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Posted Date: 26 March 2026

doi: 10.20944/preprints202603.2135.v1

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Article

Forecasting Domestic Water Demand in Saudi Arabia Toward the 2060 Net-Zero Horizon: A Deterministic Polynomial Regression Approach

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Abstract

Saudi Arabia faces extreme water scarcity with renewable freshwater levels well below water poverty line, circa 71 m³ per capita yr⁻¹. In contrast, water demand in domestic sector has grown rapidly in the last four decades. This study forecasts domestic water demand to 2060 under a Business As Usual (BAU) scenario to provide a baseline for water conservation policy. A second-order polynomial regression model was developed using historical demand (1995–2020). Domestic water demand has been used as the dependent variable whilst population growth as the independent variable. The model demonstrated high predictive reliability with an R² (>0.93) and a Mean Absolute Percentage Error (MAPE) of 3.6%. Results indicate that aggregate domestic demand will nearly double, rising from 3,556 million cubic meters (MCM) in 2020 to 6,853 MCM by 2060. This 92.7% increase significantly outpaces the projected 66.3% population growth, driven by a 20.5% rise in per capita consumption from 297 l/d to 385 l/d. We conclude that current consumption patterns are unsustainable, requiring a doubling of desalination capacity that threatens national net-zero carbon goals. Policy must shift from supply-side expansion to strict demand-side management, including smart infrastructure and mandatory efficiency standards, to ensure long-term water security.

Keywords: domestic water demand; polynomial regression; business as usual forecast; population growth; Saudi Arabia

1. Introduction

Gulf Cooperation Council (GCC) countries are located in the Arabian Peninsula, one of the driest regions in the world, characterized by an extremely poor endowment of freshwater resources, low precipitation, and high temperatures and evaporation [1]. GCC countries are among the most highly water stressed countries in the world, with the least renewable freshwater available per capita [2]. Renewable resource per capita is below 500 m³ yr⁻¹, a condition that is now common throughout GCC countries and which according to the Falkenmark water stress index places GCC countries in “absolute water scarcity”, placing them among the least water secure countries [3].

The severity of freshwater shortage began at the turn of the 1970s when GCC oil wealth led to exceptional economic and social transformation. Population grew rapidly, at about 3.5% yr⁻¹ [4,5], plus acceleration in agricultural development, industrialization, and urbanization, and changing consumer lifestyles. This transition led to a substantial increase in water demand, met initially by significant exploitation of groundwater aquifers, the only natural source of freshwater in the region [6]. Population growth and a declining groundwater resource has resulted in a dramatic drop in renewable freshwater per capita (Table 1) which has led GCC countries to construct desalination plants and draw down fossil groundwater [7,8]. Unlimited by supply side constraints, water demand has increased sharply. Domestic demand increased from 2,553 Million Cubic Meters (MCM) in 1995

to 4,695 MCM in 2010, an increase of 84%. Agricultural demand also escalated as countries sought to achieve food self-sufficiency, with demand growing from 17,009 MCM in 1995, to 24,476 MCM in 2010, an increase of 43.9%. Despite the use of some conservation measures to protect strategic fossil aquifers, demand and water stress continued to increase, in an unsustainable manner.

This growing water stress led GCC countries with sufficient oil wealth to invest heavily in desalination [9,10], which overcame the immediate water scarcity [11,12]. Today, desalination meets more than 90% of domestic and industrial needs in most GCC countries [13,14], such that according to the Economic and Social Commission for West Asia (ESCWA), GCC states feature in the top ten of countries that desalinate water [15]. Saudi Arabia tops the list with 22% of the world's daily desalination production, followed by the United Arab Emirates (UAE) with 14%, while Kuwait ranks sixth with 4%. By way of comparison, USA's desalination production is equal to that of UAE with 14%; whilst China at 4% matches that of Kuwait. Collectively Saudi Arabia, UAE, and Kuwait are responsible for more than one third of global desalination capacity [16].

Table 1. Renewable freshwater per capita in GCC (m³/yr).

Country	1970	1980	1990	2000	2010	2012
Bahrain	524	329	219	164	83	3
Saudi Arabia	670	411	244	186	134	82
Oman	215	116	75	73	44	2
Qatar	1,245	817	553	373	321	250
UAE	450	218	103	85	28	2
GCC region	864	182	107	59	24	16

Source: Al-Zubari et al.[1]; World Bank [2].

