

Climate change and water resources in Cyprus

Introduction

Water is a natural resource necessary for human life. It is being used for both drinking and food production.(Liang, 2010) Places with limited rainfall such as Cyprus, aim to increase the supply of water and decrease the demand. Common solutions on the supply side are:

- [reservoirs such as dams](#)
- [desalination plants](#)
- [wastewater recycling](#)

On the demand side, possible solutions include education, conservation and fixing of any damaged pipes.(Liang, 2010)

According to the [Water Framework Directive](#), Cyprus is considered to be one river basin district.(Liang, 2010) Eastern Mediterranean climate which consists of long hot summers with low mean annual precipitation results to rivers without perennial flow along their entire length.

“Until 1997 the main source of water in Cyprus was rainfall. According to a long series of observations, the mean annual precipitation, including snowfall was estimated at 503 mm, and from 2000 until now has been reduced to 463 mm. The quantity of water falling over the total surface area of the free part of Cyprus is estimated at 2.750 million cubic meters (mcm), but only 10% or 275 mcm is available for exploitation, since the remaining 90% returns to the atmosphere as direct evaporation and transpiration.” ([Water Framework Directive](#))

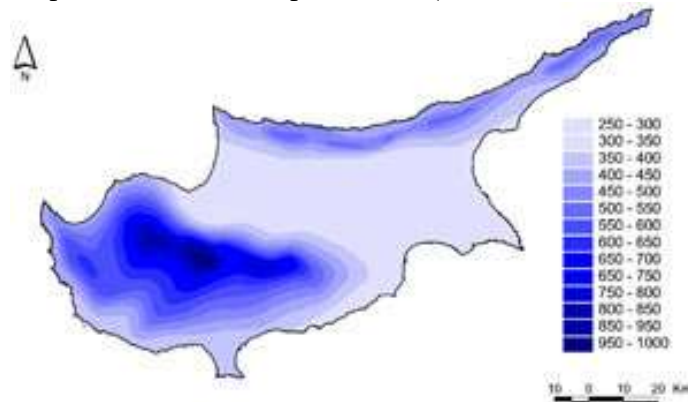


Figure 1: Average annual net rainfalls in million cubic meters (Picture taken from [Water Framework Directive](#))

Most of the rivers flow 3 to 4 months a year and are dry during the rest of the year. Only parts of Xeros, Diarizos, Kargotis, Marathasa, Kouris and Germasogeia which are located upstream in the Troodos areas have a continuous flow. Most rivers have a rather steep slope except for the rivers in the lowland areas along the southern coast. Most part of the rivers is, however, at mid-altitude. ([Water Framework Directive](#))

There are only 5 natural lakes in the island and can be characterized as dynamic systems. These are brackish or salt lakes and they dry up regularly but not every year depending on the rainfall. Consequently, the water level and size of the lakes is variable.

“Most of the aquifers in Cyprus are phreatic, developed in river or coastal alluvial deposits. These are the biggest and the most dynamic aquifers, replenished mainly by river flows and rainfall. There are three large coastal aquifers that include all the perpendicular riverbeds. The coastal parts of these aquifers are composed by sands, silts, limestones, conglomerates and clays. Riverbeds consist of alluvial deposits, gravels, sands and silts. These aquifers are phreatic and are around 30 m deep. All the aquifers of Cyprus (66) have been grouped into 20 groundwater bodies, mainly based on lithology, the hydraulic characteristics, the pressures and the importance of each aquifer. Ten groundwater bodies have a connection with the sea.”
 (Water Framework Directive)

The main contributor of water in Cyprus is the Kouris Dam which has capacity of 115 million cubic meters and its water is used for domestic and agricultural needs along the southern coastline as well as the central areas of the island.(Liang, 2010)



Figure 2: Map of Ground Water Bodies of Cyprus (Taken from [Water Framework Directive](#))

