}^{j=3} WUPI_{j,i}^{\;w^*{}_j} \qquad (7)$$

where:
j refers to each of the components used to construct the WUPI
w^*_j is the weight of component *j*

Alternative 3: Technique for order preference by similarity to the ideal solution (TOPSIS)

By applying the TOPSIS as an aggregation rule, we used a multi-criteria decision making approach for the aggregation of the indicators. This method is an alternative to the most common additive aggregation functions, i.e., the weighted sum of indicators, for the construction of composite indicators. The mathematical expression for the calculation of the WUPI using TOPSIS as the aggregation method is as follows:

$$WUPI_{TOPSIS\,,\;i} = \frac{\sqrt{\sum_{k=1}^{k=12}(w^*{}_k I_{ki} - \min\{w^*{}_k I_{ki}\})^2}}{\sqrt{\sum_{k=1}^{k=12}(w^*{}_k I_{ki} - \max\{w^*{}_k I_{ki}\})^2} + \sqrt{\sum_{k=1}^{k=12}(w^*{}_k I_{ki} - \min\{w^*{}_k I_{ki}\})^2}} \qquad (8)$$

TABLE 5
Descriptive statistics of the WUPIs calculated

Composite indicator	Min	Max	Mean	St deviation	Variance	Kurtosis	Shapiro-Wilk
2010							
$WUPI_{additive\_AHP}$	0.345	0.848	0.595	0.154	0.024	−0.581	0.679
$WUPI_{hybrid\_AHP}$	0.000	0.830	0.458	0.275	0.076	−0.513	0.092
$WUPI_{TOPSIS\_AHP}$	0.404	0.754	0.561	0.097	0.009	−0.088	0.888
$WUPI_{additive\_EW}$	0.352	0.850	0.587	0.153	0.023	−0.520	0.609
$WUPI_{hybrid\_EW}$	0.000	0.842	0.464	0.276	0.076	−0.371	0.068
$WUPI_{TOPSIS\_EW}$	0.411	0.768	0.558	0.103	0.011	0.071	0.503
2012							
$WUPI_{additive\_AHP}$	0.268	0.870	0.613	0.189	0.036	−1.096	0.364
$WUPI_{hybrid\_AHP}$	0.000	0.823	0.450	0.295	0.087	−1.110	0.082
$WUPI_{TOPSIS\_AHP}$	0.375	0.729	0.571	0.116	0.013	−1.331	0.325
$WUPI_{additive\_EW}$	0.187	0.907	0.628	0.208	0.043	−0.351	0.434
$WUPI_{hybrid\_EW}$	0.000	0.882	0.496	0.313	0.098	−0.925	0.085
$WUPI_{TOPSIS\_EW}$	0.316	0.765	0.583	0.132	0.017	−0.586	0.460

TABLE 6
Pearson correlation coefficients for the WUPIs calculated (2010 and 2012)

	$WUPI_{additive\_AHP}$	$WUPI_{hybrid\_AHP}$	$WUPI_{TOPSIS\_AHP}$	$WUPI_{aditive\_EW}$	$WUPI_{hybrid\_EW}$	$WUPI_{TOPSIS\_EW}$
$WUPI_{additive\_AHP}$		0.837$^{(**)}$	0.993$^{(**)}$	0.920$^{(**)}$	0.806$^{(**)}$	0.903$^{(**)}$
$WUPI_{hybrid\_AHP}$	0.878$^{(**)}$		0.830$^{(**)}$	0.845$^{(**)}$	0.978$^{(**)}$	0.814$^{(**)}$
$WUPI_{TOPSIS\_AHP}$	0.998$^{(**)}$	0.884$^{(**)}$		0.930$^{(**)}$	0.805$^{(**)}$	0.927$^{(**)}$
$WUPI_{additive\_EW}$	0.960$^{(**)}$	0.915$^{(**)}$	0.958$^{(**)}$		0.889$^{(**)}$	0.992$^{(**)}$
$WUPI_{hybrid\_EW}$	0.842$^{(**)}$	0.990$^{(**)}$	0.848$^{(**)}$	0.910$^{(**)}$		0.864$^{(**)}$
$WUPI_{TOPSIS\_EW}$	0.966$^{(**)}$	0.915$^{(**)}$	0.965$^{(**)}$	0.998$^{(**)}$	0.907$^{(**)}$	

Grey cells refers to 2012.
(**) Significance level $p<0.01$.

