Future Technology
Open Access Journal
ISSN 2832-0379

February 2023| Volume 02 | Issue 01 | Pages 01-12

Journal homepage: https://fupubco.com/futech

https://doi.org/10.55670/fpll.futech.2.1.1

Future Publishing LLC

Review

# Climate change, water resources, and wastewater reuse in Cyprus

**Hüseyin Gökçekuş [1,3,4], Youssef Kassem [1,2,3,4], Marcus P. Quoigoah [5*], Prisca Nashon Aruni[5*]**

[1]Department of Civil Engineering, Civil and Environmental Engineering Faculty, Near East University, 99138 Nicosia (via Mersin 10, Turkey), Cyprus
[2]Department of Mechanical Engineering, Engineering Faculty, Near East University, 99138 Nicosia (via Mersin 10, Turkey), Cyprus
[3]Energy, Environment, and Water Research Center, Near East University, 99138 Nicosia (via Mersin 10, Turkey), Cyprus
[4]Engineering Faculty, Kyrenia University, 99138 Kyrenia (via Mersin 10, Turkey), Cyprus
[5]Department of Environmental Engineering, Civil and Environmental Engineering Faculty, Near East University, 99138 Nicosia (via Mersin 10, Turkey), Cyprus

**ARTICLE INFO**

*Article history:*
Received 05 August 2022
Received in revised form
04 September 2022
Accepted 08 September 2022

Keywords:
Water, water resources,
climate change, wastewater reuse,
Cyprus

*Corresponding author
Email address: mquoigoah@gmail.com

DOI: 10.55670/fpll.futech.2.1.1

**ABSTRACT**

This study aims to gain a deeper understanding of climate change and wastewater usage in Cyprus. Focusing on water resources, the study was done in Cyprus. The significance of selecting Cyprus as our case study arises from the fact that it is not only one of the Mediterranean Sea countries worldwide with water resource concerns but also faces a serious danger of drought in the next years. Documentary analysis and summation of what numerous sources mentioned regarding the freshwater situation in Cyprus were used to collect data. The objective of this research was to understand the water resources available in Cyprus and the quality of fresh water, then to examine the practices and mechanisms of freshwater resource management in Cyprus, and finally to investigate the challenges faced by various water resources in Cyprus and the various means to overcome them. The initial objective was to determine the different water resources in Cyprus. Second, we analyzed the many strategies employed to manage these resources and the diverse management structures in Cyprus. In light of the foregoing, this study's main objective was to understand climate change and wastewater utilization better. Thus, linking formal and informal institutions in the management of these water resources, as well as the issues and solutions they face in dealing with salt water. Water conservation is not an individual concern. All parties are involved, including the government, non-governmental groups, local inhabitants, and all stakeholders, with differing opinions.

## 1. Introduction

The ever-increasing worldwide population is the fundamental cause of the world's most urgent water issue, which is aggravated by the insufficiency of accessible water to fulfill present demand levels. Several studies indicate that, as a result of climate change, the globe is likely to face greater water stress than was initially projected. Climate change and unpredictable weather patterns have recently significantly strained the global community. Due to population expansion, these causes have caused water scarcity in nearly all regions of the world, particularly in Sub-Saharan Africa, Africa, and Asia. The planet has been under a great deal of strain in recent years. As the global population continues to increase, the strain on the agricultural business, which serves as the foundation for all other industries, will only intensify. Water is crucial for practically all significant human activities, including industry. It is difficult to sustain life without water, as it satisfies every necessity for human survival. Because agriculture, which is the source of people's food, requires water, irrigation also requires water, and virtually all

industrial and domestic tasks require water, it is evident that without water, it is impossible to survive. Recent droughts and floods in several countries have increased interest in global warming and its possible effects on water supply. According to the Second Assessment of the Intergovernmental Panel on Climate Change [1], a human influence on the global climate is evident, and recent fluctuations are unlikely to be solely due to natural causes. A rise in greenhouse gas concentrations in the atmosphere is anticipated to result in an increase of 0.15 to 0.3 °C each decade in the global average temperature [2], with different regional effects on precipitation and evaporation rates. Climate change has a physical impact on water supply and quality. This effect may affect water resources and their management; it is a favorable effect. How an effect becomes, an impact is influenced by the features of the water resource infrastructure. A supply system consisting of a large number of tiny, independent reservoirs will be more susceptible to change than one consisting of a big reservoir with the same overall capacity. Additionally, critical thresholds within the water management system may exist beyond which the system's flexibility cannot accept change. Changes in the amount or quality of water may be manageable with the current methods, but if the changes are big, it may be necessary to make changes to the infrastructure or try something else. Almost all of the research on the effects of climate change on water resources has focused on how future climate will affect the current water management system [3]. This is a worst-case scenario method to analyze climate effects since the water management system will have developed and adapted by the time the future climate comes. Non-climatic trends will contribute to a part of this change. Changes in population and water demand, the legal environment (including national and international norms and regulations such as those of the European Union), and public and professional attitudes about water resources and their management are examples. These modifications may reduce or aggravate the consequences of climate change. As a consequence of producing more adaptive solutions, this shift is anticipated to mitigate the future effects of climate change. In reaction to a changing climate, water management may undergo some purposeful changes in the next decades. The choices may not have been optimum in retrospect. Future consequences of climate change are thus dependent on the development of water management through time and the adaptive activities taken by water managers, and the cost of climate change over the next several decades will equal the extra cost of adaptation plus the cost of inevitable impacts [4]. Almost every aspect of human, animal, plant, environmental, and ecosystem existence requires freshwater. It may imply the difference between life and death and between abundance and destitution. Therefore, proper water planning and management are essential, regardless of whether there is too little or too much water. Despite our advancements, water planning and management remain challenging. Our ignorance of the land, ocean, and atmospheric systems, as well as their interconnections and effects on water resources, has contributed to the problem. But population growth and its numerous impacts, including increasing water use, industrialization, urbanization, water pollution, and forest loss, have had a significant effect. According to WHO/UNICEF (2008) and the United Nations (2010), around 900 million people do not have access to clean drinking water, and approximately 2.6 billion people lack adequate sanitation facilities. Each year, millions of people, the majority of whom are children under the age of five, die from water-related diseases such as malaria, typhoid, and cholera, mostly as a result of these and other linked conditions. Water-borne infections are the third biggest cause of death from infectious diseases overall. As briefly described below, three important factors, among others, are anticipated to exacerbate the future water situation's complexity (or at least raise its unpredictability). Population growth, global climate change, and transboundary river basins are important factors to consider. Population growth is a major driver of water-related activities and issues, as an increase in a population typically results in a rise in water demand in virtually all sectors (domestic, industrial, agricultural, energy, and recreation), barring the development of more effective water management techniques. UN predictions say the world's population might grow from 6.7 billion in 2007 to 7.7 billion by 2020 and 9.0 billion by 2050 (2007 UN). This expansion will mostly affect emerging regions, where the population is expected to rise from 5.4 billion in 2007 to 7.9 billion in 2050. These regions already face water and sanitation challenges and extreme weather, so the situation is expected to worsen. At the global, regional, and local levels, the amplified greenhouse effect is expected to affect future water resources (positively or negatively). Most scientists believe that climate change will intensify the global hydrological cycle and cause more frequent and severe droughts and floods [5]. However, there are still concerns about the methods used to make future projections and the accuracy of results [6]. Droughts and floods make water planning and management more difficult, so climate change could cause additional problems.

