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Assessment of Water Consumption in Water Scarce Regions by Using Statistical Analysis: A Case Study of El-Maten Region, Lebanon

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Abstract

Water resources in the Middle East, a scarce water region, are of paramount importance for sustaining both biotic and abiotic systems. However, these resources face significant stress due to climate change and increasing demand driven by human development. Lebanon, located in a sub-humid climatic zone along the Eastern Mediterranean, presents a unique case for water scarcity. This study assesses domestic and sectorial water consumption in the El-Maten Region of Lebanon. It aims at identifying the key factors, impacting water supply. A total of 441 surveys were collected from household consumers in the region, and the data were processed using IBM SPSS (v. 25) for statistical analysis. The findings indicate that the average daily water consumption per capita is 150 liters. Water availability issues were reported by 34% of the surveyed population, while 56% expressed concerns about water quality. In order to meet their needs, 48% of consumers resorted to secondary water sources, such as vendors, springs, rainwater harvesting, or wells. The study concludes that over one-third of the consumers experience water shortages throughout the year, while more than their half face problems with the water quality they receive. These findings underline the inefficiencies in the current water distribution systems, and suggest the need for improvements in both infrastructure and governance. In this respect, the study calls for immediate policy interventions focused on improving water quality standards to ensure sustainable water supply throughout the year. It is also important to address climate change impacts through strengthening water conservation practices and enhance public awareness toward sustainable water resource management in Lebanon.

Keywords: *Climate Change, Water Supply, Scarcity, Sustainability, Lebanon.*

1. Introduction

Water is a crucial resource to all aspects of life as it supports the biological functions of living beings and makes habitat for numerous species, in addition to its role in sustaining ecosystems. Climate change significantly impacts water resources, particularly due to population growth and increases water consumption for irrigation and agriculture, causing stress on the planet and its ecosystems (Cloy and Smith, 2015), (Haddeland et al., 2014). There are shifts reported in the hydrological cycle and changes in evapotranspiration, humidity, precipitations, runoff and other factors that are creating different water distribution and regimes (Hagemann et al., 2013). Water scarcity is a global geo-environmental issue, worsened by population growth and climate change, particularly in the Mediterranean region, including Lebanon, where imbalanced supply/demand exists (Abou Abbass et al., 2023).

Lebanon, a small country with a population of around 4.8 million, is a biodiversity hotspot due to its unique natural characteristics and 220 km coastal length (Skaf et al., 2019; Myers et al., 2000). Lebanon's diverse physiography, characterized by three major geomorphological features: Mount-Lebanon, Bekaa Plain, and Anti-Lebanon, creates a climatic barrier that captures wet air masses, resulting in high precipitation rates including rainfall and snow (Shaban, 2019).

The quantity of water obtained from the public water sector is typically regarded as the water supply; however, alternate sources of supply are used when this quantity is not enough to meet consumer demands (Shaban, 2019). The vast majority of water comes from groundwater boreholes, bottled water, water commerce, harvested water, and pipes that the public water sector obtains (Shaban, 2016).

Lebanon faces environmental issues like desertification, land degradation, and water scarcity due to climate change, affecting precipitation, dry periods, and warmer meteorological conditions (Lelieveld et al., 2012; Haddad et al., 2014). Therefore, the agriculture sector is highly

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influenced by water scarcity, and thus, only around 50% of cultivated lands in Lebanon are irrigated. They suffer from drought spells and decrease in crop yields (Haddad et al., 2014). In addition, the extreme temperature, irregular weather patterns, and water-related consequences also affect the crops (Lesk et al., 2016).

Furthermore, Lebanon occupies 14 major rivers, more than 30 major streams, two thousand springs (> 10 l/sec), along with other water surface and groundwater resources, thus, the quantity and quality of the water resources in Lebanon are endangered. Water replenishment is changed because of deforestation, soil erosion, drainage methods, irrigation practices, and other activities. This will lead to more water scarcity and deteriorates water quality (Nehme et al., 2019; Nehme et al., (2021) (a) and (b)). Moreover, pollution is widespread across Lebanon, where pristine water sources are scarce. Rivers suffer from contamination and many aquifers exhibit elevated pollution levels (Nehme and Haydar, 2018; Nehme et al., 2019; Nehme et al., 2020; Haydar et al., 2022).

The amount and quality of water are impacted by careless water use. However, there are differences in water consumption around the world. One example of this is the water footprint variance (Hoekstra and Chapagain, 2007), which shows that patterns of water use vary greatly between geographical areas and are influenced by a variety of factors.

Water used for domestic purposes includes both outdoor and indoor applications. On the other side, outdoor water usage includes mainly car washes and watering gardens, while indoor water uses include drinking, bathing, and laundry (Grimble, 1999). The amount of water daily required by each individual to meet their household's needs is known as domestic water per capita consumption (World Health Organization, WHO, 2011).