Information sources for the base indicators

The data needed to calculate the set of base indicators that form the WUPI were obtained from official secondary sources. We consulted technical and statistical bibliographic sources, and, specifically, data from the CRA (2011, 2013), to extract key data for the calculation of the base indicators. We also consulted monthly reports submitted by FIPAG and AdeM (the water utility operators) to CRA for 2010 and 2012, to obtain detailed data regarding the water utilities performance on operational, services and economic–financial issues. The CRA reports (2011 and 2013) present the performance of the water utilities based on the monthly reports submitted by FIPAG and AdeM. It should be highlighted that the government reports (CRA, 2011 and 2013), our main data sources, include basic data regarding the performance status of the water utilities in Mozambique. In fact, as stated in the introductory section, those official reports also present 11 separate key performance indicators of the water utilities in Mozambique. Finally, the data presented in these reports is also audited on an annual basis by CRA, to verify the accuracy and reliability of the performance indicators. Tables A1 and A2 in the Appendix report the values of the base indicators used in this research, as well as the descriptive statistics of the indicators.

RESULTS

Before analysing the results obtained for the WUPIs at the water supply utility level, it is important to summarise the basic descriptive statistics for the different composite indicators calculated for the two years under analysis (Table 5). Comparison of the mean values obtained for the WUPIs in the years 2010 and 2012 revealed that, in general terms, there has been a positive evolution in the WUPIs. As stated in the methodology section, there are different factors affecting the final results of the composite indicator obtained, for instance, the weighting technique and the aggregation procedure selected. Thus, because we calculated the WUPI in 6 different ways, it is important to check whether, regardless of the techniques selected to build the WUPI, the outputs obtained are not in conflict with each other. Pearson's correlation was used to check the consistency of the WUPIs (see Table 6), and indicated a positive and significant correlation among all of the WUPIs calculated. Therefore, from a statistical point of view, there are no significant differences between the WUPIs obtained. Nonetheless, the correlation indices are much higher when comparing the WUPIs obtained using the additive and TOPSIS aggregation rules than when comparing the WUPIs obtained using the hybrid aggregation rule (irrespective of the weighting system used). Therefore, we can affirm that the construction of the WUPI is influenced more by the selected functional form of aggregation than by the weighting system used. These results are in line with other research studies that analysed a set of different composite indicators using different constructions (weighting and aggregation

TABLE 7
Results of the WUPIs and ranking of the water utilities (2010-2012)