One of the effects of climate change in Cyprus is the decreasing of rainfall. Rainfall in the island over the last decade has been declining at a rate of 1 mm per year.(Liang, 2010)
“Water and watershed systems are influenced by the amount, form, seasonality, and event characteristics of precipitation, as well as temperature, solar radiation and wind that affect evaporative loss.”(Imhoff et al., 2007) The average annual rainfall in Cyprus is about 500 mm and ranges from 300 mm in the central plain and the south-eastern parts of the island up to 1100

mm at the top of the Troodos range and 550 mm at the top of Pentadaktylos. The variation in rainfall is not only regional but annual and often two and even three-year consecutive droughts are observed. ([Water Framework Directive](#))

Health hazards associated with the reuse of water are:

- [excreta-related pathogens](#)
- [vector-borne diseases](#)
- [certain chemicals](#)

Health risks describe the probability, under particular circumstances, that these health hazards will indeed be able to influence human health harmfully. Pathogens can multiply and survive long enough in the environment to be transmitted to humans. Certain environmental factors contribute, to a greater or lesser measure, to the die-off of pathogens. These factors include time, temperature, moisture, exposure to light and ultraviolet radiation, presence of appropriate intermediate hosts, type of plant and others. Treatment of wastewater, excreta and greywater can significantly reduce the concentrations of some contaminants and thus the risk of disease transmission. ([Guidelines for the safe use of wastewater, excreta and greywater. Volume 1: Policy and regulatory aspects](#), WHO)

Discussion

Water Resources

From archaeological excavations it appears that the climate conditions in Cyprus have not changed dramatically from the ancient times until today. Long periods of summer and limited rainfall result in drought and water shortages conditions. Therefore, the water collection, storage and conveyance were matters that the Cypriots habitats were trying to solve. ([DEVELOPMENT OF WATER RESOURCES IN CYPRUS, A HISTORICAL REVIEW](#))



Figure 3: Drought effects (Taken from [Water Development Department](#))

The ancient findings show that even during the Stone Age, settlements in Cyprus were built in places where surface or underground water was available. During the Neolithic Era (8500-3900 B.C.) settlements were found in areas with springs, which gushed out throughout the year or near rivers. Choirokitia settlement for example obtained water from Maroni river. Settlements found in the Karpassia area were built close to areas where signs of springs were found. Based on the

same logic, settlements of the following periods were built near water resources.

(DEVELOPMENT OF WATER RESOURCES IN CYPRUS, A HISTORICAL REVIEW)

During the most recent years the development of the water resources can be divided into two periods:

- Period from independence up to the Turkish invasion in 1974
- Period from 1974 to date

The main characteristics of the period from 1960 up to the 1974 was the co-operation of the Ministry of Agriculture, Natural Resources and Environment, through the Water Development Department, with international and other organizations for the carrying out of studies relating to the planning of the development and construction of projects and the formulation of short and long term plans of action. Studies for many projects were carried out during this period and many dams such as Pomos, Ayia Marina, Argaka, Lefkara, Germasogeia, Polemidhia and Mavrokolymbos were constructed, while, at the same time, the domestic water supply demand of the villages was satisfied. ([Water Development Department](#))