Two or more nations share 260 river basins and 270 aquifers. Transboundary waters encompass more than half the Earth's surface and provide water for half the world's population. They have been the subject of hostilities between countries that share them and collaboration [7]. Water planning, development, and management are affected. Future population increases and climate change could complicate the planning and management of transboundary streams. Agriculture, the economic foundation of Cyprus and many other nations, as well as other significant economic activities such as industry, can produce anything without water. However, a shortage of water can affect agriculture, which in turn can have an effect on economic sectors, such as industry. However, the same water can be accessible, but if it is polluted, it can be hazardous to human health as well as the health of other living organisms, and it can therefore pose a threat; the same water is also salinized, so different methods, such as desalination, must be used to reduce the salinity of the water. Cyprus is an island located in the Mediterranean Sea, and it is one of the countries under great pressure when it comes to water-related issues. This is due to a rise in population, which increases the demand for water at a rate that exceeds the amount given or available. Water that is currently available is used to serve a wide range of businesses and activities, including agriculture, industry, and a variety of residential and daily jobs. Additionally, the available water is not fresh but rather water with high salt, necessitating a

different procedure such as desalination. Desalination helps us obtain fresh water, which is a positive step toward alleviating and reducing water stress in a variety of industries, most notably agriculture and residential activities. Currently, water shortage affects the entire planet; industrialized nations are having difficulty desalinating seawater, which constitutes a substantial portion of the total amount of available water on the planet, to create potable water for their inhabitants. As a result of climate change induced by a multitude of variables, including human and industrial activities, the entire planet is predicted to experience severe water stress by the year 2030. The only available water is highly salty seawater, which must be desalinated before it can be utilized. As a result of everyday population growth, which causes demand to exceed supply, developing nations, including those in Africa and Asia, suffer tremendous water stress. However, the entire world is going to experience severe water stress.

### 1.1 Study Area

Cyprus is an island located in the Mediterranean Sea (Figure 1), and it is one of the countries under great pressure when it comes to water-related issues. This is due to a rise in population, which increases the demand for water at a rate that exceeds the amount given or available. Water that is currently available is used to serve a wide range of businesses and activities, including agriculture, industry, and a variety of residential and daily jobs. Additionally, the available water is not fresh but rather water with high salt, necessitating a different procedure such as desalination. Desalination helps us obtain fresh water, which is a positive step toward alleviating and reducing water stress in a variety of industries, most notably agriculture and residential activities.

## 2. Discussions and Findings

### 2.1 Findings

The water supply in Northern Cyprus is extremely constrained because it is a small island with a total land area of about 3,355 km$^2$. The main source of water is groundwater, which is advantageous to both the industrial and agricultural sectors of the economy and has a sustainable production of 74.1 MCM. The Magusa, Guzelyurt, and Girne aquifers are the three most notable aquifers in North Carolina, and each has a different water-holding capacity [8]. The Margosa aquifer, which is in the east of the country and has a surface area of 45 km$^2$ overall with 20 km$^2$ in the north, was one of the most significant water sources in the nation in the 1960s. Its northernmost region is 20 km$^2$ in size. Since it was over-pumped beyond what was deemed a safe yield, it has been completely salinized by seawater. The aquifer is currently unsuitable for any applications due to its total depletion [9]. The resource's capacity to replenish itself has dropped to 15 MCM as a result of less severe precipitation during dry seasons. The aquifer can hold about 920 million cubic meters of water in total [10]. The Girne Coastal Aquifer and the Girne Mountains Aquifer are two different aquifers that together make up the Girne Aquifer. Girne Mountain's aquifers are restricted beneath a single, steep ridge that is 750 meters high and 62 kilometers broad. The center region has a storage capacity of around 10 MCM but a recharge capacity of about 5 MCM during the dry seasons because the limestone and dolomite stones are widely fractured and allow water to flow directly to the sea. The water table can range from 250 to 100 meters above mean sea level in different places [11]. Based on previous data, it was found that the aquifers could hold approximately 74.1 MCM of water per year without suffering harm. However, North Cyprus aquifers must be drained of 28.9 MCM of water per year to supply the annual water demand. The high temperatures in Cyprus cause a lot of evaporation, which reduces the amount of precipitation that falls on the land.

### 2.2 Water Resources

**i.** Groundwater: Groundwater is necessary for the survival and livelihood of both urban and rural residents. The term "groundwater" refers to the water found deep below the earth's surface in regions that are saturated with water. The water table is located at the uppermost surface of the saturated zone. Contrary to popular belief, groundwater does not produce underground rivers. Similar to how water fills the pores and cracks in a sponge, it also fills the pores and cracks in sand, gravel, and rock. Aquifers are rock materials that retain groundwater and either allow groundwater to flow naturally out of them or can be pumped out (in useful amounts). Typically, the circulation of groundwater in an aquifer is measured in centimeters per day and can vary between three and twenty-five inches. Aquifer water has the potential to remain there for hundreds or even thousands of years. In the United States, groundwater is the source of approximately 39% of the water used for agricultural purposes and 40% of the water used for public supply. From 1977 to 2018, the amount of water coming from the ground in Cyprus stayed the same, at 0 billion cubic meters per year.

