Abstract: Specific consumption is a key parameter in estimating the water demand and further optimising the sizing of Drinking Water Supply Systems (DWSS) infrastructure. DWSS are globally used to provide safe drinking water in urban and rural settings, and their design cost is critical for water authorities, especially in low-income countries. In this study, the optimal of the specific consumption value is carried out in Burkina Faso (West Africa). The methodology adopted a statistical analysis of operational data collected on 40 DWSS systems in Burkina Faso, further completed by a multiple correspondence analysis (MCA) of determinants of the water demand and cluster identification and analysis through Agglomerative Hierarchical Clustering (AHC). The results show that the actual consumption is lower than the common estimate used in sizing. Statistical analysis revealed that actual specific consumption is affected by various parameters, the most relevant of which are the reliance on alternative resources, the presence of waterways and the local climate seasonality. The average actual specific consumption is estimated at $3.83 \pm 3.43$ L/people/day. Finally, a decision tree for the choice of suitable specific consumption value as a function of the physical settings of a given area is proposed for optimal sizing of DDWS systems in Burkina Faso.

Keywords: Burkina Faso; cluster analysis; drinking water supply system; specific consumption; water demand

1. Introduction

Water in general, and drinking water in particular, is at the heart of most human activities, both domestic and socio-economic [1–3]. Globally, national programmes have been implemented to provide access to water at an acceptable price for local populations [4,5], as acknowledged in the current Sustainable Development Goals (SDGs) [6]. The average daily specific consumption (i.e., the daily domestic water demand per capita) differs depending on the type of environment (urban, semi-urban or rural environment). The accurate estimation of this parameter is complex, especially in low-income or developing countries, where the lack of monitoring data is highly prevalent [7]. While the major source of drinking water supply in urban areas comes from drinking water networks, simplified drinking water supply systems (SDWSS) are often preferred in semi-urban or rural centres because of the availability of alternative (yet often unsafe) sources. According to the definition used in the SDGs, people are considered to have access to safe drinking water if the provisioning source is “improved”, i.e., a tap (or private connection, PC), a standpipe (or stand post, SP), a borehole equipped with
a human-powered pump (HPP) or a stand-alone water point (SAWP). On the opposite, “unimproved” water sources refer to unprotected wells and springs (untreated surface water) [8,9]. This definition is based on several assumptions, including that access to an improved water source is likely to provide sustainable access to a minimum amount of 20 L of water per person and per day (L/p/day), should be located within a radius of less than 1000 m from people residence and should not constitute a large share of household income [10]. However, the minimum threshold for this share is rarely given for SDWSS in rural settings [11]. In such centres, the reliance on DWSS for water supply is in large competition with HPPs or SAWPs since such resources are free or low-cost, in comparison [12,13].

The empirical literature does not support the assumption that the various types of water supply infrastructure provide a minimum of 20 L/p/day. In Uganda, households with access to water via an SP show an average specific consumption of 15 L/p/day [14]. While there is a relationship between the travel distance to a water point and the water consumption [15], the estimates reported in [14] are far below the SDG reference values. In Mozambique, [14] showed that the amount of water collected decreased significantly from 50 to 15 L/p/day when the distance to a water point exceeded 100 metres. There was little difference in the specific consumptions (15 L/p/day) when the distance to water points increased within the range of 100 to 1000 m. Above 1000 m, however, the amounts gradually decrease to a vital minimum of 5 L/p/day. In Bangladesh, [16] showed that the impact of access to water on health is no longer significant if the drinking water point is located at a distance of more than 200 m from the residence. It should also be noted that the minimum threshold of 20 L/p/day is itself contested in some studies, which suggest instead a threshold of 50 L/p/day to meet the needs of personal and domestic hygiene [17], especially if the mitigation of water-borne diseases is considered. Recently, a study in Ouagadougou, the capital city of Burkina Faso, showed that only 5% of the population (without housing estate) has access to at least 20 L/people/day through collective distribution stand posts located within less than 200 m distance [11]. This could partly be explained by the fact that since 2006, the Government of Burkina Faso launched a major drinking water supply programme, including the construction of hydraulic infrastructures [12,13]. In 2021, a review of the functionality of these facilities revealed a larger preference of the populations for the SDWSS [18].