Growth in GCC desalination capacity has followed growth in water demand and population. For instance, UAE increased desalination capacity by 220% over 10 years (2003 – 2013), a time when population grew by 300% [17]. Kuwait increased desalination capacity from 30 MCM yr⁻¹ in 1970 to 716 MCM yr⁻¹ in 2016, an increase of 2,287%; population over the same period increased 498% [18,19]. Adopting this supply-side policy has enabled a rapid increase in per capita consumption (PCC). Daily PCC in the domestic sector in GCC countries is the highest in the world with rates well above that of other countries [14]. Average domestic PCC is about 350 liters per day (l/d) in Bahrain, 500 in Kuwait, 512 in Qatar, 240 in Oman, 315 in Saudi Arabia, and 520 in UAE [1,20]. In comparison, average domestic PCC in Germany and France is about 120 l/d and about 150 l/d in England [21,22].

2. The Case of Saudi Arabia

Saudi Arabia is the largest country in the GCC, with an area of 2.15 million square kilometer which constitutes around 85% of total Arabian Peninsula area with a population of 35.3 million [23]. Saudi Arabia is considered the largest country without perennial rivers of lake in wider Middle East and North Africa (MENA) region [24], see Figure 1. Water resources in the country consist of conventional and nonconventional resources. The conventional resources consist of limited groundwater (i.e., renewable and non-renewable) and ephemeral surface water. Groundwater represents the predominant water resource in the country, accounting for around 80% of total water supply [25]. Agricultural sector is the main consumer of groundwater with approximately 12.2 Billion Cubic Meter (BCM) demand in 2023 (c. 22.7 BCM in 2013); of which, renewable groundwater accounted for 21% of total groundwater extracted [26]. The overuse of groundwater caused by increasing farmland and urbanization has led to deplete and quality degrade of this resource to an alarming point. The average annual groundwater withdrawal rate is 12 BCM, while annual recharge is only 2.8 BCM. As a result, the strategic fossil groundwater level has decreased to 150 meter in recent years; the fossil groundwater storage is estimated at 2,360 BCM [23]. Furthermore, renewable freshwater per capita has fallen from 550 m³ yr⁻¹ in 1962 to 71 in 2018 [27].

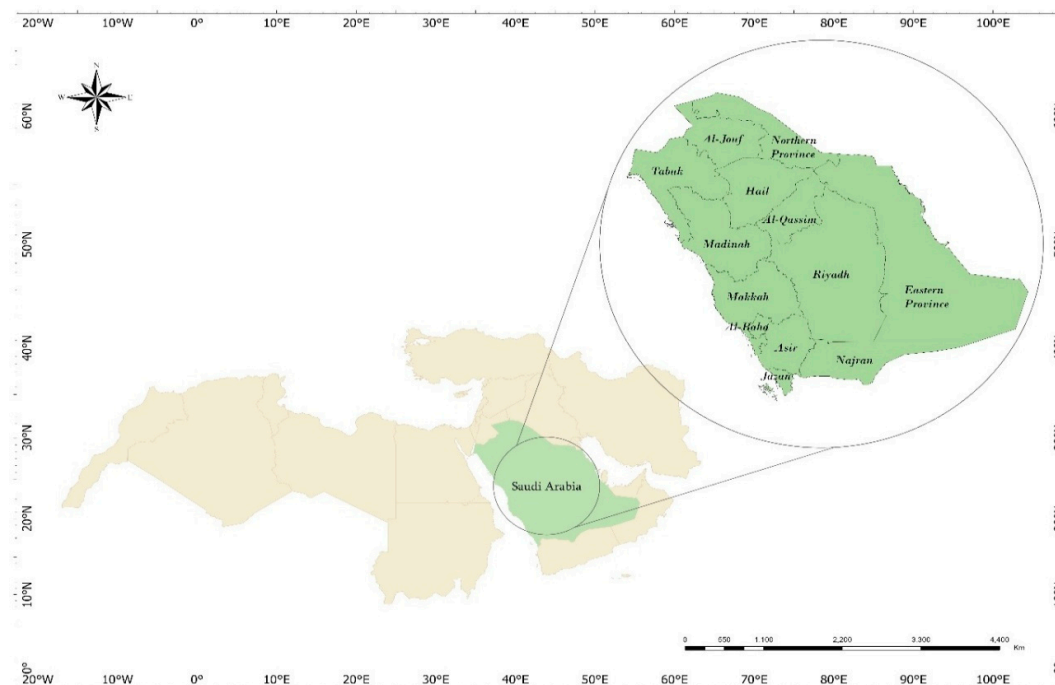


Figure 1. Saudi Arabia map shows its location in the arid MENA region.