**ii.** Surface Water: Before 1997, precipitation provided the majority of Cyprus's water supply. The expected annual precipitation average was 503 millimeters. Since 2000, it has decreased to less than 465 millimeters. The investigation was conducted on a national scale. The Water Development Department of Cyprus (WDD) estimates that evaporation accounts for roughly 90% of annual precipitation loss. It is estimated that 2.750 million cubic meters (mcm) of water falls on the entire surface of the Republic of Cyprus, but only 275 mcm, or 10 percent, is exploitable. According to the Cyprus Water Development Department, evaporation accounts for nearly 90% of annual precipitation loss.

### 2.3 Wastewater Re-Usage

The technique of recycling water waste in order to utilize it is known as water waste recycling. And water can be advantageous in a range of human activities, including agriculture, where recycled water can be used for irrigation and in industries. As an alternative to existing water sources, water reuse can be utilized to improve sustainability and resilience. As the entire planet, including Cyprus, is impacted by climate change, it substantially impacts the distribution and supply of water in many locations for human activities and other daily social and economic activities. Using a high-resolution regional climate model (PRECIS) and comparing precipitation projections from 2040-2069 and 2070-2099 to 1961-1990, the anticipated implications of climate change on the water resources of the eastern Mediterranean and Middle East region were explored [12].


**Figure 1.** Map of Cyprus

The projected change in internal water resources is expected to mirror that of precipitation. Due to the large number of tourists who use only fresh water for all of their tourist activities, such as swimming pools, the water pressure on the island is extremely high; one of the adaptation strategies provided is to ensure that water management implements measures to ensure water security both now and in the future. The government of Cyprus has endeavored to construct numerous dams to secure water storage, and between 1960 and 2009, the amount of water stored increased from six million cubic meters to 327 million cubic meters, making Cyprus one of the countries with the most developed dam infrastructures [13]. However, dam construction does not address the issue of climate change and water, which is why Cyprus has endeavored to reuse tertiary processed wastewater, of which more than half is used in the agricultural sector directly or via aquifer discharge. The government of Cyprus predicts that 28.5% of yearly agricultural demand will be met through the reuse of wastewater [14]. Generally speaking, wastewater must be treated prior to being released into the atmosphere or groundwater. Additionally, domestic water should be clean and safe to drink. Depending on its source, domestic water requires some type of treatment. Directly or indirectly, renewable energy sources have been and will continue to be utilized in water and wastewater treatment.

Sun energy, often in the form of stabilization ponds and solar detoxification, has been and continues to be utilized in many nations for wastewater treatment. Solar radiation remains the most fundamental method for desalinating and cleaning saline water. It can be turned into energy, which can be used for power pumps, ultraviolet (UV) systems, photocatalysis, reverse osmosis (RO), and conventional surface-water treatment systems. Similarly, the Persians have utilized wind energy since 1200 BC. In the early 1900s, the American Farm windmills produced water for both railroads and home usage. Still commonly utilized to pump water are windmills. Today, the United States, Argentina, and Australia have more than a million wind turbines each [15]. Similar to solar photovoltaic (PV) systems, wind turbines directly convert wind energy into electricity, which can be utilized to power water treatment facilities. In contrast, wind turbines are infrequently employed in wastewater treatment since the majority of wastewater treatment systems have high energy demands or require direct sunlight (like stabilization ponds). Renewable energy sources, as opposed to traditional power sources (petroleum-based generators and grid electricity), are primarily employed for small to medium-sized applications due to their high initial investment costs. Due to the low amount of energy necessary to purify a rural water supply, renewable energy sources are commonly utilized in many developing nations. In Cyprus, the treatment of

wastewater also uses renewable energy. For instance, the Nicosia Bi-communal Wastewater Treatment Plant (WWTP) in the Mia Mill or Haspolat district of Cyprus has the ability to treat 30,000 cubic meters of wastewater per day. It benefits around 270 000 Nicosia residents. Nicosia has the capacity to produce 10 cubic meters of treated water for agricultural irrigation each year [16].

### 2.4 Renewable energy in Cyprus

The prevailing economic conditions of the location in question are the predominant factors that determine how the vast majority of renewable energy resources are utilized. The availability of sufficient resources is crucial to the project's success and longevity. However, technological and environmental concerns are also of utmost importance in this regard. To compare distinct renewable resources, it is necessary to establish a common denominator or baseline. On this basis, comparisons are made using the total cost of capital, the price of land, and the accessibility of natural resources. In addition to wind and solar energy (Figure 2), it is also possible to utilize tidal energy. According to Barker's research, areas with an average range of greater than three meters are ideal for exploitation. Importantly, Barker has demonstrated that this potential does not exist in the Eastern Mediterranean. The hydropower potential of Cyprus is further hampered by the absence of rivers with a significant annual flow. Cyprus contains no geothermal reserves. The production of geothermal energy involves the transfer of heat from rocks to the planet's surface via fluids and steam. Wind energy and solar energy, two of the most significant forms of renewable energy, are free to use in Cyprus.