Water demand is a complex and sensitive function which depends on several factors, including socioeconomic factors [19]. There is no single, identically applicable methodology to estimate the water demand [20,21]. Ref. [22] and further [23,24] studied the demand for drinking water in small towns and cities in many African countries (including Benin, Burkina Faso, Chad, Guinea, Guinea Bissau, Mali, Namibia, Senegal and Zambia) and outlined that competition from unprotected sources of water supply could jeopardise the financial profitability and health benefits of public water points that charge for use, but also that the water demand is affected by the quality water delivery services. Ref. [25] established that in low-income countries in Sub-Saharan Africa, an increase in the price of 100 CFA (XOF), i.e., 0.17 USD per m³ of water, is likely to reduce the daily consumption to 2.5 L/p/day. The travel distance to reach water stand posts also affects the consumption [15], with a reported slight decrease after 250 m. Ref. [26] analysed the willingness to pay as a function of the water demand in Cotonou (Benin). In the same city, Ref. [27] quantified the increase in domestic water needs as a function of population growth, as opposed to the decrease in the availability of water resources on the Allada plateau. In Côte d’Ivoire, Refs. [7,28] estimated a drinking water demand function for communes in the presence of progressive tiered pricing. Ref. [29] developed a forecasting framework based on the actual water demand and the water market and therefore set realistic targets for the future, in contrast to the overestimation provided by forecasts solely based on demographic growth.

Overall, one of the recurring issues in the drinking water supply is the lack of data on the current and past situation in terms of volumes of water consumed and the actual coverage in SDWSS, especially in low-income countries. Detailed and accurate quantification of water demand is therefore hindered [30,31]. Therefore, designers adopt different strategies...
to assess present and future water demand through several approaches based on direct and indirect estimates. The indirect approach uses models based on existing practices [32]. It generally considers the consumption ratio per capita to be constant over time, often without retrospective analysis. Typical examples include the trend method, the global method and the analytical method [33]. The trend method extrapolates previous water consumption data available over time and is likely to amplify actual uncertainties into the future due to covariates, such as displacement, migration, exodus, etc. The global method estimates future population and future demand based on a fixed per capita consumption ratio. However, this method is often irrelevant since this ratio might not reflect specific spatial variations (from one municipality to another). The analytical method, finally, is based on the use of a multilinear trend model that includes various exogenous parameters [33].

The direct approach involves surveying a representative sample of potential users to assess their domestic needs and their willingness to pay for different types and levels of service. However, the uncertainties associated with such an approach are in the assumption all the domestic demand therefore estimated, is provided to the water supply network, where in reality, alternative resources are likely to cover specific uses, such as laundry, dishwashing, livestock water, etc. [8]. It, therefore, seems critical to improving our understanding of current and past use of drinking water, both considering specific features and needs of the environment, seasonality and inter-annual variability [34–36], as well as spatial variability, the diversity of individual user practices and global issues, such as climate change. To this end, monitoring the quantities of water consumed, the coverage rate and network yields are essential data to improve our knowledge of the actual demand for drinking water in the SDWSS [36–38].