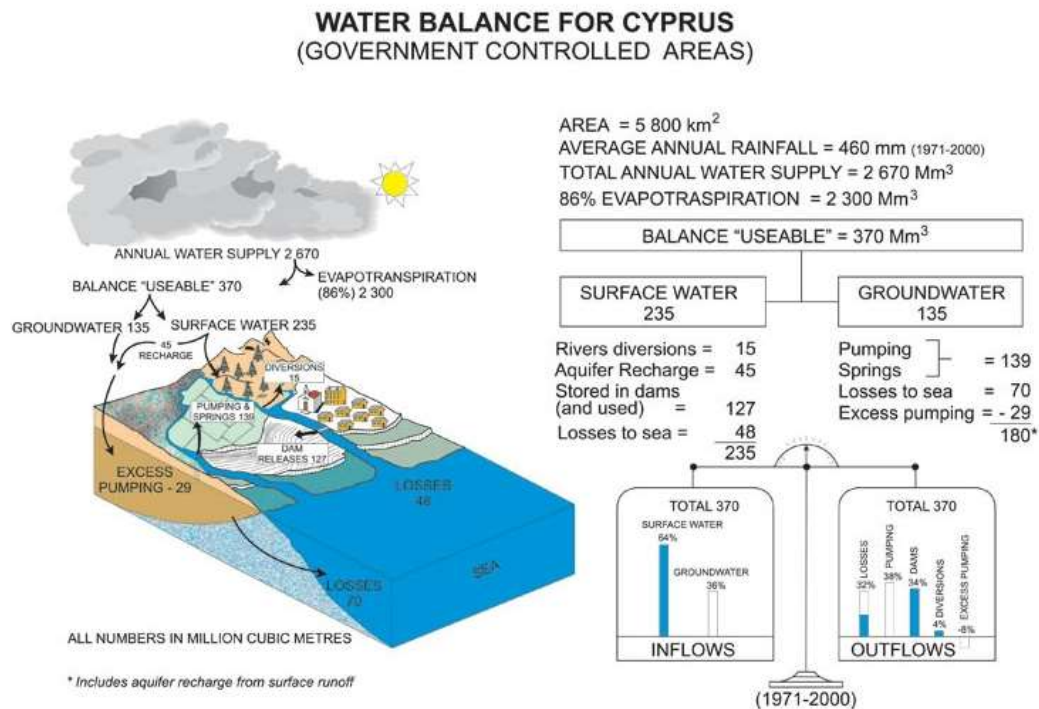


Figure 4: Water Balance for Cyprus (Taken from [Water Development Department](#))

"The period from the 1974 to date is characterized by significant achievements in the field of water development with the construction of large projects, like Paphos Irrigation Project, Chrysochou Irrigation Project, Vasilikos-Pentaschoinos Project, Pitsilia Integrated Rural Development Project and the Southern Conveyor Project. The water treatment plants of

Khirokitia, Kornos, Limassol, Tersephanou and Asprokremmos water treatment plant, which will deliver water to Paphos and sewerage schemes, sewage treatment and desalination plants were also constructed.” ([Water Development Department](#))

➤ **Reservoirs**

Paphos Irrigation Project ([Water Development Department](#))

Objective → irrigation of the coastal plain of Paphos between Chapotami river and Agios Georgios Pegias

Construction period → 1976 until 1982

Cost → 25 million Cypriot pounds

Description → It includes the construction of Asprokremmos dam on Xeropotamos river, the main canal and the western main conveyor, pumping stations, reservoirs, irrigation networks and borehole schemes.

Chrysochou Irrigation Project ([Water Development Department](#))

Objective → development of the surface and ground water resources of the Polis tis Chrysochous region for the irrigation of 3100 hectares within the Chrysochou Valley and Bay area.

Construction period → 1984 until 1988

Cost → 21 million Cypriot pounds

Description → It was implemented in two phases. The first phase includes the construction of Evretou dam on Stavros tis Psokas river, a conveyor system, earth ponds, irrigation distribution networks to provide irrigation water to an area of 2 000 hectares and drilling of new boreholes. The second phase includes the diversion pipeline from the Gialia wier and the main conveyor up to Pomos dam to provide irrigation water to a further area of 1100 hectares along the Chrysochou Bay, between Argaka and Pomos has been completed.

Vasilikos-Pentaschoinos Project ([Water Development Department](#))

Objective → development of the water resources of the area both for the agricultural development of the area and the augmentation of the domestic water supply of Nicosia, Larnaka and Famagusta districts.

Construction period → 1980 until 1987

Cost → 27 million Cypriot pounds

Description → It includes the construction Kalavassos dam on Vasilikos river and Dipotamos dam on Pentaschoinos river, Maroni diversion, Kornos water treatment plant, Kalavassos-Choirokoitia pipeline, Tokhni pumping station and the Vasilikos, Pentaschoinos and Maroni irrigation schemes.

Pitsilia Integrated Rural Development Project ([Water Development Department](#))

Objective → agricultural development and the improvement of the infrastructure of the area

Construction period → 1978 until 1984

Cost → 10 million Cypriot pounds

Description → It includes the construction of Xyliatos dam on Lagoudera (Elia) river and Agioi Vavatsinias dam on Vasilikos river, a large number of PVC lined, off-stream earth ponds and small irrigation and boreholes schemes.

