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Review and assessment of the adaptive capacity of the water sector in Cyprus against climate change impacts on water availability

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ABSTRACT

This paper presents an overview and assessment of the measures implemented in Cyprus that are considered in order to address the impacts of climate change on the water availability of the country. Considering that an adaptation framework on water resources has not yet been established either at European level or in Cyprus, specific measures that address climate change impacts on water availability, constituted the basis of the analysis. The measures reviewed are in the form of infrastructural works, policy plans and strategies, legislative actions, market-based instruments (e.g. pricing mechanisms and subsidies), technologies and practices, research, as well as awareness and dissemination activities. The measures are assessed based on their effectiveness, their robustness under climate change uncertainty and their sustainability in environmental, economic and social terms. In addition, potential barriers and risks associated to the implementation of the adaptation are identified. The results of the study revealed that although there is a substantial number of adaptation measures in place that are considered to address climate change impacts on water resources and the adaptive capacity of the water sector has considerably increased, the overall vulnerability remains high, as water demand is still not satisfied at certain areas and/or for certain uses, in times of drought. Furthermore, there should be a shift towards a more balanced and integrated approach on water management in Cyprus, according to which demand-side measures are further enhanced, while adverse impacts associated with the implementation of the measures are minimized to the degree possible.

1. Introduction

Climate change, such as increases in temperature, precipitation variability, increase in the intensity and frequency of extreme weather events (e.g. floods, droughts) and sea level rise affect freshwater systems and their management (Kundzewicz et al., 2007) with a potential for high vulnerability not only for water resources, but also for human societies and ecosystems (Bates et al., 2008). The southern and south-eastern regions of Europe and the Mediterranean region in particular, which already experience water stress, are expected to be exposed to further reductions in water availability and increases in drought frequency and intensity due to climate change (EEA-JRC-WHO, 2008; Kundzewicz et al., 2007). Moreover, the increase in water temperature and in precipitation intensity as well as the elongation of drought periods, are strongly believed to exacerbate many forms of water pollution (Parry et al., 2007). Finally, a potential sea-level rise will cause salinization of coastal aquifers with low water levels (Arnell et al., 2001; Bates et al., 2008; Kundzewicz et al., 2007).

Water resources management is also challenged by other existing and arising pressures in addition to climate change impacts, such as the increasing water demand and the human-induced deterioration of water quality, which are expected to be exacerbated with climate change (Arnell et al., 2001). Therefore, it is necessary to take into account climate change in water management decisions in the framework of an adaptation strategy to increase adaptive capacity and resilience of water resources to climate change impacts (Cisneros et al., 2014; Hallegatte, 2009; Nelson et al., 2007).

The area of Cyprus studied in this paper is the southern part of the island which is under the effective control of the Government of the Republic of Cyprus, while the northern part of the island that is occupied by Turkey is out of the scope of this paper. As the Republic of Cyprus and the international community do not recognize the self-declared Turkish Republic of Northern Cyprus, there cannot be any kind of collaboration for the management of the island's

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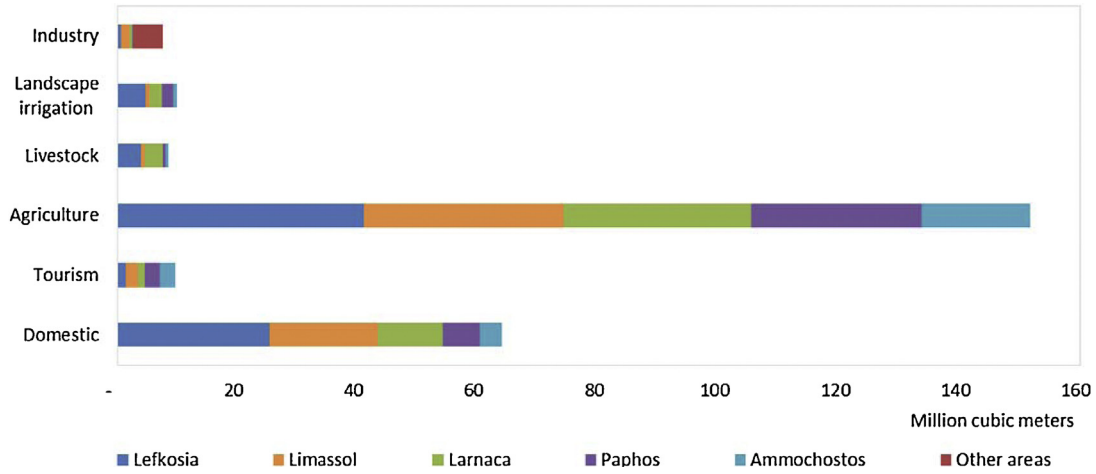

Fig. 1. Water demand per sector and region in Cyprus, year 2011.

