

Article

Strategy of Water Distribution for Sustainable Community: Who Owns Water in Divided Cyprus?

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Abstract: Although it is completely surrounded by the Mediterranean Sea, the island of Cyprus has long suffered from water problems arising from irregular rainfall, leading to sustained political conflict conditions for a long period. Water scarcity is likely to become a major issue, thus a range of options for water catchments should be examined and trialed. This article explores the connection between ownership of water and water management in a divided territory to gain an understanding of how politics are involved in water conflict. By investigating the water situation in Cyprus, this study aims to evaluate the strategies that can ensure the sustainability of new water networks for domestic and irrigation needs. This understanding can be used to minimize the gap between water supply and demand to provide water stressed countries with sufficient, safe, and reliable water for their domestic and irrigation needs. The research proposes a reinterpretation of the extraterritorial conditions of contemporary Cyprus and a plan to realign the island's water system through the creation of a new post-national territory. Thus, the study presents a vision for a sustainable water supply. In addition, the study discusses strategies and actions for water distribution networks with consideration of political and social issues to provide a potential new vision for future urbanization.

Keywords: water distribution; water war; conflict; ownership; divided Cyprus

1. Introduction

1.1. Background and Purpose

Water is a precious resource. The growing global population coupled with climate change means that water supply is one of the most significant challenges facing the world today. It is expected that by 2080, half of the world's population will experience water shortages [1]. Access to and exploitation of water resources has always been a challenging issue, causing conflicts, struggles, and even war within and between societies and countries. In the 1980s, intelligence of the United States Government identified 10 countries where water wars could break out, with Cyprus listed among those countries [2]. Cyprus suffers from the highest level of water stress in Europe, particularly during years of excessive drought [3] (see Figure 1), and by 2025 will experience ongoing water shortages. Water shortages are crucially linked to Cyprus's economic activities and are exacerbated by population growth, tourism, and the activities of other industries. Another contributing factor to Cyprus's limited water supply is the island's over-reliance on precipitation; thus, its water resources are particularly vulnerable to future changes in the volume and distribution of rainfall.

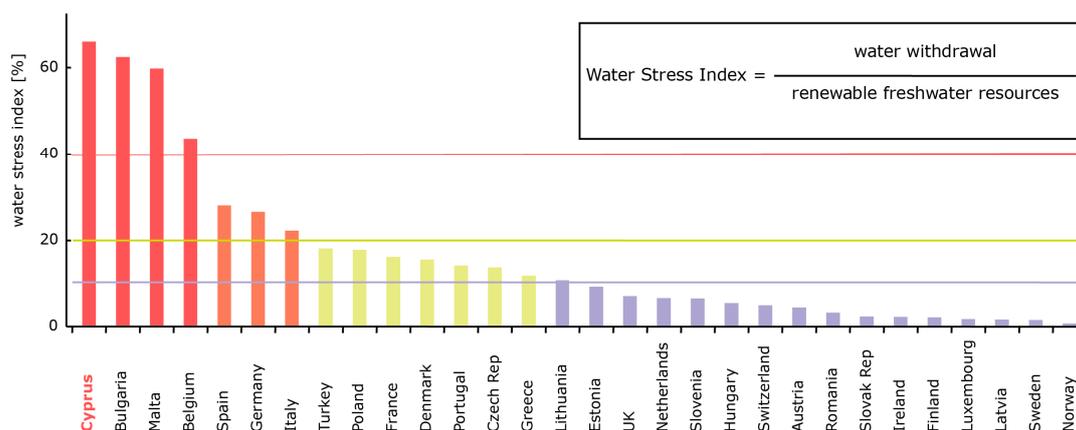


Figure 1. Water stress levels in Europe, showing Cyprus as the most water stressed country [4].

Having insufficient water resources can increase political tensions within and across countries, and water becomes a political tool for negotiation between countries. The deliberate destruction of dams and pipelines and the pollution of drinking water is a method used by governments and terrorists to engage in hostile martial action. However, while there is no historical evidence that Cyprus has ever engaged in water wars, the island's division between Greece and Turkey has been a source of great conflict, meaning that Cyprus is an excellent case for examining how an integrated policy can help to ensure safe water supply in areas of conflict. Water shortages have been a severe problem for both the Greek and Turkish Cypriot communities, and joint action on securing water supply could resolve the island's ongoing political division. Thus, possible scenarios of collaboration between the two parts of the island could lead to a "water peace" [4].

It is important to understand and manage uncertainty about the future impacts of climate change and drought on water catchment systems around the world. Moreover, there are major challenges in predicting water catchment responses associated with an uncertain future in terms of climate change and land management in divided territories. However, little research has been conducted in the context of Cyprus on its major cause of water scarcity: climate change and drought, which peaked in the winter of 2007, 2008, and 2018 [5]. In addition, there have been no studies in the context of Cyprus on spatial and temporal changes in water resources and sustainability. Thus, this research aims to suggest new strategic actions that can be taken by Cyprus to increase the sustainability of its water management and to investigate the effect on water demand and supply that arises from the political status of disputed territories. In addition, the study suggests future directions for water distribution that will allow sustainable water supply in other water stressed countries.

1.2. Research Methods and Procedures

The term "water wars" refers to conflicts in different regions arising from disputes over the use of fresh water, and describes the struggles to supply water for domestic and irrigation needs. This research analyses the causes and consequences of water conflicts, identifies the problems associated with existing water management practices, and proposes alternative strategies for water catchment and distribution in divided Cyprus. The research uses Cyprus as the study context, because it provides an example of a state that operates in a climate of political dispute. The principal goal of this study is to identify the causes and consequences of the water conflict in Cyprus, and present a strategy for improving the water distribution networks of the island with the final aim of presenting important strategies for improving water management and sustainable new water networks for domestic and irrigation water needs in other water stressed countries like Cyprus.

To achieve the objectives of this research, the study seeks to answer the following questions:

- What are the main causes of water scarcity?
- What are the priorities, delays, and causes related to water demand?
- Does political conflict lead to water conflict?
- What type of water management can lead to less water conflict in different regions?
- Which group or organization is in charge of controlling water use and plays the key role in maintaining, sustaining, and controlling the water supply?
- How can different causes and consequences of water conflicts be classified?
- What systems could allow communities to use water peaceably and sustainably now and into the future?

The methodology employed in this study addresses new methods of water collection and distribution for domestic and irrigation needs. The research also analyses whether new architecture for water collection and distribution can avert water conflicts. The research also proposes a new architectural concept that is both the object and the method of enquiry.

Practices in water management in Cyprus are analyzed based on existing data and previous research. The study envisions and suggests how architectural design can be used to devise strategies for new urbanization in Cyprus (Figure 2).

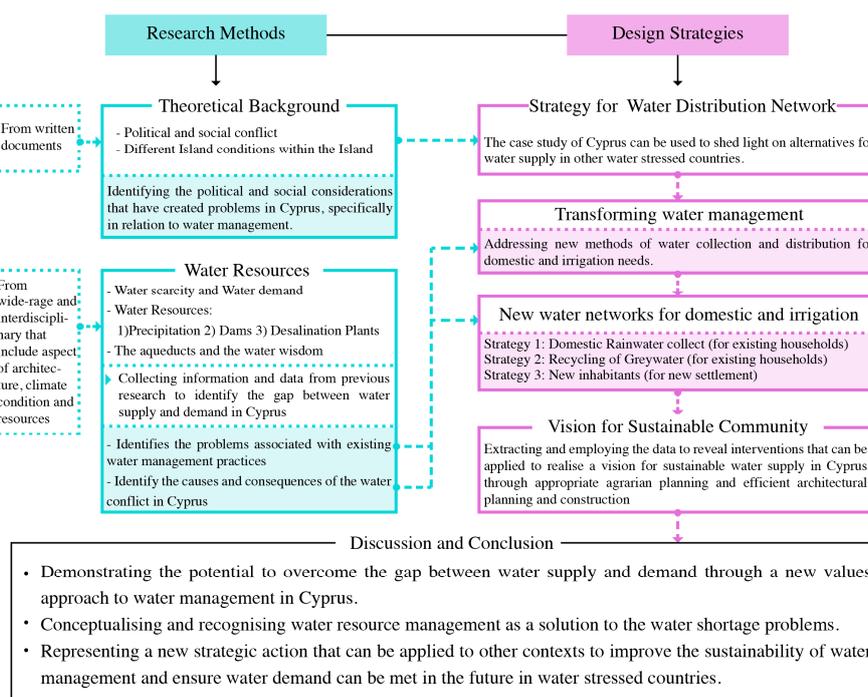


Figure 2. Methods and procedure of the study. Source: author’s drawing.