This study aims to quantitatively assess water consumption in Lebanon's El-Maten Region, updating estimates, understanding socioeconomic characteristics, and proposing technical solutions to address the water crisis due to climate change and population growth, focusing on primary and secondary resources.

2. Materials and Methods

2.1. Study area

With about 2,032,600 inhabitants, Mount Lebanon is the most densely populated region in Lebanon and accounts for 42% of the nation's total population. The districts of Baabda, El-Maten, Aley, Chouf, Keserwan, and Jbeil make up the region. Geographically, El-Maten region lies between 300 and 2,100 meters above sea level in the Lebanon. It has a population of 511,000 people and accounts for 10.6% of Lebanon's population and has the second highest number of households in Mount Lebanon, most of which are apartments. The average household size in El-Maten is 3.5 persons, slightly lower than the national average of 3.8 (Central Administration of Statistics - District Statistics Based on the Labour Force and Household Living Conditions Survey 2018-2019).

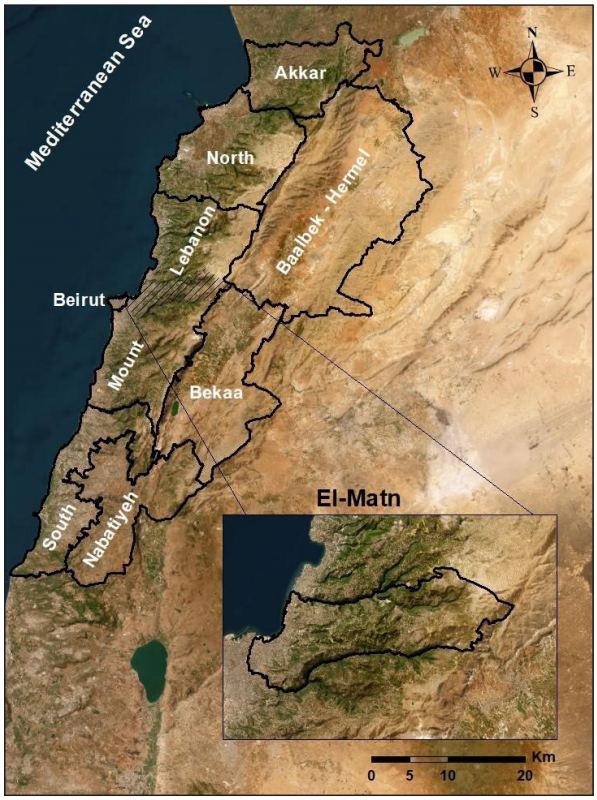

Figure 1. Map showing the study area of El-Maten Region.

2.2. Methodology

In order to calculate the consumption patterns and regimes among the population of El-Maten, an inventory and field research were done, along with a survey targeting valuable information about water consumption.

The household water consumption survey comprised three sections, while the field survey included a general section on socio-demographic information, followed by detailed sections on water consumption across various sectors in the Maten Region. Data collection was conducted using both traditional hard-copy surveys and an electronic version via the "Google Forms" platform (Figure 2).

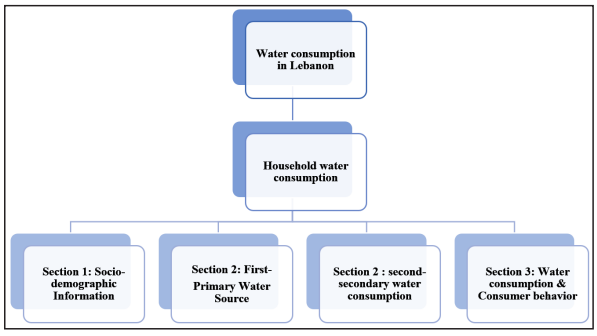

Figure 2. The organization structure of the Google form.

A pilot test was carried out to evaluate the effectiveness of the survey procedures before the full questionnaire was administered to gather data from households and sectors (Okimiji et al., 2021). The goal was to ensure a representative sample by including a diverse range of individuals from various demographic groups. Participation in the survey was anonymous and voluntary. A total of 441 responses were collected and focused on household water consumption, distributed throughout the study area.

2.3. Statistical Data Analysis

Descriptive statistics, such as frequency, percentage, mean, and standard deviation were used to summarize the data. In order to investigate the relationships and connections between independent variables (demographic and socioeconomic) and dependent variable Y (monthly water usage of households), non-parametric statistical methods (such as the Chi-square test of independence) were performed (Motho et al., 2022).

A Microsoft Office Excel file was adopted, and data was then treated using SPSS (v 25). In the study, the key characteristics of the data are described using descriptive statistics. It gives brief explanation of the measures and the sample. It serves as the foundation for almost all quantitative data analyses, along with basic graphic analysis. Pearson Chi-Square tests were used with a significance level of 0.05 in all the Pearson Chi-Square tables for relationship between categorical variables study.

