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Challenges for water resources and their management in light of climate change: the case of Cyprus

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ABSTRACT

The aim of this study is to assess the impacts of climate change on the water resources of Cyprus with special emphasis on water availability and to evaluate the capacity of the resource itself, as well as of the government and people in Cyprus to adapt to climate change. The methodology followed includes the recording of the baseline situation and the assessment of climate change impacts and vulnerabilities. For the assessment, climate projections produced by regional climate models were used. The climate change factors, which are considered to affect the water resources in Cyprus, refer to the increase in temperature, the decrease in precipitation as well as the increase in droughts and in heavy rainfall. For the impact assessment, the changes in river and groundwater flows as well as other WSIs were studied. For the adaptation assessment, the degree of freshwater and non-freshwater resources exploitation and the measures for water demand reduction and the enhancement of drought preparedness were examined. At first, priorities with regard to climate change vulnerability, the water availability for domestic water supply and irrigation in mountain areas and the water availability for irrigation in plain and coastal areas were identified, while water availability for domestic water supply was estimated to present limited vulnerability to climate change.

Keywords: Climate change; Impacts; Vulnerability; Adaptation; Water resources

1. Introduction

Climate changes, such as increases in temperature, precipitation variability and sea level rise, affect freshwater systems and their management [1] with a potential of high vulnerability, not only for water resources but also to human societies and ecosystems as a consequence [2]. Already stressed water resources are considered more vulnerable to climate change.

The water resources of Cyprus are limited due to the semi-arid climate that characterizes the island. Freshwater availability depends almost entirely on

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rainfall which is highly variable with frequent prolonged periods of drought. As a result, water demand frequently exceeds the amount of freshwater available. Although water availability has substantially increased through the exploitation of non-freshwater resources (desalinated and recycled water) and the decrease in water consumption, the pressure on water resources remains obvious. Another significant pressure posed on the water resources of Cyprus is the water demand for the tourism sector (4% of the total water demand) [3], which intensifies the competition for water between the water users, given its substantial contribution to the economy of Cyprus.

2. Methods

2.1. Impact, vulnerability and adaptation to climate change

The methodology followed for the assessment of impacts, vulnerability and adaptation (IVA) is structured upon 3 basic steps:

Step 1: Recording of the baseline situation. In this step, several data that are considered relevant for the IVA assessment were recorded, such as the water resources available, demand, environmental condition, pressures, strategy plans and management measures.

Step 2: Identification of impacts. In this step, literature review has been conducted on the observed and expected impacts of climate change worldwide and especially at the wider area, where Cyprus is located. The impacts for the case of Cyprus were identified and relevant data were presented where available. Following, the trends of the observed impacts and the likelihood of the expected impacts were evaluated.

Step 3: Vulnerability assessment. In this step, the overall vulnerability of the water resources of Cyprus to climate change was assessed and the key vulnerabilities for the sector were identified. Vulnerability was assessed with the use of quantitative and qualitative indicators of sensitivity, exposure and adaptive capacity based on the available data. In particular, sensitivity is defined as the degree to which water resources are affected by, or responsive to changes, in climate; exposure is the degree to which water resources are exposed to climate change and its impacts, while the adaptive capacity is defined by the ability of water resources to adapt to changing environmental conditions, as well as by the effectiveness of the relative existing and planned adaptation measures to address climate change impacts. Sensitivity and exposure describe the potential climate change impact on the system. When either of these terms is zero, there is no impact at all and hence, there is no vulnerability. Furthermore, the greater the impact, the greater is the vulnerability. On the other hand, adaptive capacity is inversely related to vulnerability, i.e. the greater the adaptive capacity, the lesser is the vulnerability. The relationship between these terms is considered to be better reflected by the following qualitative Eq. (1), which was presented in [4] and was applied for the prioritization of vulnerabilities in the framework of this study.

$$Vulnerability = Impact - Adaptive\,capacity \qquad (1)$$

where Impact = Sensitivity × Exposure.