2. Theoretical Background

2.1. Related Works

The term “water shortage” refers to insufficient quantities of fresh water to meet water demand, resulting in the imposition of substantial restrictions [1,2,4–8], which can affect social conflict and economic development. There is a growing body of literature examining the impact of climate change [3] on water resources at the global and continental or national level. However, relevant simulations on a local scale still face additional challenges caused by the reduction of procedures and uncertainties [9,10].

Many studies have dealt with water shortages in relation to the problem of water resources [11–14] and climate changes [3], and have emphasised the importance of water management [15] and policy [4]. Wars have already been fought in many regions of the Middle East over the desire to gain sovereignty over water sources [11]. The Mediterranean region is among the areas that will be most affected by climate fluctuations. The availability of water resources and the water use level highlight the current and future challenges and opportunities for water management [10]. It is speculated that water may become the cause of future conflicts, with the term “water wars” [2] perhaps being the first alarmist recognition of how water scarcity may lead to widespread social disruption [16]. It is widely accepted that the access to and exploitation of water resources has always been a challenging issue, causing water conflicts, struggles, and even wars within and between different societies and countries. The term “water wars” refers to conflict among groups, societies, or countries over gaining access to water supplies [4].

Some authors have recognized that wastewater production can address the gap between clean water demand and supply [4,13,15]. The causes of water shortage include the uneven spatial and temporal distribution of water resources and increased demand for water; thus, the development of alternative water sources, such as recycled water, brackish water, and rainwater [17], is essential for closing the gap between supply and demand [18]. As an alternative, it has been shown that water recycling in agriculture provides the benefits of increasing water availability for other activities, such as domestic and industrial use; reducing competition among users; and preventing the overexploitation and decomposition of natural bodies of water. This perspective appears to be evolving in many countries around the world [19–22] seeking to cope with the growing water demands for water and protect their water resources from overexploitation in the face of ever-increasing populations.

To produce an appropriate urban water supply, it is necessary to improve the management and operation of domestic water supply networks by simultaneously identifying challenges and opportunities for current and future network management. To date, the sustainable use of water resources faces great challenges posed by population growth, weak economic conditions, increasing demand for water, the need to ensure food security, poor quality, and aging infrastructure [23]. These challenges have not been effectively addressed in existing water governance plans, highlighting the need to develop more sophisticated water management plans in response to changing conditions and requirements. Current insights into water management consider background expertise in the field and include government services and agencies, the private sector, and the public [24,25].

Water regulates ecosystem functions, preserves the quality of the environment, facilitates human health and well-being [26], and plays an important role in supporting life [27,28]. The issue underscores the need for revised water management, especially in areas subject to demographic changes and climate vulnerability, to ensure a sustainable and secure water supply. This study highlights and discusses situations and possible solutions, such as advanced technical solutions and practices and alternative, more efficient water usage, addressing the growing environmental and health requirements, as well as new conflicts among water users. However, the consideration of water catchments and distribution through urban networks systems to improve safe water supplies is lacking. Thus, this research has three principal areas of focus:

- (1) The investigation of the political and social conflict in Cyprus to understand theoretical background of disputed Cyprus
- (2) The data collection and analysis of water resources to find ways of reducing water demand
- (3) The proposition of a preliminary conceptual design of water catchment and distribution that provide a sustainable vision of safe water supply.

2.2. Disputed Cyprus

2.2.1. Political and Social Conflict

From approximately mid-2 BC, Cyprus was dominated by different foreign countries almost without interruption until 1960, when the former colony became independent from Britain. Thus, for almost two millennia, external powers dominated the island and its people. In December 1963, violence broke out between the Turkish and Greek Cypriots over who would gain control of the island country, leading to the establishment of the United Nations Peacekeeping Force in Cyprus (UNFICYP). However, despite the role of the UNFICYP, Greece and Turkey were at risk of going into war in 1964 and in 1967. Thus, the Cyprus dispute was a conflict between the Turkish Cypriots and the Greek Cypriots over which ethnic community would gain control of the island country. Cyprus was divided in 1974, with the Greeks controlling 63% of the territory, and 37% of its territory (the northern third of the island) occupied by Turks, causing a de facto division of the island [13]. A military invasion by Turkey led to a partitioning of the island, the displacement of many of its inhabitants, and eventually a declaration of independence by the north in 1983 [29] when the Turkish Republic of Northern Cyprus declared independence from the Republic of Cyprus.

The small island of Cyprus is currently subdivided into four communities: the Republic of Cyprus, Turkish Republic of Northern Cyprus, a buffer zone between the two controlled by the United Nations, and two bases under British sovereignty [30]. The political system of Northern Cyprus is a semi-presidential democratic republic. The events that led to the current division of Cyprus and the resulting political situation are still matters of ongoing dispute (see Figure 3).

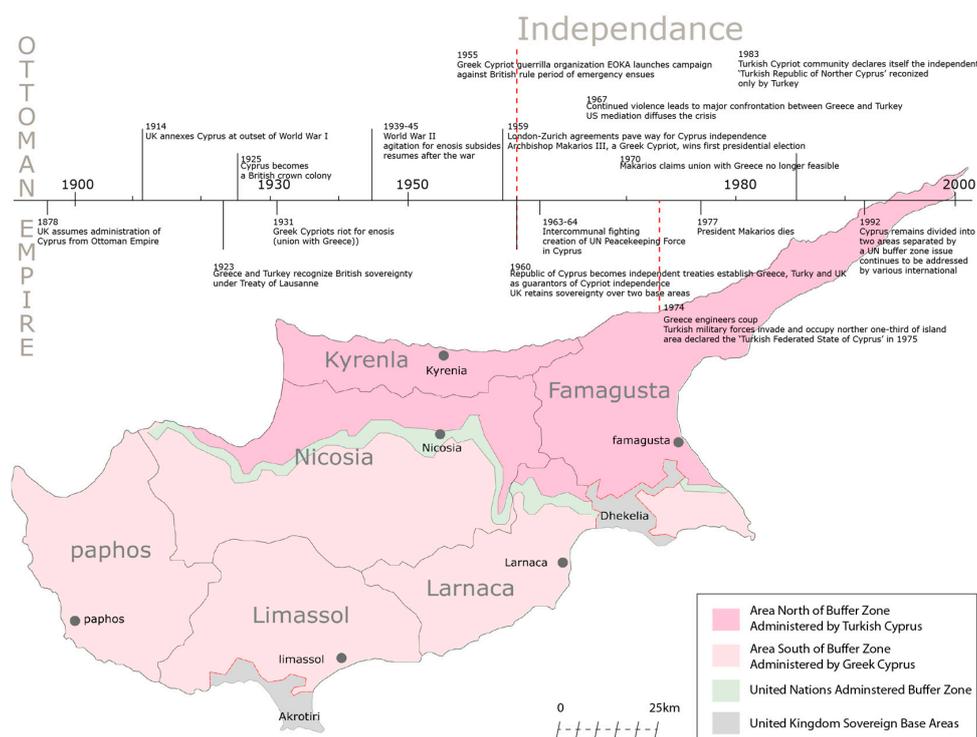


Figure 3. Political history of Cyprus. Source: author's drawing.

2.2.2. Islands within the Island

Cyprus is an island country located in the north-east of the East Mediterranean basin. With an area of 9251 km², Cyprus is the third largest island in the Mediterranean. As a result of the division, Cyprus has many different island conditions (see Figure 4). This section present the various island conditions to obtain an understanding of the political status of water management in divided Cyprus.

