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Impact of water pricing policy and climate change on future water demand in Volos, Greece

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Abstract: The aim of this study is the water demand forecasting in the city of Volos and the evaluation of various parameters affecting it, such as water price, temperature and rainfall. Time series data of water consumption levels and the number of water meters from 2007 to 2012 were collected from databases of Water Utility of Volos, while raw data concerning rainfall and temperature were retrieved from weather stations in the city of Volos. Furthermore, the elasticities of the parameters introduced in the scenarios were available from previous survey conducted by the University of Thessaly. Those elasticities indicate the grade each parameter affects the water consumption, such as the water price and climatic conditions (temperature and rainfall). Subsequently, nine scenarios were created by altering one or more parameters and via the proposed forecasting model (prediction equation), using the specific water consumption and the number of water meters. Estimations of future water demand for the years 2013-2024 under different pricing policies and climate change scenarios were performed using the WEAP model. Then, a scenario comparison was conducted in order to export more conclusions referring to the future consumption. The results of this study prove that rational water pricing can lead to remarkable water conservation.

Key words: Water demand forecasting, elasticity, water consumption, water pricing

1. INTRODUCTION

It is obvious that problems connected with water resources and their exploitation in combination with the general environmental problems have been continuously increased. The situation is expected to be sharpened still more in the near future due to the impacts from climate change (reduction of rainfalls and intensity of extreme meteorological phenomena) (IPCC, 2001, 2007). Besides, in Greece, water resources management is based in most regions in the management of its natural offer taken water demand for granted. This confrontation is ineffective, and leads with mathematic certainty to an economic and environmental impasse, having as a main characteristic the exhaustion of water resources (Brundtland, 1987). The causes of crisis of water differ from country to country and from region to region depending on natural, economic, social and political conditions that prevail in each study area. However, the more systematic approach could recognize the existence of common characteristics (Serageldin, 1995).

This study aims to simulate and forecast the urban water demand in the city of Volos, as a function of all the factors mentioned above, under various scenarios, in order to propose sustainable solutions and alternative management policies.

2. STUDY AREA

Volos is the capital of the prefecture of Magnesia (Central Greece) with a population of approximately 144,420 inhabitants. Volos has a Mediterranean climate with an average annual temperature of 16.4 °C and 504 mm of annual rainfall. The Municipal Water Utility of Volos is responsible for the urban water supply in the city. Also, the Industrial Area is under the Municipal Water Utility of Volos. The water needs are covered by 5 springs and 40 wells, and the water is collected in 8 reservoirs.

The city faces problems of water adequacy, mainly due to the leakages, which are estimated to be above the 40% of the total supplied water. Furthermore, major environmental issues arose the last decades, such as, the systematically extraction of the non-renewable ground water, the contamination of ground water due to lixiviation of agricultural fertilizers, chemicals and heavy metals and the salinisation of the ground water creating many environmental problems on the quantity and the quality of the water resources (Mylopoulos and Mentes, 2005).

The broader study area was divided into five main sectors. Sectors 1, 2 and 3 cover the former municipality of Volos, whereas sector 4 the former municipality of Nea Ionia. Finally the last sector covers the Industrial Area.

3. METHODOLOGY

3.1 Development of the water demand forecasting model

The methodology is a classical process with a prediction equation used in various similar studies (Fafoutis, 2008; Alamanos and Betsios, 2014), where the future water demand depends on the number of water meters, the specific water consumption per capita per day in the base year and one or more of the following parameters: water pricing, temperature and rainfall.

The prediction equation used in the forecasting model is:

$$Q_y = N \,.\, q^* .\, (X_{1,y}/X_{1,b})^{\beta 1} .\, (X_{2,y}/X_{2,b})^{\beta 2} \dots (X_{i,y}/X_{i,b})^{\beta i} \qquad (1)$$

where:

Q_y : the residential water consumption for month m
N : the number of water meters
q^* : the specific consumption per capita per day in the base year
d_m : the number of days in each month
$X_{i,y}$: the value of parameter i in the year of prediction y
$X_{i,b}$: the value of parameter i in the base year b
β_i : the elasticity of parameter i

3.2 Data used

Time series data of water consumption levels and the number of water meters, in each consumption sector of the city from 2007 to 2012, were collected from databases of the Water Utility (Water Utility of Volos, 2011), while raw data concerning rainfall and temperature were retrieved from meteorological stations in the city of Volos.