2.4. Demographic Values

The general survey covers 441 samples, taken from the villages of Dekwaneh, Mansouriye, Fanar, Douar, Ain Saadeh, Jdeideh, Sin El Fil, Broumana, Bsalim, Zalka, Bourj Hammoud, Biaqout, Sabtiyeh and Sad El Baouchrieh. Other villages were put under the category of others in Table 1.

Table 1. Distribution of survey numbers over the villages.

El- Maten Region	Number of surveyed people in each village of El-Maten Region
Dekwaneh	168
Mansouriye	47
Fanar	20
Douar	16
Ain Saadeh	14
Jdeideh	13
Sin el Fil	11
Broumana	10
Bsalim	10
Zalka	10
Bourj Hammoud	10
Biaqout	8
Sabtiyeh	8
El Baouchrieh	7
Other Villages	89
Total	**441**

3. Results and discussion

3.1. Water Consumption for Household in El-Maten

The social and demographic composition of a community is described by socio-demographic parameters, which are essential for understanding and predicting patterns within population. Socioeconomic factors, such as occupation, education, and income are linked to demographic elements like population size, growth, density and distribution. In this study, the influence of various socio-demographic characteristics on water consumption was analyzed. 66% of the survey participants were females, and 34% were males, indicating that women, who are less busy, interested, or available, were more likely to participate. Participants came from diverse age groups, and their distribution is shown in Figure 3. This finding aligns with previous research that has demonstrated a significant correlation between gender and household water demand (Fielding, et al., 2012; Jordán-Cuebas et al., 2018; Joshi, 2020; Makki, et al., 2003; Van Koppen, 2001).

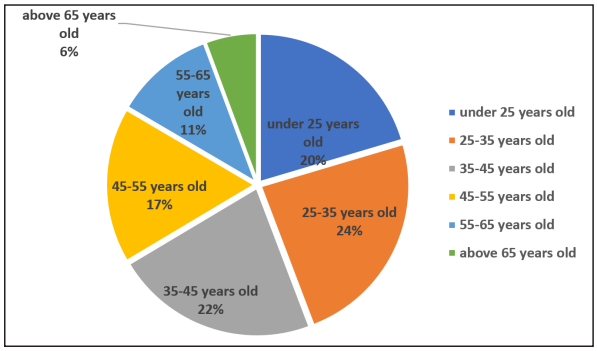

Figure 3. Distribution of the general survey participant's age groups in El- Maten Region.

The results in Figure 4 show the educational level of surveyed participants. The majority of participants (46%) holds postgraduate degrees, while only 1% of participants are uneducated. This is consistent with the idea that more educated individuals are generally more comfortable using applications and platforms like Google Forms for surveys.

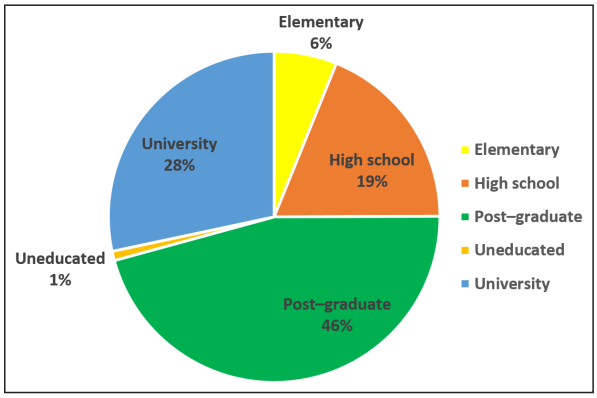

Figure 4. Percentage of surveyed educated participants in El- Maten Region.

Participants were spread between private and public sector, with students and other different occupations, which is shown in Figure 5.

The data suggest a clear trend of household downsizing in the El-Maten Region, with a significant rise in single- and two-person households and a general decline in larger family units. As shown in Figure 6, one-person households represent a remarkable 28% of the total, reflecting a shift towards more individualized living arrangements. Two-person households are the most common, making up 40% of the total survey in contrast. Four-person households account for only 5%. Similarly, three-person households comprise 16% of the total, while five-person households show a slight decrease, making up just 2%. This trend aligns with findings by Schleich and Hillenbrand's (2009) study in Germany, which reported that smaller household sizes tend to have a higher per capita water demand.

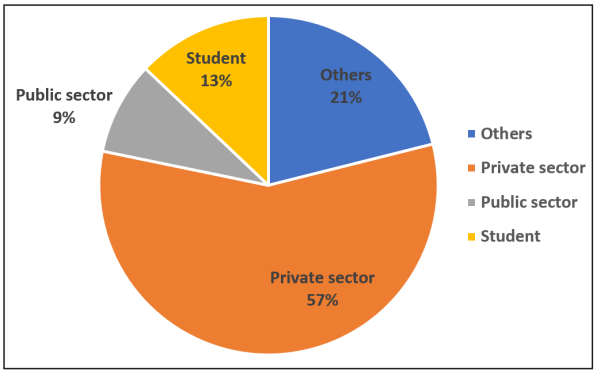

Figure 5. Distribution of the participants' occupation in El- Maten Region.