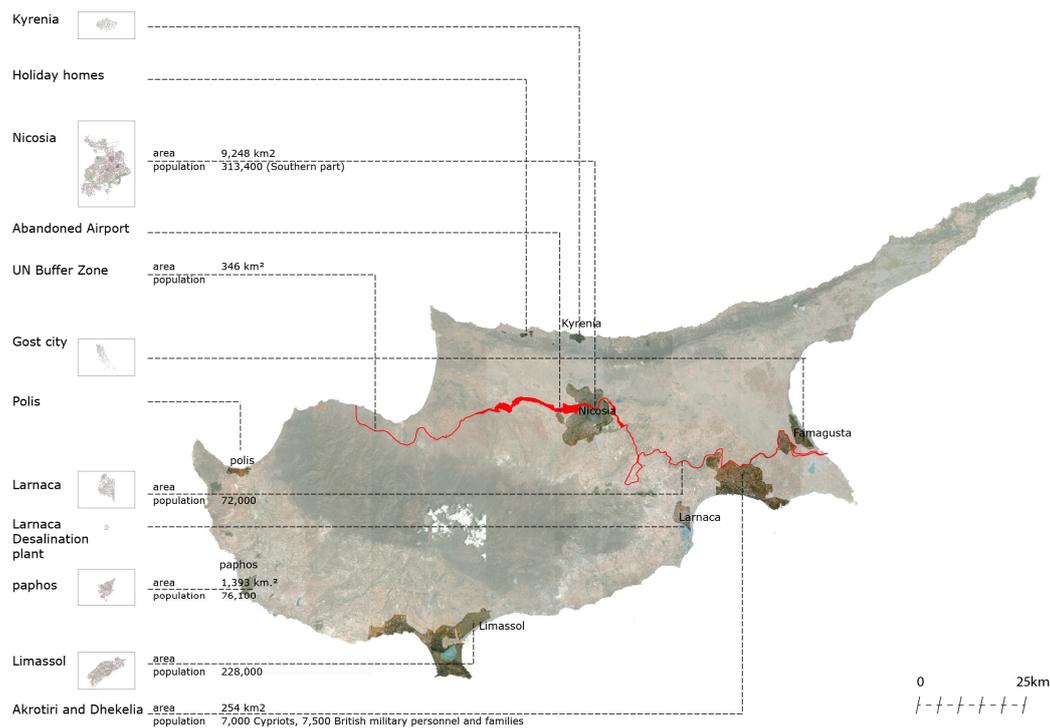


Figure 4. Island cities in divided Cyprus. Source: author's drawing.

The island conditions within divided Cyprus are as follows [29,31]: (1) Nicosia is the capital city of Cyprus, and is the only divided city in any European country. It is characterized by its political boundaries, including a wall around the city and the buffer zone that divides the northern and southern portions of the country. (2) Nicosia International Airport was used in World War II but was abandoned following the Turkish invasion in 1974. Following cessation of hostilities in 1974, it was declared a United Nations protected area and now lies within the United Nations buffer zone separating the two sides of Nicosia. (3) The Varosha quarter of Famagusta in Cyprus was one of the most popular holiday destinations in Europe. However, in 1974, what was once dubbed the “Millionaire’s Playground” suffered a number of casualties arising from the Turkish invasion that led to the division of Cyprus into north and south. (4) Akrotiri is a large Royal Air Force base in Cyprus that functions as a British foreign territory and is managed as a Sovereign Base Area. Britain has a treaty with Cyprus that guarantees British access to Akrotiri under any circumstances. (5) Cyprus achieved independence from Britain in 1956 after a protracted struggle by Greek Cypriots seeking unification with Greece. However, Britain retained two military base areas—Ormidhia and Xylotymbou—surrounded by territory belonging to the British Sovereign Base Area of Dhekelia.

3. Water Resources in Cyprus

3.1. Water Scarcity and Water Demand

Cyprus is currently suffering from a severe water shortage arising from drought in 2007, 2008, and 2018, resulting in its streams and reservoirs literally running dry [32]. The gap between water supply and water demand is increasing because of the growth of the local population, migrants settling in Cyprus, and tourism. For instance, in 1995, the population was 666,313, with a water demand of 132.5 million cubic meters (MCM). By 2000, the population had increased to 697,549, and water demand was 265.9 MCM, and by 2012, the population had reached 865,878, and water demand was 275 MCM [33,34] (see Figure 5a).

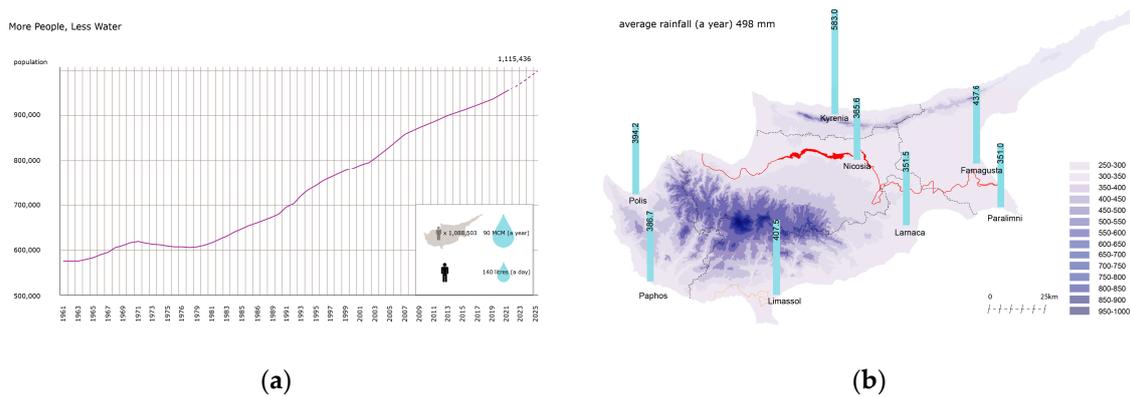


Figure 5. (a) Population growth by 2025; (b) Precipitation. Source: revised from [32].

Until 1997, the main source of water in Cyprus was rainfall, with the island relying heavily on rain to supply water. However, the average annual rainfall has decreased over the years. According to a series of observations, the average annual precipitation, including snowfall, has decreased from 503 mm in 2000 to 463 mm. Between 2001 and 2004, exceptionally heavy annual rainfall increased water reserves, with supply exceeding demand, allowing total storage in the reservoirs to increase to a record high at the beginning of 2005. However, since then, the annual supply has fallen to 498 mm, while demand has increased from local population growth, foreigners relocating to Cyprus, and an increasing number of tourists [35] (see Figure 5b).

There is an urgent need to resolve this problem. In a first step to identify ways in which to minimize the gap between water supply and demand in Cyprus, this section explores the following related factors: (1) precipitation and water cycle, (2) dams and desalination plants, and (3) water consuming sectors.

3.1.1. Precipitation and Water Cycle

The cycle of water movement from the atmosphere to the earth in the form of rain, snow, or hail and back to the atmosphere through evaporation is referred to as the water cycle [36] (see Figure 6a). The quantity of water falling over Cyprus's total surface area is estimated to be 4400 MCM [37]. However, only 10% (440 MCM) is available for exploitation, because 90% returns to the atmosphere as direct evaporation and transpiration. The remaining 440 MCM infiltrates the earth through the pores and fractures of rocks and recharges the groundwater. Of this, 195 MCM reappears on the ground surface through springs. Of the 245 MCM of surface water, 137 MCM is stored in dams and reservoirs, the total capacity of which is presently 300 MCM. During winter and spring, when the rivers have a surface flow, 182 MCM of water is used to irrigate the nearby fields [36] (see Figure 6b). A total volume of 48 MCM of surface water flows into the sea. In addition, approximately 149 MCM of water is pumped from aquifers, with 45 MCM flowing into the subsurface through the aquifers and being lost to the sea.

The values provided above represent the water balance in Cyprus when there is an average annual rainfall of 498 mm [37]. The rainfall in Cyprus is unevenly distributed geographically, with the highest level of rainfall being in both mountain ranges and the lowest level in the eastern lowlands and coastal regions. In addition, given frequent droughts that can span from two to four years, there are great variations in rainfall. Further, approximately one-third of the underground water storage flows into the sea.