The elasticity of a parameter indicates the grade that affects the water consumption. When the elasticity is positive, the water demand increases when the value of the parameter increases also. However, when the elasticity is negative, an increase of the value of the parameter leads to a decrease in water demand.

The elasticities of the parameters introduced in the scenarios were available from a previous survey conducted by the University of Thessaly (Bonaros, 2014), where the elasticity of water pricing, temperature and rainfall were estimated -0.524, 0.109 and -0.026 respectively.

3.3 Scenario analysis

For the purposes of the study, nine scenarios were developed and simulated. Analysis was formulated using the following assumptions: in all scenarios the water meters have a steady increase in the forecasting period, according to the trendline equation, which was originated from the data referring to the number of water meters in the years 1994-2012. Moreover, the specific consumption per capita per day in the base year was considered that remains constant through the forecasting years and was calculated by dividing the total annual consumption to the residents and the days of the base year.

The base year used is 2012 and projections of water consumption levels are made for years 2013 and 2024 under nine different scenarios (water pricing policy and climate change scenarios):

Scenario 1: price of water is stable from 2012 to 2024

Scenario 2: increase in water price so that the real price of water will remain stable and equal to the real price of water in 2012

Scenario 3: drought for years 2012 and 2024 (10% increase of temperature and 20% decrease of rainfall every four years)

Scenario 4: wet weather conditions for years 2012 and 2024 (10% decrease of temperature and 20% increase of rainfall every four years)

Scenario 5: 5% increase of the real price of water every four years (base year 2012)

Scenario 6: 10% increase of the real price of water every four years (base year 2012)

Scenario 7: 20% increase of the real price of water every four years (base year 2012)

Scenario 8: 20% increase of the real price of water every four years and wet weather conditions (10% decrease of temperature and 20% increase of rainfall every four years)

Scenario 9: the real price of water is stable from 2012 to 2024 and drought (10% increase of temperature and 20% decrease of rainfall every four years)

All scenarios were simulated using the WEAP software (Water Evaluation And Planning system), which supports the analysis of various scenarios for integrated water resources management and helps design the policy of their exploration.

In this study, the schematic of the city was set up first. Then, the supply sources (groundwater), the reservoirs and the demand sites for each water sector of the city were placed. Finally, all the above components were connected (transmission link) and the data of each component of the schematic were imported in the WEAP software (Figure 1).

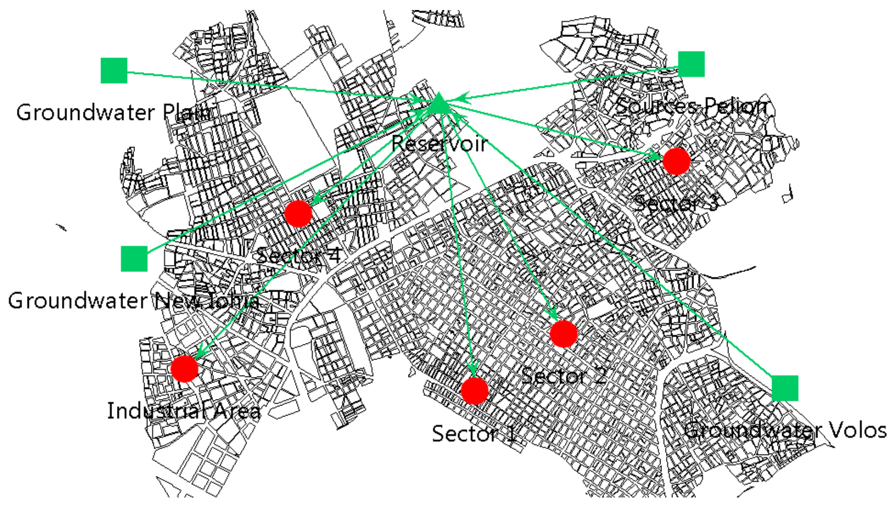

Figure 1. WEAP schematic

4. RESULTS AND DISCUSSION

4.1 Valuation

The water demand of the city of Volos, for each scenario, resulted from the forecasting model is presented in Figure 2.