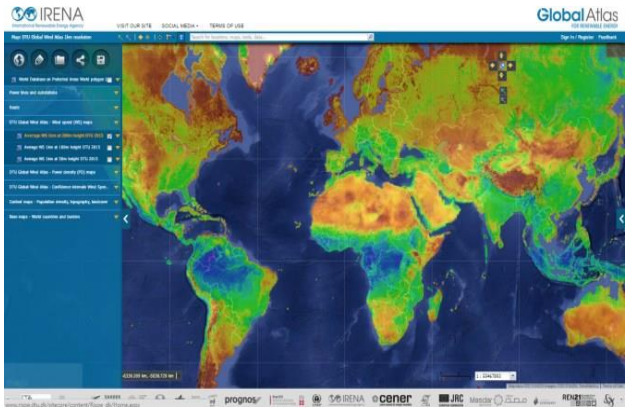


**Figure 2.** Solar Resource Map of Cyprus

When all of the essential benefits of RES for the economy and environment of Cyprus are considered, it is evident how crucial it is to incorporate RES into the energy system of Cyprus. In its White Paper, the EU recommends a RES take-off campaign to facilitate a true take-off of RES for widespread penetration. The proposed campaign will encourage the implementation of large-scale projects in various renewable energy sectors, thereby sending strong signals for the increased use of renewable energy sources. Cyprus should launch its take-off campaign as soon as possible, by EU rules, to increase the share of renewable energy sources to 10% of total energy consumption by 2010. The development and expansion of distinct renewable technologies are essential to achieving this objective. Adoption of RES may result in annual cost savings due to reduced fuel costs. This advantage could be given back to consumers by giving them money to use renewable energy sources.

### 2.5 Wind Energy in Cyprus

Cyprus is an island country that is encircled by the Mediterranean Sea on all sides. There are two distinct seasons in the climate. From November to March, depressions that travel across the Mediterranean Sea from west to east have an impact on Cyprus. Second, from early April until late October, the island experiences a protracted dry season. A shallow trough of low pressure that develops from a continental depression in Asia is currently having an impact on the island. But because of the large temperature differential between the land and the water, the local sea breeze circulation is frequently rather vigorous in coastal areas. It is necessary to look over and evaluate the local wind statistics before attempting to estimate a location's wind energy potential. Long-term wind data from meteorological stations close to the intended site can be utilized to generate rough estimations. The wind profile at the potential site should then be derived from this data with extreme caution. Data from several places on the island, including those published by Jacovides et al. and Pashardes, is collated to assess the wind energy potential of Cyprus.

Cyprus' wind regime is impacted by three key factors: (a) the eastward-moving storms that pass over the island; (b) the enormous temperature differences between the sea and the land; and (c) the effect of mountains, where discrete wind systems arise. Certain places in Cyprus have yearly mean wind speeds of more than 5 m/s at the height of 10 m, even though high wind potential is uncommon. These locations are located on the southern coast of the island and in certain exposed mountain regions. These locations are very promising for the installation of wind turbines (Figure 3). It provides a decent estimate of wind speed at numerous sites throughout Cyprus.

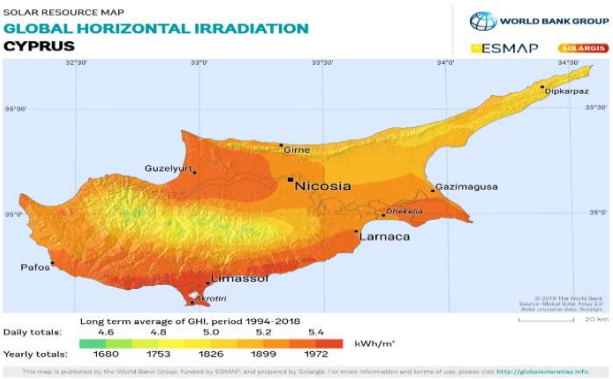


**Figure 3.** Wind Distribution Map of Cyprus

### 2.6 Solar Energy

Cyprus has a generally agreeable climate with plenty of sunny days. On average, during the entire year, the central plains and eastern lowlands receive dazzling sunlight 75% of the time the sun is above the horizon. Average daylight hours in the summer are 11.5 hours, but in the two months with the most clouds, December and January, that number drops to 5.5 hours. In the highest mountains, even in the cloudiest winter months, there are often 4 hours a day of excellent sunlight,

rising to 11 hours in June and July. The cloudiest months of the year, December and January, have an average daily global solar radiation of about 2.3 kWh/m², whereas the sunniest month of the year, July, has an average daily global solar radiation of about 7.2 kWh/m² [17]. In Cyprus, the average hourly direct solar radiation varies between 250 and 700 Wh/m². Compared to other nations in the European Union, Cyprus is in a particularly advantageous location for solar energy usage [18]. It is projected that there will be 560,000 m² of active flat plate solar collectors or roughly 0.86 m² per person. (Cyprus Union of Solar Energy Industrialists, Nicosia, Cyprus) It is said that Cyprus has built 190,000 solar water heaters. While industrial process heat currently has no commercial value, solar energy is mostly used in solar water heaters to supply hot water to homes [19]. The island is only just able to meet its energy needs despite a 25% drop in solar energy costs over the previous five years.

### 2.7 List of Previous Studies

The data for this study originated from secondary sources which were evaluated based on the findings of previous research that examined the water resources of both northern and southern Cyprus (Appendix I).

## 3. Conclusion

Extreme vigilance is required to maintain the correct amounts of groundwater to saltwater. Recharging the groundwater table or employing alternative ways could assist in reducing this intrusion. Seals on pipes leading to the sewage treatment plant should be frequently inspected and checked for leakage. In the case that saltwater has made its way into these pipes, relining or other corrective measures are required. To guarantee that treated effluent quality remains within acceptable criteria, it must be routinely monitored. It is essential to investigate each of the offered options. When it comes to the reuse of treated effluent, which is considered an input to water resources, the management techniques described below should be implemented. To keep the salinity of irrigated land under control, monitoring with the most advanced technology, such as GIS monitoring, is required (geographic information system). It is also suggested that plants with characteristics that allow them to live in salty water should be encouraged or created. Recycling water is now a necessity since it helps compensate for water shortages and can conserve considerable volumes of fresh water that would have otherwise been utilized for crop irrigation in agricultural settings. Nonetheless, utmost caution must be exercised at all times to avoid the negative repercussions associated with it. As the capacity of the environment to accept water of poor quality looks to be diminishing, it is proposed that more effort is required to improve the effluent quality that is delivered to agriculture. It appears that the ecology can only tolerate so much contaminated water for so long. Cyprus, an island country located in the Mediterranean, has a chronic water deficit issue. It is typical for there to be insufficient precipitation. The already inadequate water supply on the island is exacerbated by the rising demand for sweet water and the deterioration of the island's non-polluted water sources. Based on the previous studies, results showed that climate change has greatly affected the water resources, most especially groundwater sources in Northern and Southern Cyprus, seawater intrusion is the major source of groundwater contamination in Northern Cyprus. Recommendations:

**i.** Even if some desalination systems are already in use in both the south and the north, desalination must be carried out on a large scale so that we have access to fresh water for a variety of activities. This will save us from having to utilize salty water.

