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Temporal Variations in Water Use : The Case of The Greater Amman Municipality – Jordan

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ABSTRACT

By using Linear and Logarithmic regression procedures, this study analyzes factors which influence annual water use in the Greater Amman Municipality during the 2006 – 2015 period. The explanatory variables used in the model include: the average price of each water unit, average annual rainfall. Average maximum temperature, total number of minimum bills, changes in the Cost of Living Index, total number of subscribers, total number of big consumers, and total number of governmental offices provided with water services. The results of this research indicate that variables such as average price, total number of minimum bills, and temperature variables explaining a total of 89.7% of variations in annual water use quantities at the aggregate level in the Greater Amman Municipality. Therefore, such variables could be utilized as good predictive ones of future water needs in the study area.

Keywords: The Greater Amman Municipality; temporal variations of annual water use; linear and logarithmic regression procedures.

Introduction

Water has played a significant role in the growth of commercial and manufacturing activities in the Greater Amman Municipality. Moreover, water is considered an essential service for residential and public sectors (governmental offices) in the study area. The Greater Amman Municipality is the capital and largest urban center in Jordan. It represents according to Department of Statistics (2015) approximately 43% (4.1 million residents) of Jordan's total population (Department of Statistics 2016).

Water sources that supplied the Greater Amman Municipality consists of both groundwater and surface water sources. Due to the large of water quantities required for municipal purposes, the Greater Amman Municipality receives its needed water from Amman – Zarqa aquifers, Azraq wells, Swaqa/ Qastel wells, Walla-Hidan wells, and King Abdulla Canal (surface water) located near Dir Alla through an existing pipeline (45km) to Zai treatment plant, and finally to western areas of Amman (Greater Amman Municipality, 1988). Furthermore, the Disi Aquifers water supply source from which a pipeline extended from south Jordan transferred around 100 million cubic meter a year to the Greater Amman Municipality. This water project became operational in July 2013 (Ministry of Water and Irrigation, 2014).Fig (1)

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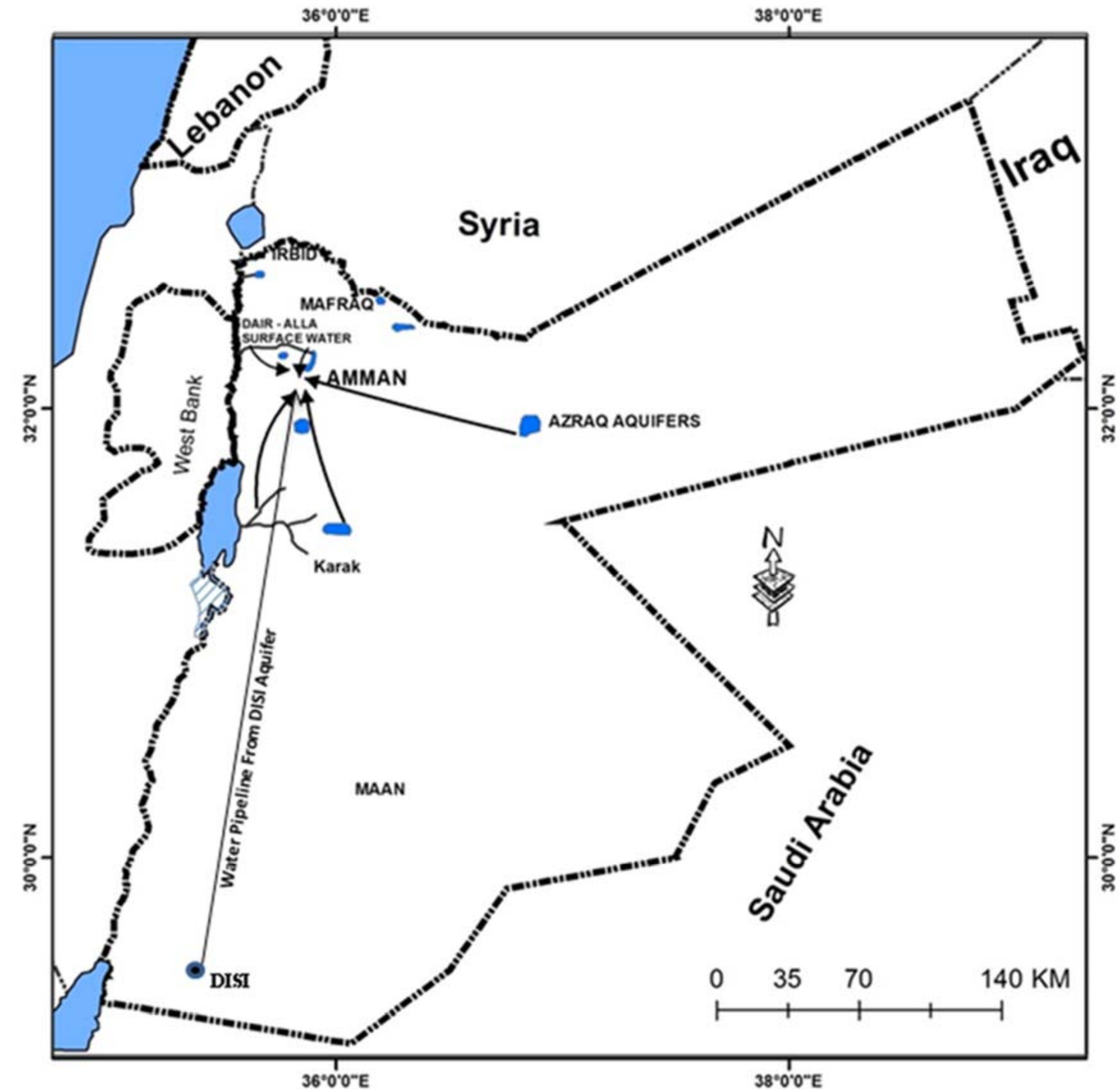