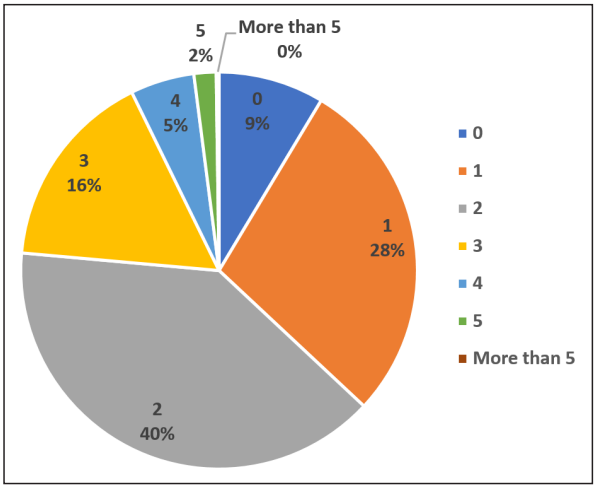

Figure 6. The number of people per household in El-Maten Region.

The majority of participants (68%) has household earnings of more than 500 $ per month, as shown in Figure 7. In the El-Maten Region, 2% of participants earn less than 100 $ per month, and 9% of participants report earning between 100 $ and 300 $ per month.

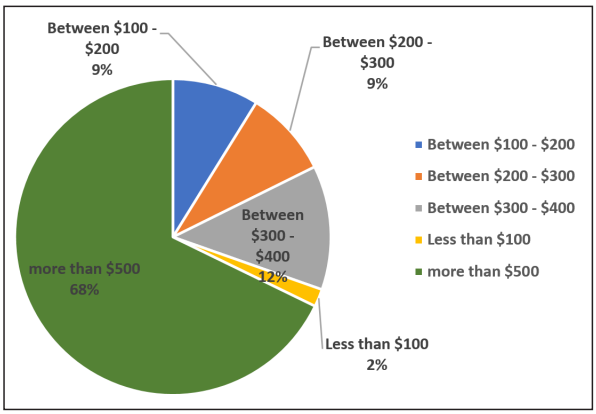

Figure 7. Distribution of the income per household in El-Maten Region.

3.2. Water Use: Primary and Secondary Resources

According to the surveyed units, 71% of the cases, the government's public water supply served as the main source of water. However, other primary sources included private wells, springs, and water harvesting, which accounted for the remaining percentage (Figure 8).

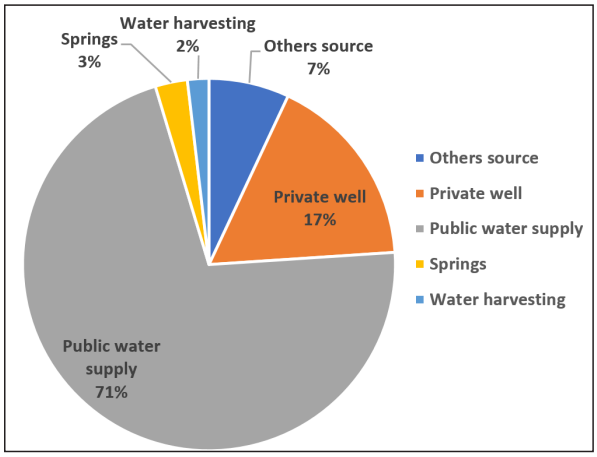

Figure 8. Distribution of primary water sources in El- Maten Region.

A full year of water availability issues was reported by 34% of participants, while 45% experienced issues during summer, and 14% during autumn as shown in Figure 9. Water availability in summer is often dependent on the volume of precipitated water during the winter and spring months. Lebanon's water resources are abundant, but seasonal climate, infrastructure issues, and regional disparities lead to varying water availability throughout the year.

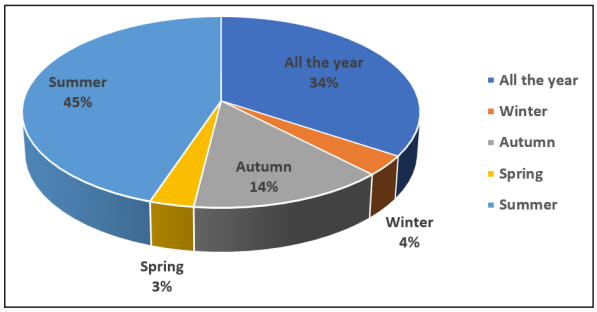

Figure 9. Seasonal availability issue of the primary water resource in El- Maten Region.

Approximately 56% of participants reported issues with the water quality from their primary source, facing various problems such as muddy water, unpleasant odor, and changes in taste, color, diseases, and other concerns.

