Assessing the impacts of socio-economic and hydrological factors on urban water demand: A multivariate statistical approach

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SUMMARY

The multivariate statistical techniques conducted on quarterly water consumption data in Mytilene reveal valuable tools that could help the local authorities in assigning strategies aimed at the sustainable development of urban water resources. The proposed methodology is an innovative approach, applied for the first time in the international literature, to handling urban water consumption data in order to analyze statistically the interrelationships among the determinants of urban water use. Factor analysis of demographic, socio-economic and hydrological variables shows that total water consumption in Mytilene is the combined result of increases in (a) income, (b) population, (c) connections and (d) climate parameters. On the other hand, the per connection water demand is influenced by variations in water prices but with different consequences in each consumption class. Increases in water prices are faced by large consumers; they then reduce their consumption rates and transfer to lower consumption blocks. These shifts are responsible for the increase in the average consumption values in the lower blocks despite the increase in the marginal prices.

1. Introduction

Water is an essential component of life and tends to be degraded continuously in both quantitative and qualitative terms. Today water is harvested but not cultivated (Baumann and Boland, 1997). The islands of Greece constitute a typical example. During the past few decades, the islands of the Aegean Archipelagos have experienced a period of economic growth because of tourism. Every year hundreds of thousands of foreign and native tourists visit the Greek Aegean islands offering a development pool for the local communities. As a result, the demand for water is extremely high during the summer period. At the same time, the natural resources of surface and groundwater are scarce and severely stressed in those areas due to the relatively small size of the land and the low annual amount of precipitation. Consequently, imbalances between inflows and outflows in the water budgets threaten the sustainability of the water resources. The only feasible solution in many cases is the desalination of seawater, which can offer the quantities of water necessary to cover demand for drinking supplies. However, desalination is not the only solution for all islands. The islands of the north-eastern Aegean have sufficient water reservoirs to cover urban demands if local authorities apply proper plans and management strategies.

The implementation of a successful integrated water resources management plan requires in-depth knowledge of the determinants influencing urban water demand. Econometric models (Martínez-Espiñeira, 2003; Garcia and Reynaud, 2004; Babel et al., 2007; Rauf and Siddiqi, 2008; Dharmaratna and Harris, 2012; Polycarpou and Zachariadis, 2013) and artificial neural networks (Lui et al., 2003; Bowden et al., 2005; Firat et al., 2010; Babel and Shinde, 2011) are becoming popular tools for predicting water demand. Alternatively, another statistical approach could be used complementarily for this purpose. Factor analysis is a widely utilized and broadly applied statistical technique in the fields of both water resources and the social sciences. Many authors have applied factor and principal component analysis with socio-economic and hydrological variables (Soares et al., 2003; Lambrakis et al., 2004; Panagopoulos et al., 2004; Papatheodorou et al., 2007; Panagopoulos and Panagiotaras, 2011; Salvati and Zitti, 2011; Zhang et al., 2011; Lin et al., 2012; Menció et al., 2012; Valder et al., 2012) to identify interconnections and interrelationships among variables in complex hydrological systems.

This paper presents the first attempt to use factor analysis to identify interconnections between the demographic, socio-economic and hydrological variables that affect urban water consumption. A typical Mediterranean city, Mytilene, was selected for the application of the proposed methodology due to data availability and the absence of an integrated water resources management plan, according to the directive of European Union 2000/60.

The remainder of the paper is structured as follows: Section 2 briefly presents the study area; Section 3 describes the data used and the methodology applied; Section 4 presents and discusses

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the results; Section 5 offers some concluding remarks as well as policy implications.

2. Study area

Lesvos is the third largest Greek island, covering a total area of 1632 km². Lesvos is located in the north-eastern part of the Aegean Archipelagos in the eastern Mediterranean region (Fig. 1a). Mytilene, the capital of the Lesvos prefecture, has a population of 37,889 (2011 census data). The boundaries of Mytilene have been extended since 1999 when the surrounding villages were integrated into the united Mytilene municipality in accordance with the Kapodistrias plan.

Mytilene has a typical Mediterranean climate with warm to hot, dry summers and mild to cool, wet winters. Most of the precipitation occurs between November and March, with an annual average rainfall of 588 mm. The mean annual temperature is 17.9 °C (Mytilene meteorological station).