Fig (1) Water Supply Sources of The Greater Amman Municipaility

Theoretical Background

Sufficient clean water is an increasingly scarce in many developing countries including Jordan. Lower precipitation rates limit water supplies and increase the risk of being unable to maintain a sustainable high standards of living (World Water Assessment Program, 2003; Hanasnki et al.2008a, b; Doll et al, 2003, 2009; Kummu et al, 2010; Vorosmarty et al, 2010; Wada et al, 2011a,b; Taylor et al, 2013; Wada and Bierkins, 2014). Moreover, population growth in such countries have stressed urban water supply sources, leading to activate management demand through conservation measures (Gliek 2003; Coome 2011).

Forecasting urban water demand was a principal issue in developed and developing countries. In the second half of 20th century, researchers focused on modeling temporal water use variations rather than spatial variations (House et al. 2011; Tanverskul and Lee 2012).

Econometric variables such as price and income were considered the impact factors on water use in urban areas (Maidmont et al. 1985; Zhou et al. 2004; Arbues et al. 2003). While climatic variables such as rainfall and temperature were seen as key factors affecting water use demand in urban areas. Furthermore, urban water use has been realized as a temporal and spatial phenomenon arising from the household size, and educated level variables affecting urban water use at temporal and spatial levels. (March and Sauri 2009; Al-Najar et al. 2011).

In the past, some municipal public water systems over the world utilized population data and per capita water use to project water demands. This projection approach assumed that water use was determined by the population growth variable and it can lead to the provision of excess water capacity (Gallagher et al. 1981). Although this variable is important in the forecasting process, it clearly does not account for all of the variations in the water quantity demanded. Therefore, the focus of this study is to define the contribution of

socio-economic, climatological, and other variables in explaining temporal variations in quantities of water use in the study area, in order to provide planners and decision makers in the water sector with a tool for projecting a long-term water demand.

Attempts to explain present water use or predict future water demand have incorporated variety of variables and have adopted two distinct approaches. Foster and D. R. Bettie (1979) have investigated the problem within a spatial framework by examining different groups of urban centers. Meanwhile, time-series approaches have determined the temporal variability of water use through incorporating several variables which anticipated to affect gross municipal water consumption.

One explanatory variable of water use is the price paid for the water unit consumed. It is argued that as price of any given product increases, the demand for the product decreases. Hanke (1970) observed that consumers curtailed their use of water after price increases by sprinkling lawns less frequently and repairing leaks in plumbing systems. In time – series studies (Grima 1973; Young 1973; Weeks 1974; Billing and Agathe 1980; Williams 1985;; Al-Qunaiet 1985; Abu Rizaiza 1988) a price variable has been used to explain temporal variations in water use. The price coefficient or elasticity of water demand ranged from -0.02 to -0.82 for the time-series studies. The negative sign of the elasticity indicates that price is negatively correlated with water use.