**ii.** Facilitating the passage of fresh water from Turkey necessitates fostering cooperation and resolving numerous arguments and conflicts between the south, the north, Turkey, and Greece.

**iii.** Instead of relying on the few badly salinized water sources, it would be preferable to construct other water sources.

**iv.** To identify what may be done to reduce the quantity of salt in Cyprus's water, scientists should design a variety of cures based on the findings of extensive investigations on the island's water. Controlling the population is a must for every nation, regardless of whether this is accomplished through reducing the birthrate or the amount of immigration.

### Ethical issue

The authors are aware of and comply with best practices in publication ethics, specifically with regard to authorship (avoidance of guest authorship), dual submission, manipulation of figures, competing interests, and compliance with policies on research ethics. The authors adhere to publication requirements that the submitted work is original and has not been published elsewhere.

### Data availability statement

Data sharing is not applicable to this article as no datasets were generated or analyzed during the current study.

### Conflict of interest

The author declares no potential conflict of interest.

### References

[1] CHANGE, I. P. O. C. (1995). IPCC Second Assessment. A Report of the Intergovernmental Panel on Climate Change, WMO-UNEP.

[2] Bruce, J. P., Lee, H., & Haites, E. F. (1996). Climate change 1995. Economic and social dimensions of climate change

[3] Kaczmarek, Z. (1996). Climate change impacts on the water supply system in the Warta River Catchment, Poland. International Journal of Water Resources Development, 12(2), 165-180.

[4] Arnell, N., Dubourg, R., Brignall, P., Davies, A., Hossell, J., Parry, M., & Pollock, C. (1995). Implications for water supply and water management.

[5] Kundzewicz, Z. W., Mata, L. J., Arnell, N. W., Döll, P., Jiménez, B., Miller, K., ... & Shiklomanov, I. (2008). The implications of projected climate change for freshwater resources and their management. Hydrological sciences journal, 53(1), 3-10.

[6] Koutsoyiannis, D., Efstratiadis, A., Mamassis, N., & Christofides, A. (2008). On the credibility of climate predictions. Hydrological Sciences Journal, 53(4), 671-684.

[7] Cooley, H., & Gleick, P. H. (2011). Climate-proofing transboundary water agreements. Hydrological Sciences Journal, 56(4), 711-718.

[8] Elkiran, G., & Ergil, M. (2002, November). A general outlook of aquifers in TRNC. In Proceedings of Second FAE International Symposium, Gemikonagi, TRNC.
[9] Ergil M., 1999: "The salination problem of Guzelyurt aquifer and rehabilitation scenarios". Ph.D. Thesis, EMU, Gazi Magosa, NC.
[10] Alkaravli M., 2002: Groundwater Resources of Northern Cyprus, Rep. No: 118/98, Department of Geology and Mining, Ministry of Interior, NC./ Elkiran G., 2006: Integrated water resources planning and management of NC, Ph.D. Thesis, Eastern Mediterranean University, NC.
[11] Turkman, G. E. A. Salinity Problems in Northern Cyprus and Desalination Applications.
[12] Chenoweth, J., Hadjinicolaou, P., Bruggeman, A., Lelieveld, J., Levin, Z., Lange, M. A., & Hadjikakou, M. (2011). Impact of climate change on the water resources of the eastern Mediterranean and Middle East region: Modeled 21st-century changes and implications. Water Resources Research, 47(6).
[13] Zachariadis, T. (2010). Economic Effects of Climate Change on Scarcity Costs and Residential Water Prices in Cyprus. Cyprus Economic Policy Review, 4(2), 73-95.
[14] https://www.climatechangepost.com/cyprus/fresh-water-resources/
[15] Jung, C., Schindler, D., & Laible, J. (2018). National and global wind resource assessment under six wind turbine installation scenarios. Energy conversion and management, 156, 403-415.
[16] Gleick, P. H. (2003). Water use. Annual review of environment and resources, 28(1), 275-314.
[17] Brimblecombe, P. (1995). Meteorological Service in Fifteenth Century Sandwich. Environment and History, 1(2), 241-249.
[18] Florides, G. A., Kalogirou, S. A., Tassou, S. A., & Wrobel, L. C. (2003). Design and construction of a LiBr–water absorption machine. Energy conversion and management, 44(15), 2483-2508.
[19] Kalogirou, S. A. (2003). Artificial intelligence for the modeling and control of combustion processes: a review. Progress in energy and combustion science, 29(6), 515-566.
[20] Gokcekus, H., Iravanian, A., Turker, U., Oguz, G., Sözen, S., & Orhon, D. (2018). Massive freshwater transport: a new dimension for integrated water-wastewater management in North Cyprus. Desalination and Water Treatment, 132.
[21] Zachariadis, T. (2010). Residential water scarcity in Cyprus: Impact of climate change and policy options. Water, 2(4), 788-814.
[22] Bryant, R. E., & Mason, M. (2017). Water technology and sustainability in north Cyprus: Climate change the Turkey-north Cyprus water pipeline. Peace Research Institute Oslo Cyprus Centre.
[23] M. Dolbeshkin (2015) Cyprus water supply Issues International Water Management exchange, report
[24] Elkiran, G., Aslanova, F., & Hiziroglu, S. (2019). Effluent water reuse possibilities in Northern Cyprus. *Water*, *11*(2), 191.
[25] Başarana, S. T., Gökçekuşb, H., Orhonb, D., & Sözenc, S. (2020). Autonomous desalination for improving resilience and sustainability of water management in North Cyprus. Desalin. Water Treat., 177, 283-289.
[26] Bruggeman, A., Zoumides, C., Pashiardis, S., Hadjinicolaou, P., Lange, MA, & Zachariadis, T. (2011). Effect of climate variability and climate change on crop production and water resources in Cyprus. The Cyprus Institute, Cyprus University of Technology, Cyprus Meteorological Service
[27] Makris, K. C., & Snyder, S. A. (2010). Screening of pharmaceuticals and endocrine disrupting compounds in water supplies of Cyprus. Water Science and Technology, 62(11), 2720-2728.
[28] Aldalou, A. J. (2012). *Regional Water Balance Study for Kyrenia Range Aquifers* (Doctoral dissertation, Near East University).
[29] Kalogirou, S. A., Lloyd, S., Ward, J., & Eleftheriou, P. (1994). Design and performance characteristics of a parabolic-trough solar-collector system. *Applied Energy*, *47*(4), 341-354.
[30] Birol, E., Koundouri, P., & Kountouris, Y. (2007). Farmers' demand for recycled water in Cyprus: A contingent valuation approach. In Wastewater Reuse–Risk Assessment, Decision-Making and Environmental Security (pp. 267-278). Springer, Dordrecht.
[31] Cox, C. W. (1999). *Water supply enhancement in Cyprus through evaporation reduction* (Doctoral dissertation, Massachusetts Institute of Technology).
[32] Ansink, E., & Marchiori, C. (2009). Reallocating Water: An Application of Sequent (No. 2009.126).
[33] Papadavid, G., Hadjimitsis, D., Fedra, K., & Michaelides, S. (2011). Smart management and irrigation demand monitoring in Cyprus, using remote sensing and water resources simulation and optimization. Advances in Geosciences, 30, 31-37.
[34] Adamowski, J., & Karapataki, C. (2010). Comparison of multivariate regression and artificial neural networks for peak urban water-demand forecasting: evaluation of different ANN learning algorithms. J. Hydrol. Eng., 15, 729-743.
[35] Petrakis, M., Kambezidis, H. D., Lykoudis, S., Adamopoulos, A. D., Kassomenos, P., Michaelides, I. M., ... & Hadjigianni, A. (1998). Generation of a "typical meteorological year" for Nicosia, Cyprus. Renewable Energy, 13(3), 381-388.
[36] Tsiourtis, N. X. (2004). Desalination: the Cyprus experience. European Water, 8, 39-45.
[37] Pashiardis, S., & Michaelides, S. (2008). Implementation of the standardized precipitation index (SPI) and the reconnaissance drought index (RDI) for regional drought assessment: a case study for Cyprus. European Water, 23(24), 57-65.
[38] Economidou, Y., Doula, M. K., & Zorpas, A. A. (2021). Mitigation of the effects of climate change in the agricultural sector of Cyprus, through optimization of benefit. Water Supply, 21(6), 2947-2958.
[39] Caligiuri, S., Camera, C., Masetti, M., Bruggeman, A., & Sofokleous, I. (2019, January). Testing GR4H model parameter transferability for extreme events in

