

## Chapter 2

# Water Resources in Cyprus: Endowments and Water Management Practices

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**Abstract** The availability of water resources in the island and the supply – side of water resources, including inter-annual characteristics of precipitation and its geographic distribution; surface catchments and runoff; groundwater basins and their current water balance; surface water impoundment works; inter-basin transfers; treated municipal wastewater reuse are presented; Given that desalination is an important parameter for the situation of water resources in Cyprus, the island's experience in this supply-side enhancement method is highlighted, and its advantages and disadvantages are explained. In conclusion the water policies and projects planned to regulate and manage water shortages and assessing their adequacy are presented.

**Keywords** Availability, balance of water resources • Groundwater basins • Water quality • Water Infrastructure • Major irrigation schemes • Seawater desalination • Water recycling • Measures for drought

## Introduction

As already indicated in the introductory chapter of this book, Cyprus has a chronic water shortage problem. This problem imposes an increasing burden upon the state administration and the policy makers, and calls for intelligent and economic solutions and prudent water management. The water management problems of Cyprus are exacerbated by the location of the island, which makes it impossible to draw on more distant water sources. Moreover, management problems are intensified by the threat of seawater intrusion, which reduces the utilization of existing, near-shore aquifers. The overall problem becomes even more complex due to the large seasonal

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water consumption by tourism. In this chapter of the book, we describe water resources endowments in Cyprus and introduce the policy instruments used for long-term water resources management.

Cyprus is the third largest island in the Mediterranean. The Government of Cyprus controls 63% of the island, with the remainder under Turkish occupation since 1974. (Unless specified, the figures used refer to the areas under government control). The total population of Cyprus is estimated to be 730,000 people (Statistical Service of the Republic of Cyprus 2001). In the government-controlled (GC) areas, the population is estimated to be 638,000 of which 68% is urban and 32% is rural (Statistical Service of the Republic of Cyprus 2001). Low population growth rates, around 1%, suggest that the population in 2020 will reach 800,000. Administratively, the island is divided into six districts: Nicosia, Larnaca, Limassol, Paphos, Famagusta and Kyrenia. The latter two districts are partly or entirely under Turkish control.

Two mountain ranges run east to west: The Troodos mountains cover approximately 3,500 km<sup>2</sup> in the west and rise to nearly 2,000 m. The Kyrenia mountain range along the northern coast covers 400 km<sup>2</sup> and rises to 950 m. In between these two mountain ranges lies the central plain of Mesaoria covering 2,500 km<sup>2</sup>. The remaining land forms narrow coastal plains which are good for agriculture. There are no perennial streams. Most of the winter streams traversing these plains originate in the Troodos Mountains, and have deep alluvial beds in which substantial volumes of groundwater can be stored.

Due to the arid climate, evapotranspiration consumes as much as 80% of the total annual precipitation. In general, full irrigation is necessary from late spring to late autumn to sustain crop production. Of the total land area in Cyprus, approximately 47% is arable. The remaining 34% is uncultivated land, consisting of bare land, fallow land, built-up areas and water surfaces. Forests are mainly state owned and cover 19% of the island (Agricultural Statistics 2001).

Farm sizes in Cyprus are small on average (mean size 3.8 ha) and fragmented. Part-time farming is the norm, representing 60% of farmers, while most farm-labor is family labor. The agricultural labor force has declined from 17% in 1980 to 11.6% in 1994. Cyprus's accession to the European Union (EU) has altered agricultural marketing strategies in the island, as the market for agricultural products is now open to agricultural imports from the rest of Europe.