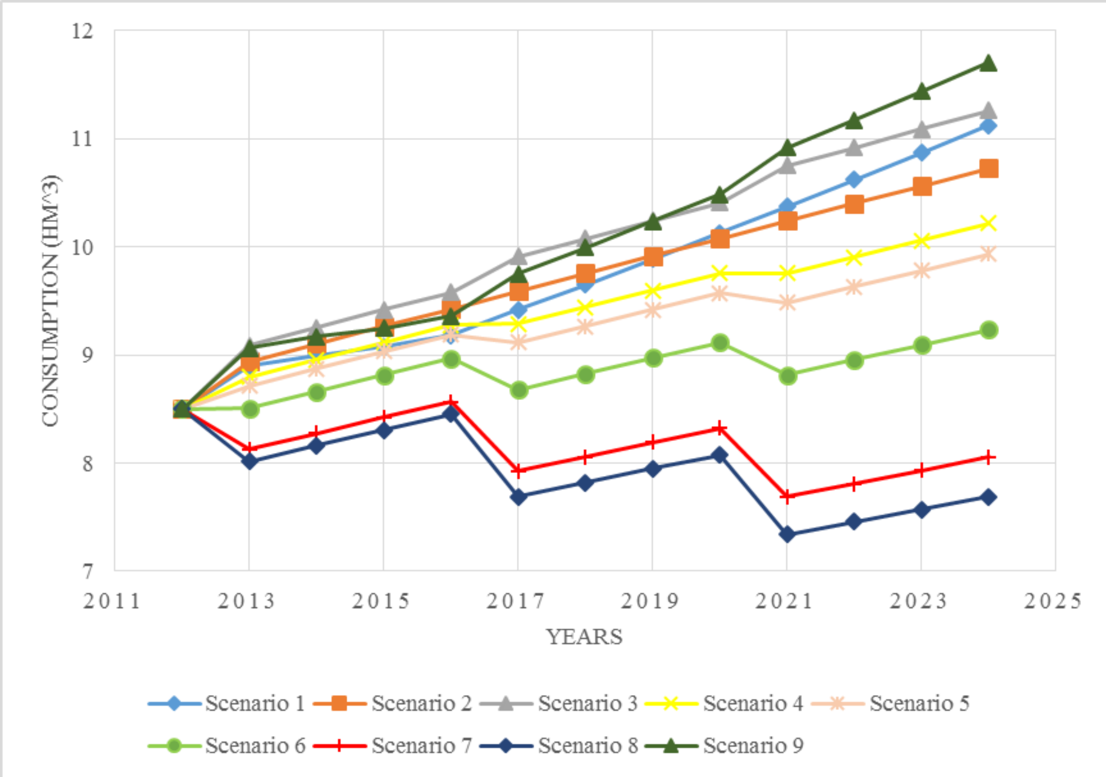

Figure 2. Total water consumption (m^3) for years 2013-2024 under scenarios 1-9

It is evident that there are notable differences in water demand levels under the nine different scenarios. Important increases in water consumption levels appear under scenarios 1, 2, 3, and 9. Only under scenarios 7 (where the real price of water increases 20% every four years) and 8 (where the real price of water increases 20%, the temperature decreases 10% and the rainfall increases 20% every four years) there is a decrease in water consumption. Under scenarios 4, 5 and 6 water demand increases at lower scales in relation to the increase noticed under scenarios 1 and 9.

If the average annual water supply of the years 2007-2012, is assumed until 2024 and an average of 40% network losses is applied for the same time period, then the water balance can be calculated for every prediction scenario.

The findings mentioned above are fully justified: the water balance of scenario 1 is in line with the predictions of the continuous deterioration of the available water resources. Thus, the necessity of reducing the water losses is proved to be immediate. Regarding the water balance of the other scenarios, compared to scenario 1 (do-nothing), it is observed that the increasing water price has a positive impact on the water balance (scenarios 5, 6 and 7), otherwise the unmet demand will be significant (scenarios 2 and 9). The results of scenarios 3, 4 and 8 were as expected, due to their extreme climate changes.