Municipal water demand studies (Hijazi and Deyabi 1997) used models include the price variable of closely related goods (substitutes and complements) as well as the price of consumed water units.

However, since water has no close substitute, it is complementary to durable goods such as washing machines in the sense their price will not affect the use of water (Al-Quanaibit 1985). Meanwhile, Al-Qunibet employed the cost of living index (in which water costs assumed to be minor of the total expenditure of the subscriber) as an explanatory variable in estimating municipal water demand in Kuwait.

Water use is strongly related to climatic variables. For example, in hot, dry climates water use may rise considerably during the summer months because of lawn watering. In Fort Collins, Colorado, Anderson et al. (1980) described the savings which were made following lawn watering restrictions during dry years. Although critical of true levels of water conservation achieved, the authors stressed the importance of lawn sprinkling as part of water usage.

Climatic factors (precipitation and temperature) have been used in a number of time – series studies (Morgan, and Smolen 1976; Hansen, and Marayanan 1981). These variables might explain a large degree of the variability in water use. In general, precipitation is negatively correlated with water use, while temperature is positively correlated. However, results of Williams Byung S. study (1986) revealed a low to high coefficients of temperature variable which ranged from 0.021 to 0.618.

The amount of water used is positively correlated with the number of subscribers in the water service. Hijazi and diyabi (1997) have suggested that this variable is one of the most effective in explaining variance in domestic water use.

Most previous studies (which employed multivariate models) reviewed in this paper explain municipal water use variations and explore the predictive potential for water use at the aggregate level. If the predictive power of these models is high, they may be extremely valuable in water resources management and eventually lead to greater efficiency in planning water facilities. However, if the goal of water resources planning is sufficiency in providing such vital services under the circumstances of public opposition of grey water reuse in Jordanian cities (Jamra 2008), then further studies must be done.

Purpose of the Study

The goal of this study is two folds. Firstly, to explain the temporal variations (annual) in water use patterns in the Greater Amman Municipality. Secondly, to determine those variables which best explain the temporal variations in total water use in the study area. The results will then be compared with water use models from other study areas.

It is hoped that this study will provide some insight into the factors determining temporal water use variations in the Greater Amman Municipality. An understanding of the temporal variations in water use rates and the factors affecting it, is necessary before conclusions can be drawn regarding the adequacy of water supply sources and facilities to meet the present and future water needs. Some understanding determinants of the temporal water use would also of great value in projecting future water needs in the study area especially if the determinants can be validly projected.

Data Sources and Methodology

As noted previously, several factors are anticipated to affect the annual quantity of water used in the Greater Amman Municipality. The model employed in this study assumes that the annual quantity of water used is a function of the average price per unit of water consumed (m^3), precipitation, temperature, changes in the cost of living index, total number of water service subscribers (customers), total number of governmental offices provided with water service in the study area, total number of big customers (hotels, restaurants, industrial and commercial establishments), and finally, the number of minimum bills. A simple linear regression, and a logarithmic regression models will produce coefficients or elasticities that demonstrate the comparative effects of variations of these variables upon the total amount of water used or consumed in the study area. Data of these variables were gathered from different sources and methods of analysis discussed below.

Jordan's Water Authority through the Directorate of information and Computer Section provided their records which include summary data on annual water use. Both administrative and technical water losses in the study area were taken into consideration, such water losses estimated to be around 38.5% of water supplied to the Greater Amman Area (Ministry of Water & Irrigation 2006-2015), number of minimum bills, revenues produced from water, and total number of water service subscribers which consists of governmental offices subscribers, and big subscribers. Customers served by the water authority – Meyahona Company, in the study area are predominantly residential users, industrial, public, and commercial users. Until recently, data was not available from the study area by class of user. Therefore, no attempt was made to analyze water use variation patterns by user class.

The dependent (explained) variable was total water use (quantities of water consumed) in cubic meters recorded per year: 2006 – 2015. One of the independent variables included in the analysis is the average price per unit of water used in the study area. Water rates in Jordan , in general , and in the Greater Amman Municipality in particular, are based on metered consumption of each subscriber. A price of each water unit (m^3) is specified for each amount (block) of water used, with the price per block increasing as the quantity of water use increases. Since the rates are not identical to determine the increments of water in each rate structure, a new measure of price had to be selected. The variable designated was the average price of each consumed water unit in fils. This measure was obtained dividing total yearly revenue collected by that year's corresponding water consumed in million cubic meter.