Surface water resources are scarce as the country is in a hyper-arid region where receives little precipitation annually and primarily formed as temporary wadis that flow following rainfall. Despite the limited surface water availability in Saudi Arabia, the government has invested in construction dams and reservoirs along over the country to improve the management and enhance the efficiency of rainwater harvesting [23]. Currently, the country has 564 dams with a storage capacity of 2.3 BCM [28]. These dams are essentially built to recharge groundwater, satisfy water demand, irrigation, and flood controlling.

In contrast, nonconventional water represented in seawater desalination and treated wastewater have been utilized to cover the water shortage in the country. Nonconventional water is currently considered a vital source in water sector. Desalination production and capacity have been increasing rapidly in recent years because of high population growth associated with socioeconomic developments (i.e., urbanization and industrialization). At present, Saudi Arabia run 30 desalination plants along the east and west coastlines under the management of Saline Water Conversion Corporation (SWCC) [29]. The current total production capacity of these plants is 9.5 MCM per day, 3,468 MCM per annum [30]. Its capacity has risen sharply since 1980s when capacity was 200 MCM yr^{-1} . The technologies used in desalination are thermal and membrane, with a shift to increase the membrane technologies in the future as it more energy-efficient and environmentally friendly [31].

Treated wastewater has received more interest from private stakeholders and officials due to its potential to shorten the gap between water demand and supply [27]. The incessant water shortage has steered to increase the investment in wastewater treatment infrastructure. At the turn of the 1990s, 40% of wastewater was discharged to the sea without any form of treatment [30]. The remaining portion of wastewater was treated by secondary treatment technology; most of the treated water was also discharged into the sea. At recent years, the focus has been shifted to expand benefit from treated wastewater to be used in different water uses (i.e., agricultural, industrial, and landscaping). For in-stance, as of 2021, Saudi government has owned c. 133 wastewater treatment plants with several advanced technologies, e.g., tertiary and membrane filtration. The capacity for wastewater treatment has increased from 110 MCM yr^{-1} in 1980 to 2,044 MCM in 2021.

2.1. Agriculture Water Sector

At the turn of the 1970s, water demand in agriculture sector increased considerably. Farmland areas have grown from approximately 400,000 hectares in 1971 to 1.6 million hectares in 1992 [32]. The expanded cultivated areas were mainly satisfied by over-mining fossil groundwater aquifers. The significant growth faced was a result of receiving a substantial governmental support policy. This policy was a part of a thorough development that aimed to achieve self-sufficiency in the agriculture sector and thus food security. For instance, in efforts to achieve food security, the government has granted land to arable farmers who have subsequently overexploited available water resources. Mining groundwater to irrigate crops is free of charge, and ultimately, the government purchases crops from farmers at high prices to motivate them to continue cultivating yields. As a result of such practices, the volume of water used for irrigation grew from 7.4 BCM in 1980 to 17.7 BCM in 1995. Accordingly, 35% of strategic fossil aquifers in Saudi Arabia have been depleted in just 15 years [22,33]. Nevertheless, it contributes no more than 2% of the gross national product, where the cost of production is much higher than the revenue [34].

Later, Saudi government realized that the generous policy was at the expense of non-renewable water resources. Thus, in 2008, the government managed a thorough review of its food self-sufficiency policy and irrigation water conservation programs to alleviate excessive irrigation water consumption [35]. Consequently, water demand has decreased sharply to reach 11.4 BCM in 2021; however, demand share in the sector represents 71% of total water demand in the country [23].

2.2. Industrial Water Sector

Of late, Saudi Arabia has witnessed significant industrial growth, which led to a rapid increase in water demands. The industrial sector includes a collection of industries, including petrochemicals, cement, steel, fertilizers, mining, basic metals, textiles, and food and beverage production. Water demand in this sector has increased since the 1980s, when demand jumped from 0.06 BCM to 0.63 BCM in 2020. This trend is anticipated to continue, touching 2.4 BCM by 2060, because of deep economic reforms to move away from an oil-based economy [29].