Specific consumption in SDWSS varies according to the year, the season and even features day-to-day variations [39]. It is closely linked to the standard of living, which is constantly changing, but also to weather conditions, household domestic needs [40], the availability of alternative sources for water supply, the cultural habits, standards, lifestyles, cost and quality of the water resource provided through SDWSS and alternative sources [40]. In Burkina Faso, of the 58 SDWSS managed by the Association for the Development of Drinking Water Supply Systems (Association pour le Développement des Adductions d’Eau, ADAE, in French), only 21 (i.e., 36.2%) operated continuously in 2017; 10 SDWSS (i.e., 17.3%), operated discontinuously between six and eleven months, and 09 SDWSS (i.e., 15.5%), including 06 described as seasonal sites, operated between one and five months. 18 SDWSS (i.e., 31%) never worked due to poor sales or very low supply flow rates. Therefore, people in these centres rely on alternative resources (wells, boreholes, natural watercourses, still water) to meet their needs [41].

A more sound and scientific approach, relying on field observations and robust analyses, is needed for accurate estimation of the actual specific consumption in SWDSS in Burkina Faso. Moreover, the assessment of the factors affecting this specific consumption and its optimal values for targeting effective design is critical. The aim of this study is threefold: (i) assess the actual daily specific consumption in Burkina Faso through field observations collected across a sample of SDWSS systems; (ii) identify the determinants of the average specific drinking water consumption in Burkina Faso; (iii) propose optimal specific consumption values as a function of these determinants.

2. Materials and Methods

2.1. Study Area Description

Burkina Faso is a landlocked country within the West African Sahel [42]. The study area covers the Hauts-Bassins, Cascades and Sud-Ouest regions in Burkina Faso (Figure 1). The total annual rainfall is between 900 mm and 1200 mm and is characterised by two contrasting and alternating seasons: a dry season from November to May and a rainy season from June to October [43]. These regions are well-drained, with important rivers, such as the Comoé, the Noumbiel, the Mouhoun and its tributaries, (the main ones being the Dienkoa, the Guenako, the Kou and the Plandi) [44,45]. Groundwater resources are abundant, and
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2.2. Study Data and Analysis

2.2.1. Data Preparation

The operational management data from a total of 40 SDWSS in the year 2017, including annual management reports, socio-economic and technical reports and analyses) were collected for this study, along with discussions and interviews with the managers and water users of these centres. These SDWSS centres were designed based on a specific daily water demand of 20 L/p/day, as set by the national standard [12,13]. For comparison, the actual water demand is estimated with the analysis of volumes of water sold through meter readings and further normalised to the size of the population.

The SDWSS centres were refined in 6 consumptions classes (presented in Table 1) to distinguish between those functioning relatively well (average specific consumption of more than 10 L/p/day) and those having difficulties and therefore showing a very low demand for water (less than 10 L/p/day).

Table 1. Description of consumption classes used in this study.

<table>
<thead>
<tr>
<th>Class Name</th>
<th>Description (Cs)</th>
<th>Number of SDWSS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class 1 (Cs_2)</td>
<td>Cs &lt; 2 L/p/day</td>
<td>13</td>
</tr>
<tr>
<td>Class 2 (Cs_2_5)</td>
<td>2 &lt; Cs &lt; 5 L/p/day</td>
<td>17</td>
</tr>
<tr>
<td>Class 3 (Cs_5_10)</td>
<td>5 &lt; Cs &lt; 10 L/p/day</td>
<td>7</td>
</tr>
<tr>
<td>Class 4 (Cs_10_15)</td>
<td>10 &lt; Cs &lt; 15 L/p/day</td>
<td>3</td>
</tr>
<tr>
<td>Class 5 (Cs_15_20)</td>
<td>15 &lt; Cs &lt; 20 L/p/day</td>
<td>0</td>
</tr>
<tr>
<td>Class 6 (Cs_20)</td>
<td>Cs &gt; 20 L/p/day</td>
<td>0</td>
</tr>
</tbody>
</table>

Total 40

Note: 1 Cs refers to the average daily specific water demand (in L/p/day).
2.2.2. Selection of Explanatory Variables

In this study, to relate the average daily specific water consumption to the appropriate determinants, the following factors are identified (through a literature survey) as exogenous factors affecting water demand.