Changes in the Cost of Living Index data was obtained from the Central Bank of Jordan Annual Reports (2006 – 2015). It is based on retail prices of a fixed market basket collected from a selected stores in seven cities, including the Greater Amman Municipality.

Similar to semiarid areas of Jordan, a good portion of the Greater Amman Municipality's water use is for garden irrigation, and for commercial and industrial intensive water uses especially during summer periods. Therefore, climatic variables are important factors affecting the consumption of municipal water over time. Weather data on average yearly precipitation and summer temperature were obtained from records of Meteorological Department in Amman (2015).

It was hypothesized that a multivariate analysis consisting of eight principal variables should explain the temporal variance in the Greater Amman Municipality water use patterns (as a dependent variable). A model was tested, therefore, using climate variables (average maximum temperature and average yearly rainfall), average price of consumed water units, changes in the cost of living index, number of subscribers in water service, number of a big subscribers, number of governmental offices provided with water service, and number of minimum bills as the independent variables.

The general form of the model used to explain the temporal variance in water use in the study area is:

Wu = f(T, P, Pr, CLI, NS, NBS, NGO, NMB)

Where:

Wu : Quantity of water used annually in cubic meters

T : Temperature (average maximum Temperature during summer months in c(

P : Average yearly precipitation in (mm)

Pr : Average price of each water unit consumed (m^3) in fills.

CLI : Percent of changes in the cost of living index.

NS : Total number of subscribers in water services.

NBS : Number of big subscribers of water.

NGO : Number of governmental offices served by water service.

NMB : number of minimum bills a year.

It was hypothesized that the temperature, total number of subscribers, total number of big subscribers, and total number of governmental offices variables would all be positively correlated with water use, while precipitation, average price of water, changes in cost of living, and number of minimum bills variables would be negatively correlated with water use trends.

One correlation matrix was utilized in order to provide a basis for judgment concerning effects of interdependence between specific explanatory variables.

A logarithmic regression form of the model was fitted in this analysis. Therefore, logarithmic transformations were performed to insure linearity between dependent and independent variables in the following equation:

$$\text{Log Wu} = \text{Log a} + b_1 (\text{Log T}) + b_2 (\text{Log P}) + b_3 (\log \text{Pr}) + b_4 (\log \text{CLI}) + b_5 (\text{Log NS}) + b_6 (\text{Log NBS}) + b_7 (\text{Log NGO}) + b_8 (\text{Log NMB}) + e$$

Where:

Log Wu, Log T, Log P, Log Pr, Log CLI, Log NS, Log NGO, Log MB, are all the logarithms of the original variables included in the first equation, Log (a) is the intercept, and (e) is the error term.

A stepwise multiple regression program was employed to analyze the temporal variations in water use data in the study area. The procedure involved entering one variable at a time into the model so that each independent variable is accepted based on the extent of its explanation of the remaining variance. The best fit model was derived such that the independent variable explaining the greatest variance entered in the model first, the variable which explained most of the remaining variations entered second and so on. Variables which did not explain a significant amount of variance were excluded from the model.

Results and Discussions

Annual Variations in Total Water Use in the Greater Amman Municipality:

The steady increase in total water use (all four categories: residential, Commercial, Industrial, and Public use) was clear during 2006 - 2015 period. The totals show a period of slight decrease 2006 to 2011, followed by a rapid increase in use after the year 2011 in which an influx of Syrian refugees has come escaping the spring uprising. Quite large numbers of refugees resided in the Greater Amman area. There is a plateau of steady increase in water use through the remaining of the period. The continued increase in water use in the study area can be probably attributed to changes (increases) in population expressed in increases of subscribers or customers of water during 2006 – 2015, and may related to changes in standard of living, commercial and industrial activities. But the important question that should be answered is that: what are the major factors (or variables) influences the temporal variations in total water use in the study area?