2.3. Domestic Water Sector

The domestic sector is a rapidly growing sector that gradually increases its share against other sectors (i.e., agricultural and industrial). This is as a consequence of growing population (nationals and expats) associated with growing urbanization over the years. Aggregate water demand in this sector has increased from 446 MCM (4.5% share of total water sector demand) in 1980 to reach 3.6 BCM (25% of total demand) in 2021. A significant portion of this demand (approximately 65%) was met through desalinated seawater production, which amounts to 2,320 MCM. The remaining demand is met by groundwater. On a disaggregated basis, PCC rose from 139 liters per day (l/d) in 1980 to 300 (l/d) in 2021, representing a 116% increase [29].

Despite the domestic sector's increasing demand and its rising share relative to other sectors, there remains a significant dearth of research focused on long-term forecasting within this specific domain. Hence, this study aims to forecast domestic water demand under a BAU scenario until 2060, providing a baseline for officials and policymakers to move beyond supply-side expansion toward strict demand-side management and sustainable water security. The forecast horizon was set to 2060 to align with the Saudi government's target for achieving net-zero carbon emissions, providing a BAU baseline for long-term sustainability planning.

The originality of this research stems from its long-term forecasting horizon. Unlike existing studies that prioritize short-term fluctuations, this work aligns its projections with the Saudi Green Initiative's target year for achieving net-zero carbon emissions. This alignment introduces a significant element of novelty; by bridging the gap between future water demand and the energy-intensive desalination processes required to meet it, the study serves as a critical stress test for national policy. It evaluates the feasibility of meeting growing water needs while simultaneously adhering to the country's aggressive decarbonization mandates, thereby providing a unique framework for integrated resource management and strategic policy assessment.

3. Materials and Methods

In this study, a deterministic quantitative approach was adopted to develop a BAU forecast model for domestic water demand in Saudi Arabia. The model utilizes a second-order polynomial regression to project water demand through 2060. The development of the model relies on two primary variables: (i) domestic water demand as the dependent variable, and (ii) aggregate population growth as the independent variable. The methodology followed a five-stage process: first, a systematic review of the literature to collate historical datasets; second, data preprocessing for regression analysis; third, the evaluation of various trendline models to identify the optimal fit with a high coefficient of determination (R^2); fourth, model validation using forecast error metrics to test the accuracy of modeled values against actual ones; and fifth, the extrapolation of the validated model to the 2060 horizon.

3.1. Water Use Data

Through a systematic data acquisition process, a consistent dataset of actual domestic water demand was compiled at five-year intervals from 1995 to 2020. These aggregate demand values were modeled against population growth using second-order polynomial regression to extrapolate domestic water requirements through the 2025–2060 period. Table 2 summarizes the historical water demand data used for model development.

Table 2. Actual water demand in the domestic sector (1995 - 2020)

Year	Actual demand (MCM)
1995	1,508
2000	1,750
2005	2,283
2010	2,420
2015	2,800
2020	3,556

3.2. Population Statistics

The development of the forecast model required two primary population datasets. First, historical aggregate population data for Saudi Arabia from 1995 to 2020 was sourced from the General Authority for Statistics (GASTAT). Second, a robust population projection through 2060 was required to develop the BAU water demand forecast, as demographic trends serve as the principal predictor in this study. Given that generating original population projections is beyond the scope of this research, the study utilizes external, high-fidelity demographic data to build the BAU scenario. Specifically, the United Nations (UN) World Population Prospects (WPP) for Saudi Arabia was adopted. The WPP employs a probabilistic cohort-component methodology, providing ensemble projections with a median variant that accounts for fertility and mortality rate trends. Figure 2 illustrates the integrated population dataset utilized for the model's time horizon.

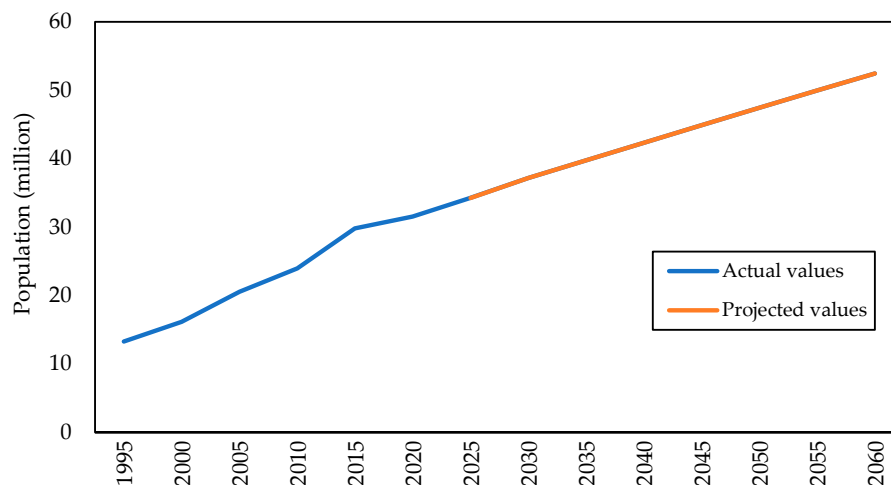


Figure 2. The UN-WPP population projection of Saudi Arabia to 2060.