1. **The centre size**: population is one of the main determinants of water demand for drinking water. When sizing SDWSS networks, a common and simple method of estimating future demand is to multiply the total population by the specific consumption. In our sample, the population size of the centres varies between 2465 and 16,965 inhabitants, with a mean of 7153 and a standard deviation of 3369 inhabitants. To relate, the national standard [12,13] defines a minimum threshold of 3000 inhabitants for a centre to benefit from an SDWSS. We define three (03) modalities according to the size of the population for a given centre, i.e., “unsuitable” (population < 4627 inhabitants), “suitable” (4627 < population < 9090 inhabitants) and “highly suitable” (population > 9090 inhabitants). The thresholds of 4627 and 9090 inhabitants are, respectively, the first (Q1) and third (Q3) quartiles of the population size distribution in our sample of SDWSS centres.

2. **The centre status**: which is either semi-urban or rural. The drinking water demand is generally higher in semi-urban areas but relatively low in rural areas [47]. In this study, the sample of 40 SDWSS includes 36 “semi-urban” centres and 4 “rural” centres.

3. **The abundance of alternative water sources**: this includes alternative water points, such as boreholes and permanent or temporary wells existing in the locality. The number of such alternative water sources is translated into a coverage ratio ($\text{Tr}_{\text{aws}}$), calculated as in Equation (1):

\[
\text{Tr}_{\text{aws}} = \left( \frac{N_{\text{sawp}} \times 300}{\text{Pop}} \right)
\]

where $N_{\text{sawp}}$ is the number of working Stand-Alone Water Points (SAWP) in the centre, $\text{Pop}$ is the population size in the centre, and 300 refers to the population supplied through a given SAWP, as defined in [12,13]. We defined three modalities for $\text{Tr}_{\text{aws}}$: “scarce” ($\text{Tr}_{\text{aws}} < 0.7$, i.e., 10 centres), “abundant” (0.7 $\leq \text{Tr}_{\text{aws}} < 1.0$, i.e., 10 centres) and “very abundant” ($\text{Tr}_{\text{aws}} \geq 1.0$, i.e., 20 centres). The $\text{Tr}_{\text{aws}}$ factor has a direct influence on water consumption in rural and semi-urban areas since it has been observed that after the implementation of an SDWSS, the population rarely change their water use pattern and continues to rely on alternative sources, often for washing or dishwashing purposes [48].

4. **The geological nature of the subsoil**: either sedimentary or basement. From a geological point of view, a sedimentary area is more favourable for wells and boreholes than a basement area. Centres located in a basement area sometimes struggle to have positive wells [46]. Moreover, the wells realised in such contexts often run dry during the dry season. In such cases, the population has no choice but to rely on SDWSS. In the study sample, 25 centres were located in the sedimentary area and 15 centres in the basement area.

5. **The presence of waterways**: in the study sample, 27 centres feature the presence of waterways and for which the use of such alternative water sources by populations is highly likely [40,49].

6. **The seasonality of the centre**: in centres with a high level of agricultural activity, water consumption is typically influenced by the season, as a strong migratory movement of the population towards crop hamlets is often observed at the onset of the rainy season. This behaviour is, however, less pronounced in centres where agricultural activities are limited or barely existent [50]. In our sample, nine centres are classified as “seasonal sites”.

7. **The energy supply source**: either electric, thermal or mixed. The energy source used to power the system defined the cost required per cubic meter pumped within the SDWSS and, therefore, the water pricing [51–53]. In our study sample, 18 centres are
supplied by the electric power grid, 20 centres through a power generator, and 2 are mixed power supplied centres.