Initially, a careful perusal of the correlation matrix (Table 1) for all variables included in the study indicates a minimal amount of interdependency among the explanatory variables. Therefore, no attempt was made to specifically apportion the explanatory effects to given variables. The variables deemed most important were those that were repeatedly significant in the reduced equation (an equation with variables that were all significant at least at the 0.10 confidence level).

Table (1): Correlation Matrix Between Logarithmic Values of the Explanatory Variables assumed to Affect Temporal Variations in Water Use in the Greater Amman Municipality.

Variable	T	P	Pr	CLI	NS	NBS	NGO	NMB
T	1.00	0.44	0.20	0.35	0.40	0.55	0.08	0.15
P		1.00	0.34	0.018	-0.45	0.41	0.51	0.38
Pr			1.00	0.37	-0.21	0.12	-0.55	0.23
CLI				1.00	0.09	0.08	0.22	-0.40
NS					1.00	0.53	0.16	0.30
NBS						1.00	0.14	0.49
NGO							1.00	0.34
NMB								1.00

Results of the variables studied through using a multiple Linear regression procedure for the Greater Amman Municipality were found in Table (2). The preliminary results revealed that unlike other studies. The rainfall variable had statistically insignificant effect in explaining changes in total water use. This may in part be due to the nature of the data (aggregate total water use data, i.e. all types of water uses). The Water use for irrigating residential gardens, as part of the total water used most affected by this climatic variable (rainfall), is expected to represent a partial amount of water out of total water used for this variable to influence the overall water use function. Therefore, the rainfall variable was excluded from the model.

Table (2): Summary of Multiple Linear Regression Procedure for Explanatory Variables Related to Water Use Variations (a dependendent variable) in the Greater Amman Area.

Variable	Coefficient (b) values	Std. Error of Reg. Coeff.	T. value	P. value
a intercept	-6.1E+07			0.06
Pr	-128108.5	55113.68	2.32	0.05*
NMB	163.26	110.817	1.94	0.10**
T	2.284132	1196285	1.98	0.10**

R^2 : Multiple Coefficient of Determination = 0.916

e : the error term 2300602

*: Estimated coefficient significance at 0.05 probability level.

**: Estimated coefficient significance at 0.1 probability level.

Table (2) provides a summary of multiple linear regression equation. It includes only those variables which were significant at least at the 0.10 level of confidence. Variables of average price of each water unit and the number of minimum bills (i. e. subscribers who consumed less than 20 m^3 of water during any cycle) were found to be statistically significant at 5% and 10% probability levels respectively.

Rainfall along with other variables, such as total number of subscribers, total number of big customers, total number of Governmental Offices, and cost of living index variables were excluded from consideration for multivariate analysis due to their insignificance in explaining the temporal variations in water use in the study area.

One multiple logarithmic regression (stepwise procedure) was then performed on the remaining independent variables of average price of each water units used, total number of minimum bills, and temperature. The results are presented in Table (3). Table 3 provides a summary of stepwise regression equation. It includes only those variables which were significant at 0.05 confidence level.

The estimated logarithmic equation for three assumed explanatory variables is:

$$LogWu = 2.155 + (-)0.848 \log Pr + 1.289 \log NMB + 0.334 \log T + 0.02643$$

$$(0.31) \qquad (0.503) \qquad (0.12)$$

The standard errors of the respective regression coefficients are listed in parentheses below the coefficients. In this log equation, three variables were significant at less than 0.05 confidence level: the average price of each water unit consumed, number of minimum bills a year, and average maximum temperature during summer months.

The total variance explained by the model with three independent variables is 0.897. This R^2 value is slightly lower compared to the models produced by Morgan (1974) and Hijazi (1997) which had levels of explanation as high as 0.93 and 0.97 respectively. However, those studies were conducted in an arid geographical areas where the sprinkling components represented a substantial proportion of total water use. In such climatic regions, the seasonal factors (rainfall and temperature) would appear to explain much more of the variance.

Table (3): Summary of Stepwise Regression Procedure for selected logarithmic explanatory variables.

Variable	Coefficients b (values)	Std. Error of Reg. Coeff.	T Value	P Value
a intercept	2.155			
Log Pr	-0.848	0.31	2.735	0.015*
Log NMB	1.289	0.503	2.748	0.015*
Log T	0.334	0.12	2.563	0.022*

*: Estimated Coefficient Significance at 0.05 probability level.