## The Availability of Water Resources

In Cyprus more than two thirds of the rainfall occurs between October and April, while water consumption for irrigation and tourism, is highest in summer. Average annual rainfall is 500 mm,<sup>1</sup> but varies from 300 mm in the central plains and the southeastern parts of the island to 1,100 mm in the Troodos Mountains and 550 mm

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<sup>1</sup>mm stands for millimeter.

in the Kyrenia Mountains. The variation in rainfall is not only regional, which necessitates costly inter-basin transfers, but also annual. Water scarcity is exacerbated with large inter-annual variations that can result in two, or even three, year droughts with rainfall under 300 mm. This incongruity of water availability with demand define, to a large extent, water management strategies and necessitates drought planning.

### ***The Water Resources Balance***

Based on the 30-year period between 1951 and 1980, for which data for the whole of the island exists, the average rainfall is 477 mm. Based on data that covers the period from 1916 until today (not consistently available for the whole of the island), the long-term average rainfall is 500 mm. The average annual water crop for this period amounts to 780 million cubic meters (MCM), of which 65% (510 MCM) is surface runoff. The remainder of the annual water crop (270 MCM) directly replenishes the island's aquifers. Some 27% (140 MCM) of the total surface runoff infiltrates into riverbed aquifers and coastal alluvial fans (Iacovides 2001). Part of this water is extracted from wells and boreholes, and the remainder goes to the sea. These add up to an annual total aquifer recharge of 410 MCM. However, due to long-term over-pumping, an annual groundwater deficit of 40 MCM has been documented, while seawater has intruded in major coastal aquifers. Of the total surface runoff only 45% (230 MCM) is lost to the sea. These figures indicate the high level of surface runoff utilization achieved in Cyprus over the last 40 to 50 years. This level of utilization is indeed an achievement, if one considers that a large proportion of the losses to the sea are overland flow and flow from minor streams, which cannot be controlled. Eight percent (40 MCM) of surface runoff is diverted for spate irrigation in late winter or early spring. A large quantity of the surface runoff is captured in surface reservoirs which provide inter-annual storage. The island's total surface reservoir capacity is 300 MCM. Current annual use of stored water for irrigation and domestic supply is about 100 MCM.

Statistical analysis of the precipitation records for the period 1916–2000 shows a significant change in rainfall after 1970. The rainfall time series can be divided into two separate stationary periods. The mean precipitation of the period 1970–2000 is 15–25% lower than the mean precipitation of the 1916–1969 period.<sup>2</sup> Further reduction in stream flows was caused by human intervention, such as exploitation of aquifers. As a result, the decrease in the mean annual inflow to dams compared to their design estimates varies between 24% and 58%. Thus, the actually available surface water on the island is indeed substantially less than what had been used as a basis for the development of water related infrastructure.

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<sup>2</sup>Mean annual long-term precipitation rates are further discussed in Chapter 6.

## ***Groundwater Basins and Their Current Water Balance***

Groundwater accounts for about 130 MCM. Almost all aquifers exhibit a negative balance, and at least one aquifer, the Kokkinochoria, has been “mined” down to an average of 15% of the original reserves. Coastal aquifers suffer from serious sea-water intrusion. Although the reduction of the natural recharge due to the cut-off caused by upstream dams, was supposed to be substituted by releases from artificial recharge, this has not been the case in the last few years due to existence of extreme drought conditions.

Groundwater was the traditional source of water for domestic and agricultural uses, due to its availability throughout the year (as opposed to rainfall which occurs mainly during winter). Nowadays, in spite of the construction of a significant number of dams that serve as water storing places, groundwater remains the main source of water for the non-governmental managed irrigation sector and most of the village water supply. The biggest and most dynamic aquifers are phreatic aquifers developed in river or coastal alluvial deposits. During the 1990s, aquifers exhibited serious depleting trends. Repeated and persistent drought episodes reduced direct and indirect groundwater recharge, while the construction of dams further reduced recharge of downstream aquifers (Rossel 2001). Farmers have continued extracting the same quantities of groundwater and in many cases have increased these quantities. Recent estimates of groundwater resources on the basis of the hydrogeological conditions of 1991–2000, which cover 66 aquifers within the Government controlled area, are shown in Table 2.1.