Cyprus: evaluation of a cluster analysis approach. In Geophysical Research Abstracts (Vol. 21).
[40] Elkiran, G., Aslanova, F., & Hiziroglu, S. (2019). Effluent water reuse possibilities in Northern Cyprus. Water, 11(2), 191.
[41] Fatta, D., Arslan Alaton, I., Gokcay, C., Rusan, M. M., Assobhei, O., Mountadar, M., & Papadopoulos, A. (2005). Wastewater reuse: problems and challenges in Cyprus, Turkey, Jordan, and Morocco. European water, 11(12), 63-69.
[42] Park, E. J. (2020). Strategy of water distribution for sustainable community: who owns the water in divided Cyprus? Sustainability, 12(21), 8978.
[43] Bamisile, O. O., Babatunde, A. A., Dagbasi, M., & Wole-Osho, I. (2017). Assessment of solar water heating in Cyprus: utility, development and policy. International Journal of Renewable Energy Research (IJRER), 7(3), 1448-1453.
[44] Atun, Y., & Atun, A. (2020). Strategic and Politic Effects of Water from Anatolia to Cyprus. Open Journal of Political Science, 10(02), 204.
[45] Neal, C. and Shand, P.: Spring and surface water quality of the Cyprus ophiolites, Hydrol. Earth Syst. Sci., 6, 797–817, https://doi.org/10.5194/hess-6-797-2002, 2002.
[46] Papadaskalopoulou, C., Katsou, E., Valta, K., Moustakas, K., Malamis, D., & Dodou, M. (2015). Review and assessment of the adaptive capacity of the water sector in Cyprus against climate change impacts on water availability. Resources, Conservation and Recycling, 105, 95-112.
[47] Mederer, J. (2009). Water Resources and Dynamics of the Troodos Igneous Aquifer-system, Cyprus-Balanced Groundwater Modelling (Doctoral dissertation, Universität Würzburg).
[48] Savvides, L., Dörflinger, G., & Alexandrou, K. (2001). The assessment of water demand of Cyprus. WDD and FAO: Reassessment of the Island's Water Resources and Demand (TCP/CYP/8921). Ministry of Agriculture, Natural Resources and the Environment, Nicosia.
[49] Georgiou, M. C., Bonanos, A. M., & Georgiadis, J. G. (2016). Evaluation of a solar powered distillation unit as a mitigation to water scarcity and climate change in Cyprus. Desalination and Water Treatment, 57(5), 2325-2335.
[50] Nikolaou, S., Efstathiou, P., Tiggiridou, M., Arabatzis, N., Piera, Y., & Aletrari, M. (2017). Monitoring of pesticides in drinking, surface and ground water of Cyprus by liquid-liquid and solid phase extraction in combination with GC/MS and UPLC/MS/MS. Journal of Water Resource and Protection, 9(10), 1184.
[51] Sofroniou, A., & Bishop, S. (2014). Water scarcity in Cyprus: a review and call for integrated policy. Water, 6(10), 2898-2928.
[52] Atun, Y., & Atun, A. (2020). Strategic and Politic Effects of Water from Anatolia to Cyprus. Open Journal of Political Science, 10(02), 204.
[53] Polycarpou, A., & Zachariadis, T. (2013). An econometric analysis of residential water demand in Cyprus. Water resources management, 27(1), 309-317.
[54] Christia, C., Tziortzis, I., Fyttis, G., Kashta, L., & Papastergiadou, E. (2011). A survey of the benthic aquatic flora in transitional water systems of Greece and Cyprus (Mediterranean Sea).
[55] Nikolaou, G., Neocleous, D., Christophi, C., Heracleous, T., & Markou, M. (2020). Irrigation groundwater quality characteristics: a case study of Cyprus. Atmosphere, 11(3), 302.
[56] Özdemir, E. (2019). Documenting surrender: water privatization and governing dependence in North Cyprus. Center for Policy Studies–CEU, Working Paper Series, 3, 1-29.
[57] Charalambous, B. (2005, September). Experiences in DMA redesign at the Water Board of Lemesos, Cyprus. In Proceedings of the IWA Specialized Conference Leakage, Halifax, Nova Scotia, Canada.
[58] Hoffmann, C. (2018). From small streams to pipe dreams–the hydro-engineering of the Cyprus conflict. Mediterranean Politics, 23(2), 265-285.
[59] Georgiou, M. C., Bonanos, A. M., & Georgiadis, J. G. (2016). Evaluation of a solar-powered distillation unit as a mitigation to water scarcity and climate change in Cyprus. Desalination and Water Treatment, 57(5), 2325-2335.