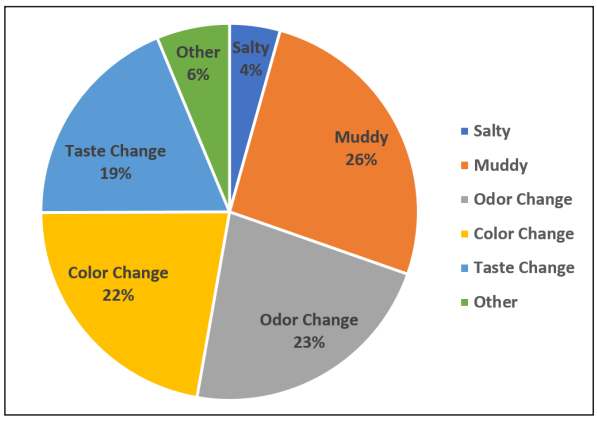

Figure 10. Percentages of water quality problems encountered in El-Maten Region.

As shown in Figure 11, only about half of the participants relies solely on their primary water source, while approximately 48% of surveyed households depend on a secondary water source to meet their water needs. These secondary sources include vendors, springs, rainwater harvesting, or wells, underscoring the necessity of diversified water supply strategies in water-stressed regions.

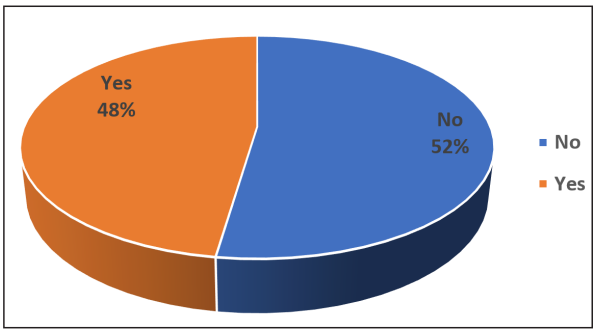

Figure 11. Presence of a secondary water source in El- Maten Region.

Agricultural use can be considered as lower for secondary water sources due to the higher cost associated with application uses. In contrast, the reliance on secondary sources for drinking water was higher, which can be attributed to low satisfaction levels with the quality and safety of drinking water from primary sources (as shown in Figures 12 and 13). This highlights the critical issue of access to safe drinking water, driving many households to seek alternative sources.

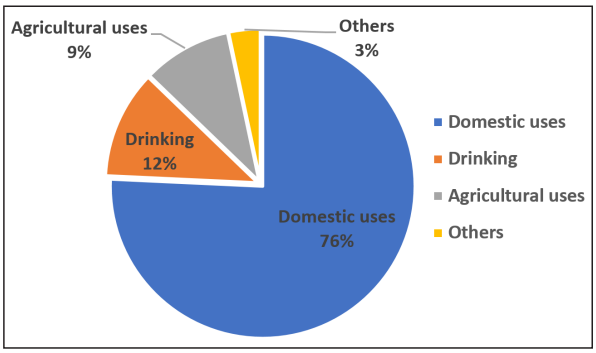

Figure 12. Purposes of use of the primary water resource in El-Maten Region

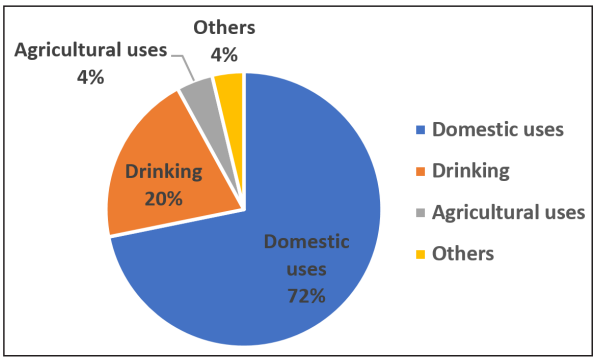

Figure 13. Purposes of use of the secondary water resource in El-Maten Region.

Income plays a significant role in influencing water consumption, as customers tend to adjust their water use based on price levels. Households with higher income consume more water than those with lower income. The consumption increasing as income rises and decreasing when the primary breadwinner loses employment (Willis et al., 2013; Agthe and Billings, 2002). However, due to inconsistent public water service provision, 48% of households also rely on water trucks as an additional source. 16% of consumers purchased more than 20 barrels (1 barrel equal to 200 liter) of water per month, with one barrel equaling 200 liters (Figure 14). The cost of water varied, with prices ranging from less than 1 USD per barrel to over 3 USD per barrel, as illustrated in Figure 15.