4. Results

4.1. Trendline Fit Exercise

A trendline fitting exercise was conducted to identify the optimal functional form for the forecast model. Various regression models were evaluated against historical demand and population growth (extrapolated to 2060). The second-order polynomial regression model demonstrated superior performance compared to alternative models, achieving a coefficient of determination (R^2) exceeding 0.93. The polynomial model equation is as follows:

$$y = 2 \times 10^{-12}x^2 + 3 \times 10^{-05}x + 905.74 \quad (1)$$

where y refers to the value on the vertical axis (dependent variable), whilst x refers to the value on the horizontal axis (independent variable). x^2 denotes to the positive coefficient that indicates the line is curving upward (a parabola opening upwards), suggesting that as x gets very large, y will begin to increase at an accelerating rate. The value of 905.74 refers to the y -intercept, representing the theoretical value of y when x is zero.

The second-order polynomial regression model has been selected and applied to extrapolate water demand until the forecast end-year target to capture the non-linear relationship between population growth and domestic water demand. Domestic water consumption in Saudi Arabia does not follow a simple linear trajectory; rather, it exhibits accelerating patterns influenced by rapid urbanization and shifting per capita usage. The polynomial approach allows the model to reflect the accelerated pace of demand even as population growth rates begin to stabilize toward 2060. Higher order polynomials were avoided to prevent the wiggly fitting characteristic of over-fit models, ensuring the 2060 projection remains a credible extension of historical domestic sector behavior. Figure 3 illustrates the trendline for the domestic water demand forecast.

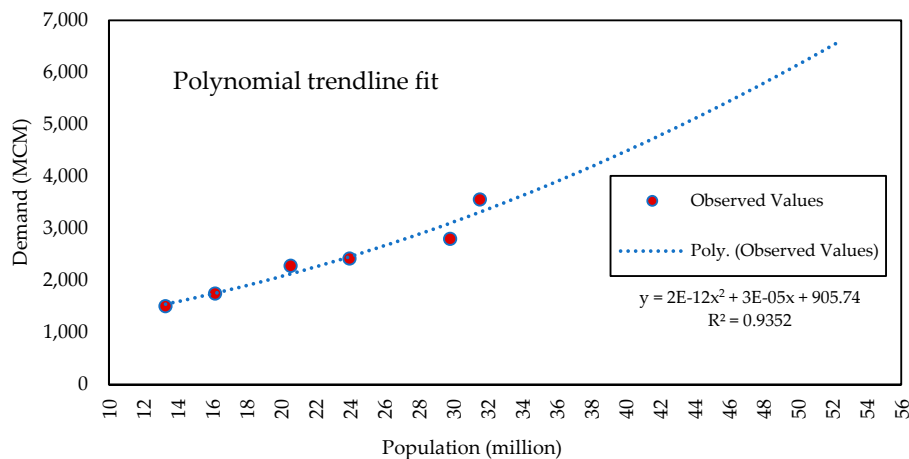


Figure 3. Polynomial trendline fit for domestic water demand.

4.2. Forecast Model Validity and Accuracy

A model validation and accuracy test analysis is required to ensure the model is accurate and reliable. There are many accuracy tests used to compare predicted and actual data to a model. The most common tests are the forecast error (residual) tests that measure accuracy for continuous variables; representing in two metrics groups; (i) scale-dependent error tests such as Mean Absolute Deviation (MAD), Mean Squared Error (MSE), Mean Absolute Error (MAE), and Root Mean Square Error (RMSE); and (ii) scale-independent error also known as percentage error such as Absolute Percentage Error (APE), Mean Percentage Error (MPE), and Mean Absolute Percentage Error (MAPE), or the so-called Mean Absolute Percentage Deviation (MAPD). Those tests are used to find the difference between the actual values against the forecasted values.