R^2: Multiple Coefficient of Determination = 0.897

e: The Error term = 0.02643

In the Greater Amman Municipality model, the variable which explained the greater variance in water use was the average price of each water unit (Pr). Total number of minimum bills (NMB) and temperature (T) were the second and third variables to enter the model, respectively. Table (3) shows the order in which variables entered the equation.

The water use quantities were strongly related to average price of water units used. The amount of variance explained by this variable was -0.848. Billings and Agthe (1980) found this particular variable explained a significant proportion of the variance in the water use rates. Price elasticity was estimated in this study as -0.46. This value is in the range of those found by Martin and Wilder (1993), who found that price elasticity ranged from -0.32 to -0.70 using a logarithmic function for the demand model.

Total number of minimum bills was the second variable to enter the logarithmic regression equation and explained an additional 5.6 % of the variation in water use quantities. Abdallah (1997) established a different result in his study, in which he found that this variable explained an additional 28.6% of the variance of water use amounts.

Temperature, the third variable to enter the equation, had an elasticity of demand that was quite low at 0.21. Although the temperature explains relatively little of variance, 4.5%. The sign of the coefficient on this variable is the same as had been hypothesized. Results of Danielsons (1979) study yielded a much higher temperature elasticity of 0.316 associated with annual water use which reflects the greater amount of water sprinkling in his study area (North Carolina), and the dependence of this demand on temperature changes.

These results produced to some extent a clear explanation of annual water use variations in the Greater Amman Municipality, and established certain relationships between variables at the aggregate level of analysis. These aspects could be pursued in further studied to determine which additional factors explain the remaining variations in water use data.

Conclusion

Water is one of the most basic perquisites for civilized life generally in Jordan, and particularly in the Greater Amman Municipality. Also water used with great worries about its costs, quality, and availability to the average Jordanian citizen. A much better understanding of present and future water needs for the Greater Amman area could be achieved in the light of the insight which has been gained into the factors affecting temporal variations in water use. It was established that in the Greater Amman Municipality total annual water use has been increasing throughout the 2006 – 2015 period.

The variance explained by this model was 89.7% of the total variance in annual water use quantities for the period 2006 – 2015, in the Greater Amman Municipality. Such value was relatively high compared to values reported in studies based on aggregated data. Very few investigations have been concerned with aggregated data, and of those, not all have used the same independent variables as this study. Conclusions, therefore, cannot be reached as to whether this model is better or worse than others on the basis of explanatory power.

The most notable fact to emerge from the results of present study was the importance of average price of water, total number of minimum bills, and temperature in determining temporal water use variations. Whether considered variable was found to be a significant determinant of water use quantities. Price of water did change during the time period covered by the analysis. A price increase did go into effect in January 2014. The effect of price on water use could be addressed in future research. For Jordanian decision makers this would imply that the planning efforts for future water use could be improved by incorporating price, minimum bills, and temperature data into projected water needs for the study area.

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التباينات الزمانية للمياه الستهلكة: أمانة عمان الكبرى – الأردن حالة دراسية

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ملخص

تسعى هذه الدراسة إلى بناء نموذج يهدف إلى تفسير التباين في كميات المياه المستعملة خلال الفترة 2006 –2015 في أمانة عمان الكبرى، وذلك من خلال المتغيرات المحددة الرئيسة لذلك التباين الزماني. وقد تم استخدام أسلوب الانحدار المتعدد ذات الخطوات المتسلسلة لتحليل بيانات المياه المستهلكة فعلاً (المفوترة) بغية تحديد مدى ارتباطها بالمتغيرات الثمانية التي اشتملت عليها الدراسة. أظهرت نتائج الدراسة وجود ثلاثة عوامل رئيسة (معدل سعر المياه، ومجوع فواتير الحد الأدنى، والحرارة) فسرت 89.7% من التباين الكلي لكميات المياه المستعملة سنوياً في منطقة الدراسة. وقد أوصت الدراسة بإمكانية استخدام نموذج الانحدار المتعدد الذي تم التوصل إليه في التنبؤ بالاحتياجات المستقبلية من المياه في منطقة أمانة عمان الكبرى من قبل واضعي الاستراتيجيات المائية في الأردن.

الكلمات الدالة: أمانة عمان الكبرى، المياه المستهلكة، التباينات الزمانية، معدل سعر المياه.

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