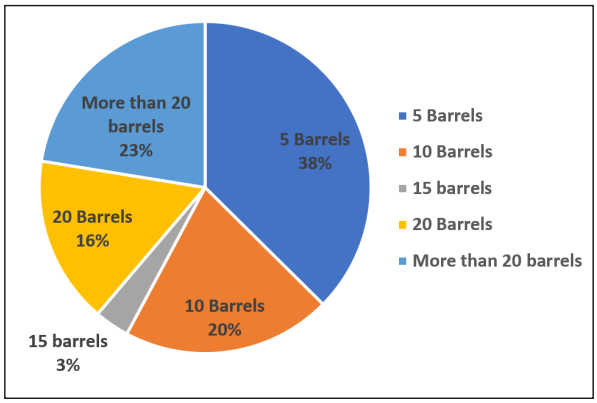

Figure 14. Purchased water percentages in El- Maten Region.

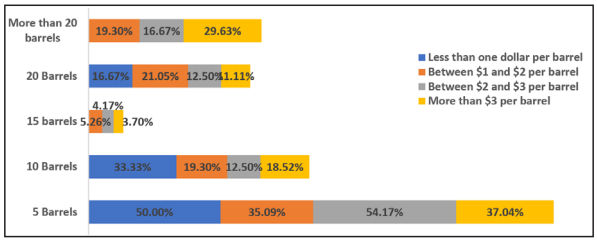

Figure 15. Variation of the amount of money paid on extra water resources with bought quantity in El- Maten Region.

The proportion of individuals with higher education degrees is greater among those with medium to high levels of water knowledge, as shown in Figure 16.

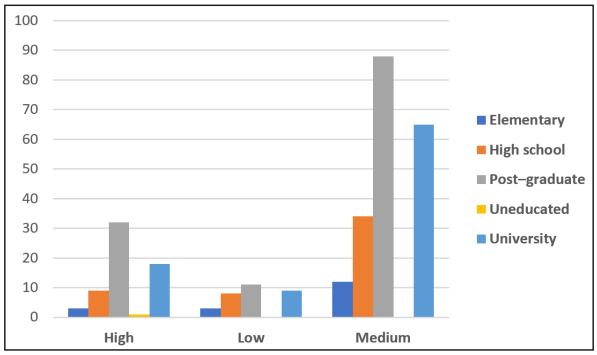

Figure 16. Assessment of the knowledge about water resources with respect to the educational level in El- Maten Region.

While most participants are well-educated and reported as having moderate to high awareness of water-related issues, only 10% indicated in the Figure 17. That is due to the installation of water-saving devices such as low-flow showerheads, sensors, or flow restrictors in their homes. This suggests that water conservation is not effectively promoted through current knowledge or innovative approaches targeted at building professionals, homeowners, or practitioners, indicating a need for better guidance and

incentives in adopting water-saving technologies. Reduced water consumption could impact employment in agriculture and industry but may also create new opportunities in water management and conservation, depending on economic adaptation.

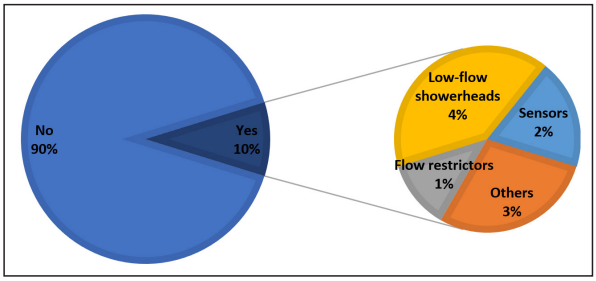

Figure 17. Installation of water-saving devices at home in El-Maten Region.

Approximately two-thirds of participants expressed dissatisfaction with their access to safe drinking water, leading 93% to prefer bottled water as the primary source. Additionally, about two-thirds of the participants indicated a willingness to pay more for sustainable water solutions.

Sustainability is increasingly becoming a priority for consumers in their purchasing decisions. The results indicated that 65% of surveyed consumers were willing to pay more, even beyond their current water bill to improve water supply and support sustainable water solutions. This demonstrates a growing recognition of the importance of sustainability in water management.

The survey on drinking water needs varies across age groups due to differences in body composition, activity levels, and overall health. The quantity of drinking water consumed, as shown in Figure 18, predominantly ranges between 1 and 2 liters/day/capita across all age groups.

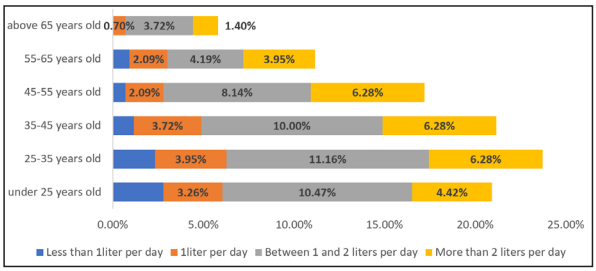

Figure 18. Drinking water consumption by age group in El-Maten Region.