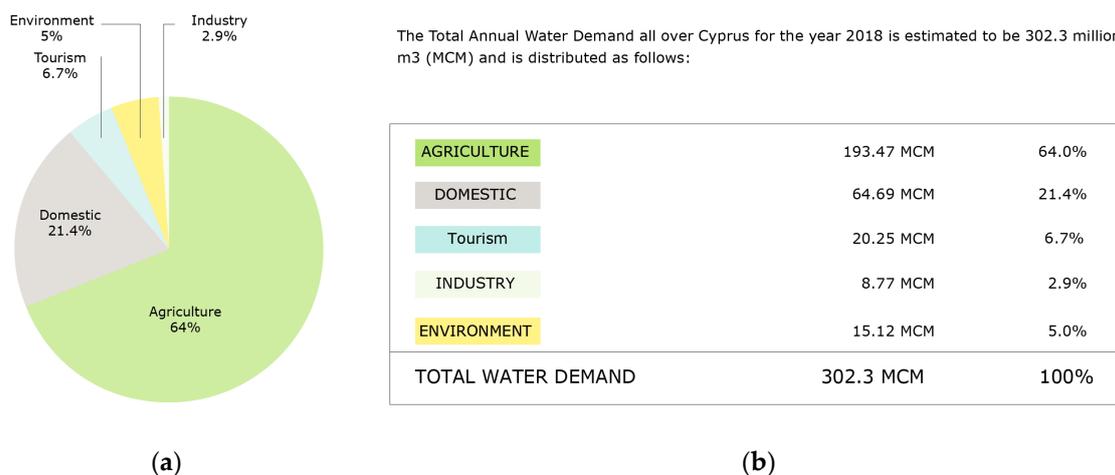


Figure 7. Water demand in Cyprus: (a) Water usage by sector; (b) Total water demand and distribution in 2018. Source: revised from [4,41,42].

3.2. Water Resources in Cyprus

3.2.1. Water in Southern Cyprus: Desalination Plants

Despite the construction of desalination plants in the southern Greek sector of Cyprus, the island faces an acute water crisis that has been aggravated by several years of drought and an increased demand for water by the growing population. The ongoing water crisis is also beginning to affect tourism, one of the island's main industries, thus risking revenue from the three million tourists who visit Cyprus each year [43]. The extended drought in Cyprus has resulted in unsatisfactory levels of water stored in dams and created the need to build seawater desalination plants to supply drinking water to the large urban and tourist centers without relying on rainfall. To meet demand, in the early 1990s, Cyprus began building desalination plants, which now supply most of the drinking water in the southern part of the island. There are currently four desalination plants in operation: Dhekelia, Limassol (Episkopi), Vassilikos, and Larnaca. In addition, the construction of a desalination plant in Paphos was expected to commence at the end of 2019 [44] (see Figure 8). The desalination plants in Dhekelia and Larnaca meet a significant portion of the drinking water needs for Nicosia, Larnaca, and Free Famagusta, with a total production capacity of at least 32.8 MCM annually. The desalination plants of Limassol (Episkopi) and Vassilikos meet a significant proportion of the drinking water needs of Limassol and some of the needs of Free Famagusta, with a total production capacity of at least 32.8 MCM annually [32,44]. Desalination plants contribute greatly to solving the water problem in Cyprus. However, the total capacity of desalination plants does not meet demand during severe drought because of the illegal and uncontrolled overextraction of groundwater, tragically leading to the permanent and irreversible depletion of underground aquifers and irreversible salinization of the coastal aquifers [4]. Thus, sustainable management of water resources is needed to help Cyprus effectively address water shortages during drought periods every year.

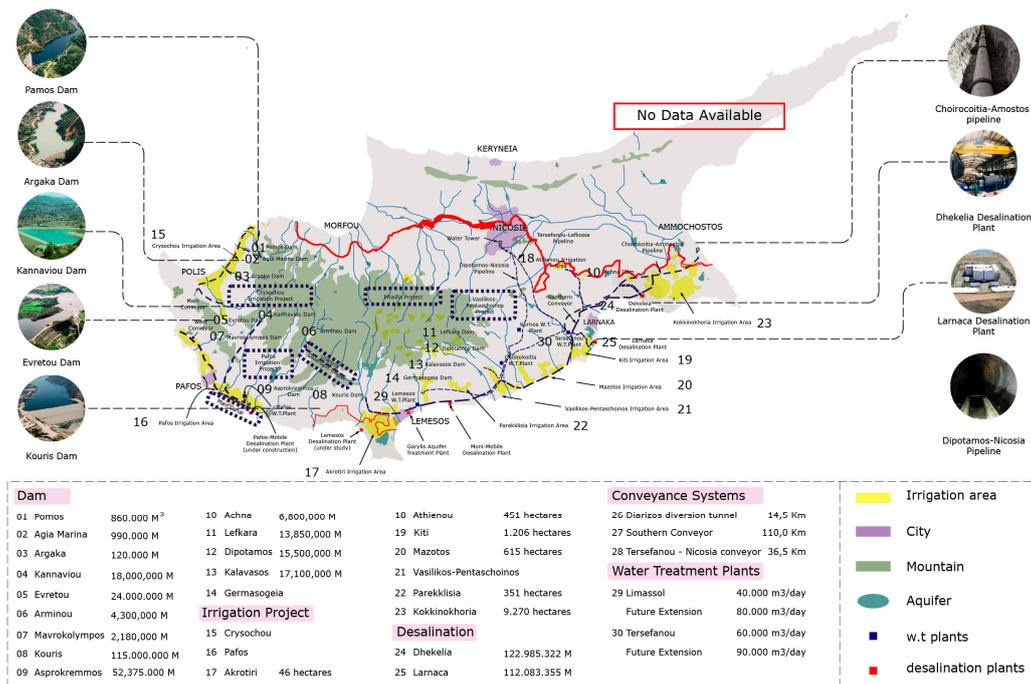


Figure 8. Water works in Southern Cyprus. Source: author’s drawing.

3.2.2. Water in Northern Cyprus: Water Pipe from Turkey

In 2012, the Turkish Cypriot government signed an agreement to build an undersea pipeline that would pump fresh water from Turkey to the northern part of the island. The pipeline will bring water from southern Turkey to the small village of Geçitköy in the Turkish Republic of Northern Cyprus. Approximately 25 km of the pipeline will be on land, while 80 km will be under the Mediterranean Sea. Turkey appears to be serious about implementing this project to bring fresh water to Northern Cyprus through an undersea pipeline [43] (see Figure 9). The plans for the water pipeline are that it will supply water to the Turkish Republic of Northern Cyprus only.

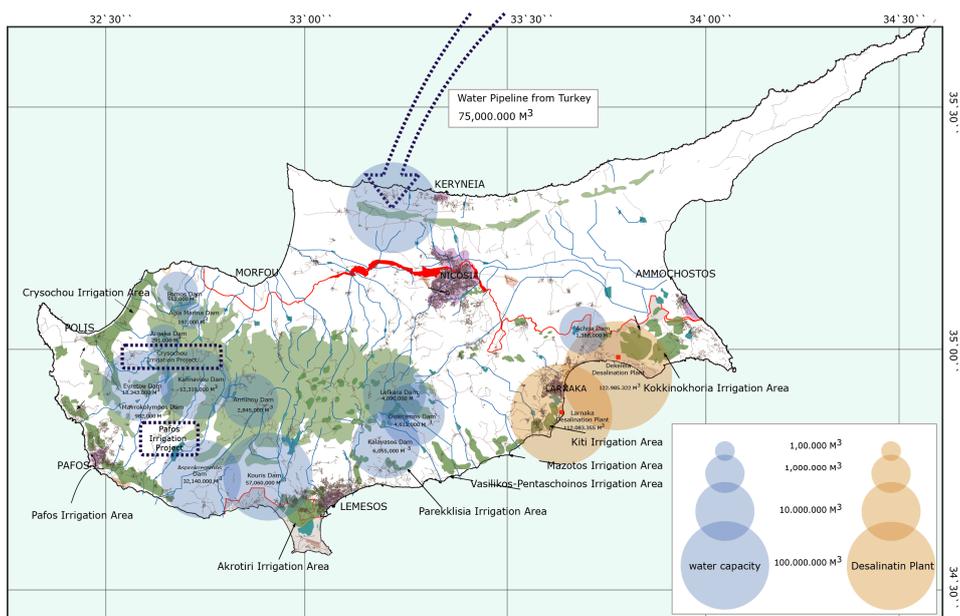


Figure 9. Water consumption in Cyprus. Source: author’s drawing.