Water utility	Weights using AHP						Weights using EW					
	$WUPI_{aditive}$		$WUPI_{hybrid}$		$WUPI_{TOPSIS}$		$WUPI_{aditive}$		$WUPI_{hybrid}$		$WUPI_{TOPSIS}$	
	2010	2012	2010	2012	2010	2012	2010	2012	2010	2012	2010	2012
Maputo	0.345(15)	0.422 (13)	0.315 (12)	0.373 (9)	0.404 (15)	0.445 (14)	0.352 (15)	0.451 (13)	0.328 (12)	0.450 (9)	0.411 (15)	0.466 (13)
Xai-Xai	0.620 (6)	0.870 (1)	0.486 (9)	0.823 (1)	0.574 (6)	0.729 (1)	0.713 (3)	0.885 (2)	0.610 (5)	0.864 (2)	0.640 (3)	0.758 (2)
Chokwe	0.769 (3)	0.850 (3)	0.734 (3)	0.764 (3)	0.651 (3)	0.716 (3)	0.685 (5)	0.882 (3)	0.671 (4)	0.831 (3)	0.604 (5)	0.754 (3)
Inhambane	0.848 (1)	0.869 (2)	0.830 (1)	0.817 (2)	0.754 (1)	0.724 (2)	0.849 (2)	0.907 (1)	0.842 (1)	0.882 (1)	0.768 (1)	0.765 (1)
Maxixe	0.834 (2)	0.749 (4)	0.766 (2)	0.488 (7)	0.706 (2)	0.652 (5)	0.850 (1)	0.786 (4)	0.814 (2)	0.573 (7)	0.733 (2)	0.677 (5)
Beira	0.625 (5)	0.741 (5)	0.513 (8)	0.736 (4)	0.572 (7)	0.670 (4)	0.591 (7)	0.782 (5)	0.513 (9)	0.780 (4)	0.549 (8)	0.680 (4)
Manica	0.359 (14)	0.448 (11)	0.000 (13)	0.319 (11)	0.421 (14)	0.472 (11)	0.371 (14)	0.563 (10)	0.000 (13)	0.477 (8)	0.422 (14)	0.534 (10)
Quelimane	0.597 (8)	0.654 (7)	0.587 (6)	0.636 (6)	0.563 (8)	0.593 (7)	0.534 (11)	0.745 (6)	0.445 (10)	0.737 (5)	0.520 (11)	0.655 (6)
Tete	0.478 (12)	0.738 (6)	0.396 (11)	0.720 (5)	0.486 (12)	0.649 (6)	0.550 (9)	0.713 (7)	0.536 (8)	0.705 (6)	0.530 (9)	0.625 (7)
Nampula	0.540 (10)	0.418 (14)	0.424 (10)	0.315 (12)	0.524 (10)	0.451 (13)	0.538 (10)	0.484 (12)	0.423 (11)	0.381 (11)	0.521 (10)	0.490 (12)
Nacala	0.575 (9)	0.568 (9)	0.546 (7)	0.391 (8)	0.549 (9)	0.542 (9)	0.588 (8)	0.570 (8)	0.540 (7)	0.405 (10)	0.554 (7)	0.542 (8)
Angoche	0.734 (4)	0.447 (12)	0.667 (4)	0.000 (13)	0.635 (4)	0.465 (12)	0.605 (6)	0.489 (11)	0.553 (6)	0.000 (13)	0.557 (6)	0.493 (11)
Lichinga	0.463 (13)	0.510 (10)	0.000 (13)	0.000 (13)	0.480 (13)	0.506 (10)	0.444 (12)	0.406 (14)	0.000 (13)	0.000 (13)	0.470 (12)	0.447 (14)
Cuamba	0.524 (11)	0.268 (15)	0.000 (13)	0.000 (13)	0.513 (11)	0.375 (15)	0.433 (13)	0.187 (15)	0.000 (13)	0.000 (13)	0.463 (13)	0.316 (15)
Pemba	0.619 (7)	0.639 (8)	0.603 (5)	0.372 (10)	0.576 (5)	0.576 (8)	0.695 (4)	0.565 (9	0.690 (3)	0.352 (12)	0.622 (4)	0.537 (9)

systems) (see Gomez-Limon and Sanchez-Fernandez, 2010; Gine-Garriga and Perez-Foguet, 2010).

Table 7 shows the overall results obtained for the WUPIs for each water supply utility and year under analysis. Taking into consideration the results obtained for the WUPIs, the performance level among the different water supply utilities evaluated throughout the country is heterogeneous and has evolved (comparing the results of years 2010 and 2012) in an uneven form. It is possible to differentiate 3 different types of behaviours: (i) water supply utilities that maintain a stable performance over time (Inhambane water supply utility), (ii) water utilities that experience significant increases in their performance (Tete water supply utility) and (iii) water supply utilities that present decreasing performance levels (Angoche water utility).

In general, the WUPIs calculated with the hybrid aggregation form show a reduction in performance level of the water supply utilities, relative to those obtained with the additive and TOPSIS aggregation rules. Although this result was expected, because hybrid aggregation integrates the multiplicative function for the aggregation of the three components of the WUPI (non-compensation among the components), there are water utilities that show a significant reduction in WUPIs obtained using the hybrid aggregation rule. These results allow us to characterise three different types of water utilities with respect to the WUPI values (for 2012):

- **Water supply utilities with high levels of performance.** This group of water supply utilities (Xai-Xai, Chókwè, Inhambane, Beira, Quelimane and Tete) presents high levels of performance regardless of the weighting and aggregation system used to construct the WUPI. The average value of the WUPI for this group was 0.75.
- **Water supply utilities with low levels of performance.** This group presents the lowest average WUPI value, i.e., 0.44. This group, which comprises the water supply utilities of Maputo, Manica and Nampula, presents low levels of performance for the six WUPIs calculated.
- **Water supply utilities with unbalanced performance.** This group comprises those water supply utilities (Maxixe, Nacala, Lichinga, Cuamba, Angoche and Pemba) that show a significant reduction in the $WUPI_{hybrid}$ values compared with the $WUPI_{additive}$ and $WUPI_{TOPSIS}$ values. This trend in WUPI values indicates an unbalanced performance, i.e., some functional areas of the water supply utility present low levels of performance that are not being compensated by those areas in which the utility presents a high level of performance.