In order to quantify the future vulnerability potential of water resources against climatic change, impact, adaptive capacity and vulnerability were evaluated with the use of a qualitative 7-scale ranging from "None" to "Very high" (Table 1). The key vulnerabilities have been identified as those impacts gathering an overall vulnerability score ranging from "Moderate" to "Very high".

The general concept of the methodology followed was adopted by the "Impacts, Adaptation and Vulnerability" assessment reports of the Intergovernmental Panel on Climate Change (IPCC) [5], while the assessment was further elaborated by the CYPADAPT[1] project team. The basic idea of this concept has been applied with small variations in other regions as well, such as in the Nordic countries for the assessment of vulnerability and adaptive capacity in the framework of the Caravan project [6].

The main sources of information used at international and European level were technical reports of the IPCC [2,7], the European Commission [8], the European Environment Agency (EEA) and the Joint Research Centre [9,10] as well as other scientific publications on the subject. For the case of Cyprus, the main source of information was the Water Development Department (WDD) of the Ministry of Agriculture, Natural Resources and Environment, as well as several academic and research institutions and private companies in Cyprus.

2.2. Climate change projection

To assess the impacts of future climate change in Cyprus on the water sector, the climate projections output produced by the PRECIS (Providing Regional Climates for Impact Studies) regional climate model was used. PRECIS study domain is the Eastern

[1]LIFE+ project with title "Development of a national strategy for adaptation to climate change adverse impacts in Cyprus", LIFE10ENV/CY/000723.

Table 1
Impact, adaptive capacity and vulnerability scales

Degree of impact and adaptive capacity		Degree of vulnerability	
None	0	None	$V \leq 0$
Limited	1	Limited	$0 < V \leq 1$
Limited to Moderate	2	Limited to Moderate	$1 < V \leq 2$
Moderate	3	Moderate	$2 < V \leq 3$
Moderate to High	4	Moderate to High	$3 < V \leq 4$
High	5	High	$4 < V \leq 5$
High to Very high	6	High to Very high	$5 < V \leq 6$
Very high	7	Very high	$6 < V \leq 7$
Not evaluated	–	Not evaluated	–

Mediterranean and the Middle East in the centre of which lies Cyprus. Two time periods, namely the control period (1961–1990) and the future period (2021–2050), were examined based on the IPCC A1B emissions scenario [11].

3. Results and discussion

3.1. Climate change and their impacts on water resources

Water resources are closely interrelated to climate as the water cycle strongly depends on climate factors. Some of the main components of the water cycle are evaporation, evapotranspiration, condensation, precipitation, infiltration and runoff. Changes in temperature, precipitation patterns and snowmelt can have impacts on water availability [12]. Changes in the volume and timing of precipitation, as well as in evaporation induce changes in river flows. Furthermore, changes in the amount of effective rainfall and in the duration of the recharge season alter groundwater recharge rates [1]. In addition, climate affects soil moisture and, consequently, causes infiltration of water to groundwater bodies. Extreme climatic events, such as heavy rainfall and flooding hamper water storage, result in significant water losses.

According to the Fourth Assessment Report (AR4) of IPCC, it is believed that with high confidence that higher water temperatures, increased precipitation intensity and longer periods of low flows exacerbate many forms of water pollution. Increased temperatures, decreased precipitation and increased evapotranspiration may lead to condensation and eutrophication of water bodies due to lower dissolution of sediments, nutrients, dissolved organic carbon, pathogens, pesticides and salt. What is more, sea level rise threatens coastal groundwater bodies with salinization.

However, there is no evidence for climate-related trend in water quality [12] and thus the impact, vulnerability and adaptation assessment in the framework of this study will focus on the climate change impacts on water availability.

The observed and expected climate change factors in Cyprus, which are considered to affect water resources, are the increase in the annual mean air temperature, the declining trend of precipitation, the increase in the frequency and intensity of prolonged drought periods, the increase in heavy rainfall events and the increase in evapotranspiration.

