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INVESTIGATION OF VARIABLES THAT AFFECT THE URBAN WATER CONSUMPTION OVER SOME DISTRICTS OF KONYA CITY

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Abstract – As it is known, the importance and consumption of water are increasing day by day due to industrial growth, population growth, advancement of technology and increasing living standards. Because of the limited water resources, the design, planning, forecasting of water transmission and distribution systems should be made more carefully and the water resources should be used more efficiently. In this context, the importance of the factors affecting water demand is increasing day by day. Population, economic cycles, education, technology, climatic conditions, price, and many other factors have their effects on water consumption. By designating these effects in a healthy and reliable way, it is possible to design systems that are more reliable and to use water resources more efficiently. In the present study, by using water consumption data of 4 different neighborhoods of the central districts of Konya with different characteristics, the effects of meteorological variables on water consumption according to the characteristics of neighborhoods were investigated by using Multiple Regression *Analysis.*

Keywords – *Konya, water, unit water consumption, multiple regression analysis, meteorological variables*

I. INTRODUCTION

Water is undoubtedly one of the most important substances that ensure the survival and vitality of the world. In this respect, determining the amount of water required by each variable in need of water is a necessary engineering service for the optimum use of water resources. Therefore, while there are many parameters affecting unit water consumption, the degree and rate of these parameters have been the subject of some researches in recent years. In the previous studies, which parameters affect how much water consumption has been investigated by using a large number of variables and different methods and are still being investigated.

Dandy et al. (1997), price, income, social-economic and climate variables are used as parameters. By using regression models, they suggested that water consumption is directly related to the price of water. Jain et al. (2001), in their study for short-term water forecasting in Kanpur Institute of Technology they investigated new techniques of artificial neural networks, Socio-economic and climatic factors were used in the study. Regression analysis and time series analysis were also used for comparison. A total of 6 different neural network models, 5 regression models and 2-time series models have been developed and compared. It was stated that the most successful artificial neural network model error was 2.41%. As a result of the study, it was stated that population, income, water price and house characters are important for long-term estimation, whereas climate factors are more important for short-term and seasonal water need.

Maidment et al. (1984), in their study, they made time series analysis on the data of six cities in Texas. Population, number of connections, household income and water price have been used as factors. In this study, it is stated that the population is the most effective and important factor. It has been also stated that rainfall has a significant effect on water consumption in 3 cities which are in high places. Khatri and Vairavamoorthy (2009), examined the effect of population, climate change and economic growth factors for the estimation of future water demand by using regression models in their study. The study was conducted to estimate the UK's water demand in 2035. From the analysis, it was stated that the future water demand (at the total monthly level) was largely due to socio-economic changes rather than population changes and climate change.

Ruth et al. (2007), focused on the city of Hamilton in New Zealand to investigate possible water use and infrastructure needs for a range of population and climate characteristics. Changes in water demand were largely caused by population changes and were not significantly affected by climate change.

However, it is also one of the results that the impact of climate change on per capita water demand increases as the population increases.

In the study conducted by Akuoko-Asibey et al. (1993), the effects of climate factors on water consumption were investigated for Calgary City. Weekly unit water consumption data between 1982 and 1989 were used.

Gedefaw et al. (2018), in their study, investigated the multiple regression methods used for the selection of the variables required for water demand estimation for the city of Gondar. Principal component analysis was chosen as the most appropriate multiple regression method.

Oyebode et al. (2019), compared models which stablished by artificial neural networks, multiple regression analysis and support vector machines for water demand prediction in their study. Artificial neural networks were found to be the most appropriate method.

II. MATERIALS AND METHOD

A. *Material*

In the present study, the effects of meteorological variables on unit water consumption were examined by using the Multiple Linear Regression Method. Monthly water consumption values of 4 different districts of Konya city with different characteristics and monthly data of 13 different meteorological variables measured in the same period have been used. 4 different neighborhoods of Konya with different characteristics were chosen as the study area. These neighborhoods names are Saraçoğlu, Lalebahçe, Gödene and Yazır. Some characteristics of these neighborhoods are given in Table 1 below. In this way, it is another aim of this study to examine the possible effects of socioeconomic variables and neighborhood characteristics on water consumption.