Southern Conveyor Project ([Water Development Department](#))

Southern Conveyor Project is the largest water development project undertaken by the Government of Cyprus.

Objective → collect and store surplus water flowing to the sea and convey it to areas of demand for both domestic water supply and irrigation.

Construction period → 1984 until 1994

Cost → 163 million Cypriot pounds

Description → Phase I: construction of Kouris dam on Kouris river, the main conveyor, a 110 Km long pipeline, Achna terminal reservoir, the telemetry system and Kokkinokhoria, Athienou, Troulloi and Avdellero irrigation schemes on a total area of about 9 767 hectares.

Phase II: “*Diarizos diversion, conveying water from Diarizos river through a 14,5 Km long tunnel to Kouris dam, Chapotami scheme, Limassol and Tersefanou water treatment plants, Tersefanou-Nicosia conveyor, a 36,5 Km long pipeline, water supply to villages west of Limassol and the Akrotiri, Parekklisia, Mazotos, Kiti and Aradippou irrigation schemes on a total area of about 4159 hectares. The Limassol and Tersefanou water treatment plants, the water supply to villages west of Limassol, the Akrotiri, Parekklisia and Kiti irrigation networks, Diarizos diversion, Tersefanou-Nicosia conveyor and the Chapotami scheme have been completed.*” ([Water Development Department](#))

➤ **Desalination plants**

Desalination plants introduced in April 1997 with the operation of Dhekelia Desalination Plant. It has a nominal capacity of 40.000m³ of water per day and it serves the needs of the free area of Famagusta and part of the needs of Larnaca and Nicosia. ([Water Development Department](#))



Figure 5: Dhekelia Desalination Plant (Taken from [Water Development Department](#))

Larnaca Desalination Plant was put in operation on May 2001 with nominal capacity of 52.000m³ per day. ([Water Development Department](#))



Figure 6: Larnaca Desalination Plant (Taken from [Water Development Department](#))

Water Desalination Plants consist of: ([Water Development Department](#))

1. Pipeline for transportation of seawater to the plant
2. Pumping station at the coast
3. Main plant
4. Pipeline for brine disposal

Seawater is taken through a 1200mm diameter and 500m (Dhekelia) or 1000m (Larnaca) long pipeline. After chlorination, seawater passes through a screen system and is then pumped to the main building which is located at a distance of 500 – 800 m from the coast.

Seawater treatment: ([Water Development Department](#))

Pretreatment → Microorganisms destroyed and suspended solids removed, so that micro-organism growth and salt precipitation does not occur on the membrane via:

- Prechlorination of seawater
- Coagulation of colloid particles
- Fine filtration
- Acid addition (pH correction and inhibit precipitation)

Reverse Osmosis → High pressure pumps supply the pressure needed to enable the water to pass through the membranes and reject the salts. The recovery is 50% and the seawater with double salt concentration returns to the sea through the high pressure pumps which gain part of the energy (25 -30%) they need.

Post Treatment → The desalinated water is transferred to a tank where chemicals like lime and carbon dioxide or sulphuric acid are added for pH correction and for increasing its hardness, and it is finally post-chlorinated.

➤ **Wastewater recycling**

The recycled water, which is produced from the domestic wastewater treatment, is used for irrigation of existing agricultural cultivations and for re-charge of underground aquifers.

There are several wastewater treatment plants in Cyprus:

Paphos	Limassol	Platres
Larnaca	Apostolos Louca housing	Ayia Napa
Agros	estate	Pelentri
Palechori	Livadia	Paralimni
Askas	Kofinou	Anthoupolis
Alassa	Arediou	Vathia Gonia
Kakopetria	Kyperounta	Etc.