Altunkaynak et al. [36], Donkor et al. [37], and Herrera et al. [38] stated that MAPE, RMSE, and MAE are frequently used in water demand estimations to select the best-fit technique. MAE, MAPE, and RMSE share the same principle of measuring the accuracy where indicates the discrepancy between the actual and estimated values in which lower values of these metrics consider a sign of well-fitting [39]. However, MAPE is preferable compared with the mentioned metrics because it is independent of system capacity [40]. Thus, MAPE test has been utilized to test the accuracy of the developed model.

$$MAPE = \sum_{t=1}^n \frac{|A_t - f_t|}{A_t} \times 100 \quad (2)$$

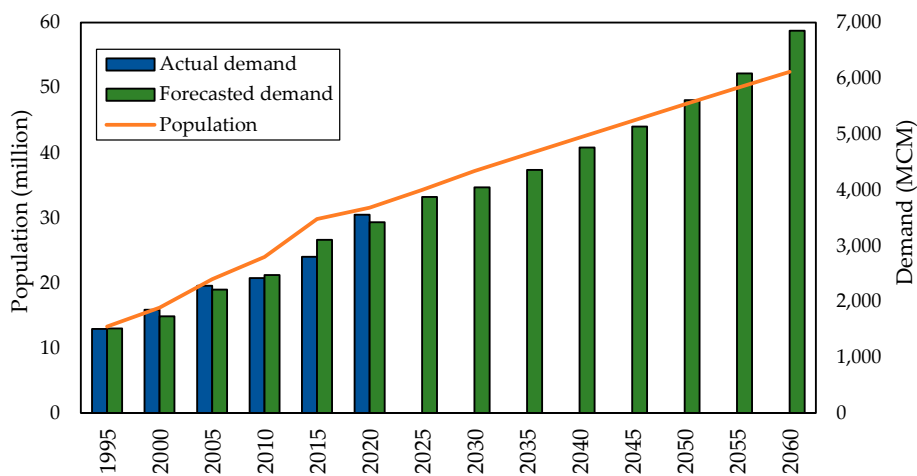
where N is refers to the total number of forecast period or data points; A_t deems to the actual for a given period; and f_t referred to the predicted value for the same period. The output of the accuracy test has shown 3.6% MAPE degree (Table 3). The achieved MAPE of 3.6% indicates a high degree of predictive accuracy, falling well within the highly accurate category (typically defined as <10%) for long-term resource forecasting [40–43]. This performance compares favorably to other domestic water demand studies, suggesting that the second-order polynomial successfully captures the underlying demographic drivers of water use in Saudi Arabia. Consequently, the model provides a reliable baseline for evaluating the impact of future supply-side strategies and identifying the necessary shift toward strict demand-side management through 2060.

Table 3. MAPE accuracy test for the domestic water forecast.

Year	Actual demand (MCM)	Forecasted demand (MCM)	Error	Error	%Error
1995	1,508	1,516	-8	8	0.5
2000	1,750	1,735	15	15	0.9
2005	2,283	2,213	70	70	3.1
2010	2,420	2,475	-55	55	2.3
2015	2,800	3,105	-305	305	10.9
2020	3,556	3,420	136	136	3.8
				Total	21.4
				MAPE	3.6

4.3. Business as Usual Forecast to 2060

On aggregate, water demand in the domestic sector increases from 3,556 MCM in 2020 to 6,853 MCM in 2060, an increase of 92.7%, with highest annual increase of 13.3% in 2025 where demand reaches 3,875 MCM, and lowest increase of 4.4% in 2030 where demand is 4,046 MCM; the average increase rate of the forecast horizon is 9.1% yr⁻¹. On disaggregate, PCC water consumption increases from 297 l/d in 2020 to 385 l/d in 2060, an increase of 29.7%. Peak annual increase rate is in 2030, the increase rate at 7.2%, whilst the lowest rate is 1.5% in 2050. The average annual increase rate for the forecast period is 3.3%. In contrast, population increases from 31.5 to 52.4 million, an increase of 66.3%. Peak annual increase rate is in 2025, where increase rate at 8.6%, whilst the lowest rate is 5% in 2060, showing that population growth trend is decreasing, see Figure 4, Figure 5, and Figure 6. The average increase rate for the forecast period is 6.6% yr⁻¹. The gap between water demand and population growth rates is 2.5%, on annual basis. Consequently, the annual rate of water demand exceeds the total population growth rate (natural and net migration) by a margin of 2.5%.