4.2 Comparison

4.2.1 Water pricing policies

The scenarios referring to water pricing policies are 1, 2, 5, 6 and 7. In these scenarios the water demand levels are affected by the real price of water, besides the increase of water meters that affect all scenarios studied (Figure 3).

Scenario 1 simulates the future demand by assuming that no pricing measures are taken by the Municipal Water Utility of Volos. The differences in water demand levels, by comparing scenarios 2, 5, 6, 7 with scenario 1, are caused exclusively by the changes of the real price of water. Therefore, it is obvious how the real price of water eventually affects the future water consumption.

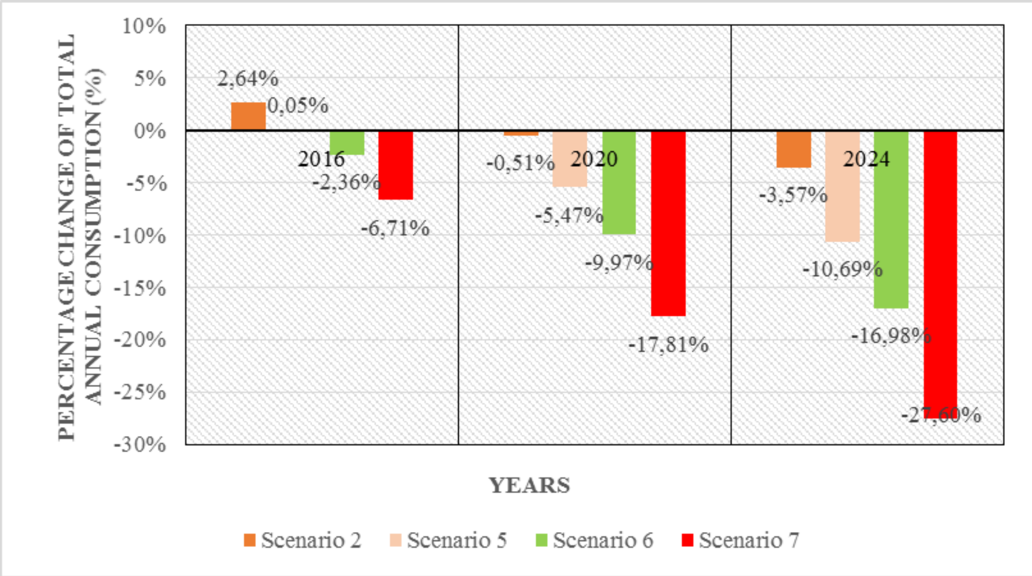

Figure 3. Percentage change (%) of total annual consumption every four years under scenarios 2, 5, 6, 7 compared to scenario 1

So, if in the upcoming years the Water Utility will not be able to provide larger amounts of water, and at the same time the water meters (number of consumers) increase, a water pricing policy, similar to scenario 7, will result in a total water consumption remaining almost stable until 2020 and then reducing until 2024.

If the amounts of water available in the upcoming years are larger than today, a water pricing policy corresponding to scenarios 5 and 6 should be adopted, because one of the basic principles of water resources sustainable management is the water demand management and not the ongoing supply increase (supply management).

Furthermore, the pricing policies of scenarios 1 and 2 must definitely not be adopted, since the water consumption level provided is very high and trying to cover this requirement, it will have very negative impact on the environment.

Hence, it is necessary to adopt a pricing policy, where the real price of water will increase in upcoming years as part of the water demand management.

4.2.2 Climate change scenarios

The climate change scenarios are 3 and 4. By comparing them, it is investigated how the climatic conditions eventually affect the future water consumption. Scenarios 3 and 4 examined the assumptions of drought and wet conditions for the upcoming years respectively, using as base scenario the pricing policy described in scenario 2 (where the real price of water remains constant and equal with that of 2012 for the forecasting period). In scenario 2 the future consumption is affected only from the increase of water meters, while in scenarios 3 and 4 the future consumption is affected additionally from the climate changes (Figure 4). Therefore, the differences in the future consumption levels are due to the changes in temperature and rainfall.