Water for the pipeline will be supplied by constructing two dams, one in Geçitköy in Northern Cyprus and the other in Alaköprü in southern Turkey. Turkey has previously built dams to store water, and one of these dams, in Allianoi in north-western Turkey, is feared to lead to the flooding of an ancient Roman spa that is still more than 80% non-excavated. Turkey has also constructed a series of dams on the Tigris and Euphrates rivers, which has curtailed the flow of these historical rivers to other countries in the region [32]. Even if successful, the water pipeline project from Turkey to Northern Cyprus will take several years to build, and will necessitate completion of the construction of the dams at Alaköprü and Geçitköy. Connecting the northern part of Cyprus to the Turkish mainland by this water pipeline will emphasize the division of the island into Greek and Turkish sectors, with the result being that the two divisions will work separately rather than together to solve the island's water needs. In addition, Turkey's own water supplies are dwindling, which may reduce the share of its water resources it gives to Northern Cyprus. Thus, having separate water sources for the island may exacerbate the continuing political divisions between Greece and Turkey that have resulted in many serious problems in Cyprus over the years. Further, many Cypriots believe the 77 km undersea pipeline to be laid in very deep water is a fantasy. Moreover, while this solution may work in the short term, it is not a permanent solution, because Turkey itself may not always have sufficient water to supply the Turkish part of the island [43].

3.2.3. Water Ownership

In Cyprus, a water storage tank is installed in almost every household, usually on the roof to provide sufficient water pressure [44]. These tanks have sufficient capacity to store water for at least two days for an average family. Although it is illegal in Cyprus to have additional water storage tanks that run off current water supply, almost every household has more than one of these tanks on its roof. Another problem is that when a water storage tank dries up, people may steal from the tanks of their neighbors.

Until 2001, water supply was restricted in Cyprus, with mains water being switched on only two or three times per week. People learned to keep the mains water in bottles for drinking, and limit their use of washing machines and watering the garden to days when the mains water was on. After a series of particularly dry winters that led to the building of a desalination plant, mains water was on almost constantly, and inevitably people began taking water for granted. Despite bans on hosepipe supply and on-the-spot fines for using hoses, many Cypriots wash their patios or the pavement in front of their homes two or three times per week, with water pouring out of hoses. After two more dry winters, water restrictions were introduced again at the end of March 2008, with mains water on for approximately 12 h of every 48 h. These restrictions eased in January 2010 after one of the wettest winters on record; however, water is still considered a valuable commodity in Cyprus. Mains drainage is slowly being introduced in Cyprus, in line with European regulations, but at present, many houses have septic tanks rather than being connected to the mains for wastewater. In addition to having quarterly water bills, residents have an annual sewerage/drainage bill of approximately EUR60 per person [45]. The strict restrictions on water supply to households mean that people were receiving water for only 36 h per week, reducing independence and freedom [4,46].

Some parts of Northern Cyprus have been experiencing an unprecedented boom in construction and property sales. Turkish settlers in this area enjoy lawns and swimming pools, which require a great deal of water, while some parts of Southern Cyprus survive on as little as 35 L of water per day for their domestic use. What is interesting about this situation is that most of the properties affected by this boom are owned by Greek Cypriots who cannot visit their own houses because of the division of the country.

Here, the following questions should be posed: Who owns water in divided Cyprus? Which group or organization is in charge of controlling water use and plays the key role in maintaining, sustaining, and controlling the water supply?

3.3. Aqueducts and Water Wisdom

During the Persian rule of Cyprus (546–335 BC), Persian *qanats* (underground aqueducts) were imported to the island. The end part of the extensive Persian *qanats* was discovered by archaeologists in the early 1990s in the ancient port of Larnaca (480–300 BC) (see Figure 10a) [47]. This sophisticated water supply system brought sufficient quantities of water from suitable sources outside Larnaca's city walls. Being relatively large and protected within the city's walls, the *qanat* satisfied the needs of Larnaca's population and its busy military and commercial port.



Figure 10. Cyprus's aqueducts: (a) End part of Persian qanat in the port facilities of ancient Larnaca (480–330 BC); (b) Water channel on top of the last and most grandiose series of arches; (c) Walled city aqueduct of Nicosia [47,48].

Under Ottoman rule (1571–1878), Larnaca became the main port and most populated center of Cyprus. One of the governors during this rule was Abu Ibrahim (better known as Bekir Pasha) (1746–1748), who constructed an aqueduct for Larnaca (the Bekir Pasha Aqueduct). This 15 km long water supply system, which survives today, comprised a 7 km underground tunnel, made according to the technology used for Persian *qanats*, and 8 km of above-ground arches. The underground tunnel began below the bed of the Tremithos River and ran for 7 km towards the city. Here, the water rose to the surface and flowed for 8 km above ground atop a series of arched aqueducts passing over three small valleys. The water powered two grain mills along the way before reaching Larnaca, where it supplied seven public fountains (only two of which exist today) with running water (see Figure 10c). The three arched constructions, which remain in excellent condition (see Figure 10b), represent an important monument of a collective history of water wisdom.

Built in the eighteenth century, an ancient aqueduct was part of the old water supply system of Nicosia, bringing water from the mountains north of the city. A stone arched construction ran from Kyrenia Gate in the north to Famagusta Gate in the east, supplying water to several fountains in the inner quarters of the city. This section of the aqueduct was known as the Silihtar Aqueduct after the Ottoman governor of the time. During the demolition of a private building [48], 11 arches of this old aqueduct, which were hidden within an adjoining newer structure, were revealed, showing signs of extensive decay. The Nicosia Master Plan project was implemented, which aimed to restore the monument and redesign the surrounding area to include irrigation and drainage systems and improve walkways and passages in the vicinity.

4. Strategy for Cyprus Water Distribution Network

4.1. Transforming Water Management

After declaring the independence of Cyprus in 1960, the Cyprus government placed great importance on water management and securing the adequate provision of high-quality water to inhabitants. The government's main policy, implemented through the Water Development Department, was to increase water supply by constructing dams and conveyance infrastructure under the motto, "No drop of water to the sea" [41]. New measures included the drilling of boreholes and the construction of water treatment plants to supply water for domestic use and irrigation. In addition,

the Cyprus government was persuaded to install improved irrigation systems and impose a water charge for domestic and irrigation water. Despite these additional measures, there was still insufficient water supply to meet the increasing water demand, and the decreasing water resources became increasingly evident. Given the lack of surface water runoff in Cyprus, groundwater resources have traditionally provided water for domestic and irrigation use. Thus, the island's aquifers are overexploited, particularly during periods of drought. It is estimated that groundwater resources are heavily over-pumped by approximately 40% of the sustainable extraction level. These issues have resulted in the Cyprus government reorganizing its general water policy in an attempt to ensure that all inhabitants have access to reliable fresh water. Additional measures to ensure a secure water supply have included the use of municipal cleaning waste and tertiary-treated water for groundwater recharge and agriculture, and the introduction of a desalination plant, enabling the government to provide a continuous supply of drinking water to the country. Meanwhile, there have also been extensive efforts to conserve water through public campaigns and education. Further, there have been many revisions made to the current legal and institutional frameworks to structure an environment that will enable efficient water management and the conservation of water-related systems.

In Cyprus, all levels of society—from the national level to the individual level—have authority over water supply. Water systems in Cyprus are separate to some extent; however, they overlap and share the water systems in some instances.