**Figure 4.** BAU forecast of aggregate water demand in the domestic sector.

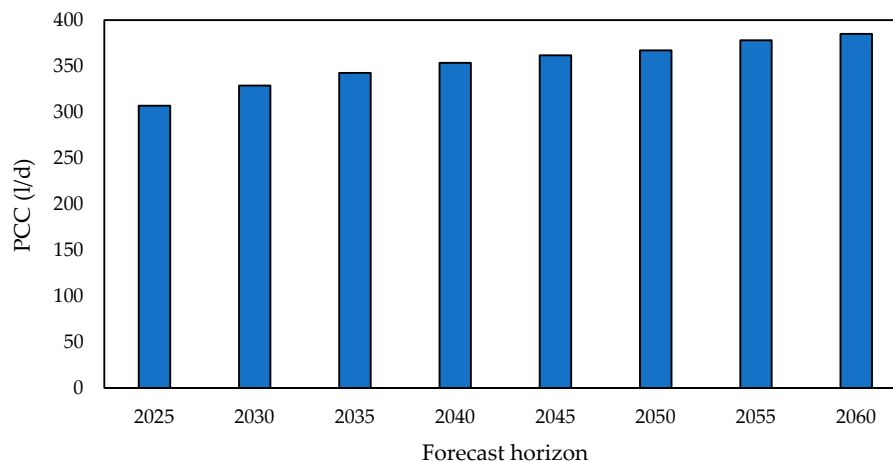


Figure 5. Forecasted PCC water consumption in the domestic sector (2025-2060).

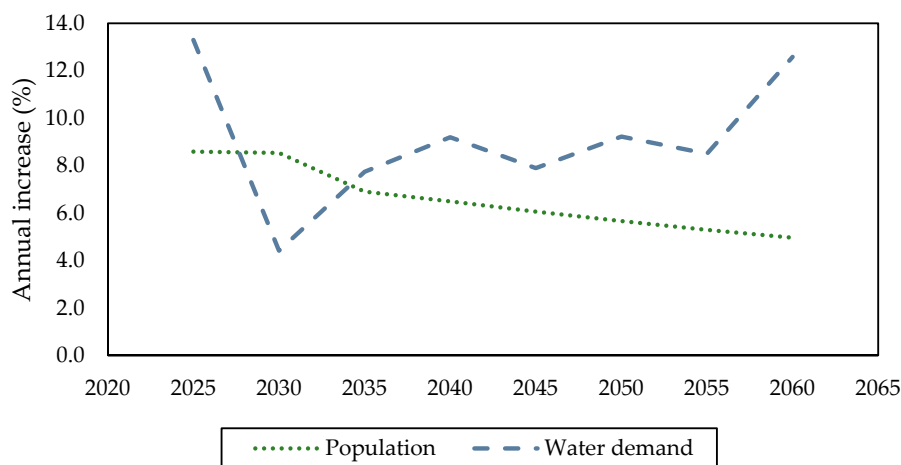


Figure 6. Annual increase rates for water demand and population growth in the forecast horizon.

5. Discussion

The core of the BAU forecast is assuming that aggregate domestic water demand will rise from 3,556 MCM to 6,853 MCM, representing an increase that significantly outstrips the projected 66.3% growth in population. The key finding of this study is that this discrepancy is driven by a projected escalation in PCC from 297 l/d to 385 l/d. Within the BAU framework, this acceleration is not a statistical anomaly but a reflection of deep-seated socioeconomic trends and infrastructure realities in Saudi Arabia. One primary driver is the ongoing transition toward modern, water-intensive urban lifestyles. As the country expands major urban hubs and develops giga-projects like Neom, the shift from traditional housing to modern villa style units increases the individual water footprint. These modern dwellings often incorporate features that are high in water demand, such as private swimming pools and extensive irrigated landscaping, which, in an arid climate, require massive amounts of water to maintain against high evaporation rates.

Furthermore, the model's projection reflects a historical reliance on a supply-side strategy that has shaped consumer behavior. By operating 30 plants, accounting for 22% of the world's daily production, the government has successfully prevented physical water shortages for decades. However, this robust supply, often supported by subsidies, has led to a lack of price elasticity and a consumer perception that water is a virtually unlimited resource. Under current BAU assumptions,

without a radical shift in the tariff structure or the immediate mandatory adoption of low-flow technologies, the model naturally extrapolates the observed trend of rising individual usage.