3.2. Impact assessment

For the assessment of the climate change impact on the water resources of Cyprus, indicators of freshwater availability in relation to precipitation were used, such as the changes in river and groundwater flows (see Sections 3.2.1–3.2.3). Furthermore, other indicators that reflect the pressure posed on the water resources of Cyprus as a result of limited availability, excessive demand and unsustainable management were used (see Sections 3.2.3–3.2.6). These indicators were selected based on the perception that systems already exposed to additional (non-climatic) pressures are considered more vulnerable to climate change [12]. The assessment of the indicators revealed a *"Very high"* impact of climate change on the water availability of Cyprus for both domestic use and irrigation. Following, the evaluation of the indicators used to assess the impact of climate change on the availability of water resources in Cyprus is presented.

3.2.1. Change in river flow

River flows in arid and semi-arid regions like Cyprus are highly sensitive to changes in rainfall. A given percentage change in rainfall can produce a considerably larger percentage change in runoff. In order to estimate the inflow to the dams in the future, the relationship between precipitation and inflow for each of the dams is Cyprus was studied, based on historical records. As every dam is characterized by different conditions (hydrological, topographic, etc.), it was found that the inflow was affected by precipitation following a similar pattern for each dam [13]. This pattern was depicted with the regression curves that best suited the relationship precipitation–inflow. Next, these relationships were used in order to predict future dam inflow based on the projected precipitation by PRECIS. The results showed a substantial decrease in the future total dam inflow of 23%, while the average change in precipitation was estimated to be −5% (Table 2). However, it must be mentioned that this method does not take into account the changes in evaporation and runoff conditions in the future which could potentially further decrease inflow.

3.2.2. Standardized precipitation index

During the period 1969–2010, Cyprus has suffered from a number of severe droughts. In all cases, the events initiated as meteorological droughts but very quickly they developed into hydrological droughts since Cyprus has no perennial rivers and the rivers' length is very short.

In order to assess the magnitude and severity of exposure of Cyprus to droughts, the Standardized Precipitation Index (SPI) [14] was used. SPI is designed to quantify the precipitation deficit for multiple time scales. These time scales reflect the impact of drought on the availability of the different water resources. Soil moisture conditions respond to precipitation anomalies on a relatively short scale. Groundwater, streamflow and reservoir storage reflect the longer-term precipitation anomalies. For these reasons, the SPI for the 12 month time scale was computed for four different areas in Cyprus (Limassol, Nicosia, Larnaca, and Panagia), using as input projection data on precipitation produced by PRECIS. Positive SPI values indicate greater than median precipitation and negative values indicate less than median precipitation. In Fig. 1, the differences between the control period (1960–1990) SPI

SPI value	*Characterization*
0–(−0,99)	Mild drought
(−1)–(−1,49)	Moderate drought
(−1,5)–(−1,99)	Severe drought
<(−2)	Extreme drought

Table 2
Observed and future estimated precipitation and dam inflow in Cyprus for the periods 1970–2000 and 2021–2050 respectively

	Dam capacity		Precipitation (mm)			Dam inflow (Mm^3)**		
Main dams	Mm^3	(%)	1970–2000*	2021–2050	Change (%)	1970–2000*	2021–2050	Change (%)
Kouris	115	41	671	623	−7.1	25.1	19.9	−20
Asprokremmos	52	19	604	611	+1.1	5.1	5.4	+7
Evretou	24	9	809	773	−4.5	5.4	4.9	−10
Kannaviou	18	6	695	664	−4.5	6.7	5.7	−14
Kalavasos	17	6	542	509	−6.1	35.6	23.1	−35
Dipotamos	16	6	462	444	−4.0	4.8	4.3	−11
Yermasoyia	14	5	608	565	−7.1	12.5	9.0	−28
Arminou	4	2	745	702	−5.8	13.5	11.4	−15
Polemidia	3	1	520	483	−7.1	2.7	2.0	−26
Mavrokolympos	2	1	564	529	−6.2	1.3	1.1	−17
Lefkara	14	5	536	517	−3.5	0.7	0.6	−11
Sum	279	84	Average		−4.7			
					Sum	113	87	
Total dam capacity	332	100			Total dam inflow adjusted to 100%	128	99	
						Average		−22.8