2.2.3. Analysis Methods

The statistical analysis of the dataset includes the following steps: first, the average values of actual daily specific consumption per site, estimated during the socio-economic surveys and the standard national reference [12,13] are compared through Student’s t-Test (at \( \alpha = 5\% \) significance level). Second, a Multiple Correspondence Analysis (MCA) is used to assess similarities between the different SDWSS and the assessing the contribution of explanatory features to such similarities. Furthermore, clusters of SDWSS systems sharing similar features are derived through the Agglomerative Hierarchical Clustering (AHC) method and analysed to highlight the contribution of the explanatory variables to the overall behaviour of the cluster. The distributions of specific consumption values are compared across the clusters identified using the non-parametric Kruskal–Wallis statistical test (at \( \alpha = 5\% \) significance level), followed by Yuen’s trimmed means pairwise test and Holm \( p \)-values adjustment method for multiple corrections. This analysis is applied through the R package `ggstatsplot` (version 0.12.0.9000) [54]. Finally, building upon the understanding of the contribution of the explanatory variables to the specific water demand, a decision tree for the choice of a suitable specific water demand given physical descriptors of a centre is developed and proposed as a practical decision-making tool to water managers.

3. Results and Discussion

3.1. Comparative Analysis of Actual and Standard Daily Average Specific Consumption

Figure 2 shows the distribution of actual daily specific water consumption for the 40 SDWSS analysed in this study. Overall, the average value is 3.83 L/p/day, with a standard deviation of 3.43 L/p/day. This high standard deviation, close to the average value, reveals that the average daily specific consumption is highly variable in rural centres and largely uncontrolled. The largest specific consumption in the sample peaks at 14.95 L/p/day (observed at Sideradougou). In comparison, in the preliminary design study for the SDWSS in these centres, the estimated daily specific consumption through socio-economic surveys was within the range of 7.45 ± 2.05 L/p/day, which appears to be significantly lower (\( p \)-value < 0.0001). Similarly, the values obtained in our study appear to be significantly lower than the standard reference of 20 L/p/day (\( p \)-value < 0.0001), suggesting that the actual daily specific water consumption is far below such standard reference [12,13].

![Figure 2. Distribution of actual daily specific water demand in the 40 SDWSS centres in this study. Values are sorted by decreasing the value of specific consumption. The average value is shown as a red dotted line (3.83 L/p/day), while the median value is shown as an orange-gold dotted line (2.63 L/p/day).](image-url)
3.2. Multiple Correspondence Analysis (MCA)

3.2.1. Variable and Individual Factor Maps

The application of the MCA to the dataset provided a decomposition of inertia across multiple dimensions. The total inertia of the dataset in this study (i.e., 1.625) spreads between 12 dimensions (shown in the scree plot in Figure 3). Axis 1 explains 22.96% of the total inertia, while the first two dimensions (Axis 1 and Axis 2) explain 38.48% of the dataset variability. To further define the appropriate number of dimensions to be selected for further analyses, the 95% quantile of total inertia percentages distribution for the random permutation of equivalent dataset size (under the hypothesis of uniform distribution) is estimated to be 31.83%, therefore suggesting that considering the first two dimensions is likely to provide significant conclusions.

![Figure 3. Scree plot of the decomposition of the total inertia in the dataset.](image)

The variable factor map, showing the contribution of each explanatory variable to the selected first two dimensions, hereafter named F1 (Axis 1) and F2 (Axis 2), is presented in the (F1, F2) plane in Figure 4a. Additionally, the individual factor map, showing the association of the observations (SDWSS) to the F1 and F2 axes, is presented in Figure 4b.

The F1 dimension opposes SDWSS centres, such as Mangodara, Toussiana, Koundoum, Darsalamy, Kangala, Loumana and Marabagasso (with a strong positive association, to the right, Figure 4b) to SDWSS such as Dande, Konandougou, Bare, Fara, Bouahoun, Bouere, Serekeni (with a strong negative association, to the left, Figure 4b). The group in which the SDWSS, such as Mangodara to Peni, stand (first quadrant, Figure 4b) shows factors whose frequency does not differ significantly from the mean (Figure 4a). These are centres with a high frequency for scarce alternative sources, geological basement type, absence of waterways, electric energy available, no seasonality and specific daily consumption between 5–10 or 10–15 L/p/day. It is also worth mentioning that the associated variables are highly correlated to the F1 dimension (Figure 4a).