A critical question arises regarding whether a projected PCC of 385 l/d by 2060 is plausible or if it suggests an inherent flaw in the model's assumptions. When compared to current global benchmarks, this figure is undeniably high; for instance, developed nations in temperate climates like Germany and France maintain domestic PCC rates of approximately 120 l/d and 150 l/d, respectively. However, within the context of hyper-arid, high-income nations, the 385 l/d forecast aligns with observed regional behaviors. Currently, neighboring GCC states already exhibit significantly higher rates, with Kuwait at 500 l/d, Qatar at 512 l/d, and the UAE at 520 l/d. The model's forecast of 385 l/d for Saudi Arabia remains conservative relative to these regional neighbors, suggesting that the polynomial regression effectively captures a realistic "lifestyle-driven" ceiling rather than an indefinite exponential explosion. The model correctly identifies that under BAU, Saudi Arabia is trending toward a level of individual consumption that mirrors the current realities of its GCC peers. This confirms that the polynomial model is functioning correctly as an alert system for policymakers. It demonstrates that population growth is no longer the sole driver of water stress; rather, it is the unchecked escalation of individual demand that poses the greatest threat to the 3,468 MCM annual desalination capacity and the 2,360 BCM of remaining fossil groundwater storage.

The implications of these forecast results are substantial for Saudi Arabia's infrastructure, economic stability, and environmental policy. To satisfy a projected increase of approximately 3,300 MCM in annual domestic demand, the country would essentially need to double its existing desalination capacity, which presently stands at 3,468 MCM per annum. Such an expansion would require massive capital investment and result in a significant increase in energy consumption and carbon emissions, potentially undermining national climate target of achieving net-zero emissions by 2060. The widening gap between water supply and forecasted demand emphasizes that continuing with current management practices will lead to adverse economic and environmental consequences. Therefore, the gap between the 66.3% population growth and the 92.7% demand growth serves as a critical warning that population management alone is insufficient; aggressive demand-side policy is required to decouple lifestyle improvements from water consumption.

To mitigate these forecasted outcomes, policy interventions must transition from traditional water supply management to aggressive, data-driven demand management. Based on the quantitative findings of this study, the study recommends implementing targeted conservation measures designed to reduce the forecasted PCC of 385 l/d back toward the 2020 baseline of 297 l/d:

- Smart infrastructure and leakage control: deploying advanced smart water metering systems and AI-driven leak detection could reduce the apparent demand by 10–15%, addressing the inefficiencies in the distribution network that contribute to high PCC figures.
- Mandatory high-efficiency standards: Transitioning households to ultra-low-flow fixtures and water-efficient appliances can reduce indoor consumption by approximately 40–60 l/d per person, a critical step in offsetting the 88 l/d increase predicted by the BAU model.
- Xeriscaping and greywater incentives: given the impact of urbanization, policies must mandate xeriscaping (water-efficient landscaping) and the use of treated wastewater for residential irrigation to de-couple lifestyle changes from potable water demand.
- Localized household modelling: developing micro-component models specifically for Saudi households will allow for surgical policy interventions that address specific high-usage habits, such as outdoor cleaning or cooling, which the aggregate BAU model identifies as a growing trend. By integrating these specific measures, Saudi Arabia can effectively bridge the 3,300 MCM gap, ensuring that future urban developments in cities like Riyadh and Neom remain within the limits of sustainable water resources.

Author Contributions: Conceptualization, H.A.; methodology, H.A., and L.A.; investigation, M.A, and S.A; resources, H.A.; writing—original draft preparation, L.A.; writing—review and editing, H.A., M.A, and S.A; All authors have read and agreed to the published version of the manuscript.

Data Availability Statement: The original contributions presented in this study are included in the article. Further inquiries can be directed to the corresponding author.

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

Abbreviations

The following abbreviations are used in this manuscript:

BAU	Business As Usual
GCC	Gulf Cooperation Council
MCM	Million Cubic Meter
ESCWA	Economic and Social Commission for West Asia
UAE	United Arab Emirates
MENA	Middle East and North Africa
BCM	Billion Cubic Meter
SWCC	Saline Water Conservation Corporation
GASTAT	General Authority for Statistics
UN	United Nations
WPP	World Population Prospects
MAD	Mean Absolute Deviation
MSE	Mean Squared Error
MAE	Mean Absolute Error
RMSE	Root Mean Square Error
APE	Absolute Percentage Error
MPE	Mean Percentage Error
MAPE	Mean Absolute Percentage Error
MAPD	Mean Absolute Percentage Deviation

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