4.2. Strategies for Current Inhabitants

This section provides a vision for a sustainable water supply in Cyprus and strategies that may be adopted by existing households and new inhabitants that use water distribution networks. The section discusses political and social issues from the perspective of their potential to lead to new urbanization in Cyprus.

4.2.1. Strategy 1: Domestic Rainwater Collection

The simplest way to collect water for daily use for existing houses is to install a rainwater tank. Rainwater tanks collect and store rainwater, typically from rooftops via gutters. Such tanks store rainwater for later use, reduce the use of mains water for both economic and environmental reasons, and aid in self-sufficiency. They provide water for drinking, livestock, irrigation, and to refill aquifers when recharging groundwater. Rainwater collected from the roofs of houses and local institutions can make a significant contribution to drinking water availability. Rainwater tanks may involve a high initial installation cost; however, many houses use small-scale tanks to harvest small quantities of water for landscaping or garden use, rather than for potable water [49].

Rainwater falling onto the roof of a dwelling is transported through the downpipes via a filter to an underground rainwater tank located in the rear garden. The rainwater is then pumped into the dwelling and supplies soft water to washing machines and external taps (see Figure 11a). Rainwater tanks also have a mains water supply so that the adequate water can be supplied during dry periods. The average daily water use for a family of four is 540 L. Maximizing the roof surface could harvest 98,550 L or more of rainwater annually (see Figure 11b). Ideally, dwellers should build a system to account for all factors affecting water resource management. By installing a rainwater collection system, each property would improve its water use efficiency and reduce its demand on the public water supply, leading to a 52% water saving (see Figure 11c). This saving is achieved by reducing the requirement for mains water and reducing surface water runoff from dwellings.

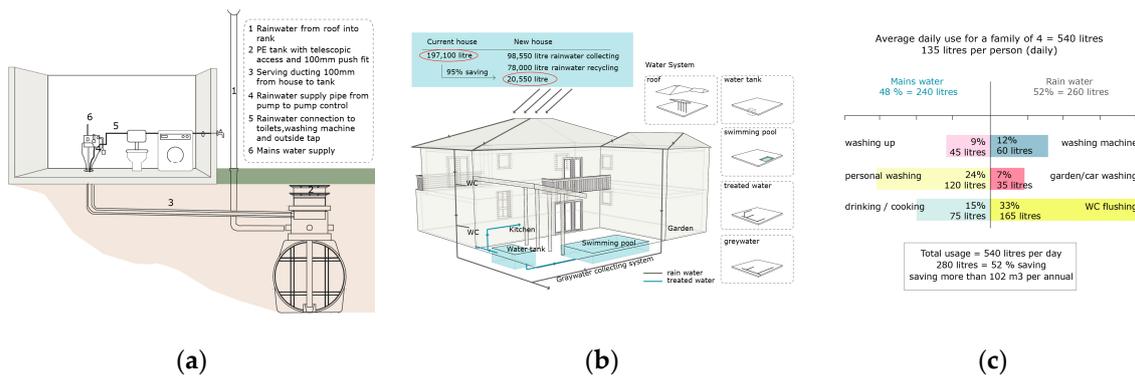


Figure 11. (a) Domestic water supply and discharge; (b) Domestic rainwater collection; (c) Average daily use for a family of four. Source: revised from [48].

4.2.2. Strategy 2: Recycling of Greywater

Another way to collect water from existing houses is to recycle greywater. Greywater is a means of reducing water consumption primarily by hotels and industries such as laundries. Greywater can be recycled onsite for garden and landscape irrigation, laundering clothes, and toilets. In Cyprus, this type of water reuse is spreading, because its benefits make it an attractive investment for households and organizations. The Cyprus government has established a subsidy program for greywater reuse at the household level [44].

Greywater differs from water from toilets, which contains human waste and is designated as sewage (i.e., blackwater) (see Figure 12a). Greywater has lower pollutant levels than does blackwater, making it easier to treat and recycle [50]. While all greywater contains microorganisms, the health hazards associated with greywater from a multiple-dwelling source are different from those associated with greywater from a single-dwelling source [51]. If collected using a separate plumbing system from blackwater, domestic greywater can be recycled directly within the home, garden, or company and either be used immediately or processed and stored [52].

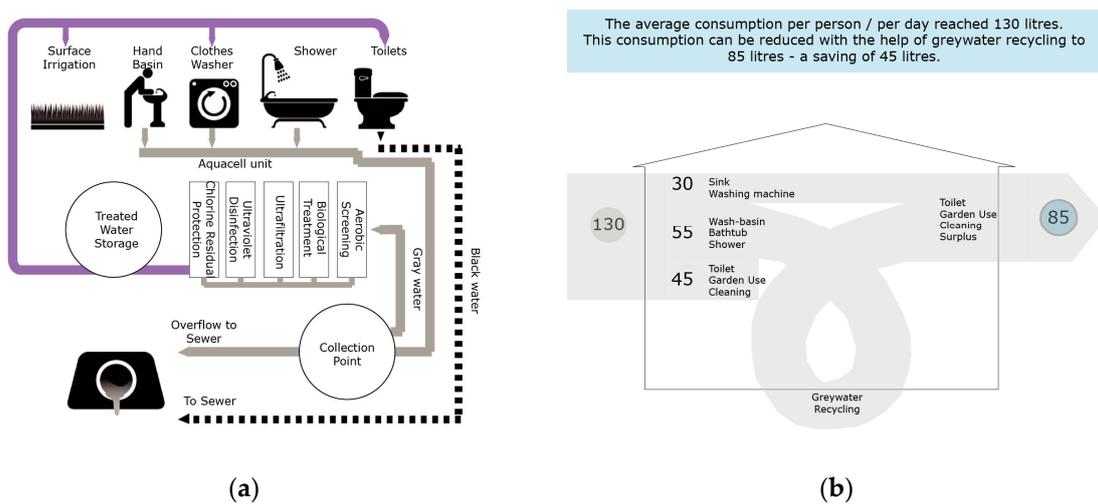


Figure 12. (a) Recycling of greywater; (b) Process of recycling greywater. Source: revised from [50,51].

When greywater is appropriately recycled, it can save approximately 45 L of drinking water per person per day in domestic use. Greywater comprises 50–80% of residential wastewater generated from all sanitation equipment except toilets (see Figure 12b). Therefore, greywater recycling is one of the most useful water solutions for Cypriots.

4.2.3. Strategy 3: New Inhabitants

Apart from water scarcity, it has been demonstrated that the most controversial aspects of water supply in Cyprus are water allocation and control. Thus, a strategy for a water distribution scheme for new inhabitants includes an understanding of the limitations of the Cyprian landscapes and the potential to create a new urbanization regime for Cyprus.

To enable the development of sustainable water distribution systems, new towns on the island should be built with distinct characteristics and spatial quality, while outlying entities should have autonomous water systems. The separation of each town will create “islands within the island” (see Figure 13).