Based on data given in WDD (2011a).

freshwater resources. Nevertheless, it is estimated that any transboundary water flow between the two parts, does not exceed 10% of the total water resources (WSM, 2002).

1.1. Water resources and climate change in Cyprus

According to the Water Development Department (WDD) of the Ministry of Agriculture, Natural Resources and Environment of the Republic of Cyprus (WDD, 2011a), the annual total water demand in the areas under government control for the year 2011 was estimated to be around 250 million cubic metres (Mm^3). The sector with the highest water consumption is agriculture accounting for 60% of overall water consumption, followed by the domestic sector with 25%, while the remaining 15% is evenly distributed (3–4%) between the other sectors. The highest share of water is consumed in the District of Lefkosia (31% of total demand), where the capital of the Republic of Cyprus is located, while the other Districts of Lemesos, Larnaca, Pafos and Ammochostos account for 22%, 19%, 16% and 10% of total water demand respectively. The water demand per sector and region is depicted in Fig. 1.

The water resources of Cyprus are considered quite vulnerable to climate change, since they are already limited due to the semi-arid climate of the island. Freshwater availability depends almost entirely on rainfall which is highly variable with frequent prolonged periods of drought (WDD, 2011a). As a result, water demand for various uses frequently exceeds the amount of freshwater available. Diminishing precipitation and increased evapotranspiration with consecutive years of drought has led to the depletion of surface water stored in reservoirs and the over-exploitation of aquifers (direct climate change effect) especially for agriculture as the irrigation period elongated (WDD, 2011a). Furthermore, restrictions in water supply imposed in periods of drought have often led private water consumers to illegally abstract water from boreholes (indirect climate change effect), which resulted in further deterioration of groundwater quantitative status. The Water Exploitation Index (WEI), which expresses the share of the annual total amount of freshwater abstraction for a given country to its long term average available freshwater resources (Raskin et al., 1997), is for the case of Cyprus 70% (average for the period 2003–2013) (Eurostat, 2015b), which is well beyond the upper threshold of 40% indicating severe water stress.

With respect to the qualitative status of Cyprus' water resources, groundwater bodies are considered particularly vulnerable to quality deterioration, considering that almost half of its groundwater bodies are characterized as in bad qualitative condition according to the Water Framework Directive (WDD, 2011a). A potential sea level rise would exacerbate seawater intrusion to coastal aquifers, while lower recharge rates may further increase concentration of pollutants. Surface water bodies in Cyprus are mainly comprised of the storage reservoirs with no inflows during summer months (WDD, 2011a), thus resulting in low pollutant dilution capacity. Finally, droughts affect both water availability and quality. Drought phenomena in Cyprus are very frequent, persistent and severe and have lasted up to 8 consecutive years. In particular, Cyprus registered among the highest frequencies of droughts in Europe during the period 1976–2006 (EC, 2008).

According to the output of the PRECIS regional climate model for the A1B emissions scenario of the Intergovernmental Panel on Climate Change (IPCC), the expected future climate changes in Cyprus which are considered to adversely affect its water resources are: the increase in annual mean air temperature; the decrease in precipitation; the increase in the frequency and intensity of drought periods and; the increase in heavy rainfall events (Papadaskalopoulou et al., 2015). The projected future climate change is expected to significantly deteriorate the already water stressed situation in Cyprus.

The current water policy of Cyprus does not take into consideration climate change in its programme of measures, although many of the measures foreseen in the policy may be considered as adaptation measures, given that they share the same ultimate objective that is to meet water demand.

The aim of this paper is to identify the measures implemented in Cyprus that contribute to increasing the resilience of the water sector to climate change and to assess them with respect to their effectiveness; their robustness under climate change uncertainty and; their environmental, economic and social sustainability. In addition, the paper aims to identify the potential barriers and risks associated to the implementation of the adaptation measures.

2. Adaptation in the water sector

Adaptation is defined as the adjustment of a system to changing climatic conditions and their effects, in order to alleviate adverse impacts or to exploit opportunities (Adger et al., 2005; Parry et al., 2007). Adaptive capacity is the ability of a system to prepare for expected changes in climate, as well as to respond to the effects caused by these changes (Smit et al., 2001).

Climate change is increasingly taken into consideration by the authorities throughout the world when developing long-term management plans (Arnell et al., 2001). The adaptation options in water management for meeting water demand can be broadly categorized