Groundwater resources in Cyprus are overexploited by about 40% of sustainable extraction. The average annual extraction for domestic water supply over the period of 1991–2000 was 25 MCM; for irrigation 102 MCM and for industrial use 3 MCM. The use of groundwater for domestic water supply has been significantly reduced in recent years, as it was replaced by seawater desalination, mainly due to quality deterioration. Intensive agriculture and excessive use of fertilizers have resulted in nitrate

**Table 2.1** Annual groundwater balance of Cyprus in million cubic meters (average 1991–2000) (Georgiou 2002)

Natural recharge from		
• Rainfall	205	
• River flows	45	
• Return flow from irrigation/domestic	22	
• Groundwater inflow	9	
• Dam losses	2	283
Artificial groundwater recharge		10
Sea intrusion to aquifers		13
Total replenishment		306
Outflow from aquifers		
• Extraction	129	
• Groundwater outflow	167	
• Sea outflow	25	321
Total outflow		321

pollution of many aquifers. Similar nitrate pollution problems appear in aquifers developed in inhabited areas, because of direct sewage disposal in adsorption pits.

Subsurface losses to the sea derive from minor aquifers during early spring when water is not needed for irrigation and from river delta deposits during winter. The major aquifers also lose a small proportion of water, which is needed to control sea intrusion. All in all, it appears that Cyprus's water development is approaching its limits. Only improved water management and redistribution to water conserving uses would be able to provide additional water in the future.

In a normal year, with long-term average rainfall, water availability is sufficient to cover both domestic and irrigation demands, and keep a favorable water balance overall. However, quoting a figure for total annual water availability on the island on the basis of average conditions would be misleading due to the high variability of climatic conditions. For this reason all the surface water reservoirs are planned and built on the basis of a 2–3 year inter-annual operation. As an indication of the variability in annual water availability, inflows to the surface reservoirs for the period 1987–1998, average to 81 MCM, but vary from 198 MCM in 1987, to 12 MCM in 1991 (Savvides 2001).

The occurrence of dry years greatly affects the availability of water and on many occasions the water stored in the reservoirs, both surface and underground, is far below the annual demands. Water shortages are often faced with proportional reductions in the supply of water. The impact of these supply reductions is more severe on the major cities of the island, which depend upon central surface reservoirs, whereas mountain villages that receive water from springs and borehole abstraction are less affected. Irrigated agriculture that depends on major governmental irrigation schemes also suffers considerably during droughts, because domestic supply is prioritized over other uses.

## ***Water Quality***

Water quality is generally good for domestic and irrigation uses. However, insecticide residues and high nitrate concentrations have recently been observed in dams and groundwater, especially where there is intensive agriculture. Water salinity is also increasing in coastal areas due to sea intrusion in aquifers.

## **Water Infrastructure in Cyprus**

### ***Surface Water***

Since the 1960s, Cyprus has followed a supply-side management approach that aimed to increase water shortages through the construction of dams and conveyance infrastructure. The motto of this management era was “No drop of water to the sea”.

Since 1960, the freshwater storage capacity of the island was increased by 50 times: from 6 to 300 MCM. Nowadays Cyprus ranks as one of the countries with the highest dam development in the world. Water storage capacity in Cyprus is about twice the average annual runoff. Many of the dams spilt water over their spillways only during the very wet period of 2003–2004, which is indicative of their large capacity with respect to annual runoff. Overall, it can be argued that the unit cost of water from additional dam construction will be considerably more expensive than the unit cost of water from existing dams, as the most economically efficient dams are already in place. It is also important to note that the dams were designed on the basis of the rainfall and river flow data series collected since 1917 till the day of a dam construction. Given that most dams were constructed between the 1960s and 1980s, the after-1970 period, when the significant rainfall reduction was realized, carries an insignificant weight in the calculation of the runoff averages on which the dams were designed (Rossel, 2001). The reduction in rainfall resulted in a 45% smaller runoff than the one foreseen in the design of the island's dams. As a result the expected economic benefits of the dams were overestimated: no water is now lost to the sea, but the amount of water retained in the dams is less than expected; hence the cost per cubic meter of water is consequently higher than previously calculated.