The meteorological data used in the study are monthly data between 2007-2017 obtained from Konya General Directorate of Meteorology, Regional Station which is numbered 17245. The meteorological parameters planned to be used in the study; Monthly Maximum Pressure(X_1), Monthly Maximum Humidity(X_2), Monthly Maximum Temperature (X_3), Monthly Maximum Rainfall (X_4), Monthly Minimum Pressure (X_5), Monthly Minimum Relative Humidity (X_6), Monthly Minimum Temperature (X_7), Monthly Average Pressure (X_8), Monthly Average Relative Humidity (X_9), Monthly Average Wind Speed (X_{10}), Monthly Average Temperature (X_{11}), Monthly Average Water Vapor Pressure (X_{12}) and Monthly Total Rainfall (X_{13}).

B. Method

Multiple regression analysis which is one of the statistical methods was used as the method. If there is more than one independent variable in the regression analysis, this linear analysis is called multiple regression analysis. Occasionally, while an appropriate independent variable is available for the dependent variable, the explanatory power, in other words, the coefficient of determination (indicates that how much of the change in the dependent variable is explained by the X_1 and X_2 arguments) may be small, and independent variables that can strengthen the model may be excluded from the model. Therefore, new independent variables can be added to strengthen the existing model. $Y=b_0+b_1X+\varepsilon$ includes new x independent variables. However, there should not be strong and close relationships between the independent variables used in the model. For example, if the correlation between X_1 and X_2 is 0.990, then there is not much difference between the coefficient of determination of the two-variable model and the coefficient obtained in the analysis of the one variable model where X_1 is just used. Therefore, when selecting independent variables for the model, those who do not have strong relationships among themselves will be selected (Ünver et al., 2013).

Theoretically, there are infinite independent variables for the explanation of the Y dependent variable. However, in practice, 1, 2, sometimes 3 independent variables explain a large part of the Y dependent variable. The question is how to choose the appropriate model when there are n independent variables? A scatter plot (regression diagram) is used to explain the relationship between the dependent variable and the independent variable. Helps investigate possible cause/effect relationships. The horizontal axis of a scatter diagram shows the values taken by X independent variables and the vertical axis shows the values taken by Y dependent variables. Since there is one independent variable in simple regression analysis, the scatter diagram is formed in a plane and the appropriate model is easily selected. However, when there are two or more independent variables model selection is not easy because the points corresponding to the observation values are not in a plane but within a volume. The regression model where n independent variables exist is given in Equation 1 (Ünver et al., 2013).

$$\mathrm{Y} = b_0 + b_1X_1 + b_2X_2 + \cdots + b_nX_n + \varepsilon \quad (1)$$

In this equation, Y is a dependent variable, $X_1, X_2, \ldots, X_n$ are independent variables and $b_0, b_1, b_2, \ldots, b_n$ are unknown parameters. b_0 represents the point at which the regression line intersects the y-axis and is called constant. At the same time, ε is the error term in the equation. For example, if there are two independent variables, the linear regression model would be like equation 2.

$$\mathrm{Y} = b_0 + b_1X_1 + b_2X_2 + \varepsilon \quad (2)$$

b_0, b_1 and b_2 are unknown parameters in the equation, so b_0, b_1 and b_2 statistics are again found by the least-squares method with random sample data(Ünver et al., 2013).

Two methods of multiple regression analysis were used in the analysis of SPSS, which are Enter and Stepwise methods. Enter is a regression analysis in which all available independent variables are added to the model. For the shaping of the stepwise model, significant and strong independent variables of the dependent variable are taken. The selections are made from the highest correlation to the lowest. When including the independent variables in the model, it holds only one of the 2 interconnected variables in the model, so it solves the problem of multicollinearity(Işık, 2006).

Table 1. Working areas to be used in the current study

The name of the	Name of the	2018	Building characteristics	Socio-Economic Level

neighborhood	**District**	**Population**		
Saraçoğlu	Karatay	6.725	Low-rise	Low
Lalebahçe	Meram	6.150	Low-rise	High
Gödene	Meram	14.214	high-rise	Low
Yazır	Selçuklu	61.483	high-rise	High

III. RESULTS

In this study, firstly, multiple regression analysis was performed on the data between 2007-2017 and low R^2 values and insufficient results were obtained as a result of the analysis. For this reason, in order to obtain better results, multiple regression analysis was performed by changing the year intervals and more successful results were obtained with the data between 2011 and 2017. The stepwise method was selected in the analysis and by using this method the most suitable models were found.