Similarly, it is important to analyse the performance level of each of the three components of the WUPI. The results

TABLE 8
Results of the WUPIs components

Water utility	Weights using AHP						Weights using EW					
	$WUPI_{eco}$		$WUPI_{op}$		$WUPI_{qual}$		$WUPI_{eco}$		$WUPI_{op}$		$WUPI_{qual}$	
	2010	2012	2010	2012	2010	2012	2010	2012	2010	2012	2010	2012
Maputo	0.525	0.505	0.156	0.156	0.380	0.536	0.600	0.504	0.500	0.500	0.253	0.426
Xai-Xai	0.122	0.395	0.386	1.000	0.941	0.983	0.138	0.515	0.636	1.000	0.876	0.948
Chokwe	0.376	0.263	0.844	1.000	0.880	0.995	0.500	0.350	0.500	1.000	0.777	0.985
Inhambane	0.533	0.376	0.892	1.000	0.946	0.988	0.626	0.500	0.855	1.000	0.903	0.985
Maxixe	0.300	0.038	1.000	0.923	0.949	0.928	0.400	0.050	1.000	0.955	0.924	0.928
Beira	0.114	0.712	0.885	0.885	0.680	0.674	0.131	0.769	0.932	0.932	0.621	0.748
Manica	0.000	0.075	0.000	0.195	0.696	0.731	0.000	0.100	0.000	0.523	0.557	0.689
Quelimane	0.402	0.385	0.624	0.693	0.658	0.736	0.407	0.577	0.091	0.955	0.676	0.735
Tete	0.334	0.472	0.153	0.923	0.712	0.739	0.322	0.508	0.695	0.818	0.571	0.738
Nampula	0.075	0.077	0.732	0.847	0.615	0.315	0.060	0.062	0.841	0.909	0.582	0.483
Nacala	0.594	0.038	0.321	0.784	0.707	0.653	0.555	0.031	0.190	0.709	0.695	0.670
Angoche	0.247	0.000	0.844	0.477	0.862	0.604	0.197	0.000	0.500	0.527	0.733	0.601
Lichinga	0.328	0.000	0.000	0.770	0.769	0.564	0.262	0.000	0.000	0.864	0.600	0.394
Cuamba	0.000	0.000	0.575	0.844	0.698	0.056	0.000	0.000	0.341	0.500	0.564	0.156
Pemba	0.416	0.019	0.540	1.000	0.741	0.679	0.512	0.015	0.727	1.000	0.733	0.594
Mean	0.291	0.224	0.530	0.766	0.749	0.679	0.314	0.265	0.521	0.813	0.671	0.672

obtained for this analysis are shown in Table 8. In general terms, the analysis of the performance in the economic sustainability component ($WUPI_{eco}$), shows that this component presents low performance values (mean values of $WUPI_{eco}$ for 2012 below 0.300), with the exception of the Beira water supply utility, which had a score of 0.71. It is also worthwhile to highlight that, in general terms, the $WUPI_{eco}$ values have worsened between 2010 and 2012. This fact was mainly due to the significant reduction in the operating cost coverage indicator (see Tables A1 and A2) and, to a lesser extent, the reduction in the collection ratio (COLLECT indicator). Therefore, in terms of economic sustainability, the water supply utilities analysed are not sustainable. In contrast, the operational sustainability component shows high levels of performance (mean values of $WUPI_{op}$ for 2012 above 0.750), but the Maputo, Manica and Angoche utilities have low levels of performance. However, nearly all of the water supply utilities have improved $WUPI_{op}$ during the period analysed (see Table 8). In fact, the water supply utilities have reflected a positive evolution in the EMPLOY (reduction of the number of employees by 1 000 connections) and NWR (reduction of water losses in the urban water systems) base indicators. From the point of view of the quality of services, the WUPI presents a wide array of performance behaviours, ranging from water utilities with low (see Cuamba), moderate (see for instance Lichinga) and high performances (such as Maxixe). However, the mean performance for $WUPI_{qual}$ scores medium to high values ranging from 0.670 to 0.750. It is important to point out that the mean $WUPI_{qual}$ scores for 2010 and 2012 are almost the same. Nonetheless, on closer inspection of the base indicators encapsulated in this component, a mixed evolution in the indicators can be observed, presenting positive and negative evolution in terms of their performance. In fact, we can observe improvements in the performance of the COVER, SOLWA, HOUR, DAYCOM and COMRE indicators. However, at the same time the PARAM, SAMPLE and TOTCOM indicators get worse. These results demonstrate the strengths and weaknesses in the performance of water supply utilities. To improve the overall performance of water supply utilities, specific actions should be implemented in those components that present the lowest levels of performance.