## Appendix I

**Table 1**. List of the previous studies

| References | | Location | Aim | Methods | Data | Main findings |
|---|---|---|---|---|---|---|
| [20] | 2018 | North Cyprus | identify essential integrated water management strategy plan | data collection | strategies plan on integrated water | municipal water demand, agricultural use around water recharge, and water contract |
| [21] | 2010 | Cyprus | to access the cost of water scarcity in Cyprus | field collection of data | annual costs of residential water shortages in Cyprus | water prices in all non-agricultural sectors reach to account for water scarcity in Cyprus |
| [22] | 2017 | North Cyprus | to access problems and potentialities of new water resources | field data collection | map of water delivery project from DSI | water scarcity accelerates conflict and political unrest throughout the region |
| [23] | 2015 | Nicosia Cyprus | to examine methods of obtaining fresh water | document reviewing | amount of fresh water and salinized one | water scarcity issues are relevant |
| [24] | 2004 | Girne, North Cyprus | to examine the amount of water used and which is lost | data collection and document reviewing | consumptive water requirements in TRNC | 50% of water is lost due to existing poor irrigation systems |
| [25] | 2019 | Cyprus | to explore the potential of creating alternative water resources through autonomous desalination overwatered | field collection of data | desalination and water treatment techniques | solar energy is diverted to a different significant application to convert unusable water bodies |
| [26] | 2011 | Cyprus | to access the effect of climate variability on changes in agricultural land use, production, and irrigation water demand | model | mostly average daily minimum and maximum temperature and rainfall | Rain-fed crops are very effective users of water |
| [27] | 2010 | Cyprus | or investigate the occurrence of the pharmaceuticals six known or suspected endocrine disputing compounds, one insect repellant, and one fragrance for the first time in Cyprus water suppliers | field data collection | routine physiochemical water quality characteristics | groundwater samples. and electrical conductivity values ranged between 7.2-8.6 and 770-3900 us cm, respectively |
| [28] | 2009 | Famagusta, North Cyprus | investigating the water budget of each sub aquifer | mass balance model | list of 11 sub aquifers and their details | spring flows are not worth considering as a means of water consumption from existing aquifer systems |
| [29] | 1991 | Cyprus | to examine the feasibility use of solar parabolic trough collectors for hot water production in Cyprus | data collection | solar data | parabolic trough collectors are the best plate collector method though sometimes it is costly |
| [30] | 2007 | Cyprus | to investigate Cypriots farmer's willingness to adopt new water resources namely recycled water and their willingness to pay for the water | field data collection | farm, farm household, and farm characteristics | 93.8% of farmers in selected farmers located in the Akron area are willing to participate in paying a using recycled water |
| [31] | 2007 | Cyprus | to investigate Cypriots farmer's willingness to adopt new water resources namely recycled water and their willingness to pay for the water | field data collection | farm, farm household, and farm characteristics | 93.8% of farmers in selected farmers located in the Akron area are willing to participate in paying a using recycled water |