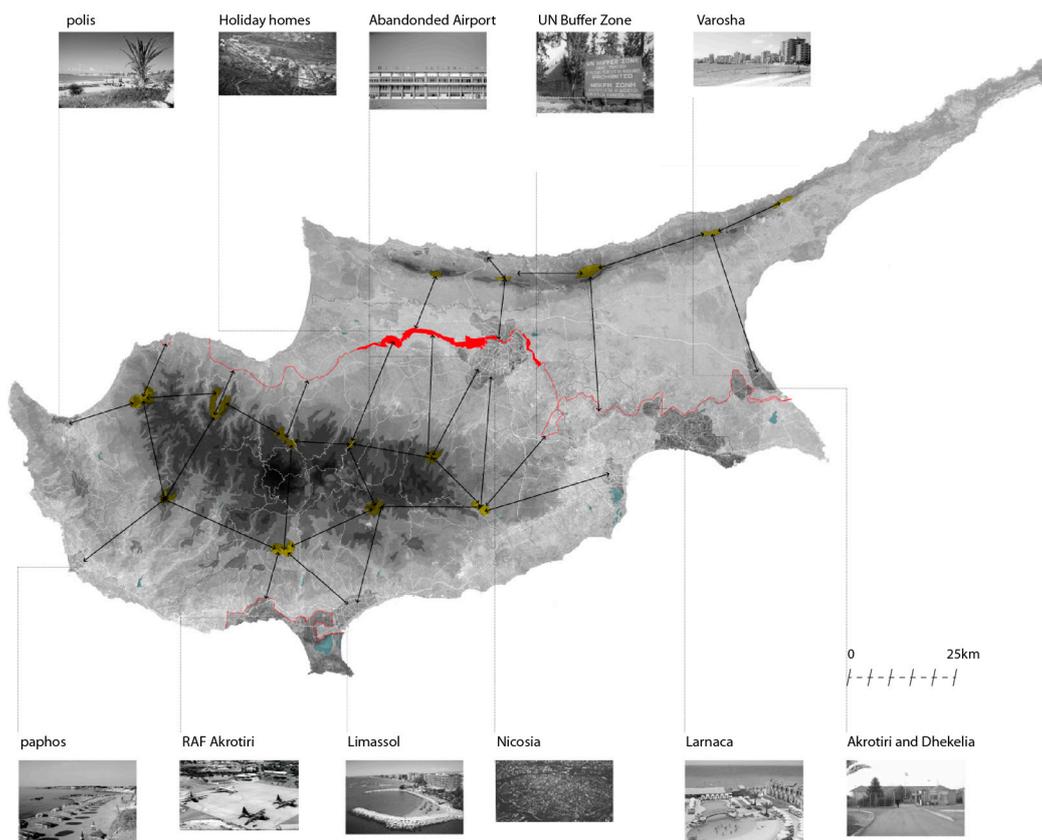


Figure 13. Creating new locations for new islands on the island of Cyprus. Source: author’s drawing.

The research involved mapping possible new settlement locations to understand how abstraction and transformation water systems may be used to supply the urban and agricultural needs of new settlement and their inhabitants. The findings of this project demonstrate that urban infrastructure models are appropriate for the natural resources and politics of Cyprus. This strategy is based on the principle that a region’s sustainable future depends on creating new autonomous cities, including those on territorial borders, that are organized around a new pattern of land use. Separating towns from each other will creates “islands” within the island of Cyprus. The location of new urban centers requires an understanding of the landscape’s limitations and potential. The many years of desertification and water scarcity in Cyprus may be reversed through landscape planning and decentralized systems of water collection, recycling, and abstraction. Figure 14 illustrates how the new water distribution system would work in Cyprus.

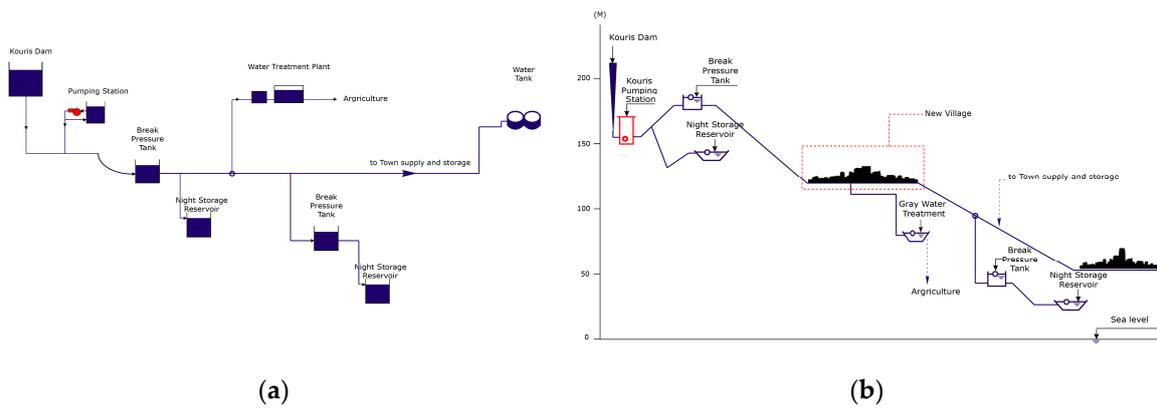


Figure 14. Water distribution schematic diagram: (a) Plan; (b) Section. Source: author’s drawing.

New inhabitants could also consider combining Strategy 1 (rainwater collection) and Strategy 2 (greywater recycling), which would significantly reduce the cost of separate systems. The average annual precipitation in Cyprus varies from 280 mm in the central plains to 1000 mm at the peak of the Troodos Mountain (with altitude 1950 m), with a mean annual precipitation of 497 mm [4]. Thus, new towns should be located on the hill. The advantage of this is that the greywater would be diluted by rainwater, allowing toilet water to be clear for much of the year.

Figure 15 shows how much water could be collected, used, and stored when the water distribution system presented in Figure 14 is installed for households of two, four, and seven members, respectively. For instance, for a family of two living in a total area of 225 m² with a roof surface of 160 m², this type of house could collect 132,080 L, comprising 96,000 L from rainfall (roof surface × average rainfall in new urban areas = 160 × 600) and 46,080 L of recycled water, saving 33,530 liter annually. Applying the same calculation, households with four and seven members could save 71,076 L and 225,715 L, respectively.

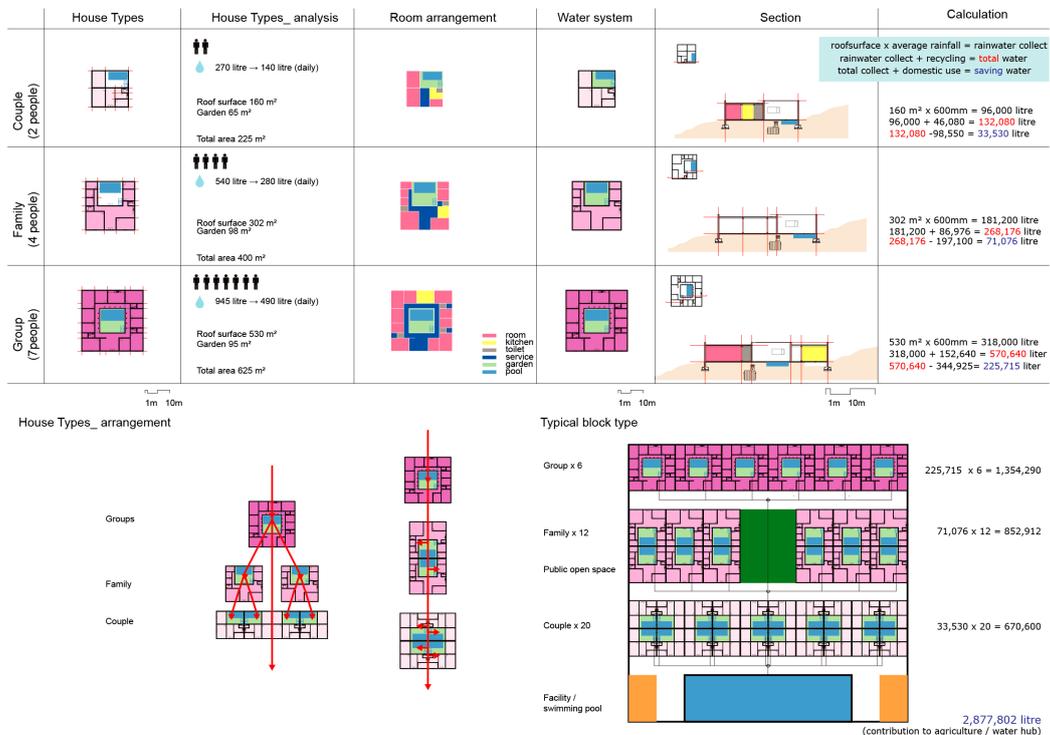


Figure 15. Strategies of water management for new inhabitants. Source: author’s drawing.

4.3. Vision of Water Distribution for Sustainable Community

This research has suggested new strategic actions for Cyprus to increase the sustainability of its water management systems. If these new strategic actions are applied to the water distribution networks for existing and new houses in Cyprus, water distribution and management using modern technologies can enable a sustainable water supply based on spatial and temporal changes. Figure 16 represents how much water can be collected, used, and stored in Cyprus if the water transformation strategies presented in Section 4.2 are installed. By appropriately relocating new inhabitants and implementing efficient water infrastructure and architectural planning, water resources are expected to increase from 62.7% to 65% in agriculture and 22% to 24% for domestic use by 2025.