3.3. Data Analysis

To estimate the monthly water consumption per capita (in liters) in the El-Maten Region, Figure 19 outlines the steps used for calculation. The total water consumption per capita is the sum of water from primary and secondary sources. The quantity from primary sources was calculated by using these formul

- $Quantity\ from\ primary\ source\ = (Availability\ from\ Primary\ Water\ Source/month) \times (\ water\ tank\ used\ in\ home) \times (Water\ Tank\ Capacity/barrel)$
- $Quantity\ from\ primary\ source\ per\ capita\ /barrel = \frac{Quantity\ from\ primary\ source}{number\ of\ household}$
- $Quantity\ from\ primary\ source\ per\ capita\ by\ litre\ = (Quantity\ from\ primary\ source\ per\ personby\ barrel) \times 200\ litre$

The quantity from secondary sources was determined by using these formulas:

- $Quantity\ from\ secondary\ source = Regularity\ of\ Water\ Purchases\ from\ Vendors \times Quantity\ of\ Water\ Purchased\ per\ Occasion$

The findings of this study reveal that the average monthly water consumption per capita is 4,501 liters in the El-Maten Region, which equates to an average daily consumption of 150.048 liters per capita. Water consumption levels in El-Maten show that 48% of the population consumes less than 75 liters per day, while 23% fall under the normal consumption level, and 29% are categorized as having higher-than-average consumption (Figure 19).

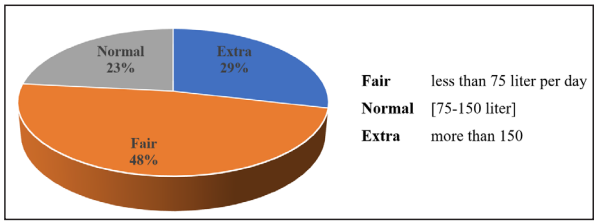

Figure 19. Level of water consumption per day per capita in El-Maten Region.

Figure 20 shows the average of monthly water consumption per capita if consumers use water for watering gardens and washing their cars equal (and other uses) to 5953 liters per capita, two times more than consumers that did not use water for gardens and cars 3541 liters per capita. Consumers that wash their cars but they do not have a garden consume 672 liters per capita less than consumers that they do not watering gardens or washing cars.

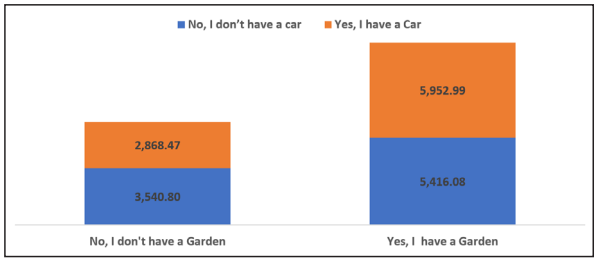

Figure 20. Average of monthly water consumption (liter per capita) with washing cars and watering gardens in El-Maten Region.

3.4. Water Consumption Per Capita among Socio- Economic Characteristics

The findings of this study reveal that respondents with university education have the highest average water consumption, at 4,885 liters per capita. In comparison, respondents with high school education consume an average of 3,347 liters per capita, while those without formal education have the lowest consumption, averaging 2,616 liters per capita (Figure 21). These findings align with previous studies, such as Clarke and Brown (2006) in Melbourne, Villar-Navascués and Alfredo (2018) in municipalities along the Spanish Mediterranean coast, and Fan et al., (2013) in the Yangling District, China. These researchers investigated the influence of socio-demographic and economic factors on domestic water consumption. These investigations also demonstrate that higher education levels are associated with increased household water usage. However, it is crucial to remember that income and education are frequently linked, making it challenging to discern how income and education affect water use.

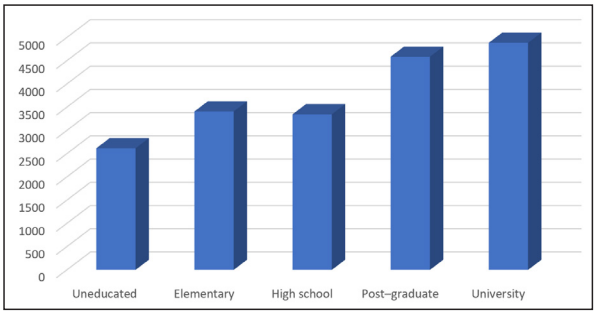

Figure 21. Histogram showing the average monthly water consumption (liter per capita) among the education levels in El-Maten Region.

Income is one of the most important elements that affects how much water households use (Mesert, 2008). Water use and income level are directly correlated, with higher incomes often resulting in higher water consumption (Schwartz and Johnson, 1992). Figure 22 illustrates that the average monthly water consumption per capita was 5,801 liters, with variations ranging from 2,04 to 5,802 liters depending on household income level. Households with an income, exceeding 1,000 $ per month, consumed at least three times more water than those earning less than $200 per month.