As a result of the study, the results of the analysis of residential subscribers are given in Table 2. When we look at the table, it is seen that R^2 values improve especially as we approach 2011 for Gödene. For the Yazır neighborhood, it has risen from 0.045 to 0.206, but it would be more acceptable if it were about 0.5. In Table 3, the analysis results of the total subscribers are given. for total subscribers, R^2 values are also increased when approached in 2011. When the two tables are examined, the analysis results of Lalebahçe, Saraçoğlu and Gödene are acceptable, but unfortunately, Yazır's analysis results are not safe and sufficient especially for residential subscribers and water demand is not much affected by climate factors.

Table 5 shows the constant coefficients and the coefficients of the independent variables of the most appropriate models for each neighborhood. In this direction, $Y = -76,859 + 0,172X_{11} - 0,059X_6 + 0,038X_6 + 0,0094X_8$ equation is found for Lalebahçe neighborhood. $Y = -51.23 + 0,073X_{11} + 0,058X_8 + 0,019X_6$ equation is found for the Saraçoğlu neighborhood. $Y = -34,064 + 0,047X_3 + 0,039X_8$ model is available for Gödene neighborhood. $Y = -38.93 + 0,138X_{12} + 0,045X_1$ model is found for Yazır neighborhood.

Referring to Table 5, for Lalebahçe neighborhood respectively the monthly average temperature, monthly maximum relative humidity, monthly minimum relative humidity and monthly average pressure; for saraçoğlu neighborhood Monthly Average Temperature, Monthly Average Pressure and Monthly Minimum Relative Humidity; for Gödene neighborhood Monthly Maximum Temperature and Monthly Average Pressure; for Yazır neighborhood Monthly Average Water Vapor Pressure and Monthly Maximum Pressure are important factors and have been selected as the most appropriate independent variables. As a result of most suitable models that emerged, it is shown that temperature is the most important factor for Lalebahçe, Saraçoğlu and Gödene neighborhoods (Tables 4 and 5). In particular, Average temperature has the largest correlation with unit water consumption. The sign of the correlation coefficient of the average temperature is + or positive, which means that when the temperature rises, the unit water consumption increases. There are some reasons why temperature can affect water consumption positively. Evaporation and water loss are higher as the temperature increases and both gardens and people need more water. As the temperature increases, people sweat more and take more baths on one side and wash more clothes on the other.

Table 4 shows the correlations and impacts of each of the 13 climatic factors with the unit water consumption for each neighborhood. If the average temperature values in Table 5 are examined, it is seen that the largest values belong to Lalebahçe and Saraçoğlu neighborhoods. On the other hand, since these neighborhoods are single storey, it can be thought that the houses in these neighborhoods have gardens and they need more irrigation when the temperature increases, especially the economic situation of the residents in Lalebahçe neighborhoods is better than Saraçoğlu neighborhood. At the same time, in general, when the temperature rises, people take more baths, sweat and wash clothes, thirst more and swim if they have pools.

After the temperature, it is seen that maximum relative humidity and minimum relative humidity for the Lalebahçe neighborhood and minimum relative humidity for Saraçoğlu neighborhood are important factors.

Table 2. Analysis results of residential subscribers

Years	method	neighborhoods			
		Lalebahçe	Saraçoğlu	Gödene	Yazır
2007-2017	stepwise	0.724	0.467	0.078	0.045
	enter	0.708	0.449	0.051	0.009

2008-2017	stepwise	0.756	0.497	0.178	0.063
	enter	0.755	0.494	0.102	0.044
2009-2017	stepwise	0.781	0.493	0.475	error
	enter	0.775	0.502	0.479	0.034
2010-2017	stepwise	0.788	0.510	0.442	0.049
	enter	0.776	0.512	0.442	0.055
2011-2017	stepwise	0.803	0.671	0.608	0.206
	enter	0.784	0.641	0.701	0.175