*The data referring to the period 1970–2000 were sourced from [3].
**Million cubic meter.

and the future period (2021–2050) SPI are depicted. As it can be seen, the frequency and severity of drought years is considerably increased in the future period in all four examined areas in Cyprus. The characterization of the SPI values is presented next.

3.2.3. Change in groundwater levels

The decrease in effective rainfall and the consecutive years of drought in conjunction with the intense agricultural development that took place during the second half of the previous century in Cyprus led to the depletion of surface water stored in reservoirs and the exploitation of aquifers (direct climate change effect), especially for agriculture as the irrigation period elongated. Furthermore, cuts in water supply by the Government imposed in periods of drought or high water pricing 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. Indicatively, it is mentioned that during the period 2005–2007, irrigation water supply was provided by 73% from non-government water works (mainly groundwater) and the remaining 27% from GWW (mainly surface water) [15]. According to the WDD of the Ministry of Agriculture, Natural Resources and Environment of the Republic of Cyprus [16], only 2 of the 19 groundwater bodies in Cyprus are not over-pumped[2], revealing the intense pressure posed on them.

3.2.4. Freshwater availability per capita

Considering that already stressed water resources are considered more vulnerable to climate change, the Falkenmark Water Stress Indicator (WSI) [17,18] was used for the quantification of water stress caused by the limited availability of freshwater resources in Cyprus. The WSI divides the volume of available water resources for a region by its population. Its threshold values indicate that water availability of more than 1,700 m^3/capita/y is defined as the threshold above which, water shortage occurs only irregularly or locally. At levels between 1,700 and 1,000 per person per year, the region is experiencing water stress, while below 1,000 m^3/capita/y, it is said to be experiencing chronic water scarcity. The water stress classification levels as proposed by Falkenmark et al. [18] are presented next.

Available freshwater resources (m^3/capita/year)	Water stress level
> 10,000	Limited water management problems
10,000–1,700	General water management problems
1,700–1,000	Water stress
1,000–500	Chronic water scarcity
< 500	Beyond the “water barrier” of manageable capability

The WSI for the case of Cyprus was calculated by the Food and Agriculture Organization (FAO) [19] by dividing the total renewable water resources of Cyprus, based on average precipitation data of the period 1960–1990 provided by the IPCC, by the total population of Cyprus in 2000, based on data provided by FAOSTAT. The corresponding value of the indicator was 995 m/capita/y which, according to the WSI thresholds, indicates that the country suffers from chronic water scarcity. The observed and projected decrease in precipitation and increase in the population of Cyprus are considered to further lower the value of the indicator, thus increasing the severity of the problem of water scarcity.

3.2.5. Water exploitation index

Another relatively straightforward indicator of the pressure on freshwater resources is the Water Exploitation Index (WEI). It relates water availability and water use and is defined as the ratio of annual water withdrawal from ground and surface water to the total renewable freshwater resources. Hence, high water stress indices can either be caused by low availability and/or excessive high water demand [20]. A WEI above 20% implies that a water resource is under stress and values above 40% indicate severe water stress and clearly unsustainable use of the water resource [21]. According to EEA [20], the WEI of Cyprus for the year 2007 was 64%, which is by far the highest WEI value among the European countries.

3.2.6. Water availability index

The difficulty faced by Cyprus in meeting water demand either for satisfying drinking water supply or for other purposes such as agriculture, tourism and industry, due to water stress, indicates the sensitivity of the sector to climate change. The Water Availability

[2]Over-pumping or non-sustainable abstraction refers to the amount of water that is abstracted in excess of the sources' recharge as a fraction of the total water abstractions.