### *Inter-Basin Transfers*

The Southern Conveyor Project (SCP) that runs from the southern to the eastern part of the island covers over 40% of Cyprus (Stefanou 1997). The plan was suggested in 1970 based on earlier ideas for integrated river basin development introduced by the joint FAO-Cyprus "Water Master Plan". The SCP is a multi-basin, -unit and -purpose development scheme using surface and ground water. It collects stores and redistributes surplus runoff from the south coast of the island, which is used by 80% of the population in the southern and eastern areas, for residential and agricultural purposes. It also covers the supply of residential water of Nicosia, the capital of the island which is located in the center of the country.

The SCP was part of the governmental policy for development of alternative sources of domestic water, as the demand for this water use was increasing due to rising population, tourism development and decreasing groundwater availability. In addition agricultural products for export markets were prioritized by the government. Water allocation to the different sectors is prioritized in the following order: domestic, tourist, industrial and irrigated agriculture. After considering the needs of existing projects and users, the surplus water of six rivers was used in the SCP. Based only on the Kouris Reservoir and diversion from the Dhiarizos River, the water availability in the SCP amounts to 65 MCM, with 26 MCM for domestic supply and 32 MCM for irrigation.

The SCP has costed US\$300 million and has been funded mainly by the World Bank, Kuwait Fund, European Investment Bank and the Resettlement Fund of the

Council of Europe. The principal features of SCP include: the Kouris reservoir with capacity 115 MCM; the 14.5 km long Dhiarizos diversion transferring 21 MCM per year from the Dhiarizos river to the Kouris reservoir; the 110 km long Main Conveyor from the Kouris reservoir to the Akhna Terminal reservoir; the Akhna Terminal Reservoir with capacity 6 MCM; the Germasogia reservoir with capacity 14 MCM; the tertiary treatment of Limassol sewage with capacity 13 MCM used as a source for artificial recharge and irrigation; irrigation development areas with pressurized distribution networks covering 13,500 ha of land; two treatment works (total daily capacity 100,000 m<sup>3</sup>) that supply domestic water to a number of urban and tourist areas; and a telemetry system to monitor and operate the whole water system.

The SCP is operated by the Water Development Department. Residential water is supplied in bulk from the water treatment works to the Town Water Boards and Village Water Commissions who undertake its distribution to consumers. A full cost recovery policy for domestic water supply is followed. The works have been designed to meet expected demand up to the 2010-year horizon. Two major areas have been developed for irrigation with three other minor areas still pending in view of the drought experienced in the 1990s. All irrigation areas contain some groundwater, which is already exploited for irrigation and which is integrated within the system.

A major part of the irrigated land in the Akrotiri area, covering 1,755 ha of land west of Limassol, is envisaged to be gradually served by reused tertiary treated sewage effluent from Limassol. In this area four night-storage reservoirs (NSR) have been constructed to provide adequate pressure and to enable conveyor water and re-pumped treated effluent, which is recharged artificially into the local aquifer, to be economically used. The easternmost area of Kokkinochoria, a major potato-producing area, makes up 60% of the SCP's irrigation water consumption. Water is supplied to 48 Central Distribution Points (CDPs) beyond which the farmers assume responsibility for its distribution. This is done through the formation of nine Irrigation Divisions. A CDP comprises of a small operational reservoir and a pumping station that boosts the water, providing sufficient pressure for on-farm irrigation equipment.