Table 3. Analysis results of all subscribers

Years	method	neighborhoods			
		Lalebahçe	Saraçoğlu	Gödene	Yazır
2007-2017	stepwise	0.525	0.392	0.176	0.333
	enter	0.508	0.366	0.135	0.303
2008-2017	stepwise	0.547	0.392	0.312	0.343
	enter	0.519	0.398	0.267	0.348
2009-2017	stepwise	0.519	0.413	0.615	0.348
	enter	0.499	0.424	0.609	0.332
2010-2017	stepwise	0.552	0.398	0.621	0.420
	enter	0.519	0.423	0.596	0.412
2011-2017	stepwise	0.569	0.458	0.780	0.557
	enter	0.583	0.564	0.770	0.508

Table 4. Correlation values between unit water consumption and climate factors of residential subscribers in 2011-2017

	Lalebahçe Neighborhood	Saraçoğlu Neighborhood	Gödene Neighborhood	Yazır Neighborhood
	unit water consumption	unit water consumption	unit water consumption	unit water consumption
unit water consumption	1,000	1	1	1
Monthly Maximum Pressure (hPa)	-0,645	-0,514	-0,492	-0,132
Monthly Maximum Humidity (%)	-0,651	-0,465	-0,523	-0,059
Monthly Maximum Temperature (°C)	0,822	0,746	0,764	0,332
Monthly Maximum Rainfall (mm=kg/m²)_OMGİ	-0,162	-0,068	-0,072	0,128
Monthly Minimum Pressure (hPa)İ	0,390	0,432	0,412	0,224
Monthly Minimum Relative Humidity (%)	-0,436	-0,297	-0,378	0,078
Monthly Minimum Temperature (°C)	0,860	0,76	0,736	0,31
Monthly Average Pressure (hPa)	-0,343	-0,194	-0,192	0,058
Monthly Average Relative Humidity (%)	-0,777	-0,646	-0,596	-0,112
Monthly Average Wind Speed (m/sn)	0,466	0,358	0,364	0,019
Monthly Average Temperature (°C)	0,870	0,774	0,757	0,301
Monthly Average water vapor pressure (hPa)	0,727	0,729	0,702	0,416
Monthly Total Rainfall (mm=kg÷m²) OMGİ	-0,341	-0,259	-0,202	0,012

Table 5. The coefficients of the most important models given by Stepwise method in SPSS for 2011-2017

Coefficients of important factors given by stepwise for 2011-2017

	R^2		B(standardized coefficients)	β (unstandardized coefficients)
Lalebahçe Neighborhood	0.803	constant	-76,859	
		Monthly Average Temperature (°C)	0,172	0,896
		Monthly Maximum Humidity (%)	-0,059	-0,243
		Monthly Minimum Relative Humidity (%)	0,038	0,166
		Monthly Average Pressure (hPa)	0,0094	0,143
Saraçoğlu Neighborhood	0.671	(Constant)	-51,23	
		Monthly Average Temperature (°C)	0,073	1,036
		Monthly Average Pressure (hPa)	0,058	0,239
		Monthly Minimum Relative Humidity (%)	0,019	0,226
Gödene Neighborhood	0.608	(Constant)	-34,064	
		Monthly Maximum Temperature (°C)	0,047	0,869
		Monthly Average Pressure (hPa)	0,039	0,221
Yazır Neighborhood	0.206	(Constant)	-38,93	
		Monthly Average water vapor pressure (hPa)	0,138	0,676
		Monthly Maximum Pressure (hPa)	0,045	0,358

IV. DISCUSSION

In order to estimate future unit water consumption of Lalebahçe, Saraçoğlu and Gödene neighborhoods, which are connected to the central districts of Konya province, the most important factor is temperature among the climatic factors and especially the average temperature has the highest correlation with the unit water consumption. By using the Stepwise method in the Spss program, we see that the average temperature is the most efficient factor given by the analysis model. Temperature is a dominant factor in unit water consumption in Konya city.

V. CONCLUSION

The aim of this study was to find out the relationship between unit water consumption and climate factors in 4 different neighborhoods and to determine which factors are more effective for which neighborhoods. Multiple regression analysis was performed using the Stepwise method. As a result of the analysis, temperature is the most important factor for Lalebahçe (average temperature), Saraçoğlu (average temperature) and Gödene (maximum temperature) neighborhoods, and wind speed and maximum rainfall are not effective. meanwhile, average pressure and maximum relative humidity are other efficient factors.

Monthly Average Water Vapor Pressure and Monthly Maximum Pressure were the most appropriate factors for Yazır neighborhood for the estimated model.

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