The group in which the SDWSS centres of Loumana, Torokoro, Marabagasso, Makongnadougou, Bouahoun, Bouere and Serekeni (third and fourth quadrants, Figure 4b) features abundant alternative sources, energy from generators, absence of waterways, geological basement type, strong seasonality and specific daily consumption between 2–5 L/p/day (Figure 4a).

The group in which the SDWSS centres of Dande, Konandougou, Koundougou, Bare, Lahtrasso, Fara to Kourinion (second quadrant, Figure 4b) stand features very abundant alternative sources and presence of waterways, sedimentary type geological setting and specific daily consumption below 2 L/p/day. Additionally, the population in such centres is unsuitable for the establishment of SDWSS (Figure 4a).
Figure 4. Factor maps of the Multiple Correspondence Analysis (MCA) in this study. (a) Variable factor map, showing the contribution of explanatory variables to the F1 and F2 dimensions. (b) Individual factor map, showing the association of observations (SDWSS centres) to the F1 and F2 dimensions.

Overall, the MCA shows that the variables with the dominant influence on the average daily specific consumption are the abundance of alternative sources, the geological type of the subsoil and the presence of waterways. The least significant variables, in comparison, are the energy supply source, the seasonality and the population size of the centre.

3.2.2. Cluster Analysis

Based on the individual and variable factor maps presented in Figure 4 above, a clustering of SDWSS centres is derived and presented in Figure 5 through the AHC method.

Cluster 1 is composed of SDWSS centres, such as Mangodara, Toussiana, Koumbia, Darsalamy, Sideradougou, Peni, Douna and Kangala. These are semi-urban centres with scarce alternative sources, located in hard rock basement areas, with an average daily specific consumption of 8.90 ± 2.83 L/p/day.

Cluster 2 is made of SDWSS centres, such as Torokoro, Loumana, Marabagasso, Bouahoun, Bouere and Makognadougou. These are sites with abundant alternative sources, using a generator as the main energy supply source and with an average specific consumption of 3.20 ± 0.89 L/p/day.
Cluster 3 is made of SDWSS centres such as Dande, Konandougou, Koundougou, Lahirasso, Fara, Dohoun, Serekeni, Soungalodaga and some other sites. This group is made of SDWSS sites with the presence of waterways and very abundant alternative resources located in sedimentary areas. In this group, the average specific daily consumption is the lowest, estimated at 1.67 ± 1.13 L/p/day.

To further outline the differences between the three clusters identified, Figure 6 compares the distribution of specific daily consumption across these clusters, revealing significant differences between all pairs (Cluster 1–Cluster 2: $p$-value = 0.00125; Cluster 1–Cluster 3: $p$-value = 0.00683; Cluster 2–Cluster 3: $p$-value = 0.000423).
3.3. Determinants of Specific Daily Consumption

For a long time, it has been considered that population size is a key factor in estimating average daily specific consumption. Yet, in many cases, two association between the two parameters is low and often non-existent. In this study, this is observed in the centre of Dande, with a population of 16,965 inhabitants, yet shows a very low daily specific consumption of 0.44 L/p/day. However, the centres of Darsalamy and Peni, with 4202 and 5952 inhabitants, respectively, have an average specific daily consumption of 8.45 and 10.20 L/p/day.