Water is supplied to the CDPs either directly from the Main Conveyor, or from the Akhna Terminal reservoir. Local groundwater extracted by the farmers themselves, is taken into account when project water is allocated. Under normal conditions the supply of water for irrigation is estimated to be 30 MCM although in drought years this supply could be halved. In such cases and on the occasion of prolonged droughts, the farmers are warned and irrigation water for seasonal crops is allocated accordingly. Farmers are free to choose the crops that they grow although a cropping pattern has been envisaged according to various parameters such as soil, climate and markets. Land consolidation has been implemented in the main irrigated areas. On-farm irrigation systems involve sprinklers, mini-sprinklers and trickle (drip).

The effect of the SCP can be seen in areas such as Kokkinokhoría with long experience in irrigation and main exporters of potatoes. The area of Kokkinokhoría was facing complete disruption of agricultural activity due to reduced water availability. This region had "mined" its groundwater reserves for more than 30 years, which led to reduced borehole yields, sea-intrusion into the aquifer and reduced

levels of aquifers' water tables, amounting to one third of the original availability. The SCP allowed agricultural activity to return to pre-water-deficiency rates. The SCP has a similar effect on the Akrotiri area, where increased pumping for domestic supply caused exhaustion and sea-intrusion in the local aquifer.

Moreover, it is fair to argue that the prolonged drought of the 1990s would have created far more serious repercussions had the SCP not been in operation, in spite of the fact that the project itself has not been able to meet all the prescribed demands due to reduced inflow to the reservoirs. The SCP has also enabled flexibility in meeting various supply problems through the installed pipelines and waterworks infrastructure. The budgetary impacts of the SCP were reduced considerably within the framework of the national economy through careful planning and phasing of the project's implementation over a 10 year period (1979–1983). However, the drought situation has brought forward desalination plants, which were envisaged for beyond 2010.

### ***Other Major Irrigation Schemes***

Other major inter-basin schemes include the Paphos Irrigation Scheme based on the Asprokremmos Dam of 51 MCM, on the Xeropotamos River and 24 boreholes in the three main local streambed aquifers (10 MCM per year). This scheme irrigates 5,000 ha of the coastal Paphos plain, between Ha-potami and Agios Georgios of Peyia. The dam was completed in 1982 at a cost of 25 million CYP<sup>3</sup> and provides water for irrigation through an open channel and pipe network. The Khrysokhou Irrigation Scheme which involves a dam of 24 MCM and irrigates some 3,100 ha in the north-western part of the island. The Vasilikos-Pendaskinos project, which has developed the water resources of the southern part of the island and provides water for local irrigation and domestic water for the towns of Nicosia, Larnaka and Famagusta. This project involves three dams, the Lefkara, Kalavassos and Pendaskinos dams with total capacity of 46.5 MCM and was completed in 1987. Some 1,430 ha of agricultural land are irrigated by this scheme. The Pitsilia Integrated Rural Development Project has among its objectives the agricultural development of the mountainous areas, which aims to discourage the relocation of village population to urban centers. This scheme was completed in 1984 at a cost of 10 million CYP. It involves two dams of 1.5 MCM, 19 off-channel reservoirs lined with geo-membrane of total capacity of 2 MCM and 20 boreholes providing 2 MCM per year. The commanded irrigable area is 1,530 ha.

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<sup>3</sup>CYP stands for Cyprus pounds.

## ***Seawater Desalination***

Aggravated water scarcity in the 1990s, especially with regards to domestic and touristic use of water, caused state intervention to ensure a stable and uninterrupted supply of good quality drinking water through seawater desalination. Two desalination plants are presently in operation. The first one was built in 1997, in the area of Dhekelia and has a daily production rate of 40,000 m<sup>3</sup> at 0.54 CYP per cubic meter. The second desalination plan was built in 2001, is located at the Larnaca airport and produces 51,000 m<sup>3</sup> per day at 0.41 CYP per cubic meter (Socratous 2001). Both plans use the Reverse Osmosis method and are successful in covering the needs of the domestic and touristic water consumption.