More than 80% of the urban water demand of Mytilene is met by the large karst spring, Hydata, which is located near the Geras Gulf coast, 10 km west of the town (Fig. 1b). The Hydata karst spring has a mean annual flow rate of 730 m³/h and supplies the urban network with 5.1 million litres per day. When the spring has insufficient discharge to satisfy the entire water supply network, two shallow wells near the spring are put into operation. Panagopoulos et al. (2012) applied a multi-criteria decision analysis technique using a GIS platform and compiled a spatial potential water demand map of Mytilene, identifying five priority zones. A large proportion of the city was classified as representing high and very high priority areas for future urban water demand, thus necessitating the adoption of appropriate policies and strategies by the local water authority, the Municipal Water Board (MWB) of Mytilene, which is responsible for supplying water and sewerage services.

3. Data and methodology

The data set used for the analyzes was provided by the MWB of Mytilene (unpublished data made available to the author). These data are for the 1993–2012 period and include information on
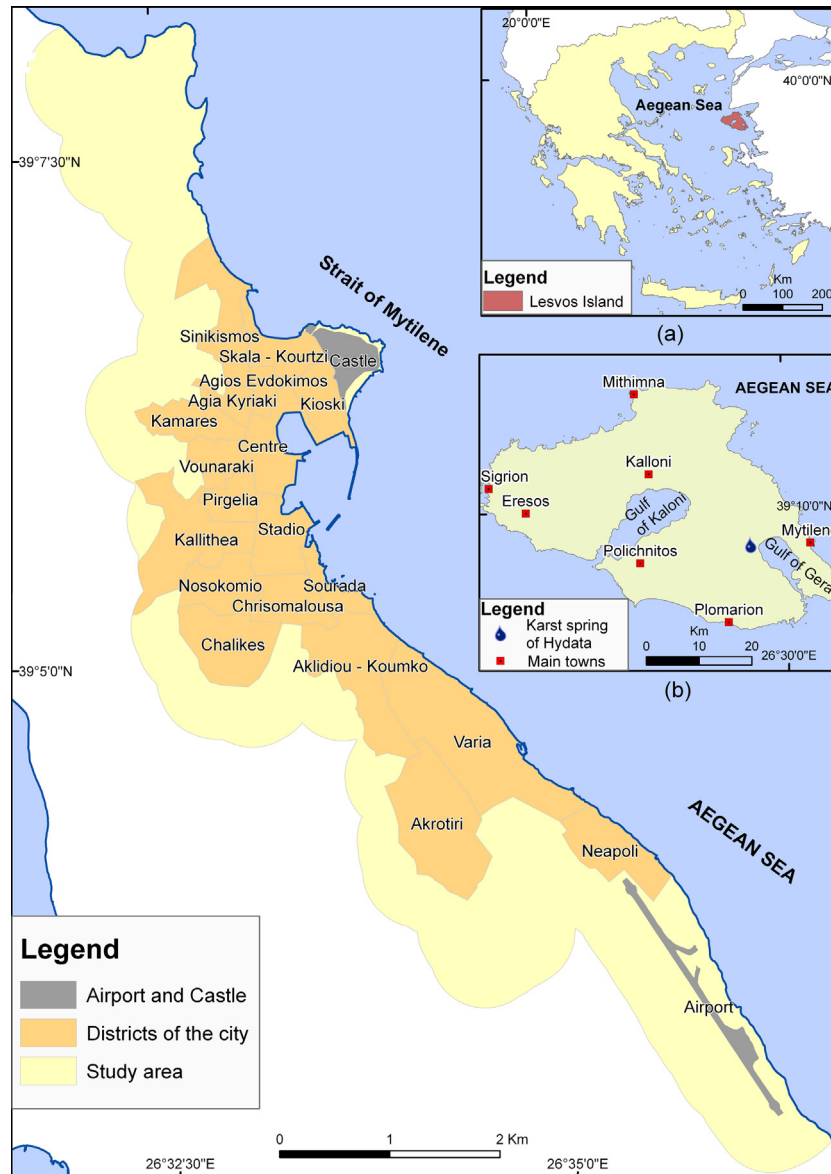

Fig. 1. Location map of the districts of Mytilene, showing the geographical position of Lesvos Island (a) and the main water supply spring (b).