On the other hand, the abundance of alternative resources and/or the presence of waterways appear to have a significant effect on the average daily specific consumption. Once an SDWSS is implemented, the population rarely changes its consumption patterns and still relies on alternative water sources, which are often unsafe [8,9,16,27]. In centres where these alternative sources are abundant, survey data showed that they could provide up to 54% of the total consumption in the rainy season, as compared to 38% in the dry season. The rate of use of public stand posts as a source of water for drinking and cooking is 19% in the rainy season, while it exceeds 80% in centres where these alternative sources are scarce [55]. Additionally, when wells are scarce, the average specific consumption per stand post is higher [25]. Similarly, a semi-urban status for a given centre is no guarantee of high specific consumption. Of the 36 semi-urban centres considered in this study, only 11 (30.56%) have a specific consumption higher than 5 L/p/day. In the remaining semi-urban sites, the lower value of the specific consumption is strongly correlated with the abundance of alternative sources and the presence of waterways. It can therefore be concluded that these two variables emerge as key factors for optimal estimation of the average daily specific consumption.

The seasonality of the centre is also affecting the average daily specific consumption [31]. In centres with a high level of agricultural activity, particularly cotton production, a strong migration of the population towards crop hamlets in the rainy season. For locations from which people are leaving, a sharp drop in the consumption rates is observed, and even in some cases, an interruption in service for SDWSS in such centres, especially in the months of May to the end of January [50].

Similarly, the energy supply source used to power the SDWSS system affects the price of water and, therefore, the specific consumption of households. SDWSS supplied through thermal energy generally sells water at 500 CFA (XOF) per m$^3$ (i.e., 0.83 USD), while solar-powered SDWSS prices 350 CFA (XOF) per m$^3$ (i.e., 0.58 USD). In the case of electric SDWSS, interestingly, savings of almost 30% are offered on thermal energy-powered SDWSS [41,56]. According to [41], for thermal energy-powered SDWSS, the diesel consumption ratio rose from 0.37 L per m$^3$ in 2016 to 0.50 L per m$^3$ in 2017 in Burkina Faso, which translates to an increase of 102 CFA (XOF) per m$^3$ (i.e., 0.17 USD). This situation reflects a decreasing performance of the power generators in use.

The attitude of the population also influences specific consumption. Although water is provided at a cost, the supply of drinking water by households is not only a question of the ability to pay for the water service [51] but also and above all, a matter of the willingness to pay for water [52,56]. In some centres, the high occurrence of water-borne diseases in the past raised population awareness thanks to the efforts of health workers, further increasing their willingness to pay for water. Along the same line, the pricing affects the daily rate of specific water consumption at the household level. In fact, in a study carried out on the pricing systems for drinking water services in Burkina Faso, it was indicated that the water market is unbalanced [56]. The actual prices do not reflect an adjustment of supply to solvent water demand. The prices are often set authoritatively by projects and programmes, resulting in an irregular and contrasting pricing strategy that varies from 250 CFA (XOF) per m$^3$, i.e., 0.41 USD (average price in HOUNDE, a large centre) to 500 CFA (XOF) per m$^3$, i.e., 0.83 USD (price in OULONKOTO, a small centre) [56]. As a reminder, in Burkina Faso, the maximum price of water is fixed at 500 CFA (XOF) per m$^3$ (i.e., 0.83 USD) in rural areas by national standards [12,13]. When water is deemed
too expensive by the rural population, little effort is carried out to consume water, and the SDWSS will appear oversized. In contrast, when water is sold too cheap, water is excessively consumed, and the SDWSS system will appear to be undersized, causing even shortfall in water provision [57]. According to [26], the demand for drinking water is inelastic to the water pricing: an increase of 100 CFA (XOF), i.e., 0.17 USD results in a decrease in water consumption of 3.5 L/p/day.

It should also be noted that the actual price or contribution paid by the local population in the SDWSS centres considered in this study was not considered an explanatory variable. The reason behind this is that in SDWSS centres in Burkina Faso, this price is generally fixed through the national standards [12,13,56]. Therefore, in the case of our study, such a factor brings zero variance to the set of explanatory variables and would not appear meaningful to the outcome of our study. Yet, it should be acknowledged that, in general, this variable is a potential incentive for local populations to rely on water provisioned through SDWSS infrastructure when it is relatively low; on the other hand, it tends to encourage the population to use water provided through the SDWSS system [15,41,51,52,55].