| | | | | | | |
|---|---|---|---|---|---|---|
| [32] | 2009 | Cyprus | to examine approaches to reallocating water rights among economic sectors | document reviewing | water demand and consumption by different sectors | mechanism to implement inter-sectoral water reallocation are concerned our framework can be used to support or complement existing instruments such as water markets or formal administrative decisions |
| [33] | 2011 | Cyprus | to integrate technological tools for developing a complete system for monitoring and coordinating irrigation demand on a systematic basis in Cyprus | data collection | meteorological data such as air temperature, atmospheric pressure, and wind speed | remote sensing and modeling modern can both be used for estimating etc |
| [34] | 2012 | Cyprus | to develop networks and methods to peak weakly demand weather forecasting | model | socio and economic variables | In Thalassa and public garden regions of Nicosia, the LMANN models were more accurate than all types of weather forecasting |
| [35] | 1998 | Cyprus | to investigate thermal performance and cost-effectiveness of thermos siphon water heaters with different soar collector tracking modes under the weather | data collection | The daily hot water consumption profile | the annual solar fraction with this mode is 87.6% with seasonal mode 79.7% with fixed surface mode |
| [36] | 2004 | Nicosia | to outline the approach the tender document contains the tender evaluation procedure, the project construction the project operation and contract management, the environmental effect, and the cost of water | data | governmental water supply projects | maximum output is when the sea water temperature is between 24-27 centigrade and water temperature affects water quality |
| [37] | 2008 | Nicosia | describing the spatial and temporal distribution of this element over the island | data collection | monthly variability of the average precipitation in Cyprus | SPI and RDI can be used for drought assessment and monitoring |
| [38] | 2021 | Cyprus | define the optimal limitation on land and water availability | linear programming model | crops with the amount of water they require | the cultivation of tomato, wheat, figs, and wine grapes prevails in the proposed cultivation pattern as well as high-rate profit compared to irrigation requirements |
| [39] | 2019 | Cyprus | to quantify stormwater retention of two substrate mixtures with two plant species | experimental | substrate component fractions by volume | the best case for reduction of average annual stormwater runoff plot types is the inclusion of 2a 0mm3 tank and grey water use |
| [40] | 2019 | North Cyprus | to analyze the effluent water reuse possibilities as a component of integrated water resources management in Northern Cyprus | document review | total water available in resources of Northern Cyprus and their percentages | Re-use of recycled water will be an alternative resource that can be utilized for some specific purpose to reduce water extraction from the ground |
| [41] | 2005 | Cyprus | to an overview of the property methodology while at the same time provide insight on exit the stings situation prevailing in various countries about wastewater management re-use | data collection | problems tree relating to efficient treatment and re-use of wastewater | water reuse has been dubbed as the greatest challenge of the next century as water supplies remain the same and water demand increases because of the increasing population |
| [42] | 2020 | Cyprus | explores the connection between ownership of | document reviewing | water stress levels in Europe show | found great potential in the use of alternative |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | | water and water management in a divided territory to gain an understanding of how politics are involved in conflicts | | Cyprus are most stressed country | water sources, rainwater recycling of wastewater, and desalination to reduce freshwater stress in Cyprus |
| [43] | 2017 | Cyprus | to access solar water heaters, utility development, and policy in Cyprus | data collection | demographic characteristics of housing unit | usage of SWH systems is popular in Cyprus,7 out of every 10 households have it installed in their homes, and out of 10 will be prepared to support registration that enforces its installation at home |
| [44] | 2020 | Cyprus | to show the aim of transforming water from Anatoliaa to Cyprus. | reviewing documents | analyze political effect aftereffects of water supply continuity | The alliance between Turkey, Israel, and the TRNC will alter political preferences in the eastern Mediterranean. |
| [45] | 2002 | Cyprus | to examine what causes increased salinity | field data collection and model | the water quality of Cyprus is associated with the ophiolitic | As a result of mixing with saline and end-member changed seawater, as well as the dissolution of gypsum and anhydrite, salinity increases. |
| [46] | 2015 | Cyprus | to determine the effect of water pricing | data collection | component of the total economic value of water resources and appropriate economic valuation | Although water price is a potentially successful economic instrument, its environmental effect is not assured, hence it may not deistically improve Cyprus's water resources management. |
| [47] | 2009 | Cyprus | to present and analyze Cyprus's experiences in water resources management policies | data collection | precipitation mm for long-term monthly mean values | very good input data quality and quantity set the base for high-resolution simulation of groundwater recharge and evapotranspiration with the water balance modeling program me |
| [48] | 2001 | Nicosia | to access water demand in Cyprus | data collection | tourism and other sectors like agricultural water demand for the various regions in the year 2000 | Cyprus is at high risk of having high water demand |
| [49] | 2012 | Cyprus | to present a simple methodology that allows an estimate of direct and indirect local water use associated with different | data collection | the associated water footprint per person per day of each five holiday | a combination of a flight closer to home and a largely vegetarian diet can make a significant difference in lessening the overall impact of a holiday |
| [50] | 2017 | Cyprus | to identify different pesticides affecting Cyprus water | data collection | quality water characteristics | Due to their locations, the water of high quality is exposed to pesticides. |
| [51] | 2014 | Cyprus | to examine the implications on the demand and supply of water | data collection | graphs of annual precipitation mm | Daily activities have an impact on Cyprus, but water constraint has a greater effect on agricultural operations. |
| [52] | 2020 | North Cyprus | to show the aim of transforming water from Anatolia to Cyprus | reviewing documents | impacts of water transferring | The partnership between Turkey, Israel, and the TRNC will alter the region's existing political biases. |
| [53] | 2012 | Cyprus | analyzing econometrically residential water demand in three major urban areas in Cyprus | field data collection and model | billed water consumption per period for residential consumers | water demand is inelastic but finds not insensitive, price elasticity is less than unity in absolute terms |

| | | | | | | |
|---|---|---|---|---|---|---|
| [54] | 2010 | Cyprus | to summarize, list, and provide a full inventory of benthic aquatic flora recorded in these transitional water systems | data collection | Greek and Cypriot transitional water system characteristics, including coordinates, surface area, and depth | The assessment of biodiversity in protected areas of transitional water systems is essential for the protection and management of natural habitats. |
| [55] | 2010 | Cyprus | to investigate possible quality changes in Cyprus groundwater resources over 10 years period | data collection | crops tolerance and yield potential are affected by water salinity | In Thalassa and public garden regions of Nicosia, the LMANN models were more accurate than all types of weather forecasting |
| [56] | 2016 | North Cyprus | to analyze if the transferred water was to be provided for the communities of north Cyprus who have been grappling with water-scarce geography daily | field research | The pipeline between Mersin - name, and geatkoy | the water in north Cyprus as it bought forward several neo-liberal policy steps hydraulic management became a location where a specific public that technical experts and actors were constituted |
| [57] | 2005 | Cyprus | reviewing the experiences gained at the water board of Limassol in striving to achieve lower levels of leakage by DMA and subsequently applying for a pressure reduction program | field data collection | water balance (m3) for the year 2003 | the more-designing and the application of pressure reduction have produced favorable leakage reduced by approximately 38% |
| [58] | 2018 | Cyprus | to show the construction of the motherlands are a reaction to environmental scarcity | document reviewing | precipitation increases and decreases from 1970 -2001 (mm) | the effectiveness of different water strategies depends on the political environment |
| [59] | 2016 | Cyprus | to evaluate the performance of a single effect distillation unit and the potential of its integration with a concentrated solar power system as a mitigation technique to the water scarcity | data collection | water exploitation index based on 2009 the latest available data | considering the existing water crisis that Cyprus is facing and the forecast annual precipitation on the island, the need for the development of new sustainable technologies such as seawater desalination is urgent |