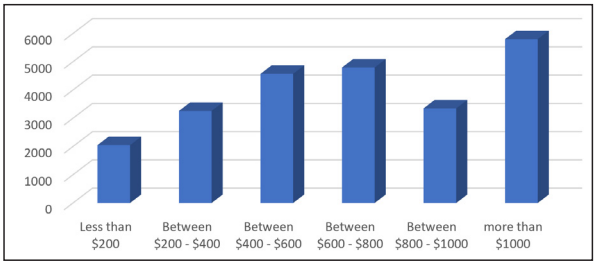

Figure 22. Histogram showing the average of monthly water cost per capita (USD) among the income levels in El-Maten Region.

The relationship between age groups and the consideration of using reusable bottled water showed an asymptotic significance of 0.843, which is greater than 0.05 (Table 2). This indicates that there is no significant relationship between age group and the use of reusable bottled water.

Table 2. Chi-Square test of age group and the use of reusable water bottles.

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	5.666[a]	10	0.843
Likelihood Ratio	5.630	10	0.845
N of Valid Cases	441		
a. 2 cells (11.1%) have expected count less than 5. The minimum expected count is 2.38.			

The relationship between education level and the consideration of using reusable water bottles showed an asymptotic significance of 0.229, which is greater than 0.05, indicating no significant relationship (Table 3). However, when comparing the asymptotic significance of age (0.843) and education (0.229) in relation to the use of reusable bottled water, education will be lower. Although both are greater than 0.05, the lower significance level for education suggests that education may have a stronger influence on the consideration of using reusable bottled water than age does.

Table 3. Chi-Square test of education and the use of reusable water bottles.

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	10.546[a]	8	0.229
Likelihood Ratio	11.609	8	0.170
N of Valid Cases	441		
4 cells (26.7%) have expected count less than 5. The minimum expected count is .38.			

The relationship between education and the disposal of bottled water revealed a significant dependence (Table 4), with an asymptotic significance of 0.003, which is less than 0.05. This indicates that education has a meaningful impact on bottled water disposal practices. The result suggests that higher levels of education are associated with greater environmental awareness, leading to more responsible disposal of bottled water.

Table 4. Chi-Square test of education and the disposal of water bottles.

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	29.407[a]	12	0.003
Likelihood Ratio	28.799	12	0.004
N of Valid Cases	441		
9 cells (45.0%) have expected count less than 5. The minimum expected count is .10.			

4. Conclusion and Recommendations

Water consumption in Mount Lebanon, specifically in El-Maten Region, was assessed through a survey of 441 participants. The results showed that 34% of respondents experienced issues with year-round water availability from their primary source, rising to 45% during the summer months. Additionally, 56% of participants reported problems with the quality of water from their primary source. Nearly half of 48% of respondents had access to a secondary water source. It can be concluded that drinking water usage from primary sources was lower due to a lack of trust in the quality of drinking water

It can be argued that the secondary water resources serve as alternative or supplementary water sources, helping to balance demand and supply when primary sources such as water from rivers, lakes, or groundwater are insufficient or unavailable. These secondary resources are significant in regions experiencing water scarcity or where primary sources are under stress. It was found that the purposes of water use between primary and secondary sources were largely similar. 76% of primary resources a re for domestic uses while 72% of go for the secondary resources.

Addressing water issues in the region requires multifaceted solutions. Education and raising awareness about climate change, water scarcity, and responsible water use are crucial. Water resources will also be significantly protected by improved water management practices, such as stronger legal frameworks and enforcement of rules, and by the sustainable supply of high-quality water. This can be followed by maintaining infrastructure, especially freshwater systems that is essential for reducing water loss

through leaks and ensuring good water quality. Investments in water-efficient technologies at the national, municipal, and household levels, along with pricing mechanisms such as tariffs or consumption-based pricing, could reduce water waste. Developing solutions for water treatment and reuse, such as wastewater treatment for non-potable uses or rainwater harvesting, would also help safeguard water resources.

The study suggests that household water consumption could be further reduced with the installation of water-saving appliances, highlighting the potential for water conservation in El-Maten region. Currently, there is a lack of detailed research on domestic water use in the region. These findings provide insights into water use patterns and offer baseline information to help develop water efficiency programs. A deep understanding of household water use would enable local water companies to better plan and manage water resources for current and future water demand. This information could also improve forecasting of water demand in the region.

Recommendations:

- The opportunities are to improve the water availability and quality, where water infrastructure is underdeveloped or poorly maintained.
- The improvement of Education and Environmental Awareness campaigns in promoting sustainable water practices.
- Maintaining water infrastructure is crucial to preventing leaks and guaranteeing the quality of fresh water. Investments in water-efficient technologies and consumption-based tariffs also significantly impact water conservation.
- The effective water management policies, including legal frameworks and stricter regulation enforcement, are necessary to protect water resources.

Declarations

Conflicts of interests: The authors declare that they do not have any conflict of interest involving the process of reviewing and publishing or any other related implementation for our manuscript.

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