Finally, the WUPI values allow us to perform a benchmarking exercise to rank the water supply utilities under analysis (see Table 7). However, it is first important to verify whether there are significant differences in the rank order of the water supply utilities for the different alternatives used to build the WUPI. For this purpose, a Wilcoxon signed-rank test was performed (see Table 9). The results of this analysis indicate that there are no significant differences between the ranks obtained with the different WUPIs. The ranking results show that the water supply utilities ranked highest in the year 2010 are Inhambane, Maxixe and Chókwè. For the year 2012, the water supply utilities positioned at the top of the ranking are Xai-Xai, Inhambane and Chókwè.

DISCUSSION AND CONCLUSIONS

This manuscript has presented a methodology to assess the performance of water supply utilities using a composite indicator approach. Within this context, the WUPI allowed us to measure the performance of water supply utilities in Mozambique in a more integrated and comprehensive manner than could be obtained through a comparison of separate single indicators. Thus, the WUPI may be a useful real-life tool in Mozambique. In fact, the WUPI could be implemented as a guiding tool for water supply utility managers and decision-makers to improve the water supply services delivered to consumers. In fact, the WUPI allows us to identify the strengths and the weakness of the water utilities; therefore allowing for prioritisation of actions to improve the overall performance of the water utility. In line with this, the WUPI may play a key role for water regulators in the monitoring of, and accountability for, the performance of water supply utilities over time. Furthermore, the WUPI could support the decision-making process for fund allocation to prioritise interventions in those water supply utilities with low WUPI values. Indeed, the policy decision-makers could establish certain levels or values of the WUPI that should

TABLE 9
Wilcoxon signed-rank test (2010 and 2012). Z values and in braquets significance level.

	$WUPI_{additive\_AHP}$	$WUPI_{hybrid\_AHP}$	$WUPI_{TOPSIS\_AHP}$	$WUPI_{aditive\_EW}$	$WUPI_{hybrid\_EW}$	$WUPI_{TOPSIS\_EW}$
$WUPI_{additive\_AHP}$		−0.240 (0.810)	0.000 (1.000)	−0.198 (0.843)	−0.387 (0.699)	−0.207 (0.836)
$WUPI_{hybrid\_AHP}$	−0.360 (0.719)		−0.496 (0.620)	−0.191 (0.849)	−0.119 (0.905)	−0.205 (0.838)
$WUPI_{TOPSIS\_AHP}$	0.000 (1.000)	−0.155 (0.877)		−0.180 (0.857)	−0.458 (0.647)	−0.205 (0.838)
$WUPI_{additive\_EW}$	−0.189 (0.850)	−0.408 (0.683)	−0.243 (0.808)		−0.442 (0.658)	0.000 (1.000)
$WUPI_{hybrid\_EW}$	−0.353 (0.724)	−0.144 (0.886)	−0.356 (0.722)	−0.238 (0.812)		−0.540 (−0.589)
$WUPI_{TOPSIS\_EW}$	−0.188 (0.851)	−0.364 (0.716)	−0.258 (0.796)	0.000 (1.000)	−0.181 (0.857)	

Grey cells refers to 2012.

be achieved by each water supply utility. A possible way to stimulate the improvement of performance and to promote competition among the water supply utilities could be to correlate the achievement of certain WUPI values with a package of monetary subsidies or access to fund facilities. Although this study has focused on the potential application of the WUPI in Mozambique, this tool could be of interest for water utilities and regulators outside Mozambique. For instance, the WUPI could be a useful tool for the Eastern and Southern Africa Water and Sanitation (ESAWAS) Regulators Association to carry out benchmarking analyses between the main water utilities located in Kenya, Mozambique, Lesotho, Rwanda, Tanzania and Zambia.