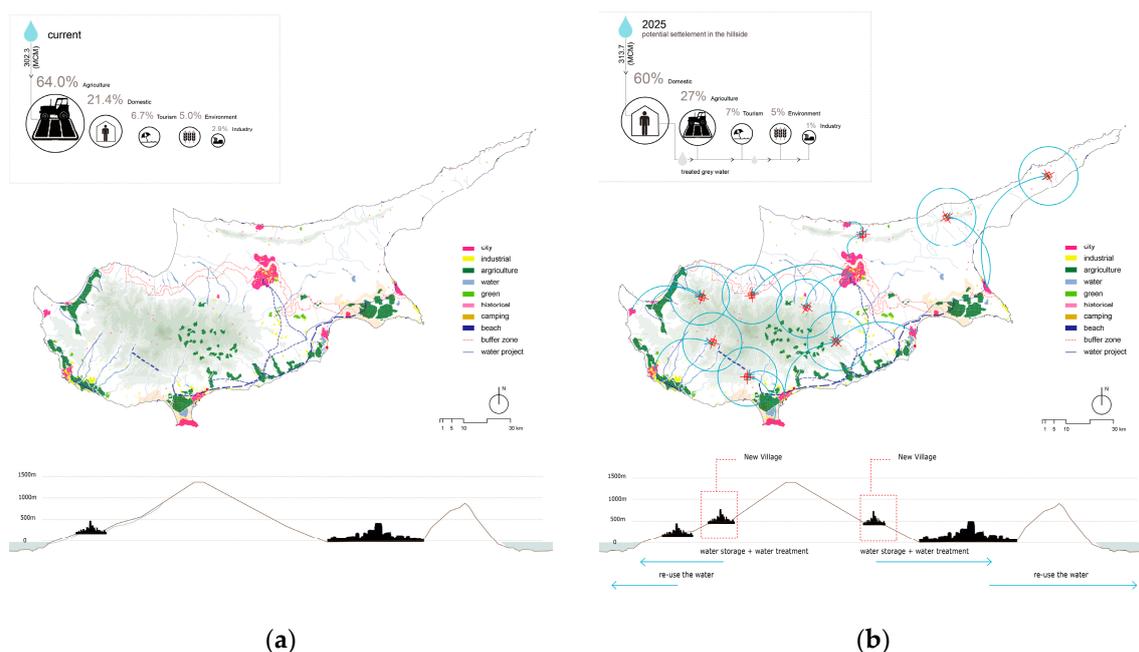


Figure 16. Water transformation system for Cyprus: (a) Current, (b) Vision for 2025. Source: author's drawing.

5. Discussion

As the century continues, increased freshwater resources will be needed in many parts of the world to meet the growing demands of populations and the uncertainties and consequences of climate change. At the same time, more efforts will be required to identify and address the issues that arise, including new threats to the quality of resources and ecosystems, as well as new demands to adjust and mitigate detrimental factors, especially in water stressed regions. This research demonstrates the potential to overcome the gap between water supply and demand using a new approach to water management in Cyprus. It also considers the political conflict in Cyprus in relation to water management. The division of territory on the island has led to conflicts over access to water at different levels of organization. In addition, there are fierce disputes between individuals and organizations over who owns the water. This research found differences in water scarcity issues at the regional and national levels. At the national level, drinking water issues have become increasingly significant for average households in all regions of Cyprus. At the regional level, although transferring water from Turkey to Cyprus may ease local water shortages in Northern Cyprus, it does not completely solve the water supply problems of Cyprus. This study also found moderate-to-high levels of water conflict related to the irrigation networks of desalination plants, which may be avoided through cooperation and the use of modern technology. In addition, areas of Cyprus with fewer water resources are more likely to face greater water conflicts. As discussed, the lack of water supply is one of the most crucial environmental issues

in Cyprus. Cyprus has learned to manage drought through experience. A similar crisis in 2008 forced the country to import water on tankers from Greece, a scenario that will not be repeated.

Overall, the main discussion of the research can be summarized as follows: First, choosing advanced technical solutions and practices that improve users' efficiency of water use should support the sustainable, water-saving resources and increasing the quality of water should be the main goal of water management. Second, an increase in the use of alternative water resources is an important option for water conservation, especially in areas already experiencing water scarcity. Rainwater harvesting and storage, particularly desalination for brackish water, also provides a basis for further expansion of water, ensures less competition for water users, and remains a viable alternative in some regions. Last, providing sanitation and safe drinking water to the population should be of high priority, supported by cost-effective and household sanitation systems. The potential impacts of increased demands and climate change on water resources and quality and the variability in quality arising from the spreading pattern of contaminants should be considered and evaluated.

Thus, the recommendations for water management in Cyprus made by this research would improve water management on the island, particularly in adverse climatic conditions. Optimizing water management networks for drought and water shortages requires the use of modern technology to develop new and sustainable methods of water distribution and management. Therefore, this study proposed the following strategies:

- Strategy 1: Transportation of rainwater from the roofs of domestic dwellings through downpipes via a filter to underground tanks located in rear gardens. Rainwater tanks should also have a mains water supply to enable households to receive an adequate water supply during dry periods. This will reduce the need for a mains water supply and reduce surface water runoff from dwellings.
- Strategy 2: Recycling of greywater to meet various water supply needs and reduce the effects of water supply needs on potentially sensitive areas. This will also reduce the volume of pollutants entering rivers and water systems, because less greywater would need to be commercially treated.
- Strategy 3: A new system of water distribution for new inhabitants. New urban areas should be designed with self-sufficient water systems.

6. Conclusions

Water is the most valuable resource in daily life and is greatly important to the political situation in Cyprus. Although Cypriots are obliged to protect and conserve water, the overextraction of groundwater from illegal and uncontrolled abstraction continues, tragically leading to the irreversible depletion of underground aquifers and salinization of coastal aquifers. The rational and sustainable management of water resources is critical for Cyprus to effectively address its water shortages during drought periods. To ensure quality of life for inhabitants and reduce political conflicts related to water supply, it is crucial to redefine water management in Cyprus to ensure a sustainable water supply and avoid extreme water shortages. Cyprus needs to reshape its water management system to be more effective in the future. With respect to minimizing the gap between water supply and demand, solutions for improving supply include increasing reservoirs such as dams and desalination plants, collecting rainwater in tanks for domestic use, and recycling of wastewater, while solutions for reducing demand include education, conservation, and the relocation of new inhabitants.

Thus, this study has achieved its aims by:

- identifying the political and social problems in Cyprus, specifically in relation to water management
- collecting data from previous research to identify the gap between water supply and demand in Cyprus
- extracting and employing the data to reveal interventions for a sustainable water supply in Cyprus through appropriate agrarian planning and efficient architectural planning and construction.

This research found great potential in the use of alternative water sources—rainwater collecting, recycling of wastewater, desalination, and a new water distribution systems as a sustainable strategy for reducing freshwater extractions in water stressed countries. The results of this study may be useful in conceptualizing and recognizing water resource management as a solution to water shortage problems. While water shortages are not a new problem for Cyprus, the island is dealing with serious water disputes and an unequal water distribution because of political conflicts and territorial division. Efficient and visionary water resource management can create a balance between water supply and demand in Cyprus and reduce the effects of the political conflicts. Through citizen participation in water management and the safeguarding of water systems, Cyprus will be better positioned to meet the difficult challenge of supplying all of its inhabitants with sufficient, clean, and reliable water for their domestic and irrigation needs.

Water scarcity is not only a problem for developing countries. This research has focused on Cyprus, which may be considered a microcosm case for managing water scarcity, highlighting potential future problems for cities and regions around world. Using the case study of Cyprus can shed light on alternatives for water supply globally. The vision of architectural and urban design presented for Cyprus represents a new strategy that may be applied in other contexts to improve the sustainability of water management and ensure water demand can be met in water stressed countries in the future.

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