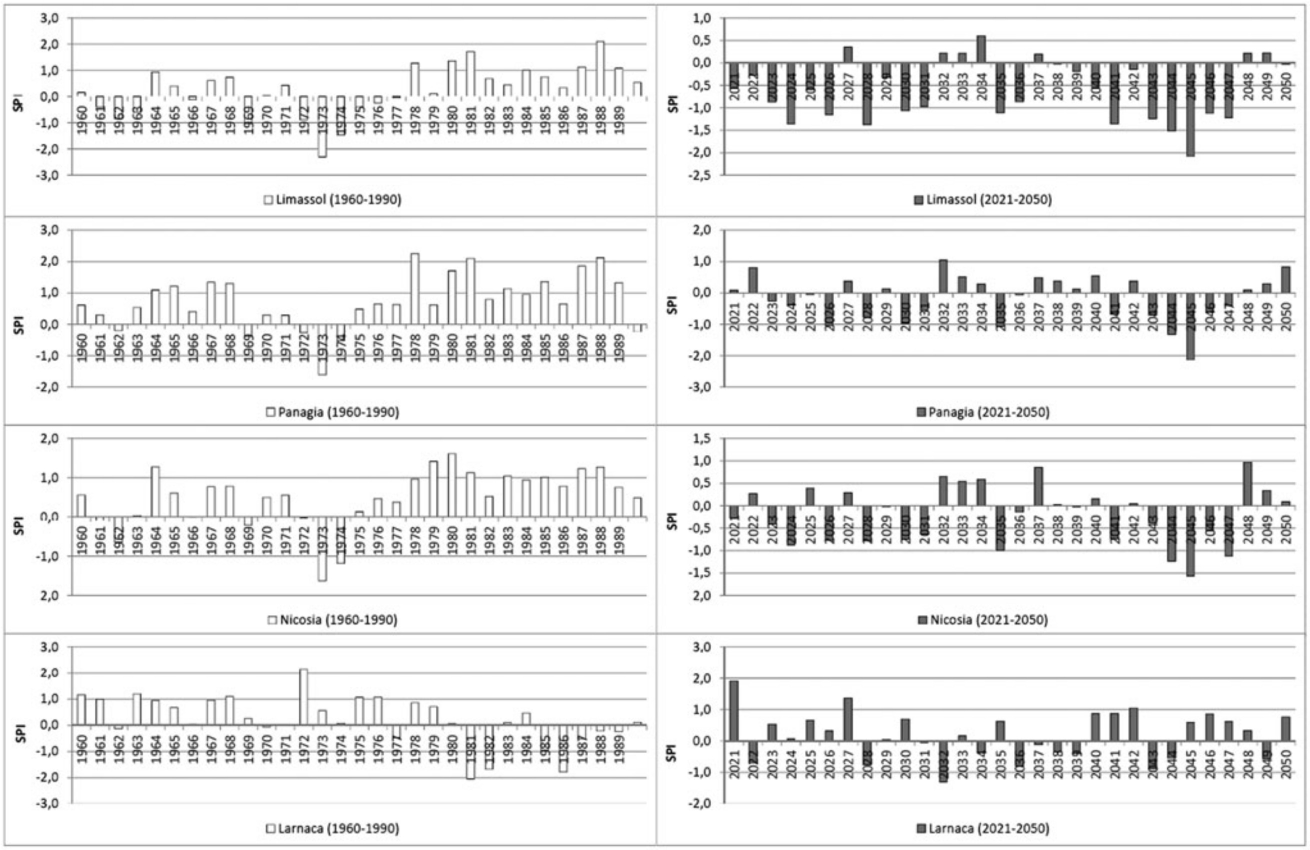

Fig. 1. Standard Precipitation Index for Limassol, Nicosia, Larnaca and Panagia for the periods 1960–1990 and 2021–2050.