## ***Water Recycling***

A substantial amount of water is reused and has become available for agriculture and the urban and rural environment. Recycled domestic water is an expanding source of water for Cyprus. Governmental intervention through 'green' policies could strengthen the role of recycled water in enhancing the urban and rural environment (green areas, parks, forestation), in satisfying agricultural water needs and in recharging groundwater reserves. It is our view that such policies should make available recycled water to only existing irrigated areas.

At present about 7 MCM of tertiary treated sewage effluent is used for agriculture and landscape irrigation. The crops irrigated with recycled water are citrus, olives, vines and fodders. It is estimated that by the year 2012 an amount of approximately 30 MCM of treated sewage effluent will be available for agriculture and landscape irrigation. The Greater Nicosia sewage scheme alone, currently under implementation, is expected to produce some 16 MCM per year. Plans are being formulated for a desalination plant using reverse osmosis to render this water useful for all kinds of crops. The Kokkinochoria area is earmarked as the possible major recipient of this water freeing an equal quantity of fresh water from the SCP for other uses.

## ***The Micro-Irrigation Program***

The micro-irrigation program, which has been successfully implemented, refers to the provision of incentives to the farmers for purchasing and installing improved irrigation systems. These incentives include subsidies and long-term low interest rate loans. Extensive field demonstrations by the government convinced the farmers of the need to use improved irrigation systems in order to save water and increase their crop-yields. The farmers gradually moved from flood irrigation to sprinklers

for vegetables, hose-basins for tree crops and other micro irrigation systems for other cultivations (Metochis and Eliades 2002).

As a result of these efforts the flood-irrigated area declined from 13,400 ha in 1974 to 2,000 ha in 1995. Over the same period, micro-irrigation coverage has increased from 2,700 to 35,600 ha. The area still under flood irrigation, which covers 2,000 ha, is mostly cropping deciduous trees in the hilly areas of the country. These crops are usually irrigated using small springs that cannot be easily replaced to improved irrigation techniques. The Ministry of Agriculture, Natural Resources and the Environment, however, is trying to improve irrigation in these areas through partial grant assistance, land leveling and infrastructure improvements.

### ***Measures to Deal with Drought***

Cyprus experiences droughts quite often. Statistical analysis of annual rainfall island-wide (1916–1974) shows that “dry years” (390–470 mm) and “most dry years” (390 mm and less) could be expected to occur once every 5 years. In order to deal with the chronic drought conditions that characterize the climate of the island, one needs to adopt demand management and water conservation measures, as well as measure that increase water supply. Current policies in Cyprus identify as the first priority the maintenance of domestic and municipal water supplies. The second priority is the maintenance of supplies for perennial crops at 80% of the recommended application levels, while irrigation of seasonal vegetables is defined as the third water allocation priority. Farmers are compensated for possible resulting loss of production (Socratous 2000).

### **Conclusions**

The water resources of Cyprus are highly developed with the most economically viable plans already implemented. A comprehensive approach to water management has been adopted involving conjunctive use of surface and groundwater and addressing the interrelationships between demands for domestic and irrigation water. In spite of the existing water management structure, Cyprus continues to face, due to current drought conditions, an increasingly serious water shortage. In this chapter we have presented the currently available water resources of the island, as they have been affected by the prolonged drought of the period 1990–2002. Exploiting the remaining scarce water resources of the island will be expensive. Difficult policy decisions will be necessary if Cyprus is to continue to meet the steadily growing water demands for irrigation, domestic, and commercial uses. The selected strategies for the water management in Cyprus need to be evaluated for their feasibility and their socio-economic repercussions. These issues are discussed in detail, in the consecutive chapters of this book.

## Glossary

CYP	Cypriot pound equivalent to US\$2.68201 in 2008 and 1.7086 euros
DO	District Officer
GC	Government Controlled
ID	Irrigation Divisions
MANR&E	Ministry of Agriculture, Natural Resources and Environment
WDD	Water Development Department

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