3.4. Decision Tree for Estimation of Suitable Specific Daily Consumption

Based on the results of this study, a decision-tree flowchart is proposed in Figure 7. This flowchart aims to assist in selecting suitable and optimal values for the specific daily water consumption given the physical characteristic of a given site before the implementation of SDWSS infrastructure.

![Flowchart decision tree for the optimal selection of specific daily consumption](image)

**Figure 7.** Flowchart decision tree for the optimal selection of specific daily consumption.

Such a decision tree is likely to assist water managers in designing optimal and cost-effective facilities to the benefit of the population while meeting the water demand. This flowchart could therefore serve as a reference for the actors involved in the water sector (Ministry of Water and consultancy firms) in the planning of water supply in Burkina Faso, especially in rural areas.

3.5. Future Areas of Research

In this study, a quantitative assessment of the daily specific consumption is carried out, along with the potential environmental factors explaining the daily specific consumption values across various SDWSS centres in Burkina Faso. Building upon the findings conveyed in this study, future areas of research could further assess the contextual factors and socio-economic influences, as in how cultural norms, household sizes, income levels, and education could influence the actual daily specific consumption value. This could involve ethnographic research and socio-economic surveys to provide a more holistic understanding of consumption patterns.

Also, the use of advanced modelling techniques, including machine learning algorithms (neural networks, random forests, etc.) to capture nonlinear relationships between daily specific consumption patterns and various potential factors could be explored [58], leading to more accurate predictions and a more tailored sizing framework for future SDWSS centres. Along the same lines, regarding the data scarcity of the context, the use and implementation of data collection and monitoring systems to collect real-time consumption data, coupled with the integration of remote sensing and Geographic Information Systems,
might further help in assessing distribution infrastructure and can provide valuable spatial insights into consumption trends to inform resource allocation strategies.

Finally, future studies could investigate the potential impacts of climate change on daily specific consumption patterns, relying both on historical and future warming scenarios for precipitation, temperature and evapotranspiration [59] offered by climate models.

4. Conclusions

This study focused on the selection of an optimal specific daily water consumption in 40 SDWSS centres in Burkina Faso. The findings showed that the demand for drinking water is affected by socio-economic factors and physical environment characteristics, with the predominant effect of the abundance of alternative sources, the geological type of the subsoil and the presence of waterways. Additionally, variables such as the energy supply source, the seasonality and the population size of the centre play a role, albeit minor in comparison.

Three clusters of SDWSS centres are further identified: the Cluster 1 contains mostly semi-urban centres with scarce alternative sources, upon hard rock basement areas, with an average daily specific consumption of $8.90 \pm 2.83$ L/p/day; the Cluster 2 comprises centres with abundant alternative sources, using a generator as the main energy supply source, with an average specific consumption of $3.20 \pm 0.89$ L/p/day; finally, Cluster 3 is made of centres with a presence of waterways and very abundant alternative resources, located in sedimentary areas, with the lowest average daily consumption, estimated at $1.67 \pm 1.13$ L/p/day. A decision tree is proposed as an outcome of this study to serve as a flowchart for the selection of an optimal and suitable average daily specific consumption value prior to the design of an SDWSS centre in a given context. This flowchart could assist water planners in the optimal and cost-effective design of water supply infrastructure in Burkina Faso but also shed light on the development of decision-process tools for similar contexts in West Africa or, largely, sub-Saharan countries.


Funding: This research received no external funding.

Data Availability Statement: The data supporting this research can be made available upon request to the corresponding author.

Acknowledgments: The authors would like to thank the World Bank Group under the Africa Centres of Excellence for Development Impact (ACE Impact) Project and the Government of Burkina Faso for their support. The authors are also grateful to the ADAE (the “Association pour le Développement des Adductions d’Eau Potable”) in Burkina Faso, who freely provided the data for this study.

Conflicts of Interest: The authors declare no conflict of interest.

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