Index (WAI) [22] takes into account surface water and groundwater resources and compares the total amount to the demands of all sectors, i.e. domestic, industrial and agricultural demands. The index is normalized to the range $-1 < \text{WAI} < 1$. A score of −1.0 indicates that there is negligible water available to meet the demands, whilst a score of 0.0 indicates that the available water meets the demands and a score of 1.0 indicates that the available water is much greater than the demands [23]. In the case of Cyprus, WAI is estimated to be −0.07 for the period 2000–2010 indicating that, on average, the demand is higher than the availability of freshwater sources. In fact, during that period, water demand exceeded available freshwater resources 7 out of 11 years (WDD[3]).

3.3. Adaptation assessment

Several measures, plans and water works have been implemented by the government of Cyprus in order to increase water availability and decrease the consumption for both domestic use and irrigation, such as the exploitation of freshwater resources (surface water and groundwater) and non-freshwater resources (sea water and treated municipal effluent), the reduction of water demand and the enhancement of drought preparedness. These actions are considered to reinforce Cyprus' adaptive capacity to climate change and therefore, they were used as indicators in the adaptation assessment. Considering that the extent of their implementation and, hence, of their effectiveness often varied depending on the local conditions, it was decided to categorize the evaluation of adaptive capacity as follows: (i) water availability for domestic water supply in urban areas, (ii) water availability for domestic water supply in mountain areas, (iii) water availability for irrigation in plain and coastal areas and (iv) water availability for irrigation in mountain areas.

The evaluation of the adaptive capacity indicators concerning drinking water availability showed that many of the measures adopted have already alleviated the problem of water scarcity in the urban areas, as continuous water supply to the domestic sector has

[3]Unpublished data provided by Mr Dimitriou Charalambos, Water Development Department of the Ministry of Agriculture, Natural Resources and Environment.

been secured mainly by desalination plants, and significant savings have been achieved in water consumption. Therefore, Cyprus' adaptive capacity to water availability for domestic water supply in the urban areas is considered to be "High to Very high" while the adaptive capacity to water availability for domestic water supply in the mountain areas is considered as "Limited to Moderate".

As for the water availability for irrigation, the measures applied have not yet managed to fully satisfy water demand, especially in the mountain areas as agriculture constitutes the main water consumer in Cyprus (over 60% of total water demand), and restrictions in water supply for irrigation are a common phenomenon during summer when the water resources are limited. Therefore, the adaptive capacity of Cyprus to water availability for irrigation in the plain and coastal areas is considered as "Moderate", while the adaptive capacity to water availability for irrigation in the mountain areas is considered as "Limited to Moderate".

The assessment of the adaptive capacity indicators is presented in detail in the sections that follow.

3.3.1. Exploitation of freshwater resources

The Republic of Cyprus, in order to satisfy drinking water and irrigation demand, has delivered a number of water works for the exploitation of the available freshwater resources, such as storage reservoirs. In particular, prior to 1997, the water policy of Cyprus focused on exploiting every drop of water ("not a drop to be lost in the sea"), by investing in dam construction and in increasing their capacity. A total of 108 dams have been constructed with a combined storage capacity of 332 Mm^3 [3]. It is worth mentioning that, by the standards of the International Commission of Large Dams (ICOLD), Cyprus is the first in Europe regarding the number of dams per square kilometer. However, dams constructed in mountain areas mainly for irrigation water supply are of limited capacity due to technical restrictions imposed by local conditions, and thus their reserves are usually depleted during drought periods.

It must also be mentioned that dams are not a panacea since their construction is linked with environmental deterioration. More specifically, dams alter the flow of rivers, block migratory fish species from their spawning and feeding sites and disrupt sediment transport downstream, thus seriously disturbing ecosystems. In addition, dam construction results in great reductions of the natural riverbed recharge of the downstream aquifers.