In Cyprus the treated effluent is used for:

- Irrigation
- Enrichment of underground water

LIMASSOL PLANT	LARNACA PLANT	PARALIMNI AYIA NAPA PLANT	VATHIA GONIA PLANT
CITRUS FRUITS	COWGRASS	CITRUS FRUITS	COWGRASS
FODDER CROPS AND INDUSTRIAL PLANTS (COWGRASS AND CORN)	CORN	OLIVE TREES	CORN
VEGETABLES	LOLIUM AND SUTAX	POTATOES	BARLEY
PUBLIC GREEN AREAS	PUBLIC GREEN AREAS	PUBLIC GREEN AREAS	FODDER CROPS
	FOOTBALL FIELDS	FOOTBALL FIELDS	GRASS PRODUCTION

Figure 7: Treated effluent uses (Taken from [Water Development Department](#))

Health effects

- **Excreta-related pathogens** ([Guidelines for the safe use of wastewater, excreta and greywater. Volume 1: Policy and regulatory aspects](#), WHO)

Bacteria → Bacteria die off rapidly on crops but may still present a health risk. Disease outbreaks of cholera, typhoid and dysentery have been associated with the use of wastewater, excreta or greywater for irrigation of vegetables.

Helminths → Major risk in agriculture, especially where untreated wastewater and excreta are used and sanitation standards are low. Hookworm infections (*Ancylostoma duodenale*, *Necator americanus*) are common in some areas where farmers do not wear adequate shoes or boots.

Trematodes → Major risk in aquaculture where trematode parasites are present. Distribution is limited to certain geographic areas. Foodborne trematodes are transmitted through food consumption (especially the consumption of raw, unprocessed fish); schistosomiasis is spread through skin contact with contaminated fresh water.

- **Vector-borne diseases** ([Guidelines for the safe use of wastewater, excreta and greywater. Volume 1: Policy and regulatory aspects](#), WHO)

Vector-borne pathogens → Risk for any water resource development activities in relevant geographic areas where vector-borne diseases are present. Most insect vectors breed in clean

water, with the exception of vectors of lymphatic filariasis, which breed in organically polluted water.

- **Certain chemicals** ([Guidelines for the safe use of wastewater, excreta and greywater. Volume 1: Policy and regulatory aspects](#), WHO)

Antibiotics (chloramphenicol) → Potential risk to consumers of aquacultural products where these substances are used in fish production.

Cyanobacterial toxins → Potential risk to consumers of aquacultural products — especially to Spirulina

Pesticides and their residues (e.g. aldrin, DDT) → Risk mostly related to pesticide application practices.

Climate Change

Atmospheric concentrations of long-lived greenhouse gases such as CO₂, CH₄, N₂O have increased, tending to warm the surface and produce other climate changes. Human activities can be considered a reason for this large increase. Global mean surface temperature has increased by approximately 0.3 to 0.6 °C over the past century.(Frederick, 1997)

Based on the IPCC's mid-range scenario, models project an increase in global mean surface temperature of about 2 °C relative to 1990 by the year 2100. Warmer temperatures will accelerate the hydrological cycle, altering in uncertain ways the prospects for more extreme droughts in places such as Cyprus or floods in other places. In addition, average sea level is expected to rise about 50cm by 2100.(Frederick, 1997)

Regarding the water resources, higher temperatures will also increase evapotranspiration rates and alter soil moisture and infiltration rates. Moreover, a growing body of research suggests that atmospheric CO₂ levels may affect water availability through its influence on vegetation, because CO₂ increase the resistance of plant stomata to water vapor transport, resulting in decreased transpiration.(Frederick, 1997)

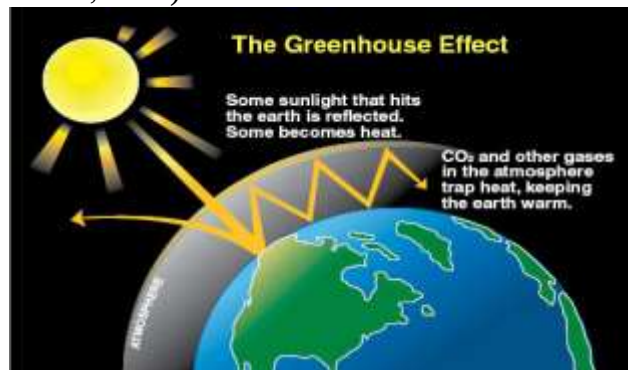


Figure 8: The greenhouse effect (Taken from [Department of Ecology](#), Washington)

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