In light of the results obtained, we can conclude that the performance level of the urban water utilities in Mozambique, at least in terms of the WUPI, has evolved positively during the period analysed. However, the WUPI values among the 15 water supply utilities are heterogeneous, with water supply utilities exhibiting both high and low scores. The results show that the water utilities which present the highest levels of performance (Xai-Xai, Inhambane, Chókwè and Maxixe) were working through water operator partnership mechanics (Coppel and Schwartz, 2011). Thus, taking into consideration this fact, those water utilities with low performances could implement working models based on water operator partnership mechanisms in order to significantly improve their performance. In contrast, our results suggest that the water supply utilities in Mozambique, even those with high WUPI values, are not sustainable from an economic point of view. If the observed trend persists over time, this finding raises some doubts regarding the medium- to long-term self-sustainability of water supply utilities and their availability to continue delivering reliable and good-quality services and to maintain operational water systems (Farolfi and Gallego-Ayala, 2014).

We presented 6 different ways to construct the proposed assessment tool for the performance of water utilities. Because there are critical steps in the construction of the composite indicators (normalisation, aggregation and weighting) that may influence the results and conclusions obtained, the calculation of a set of different WUPIs would make it possible to obtain more consistent results and conclusions compared with the results obtained using a single methodological method. Despite the merits and demerits of each of the WUPIs calculated, and with the aim of avoiding potential bias in the results obtained, further research is needed to confirm our results. Nevertheless, the most suitable way to construct the WUPI for real-life applications seems to be by using the AHP and hybrid form as weighting and aggregation techniques. This is because the AHP allows one to identify the relative importance of the indicators in the local context, and the hybrid aggregation produces more coherent results, not allowing for full compensation between components, and showing potential weaknesses in utility performance. It would be useful to perform a comparative analysis of the results obtained using alternative techniques to aggregate and weight the WUPI and different benchmarking methodologies to measure the performance of the water supply utilities, i.e., data envelopment analysis or total factor productivity (Alegre et al., 2009; Correia and Marques, 2011). Applications of these types of studies are welcomed and should be further investigated to obtain better information to support decision-making processes in the urban water supply sector.

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DISCLAIMER

The views expressed are purely those of the authors and may not under any circumstances be regarded as stating an official position of the Water Regulatory Council of Mozambique.

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APPENDIX

Values of the base indicators for the water supply utilities in 2010 and 2012

TABLE A1
Base indicators for the water utilities in 2010 (based on CRA, 2013)

Water utility	COLLECT (%)	OPCO (ratio)	EMPLOY (ratio)	NRW (%)	COVER (%)	SOLWA (%)	HOUR (h/day)	PARAM (%)	SAMPLE (%)	DAYCOM (day)	TOTCOM (ratio)	COMRE (%)
Maputo	89.00	1.04	4.00	55.00	34.99	73.00	10.00	78.00	92.00	15.00	0.08	29.00
Xai-Xai	82.00	0.90	7.00	41.00	67.43	95.00	24.00	100.00	100.00	1.00	0.12	85.00
Chokwe	90.00	0.84	24.00	17.00	52.10	99.00	24.00	100.00	100.00	1.00	0.09	68.00
Inhambane	91.00	1.01	11.00	27.00	64.87	100.00	24.00	100.00	100.00	1.00	0.08	91.00
Maxixe	88.00	0.72	9.00	21.00	60.79	100.00	24.00	100.00	100.00	1.00	0.07	100.00
Beira	82.00	0.89	8.00	28.00	39.19	95.00	24.00	52.00	99.00	7.00	0.02	40.00
Manica	67.00	0.68	15.00	52.00	13.53	88.00	17.00	90.00	100.00	8.00	0.18	53.00
Quelimane	87.00	0.92	19.00	43.00	30.30	98.00	21.00	100.00	91.00	7.00	0.08	45.00
Tete	77.00	1.27	11.00	34.00	35.64	87.00	23.00	70.00	100.00	7.00	0.05	45.00
Nampula	58.00	0.93	9.00	32.00	28.78	73.00	20.00	39.00	99.00	9.00	0.04	100.00
Nacala	84.00	1.31	18.35	38.62	13.65	94.04	18.00	81.00	100.00	7.00	0.06	100.00
Angoche	78.00	1.11	15.00	22.00	12.81	92.00	22.00	100.00	100.00	5.00	0.44	100.00
Lichinga	78.00	1.19	16.00	47.00	11.59	56.00	21.00	100.00	100.00	5.00	0.44	100.00
Cuamba	73.00	0.77	27.00	32.00	8.34	61.00	8.00	100.00	100.00	5.00	0.23	100.00
Pemba	89.00	0.93	10.00	37.00	48.85	95.00	21.00	30.00	100.00	9.00	0.09	100.00
Min	58.00	0.68	4.00	17.00	8.34	56.00	8.00	30.00	91.00	1.00	0.02	29.00
Max	91.00	1.31	27.00	55.00	67.43	100.00	24.00	100.00	100.00	15.00	0.44	100.00
Mean	80.87	0.97	13.56	35.11	34.86	87.07	20.07	82.67	98.73	5.87	0.14	77.07
Std deviation	9.36	0.19	6.46	11.25	20.42	14.39	5.02	24.29	2.96	3.87	0.13	27.18