To increase freshwater exploitation, the government of Cyprus has given special emphasis to the exploitation of groundwater aquifers in which accumulated flows (>1 year) are stored. However, droughts have substantially reduced the direct and indirect groundwater recharge while farmers, in their effort to maintain agricultural production levels, have unsustainably exploited the source. Excessive overpumping of the coastal aquifers resulted in sea water intrusion, which further led to quality deterioration of coastal aquifers as well as to the depletion of inland aquifers.

For that reason, intension of the Government Water Policy is to progressively reduce the use of groundwater by setting proposed volumes of abstraction for each of its aquifers according to their quantitative condition and to rehabilitate salinized aquifers. Nevertheless, it must be noted that the rehabilitation of a groundwater body heavily affected by sea intrusion is a very slow process and, sometimes, almost impossible [24].

3.3.2. Exploitation of non-freshwater resources

The use of non-freshwater resources such as (a) desalinated water and (b) treated municipal wastewater in water supply for certain uses can substantially alleviate the pressures on the freshwater resources which are already high in Cyprus.

(a) Desalination constitutes a secure source for safe drinking water supply, once demand management measures are fully implemented. Government policy of Cyprus is the complete independence of the water supply of the urban and tourist areas from rainfall and the satisfaction of the maximum demand during the summer period using desalination plants. The desalination capacity in Cyprus has increased from 40,000 m^3/d in 1997, when the first desalination plant in Cyprus operated, to 252,000 m^3/d in 2012 [3]. The contribution of desalination plants to domestic water supply for 2010, which was a relatively wet year, amounted to 65%. However, desalinated water is distributed mainly in the urban centres of Cyprus through government water works (GWW), while other areas, such as the mountain communities, still depend on freshwater resources (mainly groundwater) for meeting their drinking water needs.

In addition, concerns on the extensive adoption of desalination arise due to the fact that it constitutes an energy intensive process producing a residue (brine) that must be carefully treated and disposed in order to prevent environmental degradation. Hence, desalination could be considered a mal-adaptation measure unless certain requirements are taken into account, such as the use of renewable energy and the proper treatment and disposal of brine produced.

(b) Recycled water is a resource which has been given increased attention in recent years. The use of treated wastewater provides additional drought-proof water supply, favours a more local sourcing of water and avoids the use of high-quality water sources, where this is not necessary. In Cyprus, there is an immense potential for growth of water reuse practices driven by both the demand for water and the increasing volumes of treated effluent. Main aim is to use the increasing quantities of treated effluents produced for irrigation of the agricultural crops, thus substantially alleviating the pressures posed to the sector due to water scarcity. Treated wastewater is used in Cyprus for the irrigation of green spaces, athletic fields and crops (excluding edible raw vegetables) as well as for aquifer recharge. Providing recycled water through GWW reached 12 Mm^3 in 2010 of which 9 Mm^3 was supplied for irrigation and about 3 Mm^3 for artificial aquifer recharge [3]. However, recycled water is distributed mainly in the coastal and plain areas, where the necessary infrastructure for its transfer is there, while in mountain areas, this is not economical.

Finally, it must be mentioned that there is stakeholder opposition to groundwater recharge with recycled water due to quality concerns related to the risk of drinking water resources pollution. Further treatment of certain quantities of the effluent with the process of reverse osmosis is under consideration in order for the water salinity to be reduced and the final effluent to be used for the irrigation of sensitive soils and crops.