From this comparison, it is clear that the climate changes will not affect critically the levels of future consumption, although very extreme changes in temperature and rainfall are assumed, that are hardly possible to be verified.

The climate change scenarios differ from pricing policies scenarios, discussed so far, since here the changes in the parameters affecting them are independent of the human factor. Nevertheless, the results are very useful, since for example in case of drought, the consumption that will come up, requires a proper demand management policy, rational pricing and public awareness and information policy in order to cover it.

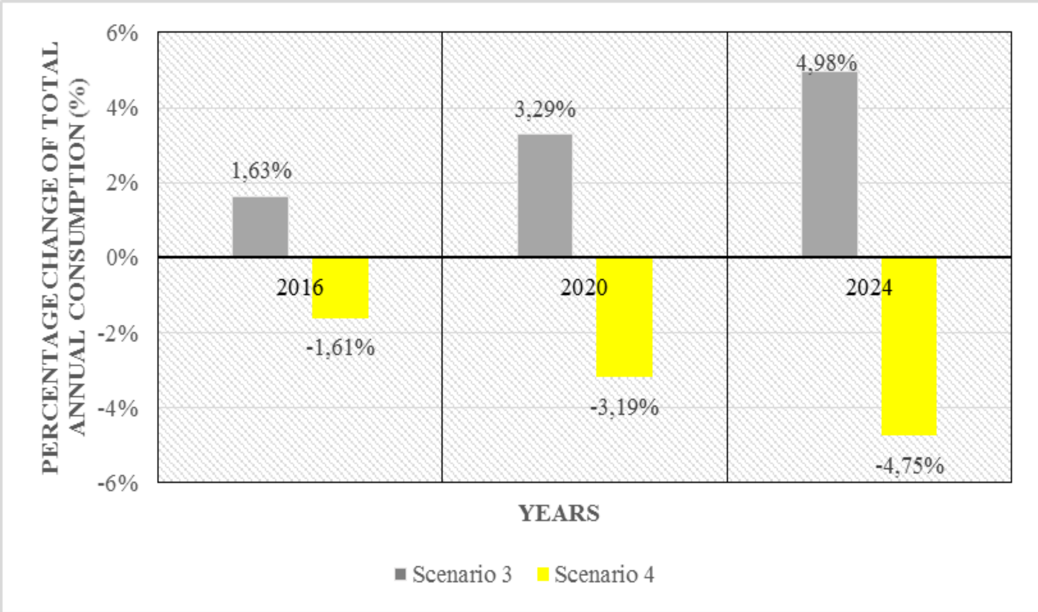

Figure 4. Percentage change (%) of total annual consumption every four years under scenarios 3 and 4 compared to scenario 2

5. CONCLUSIONS

The study attempts to propose policies in order to cover the future water consumption and cost-effectiveness, under various future conditions, in the city of Volos. Different scenarios focusing on water pricing and climate change were investigated.

The selected prediction equation shows that the effect of elasticities on the future water demand is significant, since they indicate the exponential change of each parameter. The fact that the equation allows changing each parameter separately while keeping the others constant, shows the impact of each variable on the total future consumption.

The study did not intend to define a new equation or methodology, but to simulate the condition of water supply and demand in the city of Volos. That led to the conclusion that demand increases dramatically. The exploitation of the water resources was proved insufficient, and a large number of wells are being used, damaging the aquifer. A large quantity of water is not being billed, and it shows an increasing trend after 2009.

Water pricing is proved to be a very important financial tool for the water demand management, since it is the only factor perceived directly by the consumers and is compatible with the principles of the Sustainable Water Resources Management and the Water Framework Directive 2000/60/EC (WFD, 2000; Fafoutis, 2008). This is also reinforced by the results of scenario 5, where a small price increase leads to significant water savings. In any case, the Water Utility of Volos should adopt a water policy directed towards to the water demand management, the reduction of the losses and the implementation of rational water pricing, in order to achieve water conservation and sustainable use.

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