TABLE A2
Base indicators for the water utilities in 2012 (based on CRA, 2013)

Water utility	COLLECT (%)	OPCO (ratio)	EMPLOY (ratio)	NRW (%)	COVER (%)	SOLWA (%)	HOUR (h/day)	PARAM (%)	SAMPLE (%)	DAYCOM (day)	TOTCOM (ratio)	COMRE (%)
Maputo	85.00	1.18	4.00	51.00	51.83	70.00	16.00	90.00	92.00	14.00	0.05	18.00
Xai-Xai	90.00	0.87	5.00	16.00	76.33	99.00	24.00	100.00	100.00	3.00	0.16	100.00
Chokwe	87.00	0.70	7.00	17.00	79.91	100.00	24.00	100.00	100.00	1.00	0.05	98.00
Inhambane	92.00	0.78	7.00	21.00	75.32	100.00	24.00	100.00	100.00	5.00	0.01	100.00
Maxixe	81.00	0.79	8.00	27.00	61.69	99.00	24.00	100.00	98.00	1.00	0.05	100.00
Beira	91.00	1.20	7.00	28.00	47.67	98.00	24.00	71.00	93.00	2.00	0.02	100.00
Manica	82.00	0.69	6.00	46.00	39.41	94.00	24.00	70.00	100.00	5.00	0.23	100.00
Quelimane	92.00	0.95	7.00	27.00	64.55	84.00	22.00	55.00	100.00	3.00	0.02	100.00
Tete	96.00	0.86	8.00	33.00	46.14	90.00	21.00	64.00	100.00	5.00	0.04	100.00
Nampula	73.00	0.93	8.00	29.00	53.91	82.00	16.00	100.00	56.00	5.00	0.08	36.00
Nacala	65.00	0.89	12.00	29.00	19.46	93.00	19.00	71.00	96.00	5.00	0.10	100.00
Angoche	63.00	0.71	12.00	37.00	12.76	99.00	22.00	34.00	92.00	5.00	0.30	94.00
Lichinga	64.00	0.80	10.00	31.00	14.68	70.00	20.00	16.00	100.00	4.00	0.27	44.00
Cuamba	67.00	0.54	20.00	25.00	9.47	72.00	11.00	17.00	50.00	3.00	1.57	69.00
Pemba	52.00	0.87	8.00	24.00	55.64	98.00	16.00	81.00	100.00	5.00	0.09	38.00
Min	52.00	0.54	4.00	16.00	9.47	70.00	11.00	16.00	50.00	1.00	0.01	18.00
Max	96.00	1.20	20.00	51.00	79.91	100.00	24.00	100.00	100.00	14.00	1.57	100.00
Mean	78.67	0.85	8.60	29.40	47.25	89.87	20.47	71.27	91.80	4.40	0.20	79.80
Std deviation	13.60	0.17	3.85	9.57	23.69	11.40	4.07	29.62	16.09	3.04	0.39	30.10

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