3.3.3. Water demand reduction

The government of Cyprus has implemented a series of measures for the reduction of water consumption such as (i) the replacement of water distribution networks to reduce water losses, (ii) the provision of subsidies to reduce domestic water consumption with the use of untreated groundwater or greywater in certain uses and the recycling of hot water in households, (iii) the provision of technical and financial assistance to farmers to turn from traditional surface irrigation methods to modern irrigation methods, (iv) the installation of water supply meters to observe consumption and to follow up effects of water saving measures, (v) the establishment of water allocation mechanisms under drought conditions to provide priority, firstly to maintaining domestic and municipal water supplies, then to perennial crops and finally to seasonal vegetable crops, (vi) the reduction in the fragmentation of agricultural holdings to allow for scale economies in irrigation works and (vii) the organization of awareness campaigns with lectures in schools, advertisements, distribution of informative leaflets and other initiatives. In addition, the government is investigating the formulation of an effective water pricing system for achieving water savings [25].

3.3.4. Drought preparedness

Drought management is an essential element of water resources policy and strategies in drought-prone areas such as Cyprus. Following up the recent drought management of 2008 in Cyprus, it was found that adaptive strategies were limited. Dealing with the shortfall of water resources consisted of corrective and emergency measures with the implementation of drought mitigation plans. Decision makers have reacted to drought episodes mainly through a crisis-management approach by declaring a national or regional drought emergency programme to alleviate drought impacts. Nevertheless, nothing can be done to reduce the recurrence of drought events in a region. Therefore, drought management should not be regarded as managing a temporary crisis. Rather, focus must be given on developing comprehensive, long-term drought preparedness policies and plans of actions that place emphasis on monitoring and managing emerging stress conditions and other hazards associated with climate variability in order to significantly reduce the risks and vulnerabilities to extreme weather events [3].

The WDD of Cyprus has elaborated a drought management plan (DMP) in 2010 [26] in order to address these issues. The DMP of Cyprus structures upon the EU policy on drought management and is closely linked with the Government Water Policy which is based on the Water Framework Directive criteria and objectives. The main elements of the Cyprus DMP are (i) an early drought warning system based on hydrological indicators, (ii) a correlation of indicators with thresholds for different drought stages to trigger action and (iii) a set of phase-specific measures to achieve objectives.

The DMP is considered as a significant adaptive capacity indicator in the field of proactive adaptation for the water availability in Cyprus with regard to climate change, since its implementation is expected to contribute to the timely identification of the presence of a drought and to the effective management of water resources for the limitation of the adverse climate change impacts on the sector.

3.4. Overall vulnerability assessment

The outcomes of the impact and adaptation assessment were quantified with the use of the 7-degree qualitative scale (Table 1) and inserted to the respec-

Table 3
Overall climate change vulnerability assessment of the water availability in Cyprus

		Impact (A)	Adaptive Capacity (B)	Vulnerability (A–B)
Water availability for domestic water supply	In urban areas	Very high (7)	High to Very high (6)	Limited (1)
	In mountain areas	Very high (7)	Limited to Moderate (2)	High (5)
Water availability for irrigation	In plain and coastal areas	Very high (7)	Moderate (3)	Moderate to High (4)
	In mountain areas	Very high (7)	Limited to Moderate (2)	High (5)

tive variables of Eq. (1) in order for the overall vulnerability to be calculated. The results of the vulnerability assessment for the water availability in Cyprus are summarized in Table 3.

4. Conclusions

In conclusion, the "first priority" vulnerabilities for the water sector in Cyprus are related to the water availability for domestic water supply and irrigation in mountain areas. Water supply in Cyprus is considered to be very highly affected by climate change, while mountain areas have low adaptive capacity to cope with these changes mainly due to the insufficiency of GWW attributed to techno-economical reasons. The "second priority" vulnerability of the sector is related to the water availability for irrigation in plain and coastal areas. Although water availability in plain and coastal areas is enhanced by GWW and the competition for water between the domestic and the agricultural sector is not so intense, it does not always meet actual water demand for irrigation (especially during drought periods). Water availability for domestic water supply was estimated to present limited vulnerability to climate change given that, although, freshwater resources, most of the times, are not sufficient for satisfying demand for drinking water, the government of Cyprus has markedly increased water supply with desalinated water, thus relieving the island from such a pressure.

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